
Radiation Health Series No.39

June 1995
The strategic intent of the NHMRC is to work with others for the health of all Australians, by promoting informed debate on ethics and policy, providing knowledge based advice, fostering a high quality and internationally recognised research base, and applying research rigour to health issues.
Foreword

The National Health and Medical Research Council was originally constituted by the Governor-General by Order-in-Council in September 1936. It was subsequently established by Act of Parliament on 24 June 1993. The NHMRC advises the Australian community and the Commonwealth and State Governments on standards of individual and public health, and it supports health and medical research.

The Council has nominees of State and Territory health authorities, professional and scientific colleges and associations, trade unions, universities, business, consumer groups, welfare organisations, the Commonwealth administration, including the Aboriginal and Torres Strait Islander Commission, and conservation groups.

The Council publishes its findings and recommendations extensively in many areas, including radiation protection in its Radiation Health Series.

The National Occupational Health and Safety Commission is a tripartite body established by the Commonwealth Government under the National Occupational Health and Safety Commission Act 1985 to develop, facilitate and implement a national occupational health and safety strategy. This includes the development of occupational health and safety standards, which may be adopted by the appropriate Commonwealth, State and Territory authorities.

The National Commission comprises representatives of the peak employer and employee bodies - the Australian Chamber of Commerce and Industry and the Australian Council of Trade Unions - and of Commonwealth, State and Territory Governments.

These Recommendations for limiting exposure to ionizing radiation (1995) (NOHSC guidance note) and the National standard for limiting occupational exposure to ionizing radiation were developed by an expert committee advising standing committees of both the National Health and Medical Research Council and the National Occupational Health and Safety Commission. Council adopted the Recommendations and endorsed the Standard on 7 June 1995. The National Commission declared the Standard on 23 March 1995 and endorsed the Recommendations as a NOHSC guidance note.
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Preface

The National Health and Medical Research Council (NHMRC) recognizes that, in Australia, it is within the jurisdiction of the Commonwealth and of the States and Territories to implement legislation directed towards the effective control of exposure of people to radiation. The NHMRC believes that it will be of assistance in achieving uniform methods of radiation protection throughout the country to recommend ionizing radiation protection procedures which may be adopted in State and Territory legislation or regulations. It may also be of assistance, both to regulatory authorities and to those engaged in practices which give rise to exposure to radiation, if practical guidance and advice on radiation protection is subsequently published which can supplement legislation.

This publication (referred to hereafter as the ‘Recommendations’) supersedes earlier recommendations of the NHMRC: Recommended radiation protection standards for individuals exposed to ionizing radiation\(^1\), adopted in 1980, Australia’s radiation protection standards (1989) and the Interim statement on Australia’s radiation protection standards (1991). Over the last decade, new information on the risks arising from exposure to ionizing radiation has become available. In particular, the recommendations of the International Commission on Radiological Protection (ICRP) have been revised, with ICRP Publication 60\(^2\) superseding ICRP Publication 26\(^3\), on which the NHMRC’s previous recommendations were based.

These revised Recommendations for application in Australia take into account the most recent recommendations of the ICRP, which were adopted after careful review of all available scientific evidence concerning the risks arising from exposure to ionizing radiation. It is intended that the Recommendations will be supported by the Health Series publications, to assist in the adoption of uniform methods of radiation protection. Further revision or supplementation of some aspects of the Recommendations is anticipated, as new information becomes available, or as national or international consensus is reached on radiation protection policy. In particular, it is expected that the procedures recommended for assessing radiation doses which arise from exposure to radiation and radioactive materials will be continually updated to reflect the most current scientific knowledge and expert advice.

The Recommendations were prepared by the Radiation Health Standing Committee of the NHMRC with the assistance of a drafting panel. In parallel, the complementary National standard for limiting occupational exposure to ionizing radiation was prepared by the same Committee working as an expert working group to the Standards Development Standing Committee of the National Occupational Health and Safety Commission (NOHSC). The complete draft, comprising the Recommendations and the National Standard, was released for a period of public comment between May and July 1994. Comments relating to occupational exposure and to the National Standard were reviewed by a joint NHMRC/National Commission Expert Review Group, and all the public comments together with the joint Expert Review Group report were reviewed by the Radiation Health Standing Committee. The Radiation Health Standing Committee then prepared a final draft which was
submitted to the National Health Advisory Committee of the NHMRC and to the Standards Development Standing Committee of the National Commission with the recommendation that it be forwarded to the Council and to the National Commission. The Council adopted the Recommendations and the National Commission endorsed the document as a NOHSC guidance note.

Note: Technical terms which are described in the Glossary appear in **bold type** on their first occurrence in the text. The Glossary (see Annex A) is relevant to both the Recommendations and the Standard.
1. Principles underlying the Recommendations

Radiation protection is concerned with the protection of individuals, their progeny and populations against possible detrimental effects of radiation. While the system of radiation protection described in these Recommendations does not specifically refer to other species or to the environment, it is generally believed that the standard of environmental control required for protection of people will ensure that other species are not put at risk. Risks arising from exposure to radiation should be kept in perspective with other risks, so that society's resources are not inappropriately expended in attempting to contain one particular form of risk while providing too little protection from others. The Recommendations incorporate a system of radiation protection which, if implemented properly, should ensure that risks arising from exposure to radiation remain a minor component of the spectrum of risks to which all people are exposed.

The recommended system of radiation protection, while based on all available scientific evidence concerning risks arising from exposure to ionizing radiation, does not depend on scientific concepts alone. All those concerned with radiation protection have to make value judgements about the relative importance of different kinds of risk and about balancing risks and benefits connected with particular human activities. This is no different from other areas of life in which hazards may require control. The Recommendations permit such value judgements to be made, while establishing a minimum standard which restricts involuntary individual risk below a level which the NHMRC believes society would find unacceptable.

To appreciate the principles underlying the Recommendations, it is necessary to understand a little about the biological effects of ionizing radiation and to define some dosimetric quantities. A thorough discussion of these topics can be found in ICRP Publication 60, and a summary only is included here.

Ionizing radiation is the term used to describe the transfer of energy through space or through a material medium in the form of electromagnetic waves or subatomic particles that are capable of causing ionization in matter, that is, capable of changing neutral atoms into charged atoms, called ions, by removing, or sometimes adding, electrons. When ionizing radiation passes through matter, energy is imparted to the matter as ions are formed; the energy imparted is quantified in terms of dose (see Annex B). In biological tissues, the process of changing atoms through ionization also changes the molecules containing those atoms and it may thus cause damage to the cells containing those molecules.

If cellular damage does occur, and it is not adequately repaired, it may either prevent the cell from surviving and reproducing, or it may result in a viable but modified cell. The two outcomes have profoundly different implications for the organism as a whole, the former being associated with deterministic effects and the latter with stochastic effects (see below).
Most organs and tissues of the body are unaffected by the loss of even substantial numbers of cells, but if the number lost is large enough, there will be observable harm reflecting a loss of tissue function. The probability of causing such harm will be zero at small doses but, above some level of dose (the threshold), it will increase steeply to unity (100 per cent). Above the threshold, the severity of the harm will also increase with the dose. This type of effect is called 'deterministic'. The Recommendations set limits on dose which, if not exceeded, will prevent deterministic effects from occurring.

The outcome is very different if the irradiated cell is modified rather than killed. Despite the existence of highly effective defence mechanisms, the clone of cells resulting from the reproduction of a modified but viable cell may result, after a prolonged and variable delay called the latency period, in the development of a cancer. The probability of a cancer resulting from radiation usually increases with increments of dose, probably with no threshold, and in a way that is roughly proportional to dose, at least for doses well below the thresholds for deterministic effects. The severity of the cancer is not affected by the dose. This kind of effect is called 'stochastic', meaning 'of a random or statistical nature'. If the damage occurs in a cell whose function is to transmit genetic information to later generations, any resulting effects are expressed in the progeny of the exposed person. This type of stochastic effect is called 'hereditary'. The system of radiation protection described in these Recommendations is designed to keep the probability that stochastic effects will occur from exceeding a level that is regarded as unacceptable.

The fundamental dosimetric quantity in radiation protection is the absorbed dose, $D$. This is the energy absorbed per unit mass and its unit is joule per kilogram, which is given the special name gray (Gy) (see Annex B). The probability of stochastic effects is found to depend not only on the absorbed dose, but also on the type and energy of the radiation. This is taken into account by weighting the absorbed dose by a factor related to the type of radiation. The weighting factor is called the radiation weighting factor, $w_R$, and the weighted dose is called the equivalent dose (see Annex B). (Previously, this weighting factor was called the quality factor, $Q$, and the weighted dose was called the dose equivalent.) The equivalent dose, $H_T$, in tissue $T$ is given by the expression:

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

where $D_{T,R}$ is the absorbed dose averaged over the tissue or organ $T$ due to radiation. The unit for equivalent dose is joule per kilogram with the special name sievert (Sv) (see Annex B). Values of radiation weighting factors are given in Table 1. The value of the radiation weighting factor for a specified type and energy of radiation has been selected by the International Commission on Radiological Protection to be representative of values of the relative biological effectiveness of that radiation in inducing stochastic effects at low doses.
Table 1 Recommended radiation weighting factors\(^1\)
(from ICRP Publication 60)

<table>
<thead>
<tr>
<th>Type and energy range(^2)</th>
<th>Radiation weighting factor, (w_R)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Photons, all energies</td>
<td>1</td>
</tr>
<tr>
<td>Electrons and muons, all energies(^3)</td>
<td>1</td>
</tr>
<tr>
<td>Neutrons(^4), energy (&lt;10\text{keV})</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>5</td>
</tr>
<tr>
<td>Protons, other than recoil protons, energy (&gt;2\text{MeV})</td>
<td>5</td>
</tr>
<tr>
<td>Alpha particles, fission fragments, heavy nuclei</td>
<td>20</td>
</tr>
</tbody>
</table>

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 ICRP Publication 60, Annex A.
3. Excluding Auger electrons emitted from nuclei bound to DNA (see ICRP Publication 60, paragraph 26).
4. The functional form of energy dependence recommended in ICRP Publication 60 may be used as an alternative to the values tabulated here.

The relationship between the probability of stochastic effects and equivalent dose is found also to depend on the organ or tissue irradiated. A further dosimetric quantity, \textit{effective dose}, is therefore defined which takes into account the radiological sensitivities of different tissues (see Annex B). If the whole body were uniformly irradiated, the fractional contribution of each organ or tissue, \(T\), to the total \textit{detriment} resulting from the exposure to radiation is represented by a \textit{tissue weighting factor}, \(w_T\). The effective dose, \(E\), is the sum of the weighted equivalent doses in all tissues and organs:

\[
E = \sum_T w_T H_T
\]

where \(H_T\) is the equivalent dose in tissue or organ \(T\) and \(w_T\) is the tissue weighting factor for that tissue or organ. The unit for effective dose is joule per kilogram with the special name sievert (Sv). (Effective dose replaces the quantity 'effective dose equivalent' which was used previously). Values of tissue weighting factors are given in Table 2.

Control of effective dose in the manner described in the \textit{Recommendations} will ensure that deterministic effects cannot occur in most organs and tissues. There are three exceptions, however, requiring specific equivalent dose limits for the skin, for the lens of the eye and for the extremities (hands and feet), although it is rare that \textit{practices} are affected by the application of these limits.

The process of exposure to radiation involves three components: a source which emits radiation or releases \textit{radioactive materials}, the transmission of the radiation or the translocation of the radioactive materials through the environment from the source to the exposed person, and the interaction of the radiation or...
radioactive materials with organs and tissues of the body. Control measures may be applied to all three of these components.

Source-related controls are more straightforward to implement, in principle, than individual-related controls but, for any individual, do not take account of the possibility of exposure from more than one source. Individual-related controls ensure that all sources and exposure pathways are taken into account, but may be awkward to implement, as it may prove difficult to apportion the contribution of each source and responsibility for exposure.

Table 2 Recommended tissue weighting factors

(from ICRP Publication 60)

<table>
<thead>
<tr>
<th>Tissue or organ</th>
<th>Tissue weighting factor, (w_T)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gonads</td>
<td>0.20</td>
</tr>
<tr>
<td>Bone marrow (red)</td>
<td>0.12</td>
</tr>
<tr>
<td>Colon</td>
<td>0.12</td>
</tr>
<tr>
<td>Lung</td>
<td>0.12</td>
</tr>
<tr>
<td>Stomach</td>
<td>0.12</td>
</tr>
<tr>
<td>Bladder</td>
<td>0.05</td>
</tr>
<tr>
<td>Breast</td>
<td>0.05</td>
</tr>
<tr>
<td>Liver</td>
<td>0.05</td>
</tr>
<tr>
<td>Oesophagus</td>
<td>0.05</td>
</tr>
<tr>
<td>Thyroid</td>
<td>0.05</td>
</tr>
<tr>
<td>Skin</td>
<td>0.01</td>
</tr>
<tr>
<td>Bone surface</td>
<td>0.01</td>
</tr>
<tr>
<td>Remainder</td>
<td>0.05(^{2,3})</td>
</tr>
</tbody>
</table>

1 The values have been developed by the ICRP 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 in Note 2.
Everyone is exposed to radiation from natural sources and from human activities. However, some human activities increase the overall exposure to radiation by introducing new sources and new pathways for exposure, or by modifying the pathways from existing sources to increase exposure or to increase the number of people exposed. These human activities are called 'practices', and one part of the system of radiation protection applies to them. Other human activities can decrease existing exposures by removing sources, modifying exposure pathways or reducing the number of people exposed. These human activities are described as 'intervention', and another part of the system of radiation protection applies to them. Further, for some human activities, there will be a potential for exposure but no certainty that it will occur. For example, there is a risk that an accident may occur in handling radioactive materials, resulting in radiation exposure. Such hypothetical exposures are called 'potential exposures'. It is often possible to apply some degree of control to potential exposure by restricting both the probability that an accident will occur and the magnitude of the exposure which could result if the accident did occur.

The system of radiation protection deals with exposure to radiation in three classes: occupational, medical and public. Occupational exposures are incurred at work and as a result of operations within a workplace, but may include natural radiation when so specified by the appropriate authority. Medical exposure is principally the exposure of patients as part of their medical diagnosis or treatment. Public exposure covers all other exposures: that is, all exposures that are neither occupational nor medical.

Occupational and medical exposures can usually be controlled at the source (for example, by shielding and containment), in the environment (for example, by ventilation or dispersal), and through personal protective equipment (such as special clothing or respiratory equipment). In the case of public exposure arising from a practice, controls should be applied at the source. Control measures depend on whether they are to be applied to a practice which is causing or is likely to cause exposure, or to intervention aimed at reducing exposure.

For continuing and proposed practices, the system of radiation protection requires exposure to radiation to be controlled through justification, optimization and dose or risk limitation.

* Justification involves a demonstration that there is a net benefit from a practice which leads to exposure to radiation. Most often this process occurs when a new practice is proposed and various design options are considered. Only options which can be expected to do more good than harm are selected. As the benefits and detriments to be considered encompass all aspects of the proposed practice, the decision-making process covers far more than radiation protection alone and should involve all appropriate governmental and societal decision-making agencies. Radiation protection agencies will contribute to that process. Justification is also required when existing practices are under review, particularly if new information is available concerning their efficacy or their consequences.

* Optimization is employed to make the best use of resources in reducing radiation risks, once a practice has been justified. The broad aim is to ensure that the magnitude of individual doses, the number of people exposed, and the likelihood that potential exposures will actually occur should all be kept as low as reasonably achievable, economic and social factors being taken into account (ALARA). In essence, optimization involves the examination of a suite of possible strategies, ranked in order of reduction in detriment. The optimum will have been reached when any further step to reduce the detriment would involve a deployment of resources that is out of proportion to the consequent reduction. Optimization is principally involved in the design process for the detailed operation of a practice, but the general principles of optimization should always be borne in mind in day-to-day administration of radiation protection procedures.
Limitation of dose or risk is used to place bounds on risk to individuals so that risks do not exceed a value which would be considered unacceptable for everyday, long-term exposure to radiation. The issues of what is or is not acceptable and of who is empowered to make such decisions are, of course, difficult. The International Commission on Radiological Protection has discussed the setting of dose limits at some length and the limits specified in the Recommendations are consistent with those proposed by the ICRP and detailed in ICRP Publication 60. As it is assumed that the probability of stochastic effects occurring increases with dose with no threshold, dose limits do not and cannot define a demarcation between 'safe' and 'unsafe'. Consequently, it is not sufficient merely to ensure that individual doses do not exceed the limits: they should be controlled through optimization to be as low as reasonably achievable. Conversely, it is not a matter of undue concern for a person's health if, on occasion, that person's dose slightly exceeds the dose limit, although it would certainly be cause for investigative action if this occurred during normal working operation of a practice. There are exceptional circumstances, such as in emergencies or accidents, in which it may be justifiable for doses from voluntarily-taken exposures to exceed the annual dose limits.

In some situations, the sources, exposure pathways and exposed individuals are already in place when control measures are being considered. An important class of such situations involves exposure to natural sources of radiation, such as exposure to radon in homes; another includes remedial action following accidental exposures. Often, intervention cannot be applied at the source and has to be applied in the environment or in a way which directly affects the individual. Countermeasures forming a program of intervention should be justified, in the sense that they should do more good than harm, and their form, scale and duration should be optimized to maximise the net benefit. Restricting existing exposures through the application of individual dose limits is not appropriate; decisions on the need for intervention, and on its scope, will be based on the doses which can be averted by intervening. The setting of action levels may prove useful in deciding when countermeasures should be invoked. In accident or emergency situations, dose restrictions for persons taking the intervening action will be necessary to ensure that serious deterministic effects are avoided.
2. The system of radiation protection

2.1 General principles

An increase in a person's exposure to ionizing radiation, even at low doses, is assumed to increase the risk of harm to that person's health. A system of radiation protection should aim to limit possible detrimental effects arising from exposure to radiation. These Recommendations describe the system of radiation protection recommended by the National Health and Medical Research Council.

Some human activities lead to an increased exposure to radiation: they are called 'practices'. Some human activities are designed to reduce exposure to radiation in existing situations: they are described by the word 'intervention'. Both practices and intervention should be justified - that is, they should do more good than harm - and their net benefit should be maximized. Further, the doses received by individuals from increased radiation exposure arising from practices should be limited to acceptable levels.

2.2 Radiation protection for practices

For continuing and proposed practices, the system of radiation protection, as recommended by the International Commission on Radiological Protection, is based on the following general principles, referred to in abbreviated form as 'justification', 'optimization' and 'limitation', taken from ICRP Publication 60.

"  * No practice involving exposures to radiation should be adopted unless it produces rove sufficient benefit to the exposed individuals or to society to offset the radiation ency detriment it causes. (The justification of a practice.)

  * 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 optimization of protection.)

  * 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.)"
2.3 Radiation protection in existing exposure situations

For intervention in existing exposure situations, the system of radiation protection is based on the following general principles, taken from ICRP Publication 60, which are forms of justification and optimization.

"* The proposed intervention should do more good than harm - that is, 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.

* The form, scale, and duration of the intervention should be optimized so that the net benefit of the reduction of dose - that is, the benefit of the reduction in radiation detriment, less the detriment associated with the intervention - should be maximized."

Dose limits, which are intended to restrict the increases in exposure caused by practices, do not apply in the case of intervention to reduce existing exposures. However, there will be some level of projected dose above which intervention will almost always be justified, in particular to avoid deterministic effects. Further, restrictions on the exposure of those taking part in the intervening action may need to be applied.

2.4 Classification of exposure: occupational, medical, public

The system of radiation protection deals with exposure to radiation in three classes: occupational, medical and public. Occupational exposures are incurred at work and principally as a result of working directly with radiation. Medical exposure is principally the exposure of patients as part of their medical diagnosis or treatment. Public exposure covers all other exposures arising from practices; that is, all exposures that are neither occupational nor medical.

Occupational exposure associated with a practice includes all exposure to ionizing radiation which occurs at work except for exposures that are excluded under these Recommendations. Exposure to radiation from natural sources is generally excluded from occupational exposure, except when the exposure is a direct consequence of a practice or is specifically identified by the appropriate authority as requiring control through the implementation of a program of radiation protection. Such circumstances may arise, for example, in the mining and processing of radioactive ores, in the handling and storage of specified materials containing significant traces of natural radionuclides, in working in specified underground mines and caves, and in the operation of high-flying aircraft. Exposure to radon which occurs as a direct restricted consequence of a practice, such as in the case of uranium mining, should be treated as occupational exposure. Exposure to radon in other workplaces should be treated as occupational exposure if radon levels are not reduced below the action level specified in Annex C.
Medical exposures fall into three categories: doses received by patients undergoing medical diagnosis or therapy, doses received by volunteers in medical research, and doses received knowingly and willingly by persons other than health care workers as a consequence of their proximity to an exposed patient - for example, those who give support and comfort to exposed patients.

2.5 Radiation protection in occupational exposure

Radiation protection for occupational exposure requires justification, optimization and limitation to be applied to the practice which causes the exposure.

A practice must be demonstrated to be justified before the appropriate authority can permit it to take place. This process will normally form part of the review of a proposed practice during environmental and health impact assessment procedures.

Optimization should be employed in determining the most appropriate radiation protection strategies for controlling exposure. Options examined in the optimization process will be restricted to those which allow the recommended occupational dose limits to be met and which are consistent with any additional dose constraints adopted. Optimization should, in principle, take into account both actual and potential exposures. The inclusion of potential exposure in optimization assessments should be made a requirement when practical guidance on appropriate techniques becomes available.

Dose limits for occupational exposure to ionizing radiation are given in Schedule A. The limits apply to the sum of doses from external exposure in a specified period and the committed dose arising from intakes of radionuclides during the same period. Doses incurred as a consequence of minor mishaps in operations should be included in the occupational dose which is to be compared with the dose limit, but accidental doses received during an emergency should be treated separately. The effective dose limits are expressed as long-term dose rates over a specified averaging period in years, reflecting the fact that, for low doses, it is the accumulated dose over time which needs to be limited, rather than short-term dose rate. It is implicit in the expression of dose limits as averages that secure and accessible records of doses received will need to be kept for many years. The averaging period specified in Schedule A is recommended as a compromise between practical problems associated with meeting long-term limits and the need to provide for flexibility in patterns of exposure over time.

Compliance with the occupational limit on effective dose will ensure that deterministic effects do not occur in most body tissues and organs. However, separate limits on equivalent dose for the lens of the eye, and for the skin and the hands and feet, are required and are specified in Schedule A.

In addition, it is recommended that dose constraints are used for appropriate work categories in the design of the working environment. That is, for occupations in which the nature of the work requires only minor exposures to radiation, doses should be restricted by design to be less than some value which is lower than the dose limit and which is determined through experience. While dose limits mark the lower bound of unacceptability, dose constraints promote a level of dose control which should be achievable in a well-managed practice. The number of employees who work in circumstances where it has not been possible to adopt a dose constraint in the design of the working environment should be kept as small as practicable.
The separation of employees into those covered by a dose constraint and those few who, of necessity, are not, allows for a basic level of pragmatic optimization: the direction of radiation monitoring and assessment resources into areas where they are most needed. In the operation of a practice, it may be appropriate to use investigation levels corresponding to the dose constraints, or to some fraction of the dose constraints, used in the design.

Exposure of employees who have no direct involvement in work which requires exposure to radiation should be controlled, where possible, in a manner similar to that employed for members of the public. This may be achieved by adopting a dose constraint related to the public effective dose limit given in Schedule A in the design of the working environment for this category of employees.

The basis for the control of occupational exposure is the same for women as for men, except that if and when a pregnancy is declared by a female employee, the embryo or fœtus should be afforded the same level of protection as is required for a member of the public. This may be achieved by controlling the exposure of an employee who declares a pregnancy in a manner which ensures that doses which may be received by the fœtus during the remainder of the pregnancy while the employee is at work are consistent with the public effective dose limit given in Schedule A.

Persons under the age of 16 should not be exposed to radiation occupationally and should be treated as members of the public for radiation protection purposes.

Because, for low doses, it is the accumulated dose over time which is presumed to reflect risk of harm rather than dose rate, society may decide to tolerate some rare circumstances in which employees may knowingly and voluntarily receive doses in excess of the recommended average dose limit each year for a few years, provided that the long-term risk to health does not become unacceptable. For example, it may take some time for an operation which complies with the former occupational dose limit to modify its procedures in order to comply with the limits given in Schedule A, or for an operation which complies with the normal limit given in Schedule A to develop new procedures when encountering new circumstances which cause a temporary increase in exposure.

Since it may be more difficult to ensure that adequate records are kept for longer periods, and since there are potential problems associated with the future employment of individuals who may receive a limiting cumulative dose early in an averaging period, such exceptional practices should be permitted only if they can be individually justified after thorough review. The review process should take account of appropriate regulatory, occupational health and safety and radiation protection advice, and should include consultation with the employees who will be affected. Permission to undertake exceptional practices should be given only if the implied health risks do not exceed those that would follow from long-term exposure at the recommended occupational dose limit. If all these conditions are satisfied, the appropriate authority may approve an occupational effective dose limit higher than the normal limit specified in Schedule A for a limited period or may approve an extension of the period to which the average dose limit applies. When, in exceptional circumstances, a temporary change in the dose limitation requirements is approved by the appropriate authority, the conditions specified in the footnote to Schedule A shall be observed. These conditions are consistent with those adopted through international consensus in the basic safety standards document published by the International Atomic Energy Agency and its co-sponsors.
Approval should be reviewed at regular intervals to confirm that it is still necessary. A case for review should also be considered whenever the effective dose accumulated from the start of the period of temporary variation by any employee to whom the exceptional limit applies reaches twice the value of the single-year limit given in Schedule A.

Notwithstanding any such approvals relating to exceptional circumstances, the effective dose limit for any single year specified in Schedule A applies to all practices without exception.

Recommended procedures for implementing the requirements of this section are given in Section 3.

2.6 Radiation protection in medical exposure

All medical exposures should be subject to the principles of justification and optimization in a medical context. Dose limits, which are employed to restrict occupational and public exposure to radiation, are not appropriate for patients undergoing diagnosis or therapy; the physician responsible for the patient will determine the appropriate medical care. However, recommended guidance levels for medical exposure for particular procedures may assist in optimising patient dose.

For doses received by a patient undergoing medical diagnosis or therapy, there are two levels of justification. First, the medical practice involving exposure to radiation should be justified in principle. For example, radiographic location of a foreign body in tissue may be justified as a practice; routine examination of asymptomatic patients may not. Second, each procedure should be subject to a further, case-by-case justification by the clinician who is responsible for the management of the patient and who determines that the exposure is necessary for diagnostic or therapeutic purposes. For example, in a particular case, location of a foreign body might be achieved using a diagnostic method, such as ultrasound, which does not cause exposure to ionizing radiation. The second level of justification may be waived where it has been determined by medical authorities that a particular type of medical practice is generally justified - for example, in a properly managed breast X-ray screening program.

Protection should be optimized during medical exposures. In the case of diagnostic radiology, there is often scope for dose reduction, through careful choice of exposure and image processing conditions, without loss of diagnostic information. Dose limits are not appropriate because of the individual medical requirements of each case. However, it should be possible for professional or regulatory agencies to recommend guidance levels for particular procedures as a guide to the doses likely to be received in the majority of cases with current good practice. For example, the NHMRC has made recommendations previously on limiting doses in mammography, which are expressed in terms of guidance levels in the Supplement (Part 1). The development of guidance levels for medical exposures is recommended for all relevant medical procedures.

Diagnostic and therapeutic procedures causing exposure of the abdomen of women likely to be pregnant should be avoided unless there are strong clinical indications that the procedure is necessary.
An associated category of medical exposure can be incurred by persons, other than health-care staff, who give comfort and support to patients who are undergoing a medical exposure. For example, relatives and friends who visit a patient who has radionuclides in the body for diagnostic or therapeutic purposes, or a parent holding an infant for diagnostic radiography, may incur some exposure to radiation. The justification for this type of exposure is a matter for judgement by the medical personnel responsible for the patient, following health physics advice if necessary. Such exposures should only be permitted when the person has been advised of the circumstances and incurs the exposure knowingly and willingly. In most cases, it is likely that the benefit will outweigh the detriment arising from the brief proximity of patient and visitor. There will usually be scope for optimization of exposure by sensible positioning of patient and visitor and by shielding if appropriate.

The exposure of volunteers who take part in biomedical research requires justification by an ethics committee established with the approval of the appropriate health or medical authority. The committee must be fully informed of the risks and benefits of the exposure when determining the matter, bearing in mind that it is not the individual incurring the risks who benefits directly from the exposure. Exposures should be permitted only when the volunteers understand the risks involved and willingly participate. A distinction should be drawn between volunteers who would not themselves benefit from the exposure and those who may. Recommended dose constraints for the former are given in the Supplement (Part 2). Use of a cumulative dose constraint implies that records should be kept of the estimated doses received by volunteers and that volunteers can be accepted into a research program only after investigation of their exposure histories during any earlier research. Researchers have a responsibility to provide dose information to volunteers and to enquire about previous exposure of the volunteer; volunteers have a responsibility to retain and to provide information on prior exposure history to researchers. Use of the recommended dose constraint will avoid the possibility of deterministic effects occurring in any specific organ or tissue provided that there has been no history of substantial occupational or medical exposure.

Volunteers should, where practicable, be over 40 years of age, and preferably over 50. Persons under the age of 18 should normally not be permitted to be exposed to radiation as volunteers in medical research. Young children, in particular, are not in a position to give informed consent. However, if an ethics committee regards a special case as justified, exposure of children should conform with the constraint given in the Supplement (Part 2) and be permitted only if the condition under study is related to the age of the participants and the information sought cannot be obtained using adult volunteers, and only with the approval of those legally responsible for the child. Infants under the age of 1 year and foetuses should not be exposed to radiation for the purposes of medical research unless the appropriate health or medical authority, with the permission of the parents or legal guardian, grants an exceptional approval in circumstances where the information sought is essential and cannot be obtained by other means.

The earlier advice of the NHMRC on limiting exposure of volunteers in medical research was due for review at the time of publication of these Recommendations.
2.7 Radiation protection in public exposure

Exposure of members of the public to radiation arising from a practice is subject to justification, optimization and limitation. Justification is required for a practice to begin or to continue if it exposes members of the public. This judgement usually occurs as part of the overall review of the practice during environmental impact and health impact assessments.

Optimization and limitation of public exposure to radiation arising from justified practices is exercised in all normal situations by application of controls at the source. In determining what controls should be applied, it is appropriate to estimate the effective dose to the critical group of members of the public. Groups of members of the public are identified in which the individuals within the group are relatively homogeneous with regard to age, diet and those behavioural characteristics that affect the doses received. The pathways for exposure of those groups are examined to determine the group that is the most exposed to radiation arising from the practice; that is then the critical group.

Optimization may be carried out by estimating, through modelling of exposure pathways, effective doses and collective effective doses to the critical group associated with each control option and selecting that option which reduces doses to a level as low as can be reasonably achieved. Dose constraints applied to the critical group, through modelling of the exposure pathway, imply restrictions at the source. It is not necessarily the public dose limit which determines the constraint, as allowance may need to be made for exposure of the critical group to more than one source, although clearly the public dose limit is the maximum value that an individual-related dose constraint can take. The main aim of constrained optimization in public exposure is to develop practical restrictions on the sources of exposure - for example, restrictions on the release of radionuclides to the environment.

Dose limits for exposure of members of the public are given in Schedule A. Equivalent dose limits are specified for the lens of the eye and localised areas of the skin, since these tissues may not necessarily be protected against deterministic effects by the limit on effective dose. Because the exposed individuals may show a wider range of sensitivity than the more limited population of workers, particularly if children are exposed, the recommended annual limits for equivalent dose in these tissues are lower than those for workers by an arbitrary factor of ten.

Recommended procedures for implementing the requirements of this section are given in Section 3.

2.8 Intervention

When sources of exposure and exposure pathways are already present, due to natural phenomena or to earlier practices that preceded regulatory control or to accidents, the only type of action available to control exposure is intervention. Before intervention is initiated, it should be justified; that is, it should be shown that it is likely to do more good than harm. Once justified, the form, scale and duration of the intervention should be optimized to obtain the maximum net benefit. The cost of intervention is not simply a monetary cost. Some protective or remedial actions may involve non-radiological risks or serious social impacts. For example, the
short-term evacuation of people from their homes is not very expensive, but it may cause the temporary separation of members of a family and result in considerable anxiety. Prolonged evacuation and permanent relocation are expensive and likely to be traumatic. **Intervention levels** are likely to vary from case to case, depending on the results of optimization. This does not imply an inconsistency of approach, rather it reflects the variability of the social and economic factors taken into account in the optimization process.

Three examples of circumstances which may require intervention involve radon in dwellings, radioactive residues used as land fill, and accidents.

Indoor radon makes the largest single contribution to public exposure from natural sources. Although average radon concentrations in Australian homes are quite low in comparison with some other countries, some homes may contain concentrations radon much higher than the average. Intervention involves the modification of a dwelling or of its ventilation, and there is a consequential cost. The NHMRC has previously recommended the use of an action level to draw attention to the radiation risk associated with high levels of radon, but the form of intervention should be determined through optimization. For dwellings, the owner or occupier may determine the form of the intervention, if any. For workplaces, the appropriate health authority may recommend or require intervention. For dwellings, the action level given in Annex C (a) is recommended. If long-term average radon concentrations in a home are found to exceed this value, consideration should be given to possible remedial action, within the context of optimization. For workplaces, which are normally occupied only during working hours, the action level given in Annex C (b) is recommended. If measured long-term average values in a workplace are found to exceed this level, and are not reduced below this level by intervention, the workplace should be subject to the system of radiation protection specified in Section 2.5.

Radioactive residues have sometimes been used in the past as landfill, the risks from exposure to radiation not being appreciated at the time. Where dwellings, workplaces or public buildings have been constructed over such residues, it may be desirable to take remedial action to replace or reduce the quantity of the radioactive material, depending on the cost and on the reduction in exposure to radiation likely to be achieved. For these circumstances, or any others in which external radiation from natural sources is enhanced, the appropriate authority may set or recommend action levels.

Accidents may require intervention to control exposure to radiation. Some guidance on response to incidents and accidents is given in Section 3.9.

### 2.9 Treatment of potential exposure

In principle, potential exposures should be dealt with within the system of radiation protection. In the design of a practice, there are two objectives in dealing with potential exposure: prevention and mitigation. Prevention is the reduction of the probability of the sequences of events which lead to or which may increase exposure to radiation. Mitigation is the limitation and reduction of exposures which arise should any of these sequences actually occur. Both in design and in operation of a practice, strategies should be adopted which restrict the probability of accident sequences and which limit the consequences should an accident occur.
In order to maintain a strict coherence with the treatment of actual exposures, it would be necessary to extend the concept of detriment to include the probability of occurrence of an event giving rise to the detriment. As accepted techniques for this are not yet available, no specific recommendations can be made here. However, if the expected individual doses are small, so that deterministic effects would be avoided, then it is possible for the purposes of analysis to use the product of the expected dose and its probability of occurrence as if it were a dose that was certain to occur. The conventional procedures of justification and optimization can then be applied using this product.

2.10 Review of effectiveness of radiation control

The effectiveness of the implementation of the program of radiation protection should be assessed regularly and reported to the appropriate authority, as required. It is important that the basic principles should be treated as a coherent system and that no one part should be taken in isolation. In particular, for practices, mere compliance with the dose limits is not a sufficient indication of satisfactory performance; it should be demonstrated also that optimization has been given due attention.
3. Implementation of a program of radiation protection

3.1 Regulations, approvals, authorizations and exemptions

Control of exposure to radiation in Australia is enacted through Commonwealth, State and Territory legislation. State radiation health standards are usually set through State radiation control legislation. Advice on this matter may be obtained in each State from the offices listed in Annex D.

Whatever the regulatory instruments employed, the Recommendations may be used as the basis for uniform radiation safety practices throughout Australia. In some cases, this may be achieved, in part, by adopting all or part of the Recommendations directly into regulations; in others, it may rely on making compliance with the Recommendations a condition of licence when such is granted for a practice which may lead to radiation exposure. Regulatory provisions should prohibit practices which are not regarded as justified and should require demonstration of observance of the Recommendations for practices which are justified.

Regulatory provisions may also require an approval and authorization process for justified practices. In this context, approval of a proposal to conduct an operation which may lead to radiation exposure refers to an agreement by the appropriate authority that the radiation protection aspects of the proposal are consistent with the Recommendations, while authorization refers to the agreement by the appropriate authority for the proposed operations to proceed. In some cases, a number of approvals may be required before authorization can be given - for example, an approved radiation monitoring program, an approved plan for radioactive waste disposal, approved emergency procedures, and so on. In other cases, the appropriate authority may approve and authorize with a single instrument. Approvals and authorizations may also be required to vary an existing program.

Exemptions may be sought by presenting a case to the appropriate authority. For example, the practice of installing smoke detectors containing radioactive material in buildings may be exempt from regulatory control because the radiological implications in individual dwellings and buildings are negligible. However, the assembly, importation and disposal of such devices may require control of bulk storage arrangements or of disposal strategies, in addition to any product performance standards which must be met relating to containment of the radioactive material.
Criteria for exemption are recommended in **Schedule B**. Air transport, for example, may be exempt as a practice because large doses are unlikely to be received. Similarly, workplaces in which the radon levels are below the action level may be exempt.

### 3.2 Responsibilities

Regulatory or supervisory authorities, **operators, employers** and employees involved with practices which may lead to exposure to radiation all have responsibilities to ensure proper radiation protection.

Regulatory authorities are responsible for ensuring that the radiation protection strategies adopted within a practice are appropriate and in accordance with the **Recommendations**. Exercising this responsibility involves critical examination of practices which may lead to radiation exposure, in order to issue the relevant licences, approvals and authorizations, together with monitoring the operation of those practices. Regulatory authorities have a particular responsibility to review public exposure to radiation since members of the public may be exposed to radiation from more than one source.

Operators and employers who engage in practices which may lead to radiation exposure have, in addition to a general duty of care, a responsibility to ensure that the operations under their control adhere to the **Recommendations**. This may include any or all of the following:

- ensuring that the workplace and work procedures are designed to keep exposures to ionizing radiation as low as reasonably achievable, economic and social factors being taken into account;
- obtaining all necessary approvals and authorizations;
- appointing radiation safety officers, as necessary;
- providing for consultation with and appropriate training for employees who may be exposed to radiation in their work;
- ensuring that a plan for the control of exposure to radiation is developed, in consultation with the exposed workforce, and that it is followed;
- developing and implementing a plan for monitoring exposure to radiation and for estimating doses received by those exposed;
- ensuring that doses estimated to have been received by employees comply with the relevant dose limits and are consistent with any applicable dose constraints;
- ensuring that doses estimated to have been received by members of the public from the operation comply with the public dose limits or any applicable public dose constraints;
- developing a plan for dealing with incidents, accidents and emergencies involving exposure to radiation;
- keeping records relating to radiation exposure resulting from the operation; and
- providing copies of dose records to employees on request and at the termination of their employment.
Employees are responsible for observing radiation safety practices, as set out in the plan for controlling exposure to radiation, and for complying with relevant safety instructions. A prospective employee should assist the prospective employer in obtaining the employee's prior occupational radiation dose history. Employees should participate in the development of the plan for control of radiation in the workplace.

### 3.3 Training and induction

Employers are responsible for providing induction and training to all employees who may be exposed to ionizing radiation at work. The type and level of training and its method of presentation should be consistent with the characteristics of the employees to whom it is directed and with the radiation risks associated with the workplace, and should take into account appropriate consultation with the workforce. Training and induction programs should be documented and may require approval by the appropriate authority. Employee participation in training programs should be recorded and the records retained by the employer.

### 3.4 Control of exposure

Occupational and medical exposures can usually be controlled at the source (for example, by shielding and containment), in the environment (for example, by ventilation or dispersal), and through personal protective equipment (such as special clothing or respiratory equipment). In the case of public exposure arising from a practice, controls should be applied at the source. Control measures depend on whether they are to be applied to a practice which is causing or is likely to cause exposure, or to intervention aimed at reducing exposure.

Operators and employers are responsible for ensuring that a comprehensive plan for the control of exposure to radiation is developed, in consultation with the exposed workforce, as appropriate, and that it is followed. The initial plan may be based on estimates of radiation exposure in the workplace. The plan should be refined as soon as is practicable on the basis of assessments of actual radiation exposure conditions, and radiation control measures should be designed and implemented accordingly. The plan should be reviewed at appropriate intervals and whenever changes occur within the workplace which may significantly affect radiation exposure conditions.

Control of exposure to radiation should be based on a hierarchy of measures including:

- avoidance of exposure, where practicable;
- isolation of sources of radiation, where practicable, through shielding, containment and remote handling techniques;
- engineering controls, such as local exhaust ventilation to remove contaminants from the workplace environment;
- adoption of safe work practices, including work methods which make appropriate use of time, distance and shielding to minimise exposure; and
- where other means of controlling exposure are not practicable, the use of approved personal protective equipment.
In designing work practices to optimize radiation protection, it is recommended that workplaces be designated as **controlled areas** or as **supervised areas** and appropriate working rules be established within them.

A controlled area is one to which access is controlled and in which employees are required to follow specific procedures designed to control exposure. Controlled areas are usually associated with dose rates which would imply doses well in excess of the public limit if received for a full year, or with risk of an accident which could lead to high doses and to deterministic effects. The designation of controlled areas should assist in isolating sources of radiation from all but an essential minimum number of employees. A supervised area is one in which working conditions are kept under review but in which special procedures to control exposure to radiation are not normally necessary. Supervised areas are usually associated with moderate dose rates or moderate risks. Their designation may be used to limit access of members of the public or of employees whose work does not normally involve exposure to radiation. The delineation of the boundaries of controlled areas and of supervised areas should be based on operational experience and judgement, taking account of the expected level and likely variations of radiation doses and intakes of radioactive materials and of the potential for accidents.

It may also be useful to establish investigation levels of exposure for particular occupations or categories of work, and their use is recommended where appropriate. For many types of work in a well-managed practice, the individual doses likely to be incurred in a year are well below the occupational dose limit specified in **Schedule A**. The experience gained from such practices can be used to establish dose constraints when designing the workplace environment. In operation, investigation levels, corresponding to those dose constraints, or to some fraction of them, may be used. When an investigation level is exceeded, the cause or the implications of that level of exposure should be examined. This may reveal a temporary fluctuation in environmental working conditions which requires no remedial action or it may point to a need to review the existing radiation control measures in order to rectify a defect, for example, or to take account of new sources or pathways of exposure. The use of investigation levels can help in keeping the program of radiation protection under continual review and in optimizing the effective deployment of radiation protection resources.

### 3.5 Radiation monitoring

Operators and employers are responsible for ensuring that a radiation monitoring program is developed and followed, as required by the appropriate authority. In addition to pre-operational monitoring to obtain any necessary baseline values, the program should cover all phases of an operation from its initial development, through day-to-day operation to termination and rehabilitation, as appropriate. The purpose of a radiation monitoring program is to identify all sources of radiation exposure within an operation, to enable assessments to be made of the radiation exposure of employees and of members of the public, to permit timely detection of changes in radiation parameters which may lead to increased exposures, and to produce sufficient information for optimization purposes - that is, for ensuring that exposures are as low as reasonably achievable, economic and social factors being taken into account. The radiation monitoring program should be periodically reviewed and refined in the light of operational experience.
The type and intensity of monitoring required will depend on the circumstances and level of exposure. While group or area monitoring strategies may be sufficient when assessed doses are well below the dose limits, personal monitoring should be undertaken as far as is practicable when doses may be a significant fraction of the limits. For occupational exposure to external radiation, it is usually possible to monitor individuals with personal dosemeters at moderate cost. In some circumstances, such as exposure of aircrew, routine personal monitoring is not justified as it is known that doses can only fall within a predictable range. Individual monitoring for intakes of radioactive material is more difficult, but should be used, when appropriate, for work involving exposure to unsealed sources, including exposure to radon or radioactive dusts arising from the mining and milling of radioactive ores if levels of intake are significant.

3.6 Dose assessment

Dose assessments of employees and of members of the public are required, as appropriate, to demonstrate compliance with the Recommendations. As doses cannot be measured directly, they must be assessed through measurements of relevant radiation parameters and approved computations. In general, dose estimation should follow the procedures and use the computational methods and data recommended from time to time by the International Commission on Radiological Protection or approved by the appropriate authority. Reference or default values of computational parameters should be used unless the use of other values is approved or required by the appropriate authority. When greater accuracy is possible through the use of more appropriate values, including measured values, they may be used with the approval of the appropriate authority. Appropriate allowance should be made for personal protective equipment, if worn in an approved manner - that is, in accordance with a well managed personal protective program which includes training in fitting and proper wearing of personal protective equipment and in equipment maintenance procedures.

3.7 Compliance

Compliance with the Recommendations requires measurement or estimation of the doses that people receive as a consequence of an operation and a demonstration that the dose estimates are below the relevant limits in Schedule A.

For the purposes of dose limitation in compliance with Schedule A, the dose averaging periods should be defined in terms of consecutive calendar years following the date of adoption of these Recommendations, although a temporary pro-rata limit may be needed for phasing in dose limitation requirements. Retrospective compliance should not be required.

Compliance also requires optimization of exposure to radiation by keeping exposures as low as reasonably achievable; in practical terms, this may involve a demonstration that good radiation safety practices, specified in the radiation control plan, have been followed and that appropriate radiation monitoring has been undertaken to examine whether reasonable changes in working procedures could be made in order to reduce doses.
3.8 Record keeping

For all operations to which these Recommendations apply, records should be kept, as required by the appropriate authority. Records will normally include:

- approvals and authorizations granted by the appropriate authority;
- specifications of the radiation control plan and monitoring program;
- details of training courses provided and of attendance by employees;
- estimates of doses received by employees and by members of the public;
- incidents and accidents involving exposure to radiation, and corrective measures taken; and
- environmental radiation measurements, as required by the appropriate authority.

Records should be kept available for inspection by the appropriate authority and retained for a suitable period, as required by the appropriate authority. Individual dose records should be made available to the employee on request. Dose records should be passed to the appropriate authority when an operation ceases and no other operator assumes responsibility for them. Dose assessment records should include sufficient detail to allow later reassessment, if necessary. For example, where dose estimates depend on particular circumstances or on computational factors which may change over time, such as personal protective factors or parameters taken from the scientific literature or from ancillary measurements, those factors should be recorded.

3.9 Emergencies, accidents and incidents

Operators and employers are responsible for ensuring that comprehensive emergency plans are prepared, and approved, to cover foreseeable situations in which accidental exposures to radiation may occur. Such plans should include provision for the availability of trained personnel and emergency equipment and should specify the emergency procedures to be followed, including:

- keeping exposures to a minimum, consistent with essential operations, through evacuation or otherwise;
- bringing the situation under control;
- providing access to any necessary medical or counselling services;
- obtaining information for assessing the cause of the accident or emergency; and
- obtaining information for assessing any doses received as a consequence of an accident.

While it may not be appropriate to apply the occupational dose limits of Schedule A to emergency actions to save lives or to bring an accident under control, some restriction of exposure of emergency teams will be necessary, in particular to ensure that doses are kept below the thresholds for deterministic effects. Doses received during emergency actions should be treated separately from normal occupational exposures. Once the emergency has been brought under control, doses received by employees during subsequent remedial action should be limited as for practices.
In the event of an accident which causes or which may lead to high doses of radiation or severe contamination of persons with radioactive materials, and following any immediate first aid and medical assistance provided, the appropriate authority (see Annex D) should be consulted without delay for advice on the medical management of those persons. Counselling services may need to be provided, whether or not large doses were actually received.

3.10 Health surveillance

Except in the case of accidental exposure to high doses, no specific radiation-related medical examinations are normally required for persons who are occupationally exposed to ionizing radiation, as there are no diagnostic tests which yield information relevant to exposure at low doses. Where required, health surveillance should follow general occupational medical practice for determining fitness for work.
### Schedule A - Dose limits

The dose limits for ionizing radiation shall be as follows:

<table>
<thead>
<tr>
<th>Application</th>
<th>Occupational</th>
<th>Public</th>
</tr>
</thead>
<tbody>
<tr>
<td>Effective dose</td>
<td>20mSv per year, averaged over a period of 5 consecutive calendar years&lt;sup&gt;2,3&lt;/sup&gt;</td>
<td>1 mSv in a year&lt;sup&gt;4&lt;/sup&gt;</td>
</tr>
<tr>
<td>Annual equivalent dose in</td>
<td></td>
<td></td>
</tr>
<tr>
<td>the lens of the eye</td>
<td>150mSv</td>
<td>15mSv</td>
</tr>
<tr>
<td>the skin&lt;sup&gt;5&lt;/sup&gt;</td>
<td>500mSv</td>
<td>50mSv</td>
</tr>
<tr>
<td>the hands and feet</td>
<td>500mSv</td>
<td>-</td>
</tr>
</tbody>
</table>

1. The limits shall 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.

2. With the further provision that the effective dose shall not exceed 50mSv in any single year. In addition, when a pregnancy is declared by a female employee, the embryo or fœtus should be afforded the same level of protection as required for members of the public.

3. When, in exceptional circumstances, a temporary change in the dose limitation requirements is approved by the appropriate authority, one only of the following conditions shall apply: (a) the effective dose limit shall not exceed 50mSv per year for the period, which shall not exceed 5 years, for which the temporary change is approved, or (b) the period for which the 20mSv per year average applies shall not exceed 10 consecutive years and the effective dose shall not exceed 50mSv in any single year.

4. 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 1mSv per year.

5. The equivalent dose limit for the skin applies to the dose averaged over any 1cm<sup>2</sup> area of skin, regardless of the total area exposed.
Schedule B - Exemption criteria

A practice that is most unlikely to give rise to large radiation doses may be exempted by the appropriate authority from regulatory control provided that:

* occupational exposures cannot reasonably be expected to exceed the public annual effective dose limit;
* average exposures of members of the critical group do not exceed one hundredth of the public annual effective dose limit; and
* the collective effective dose arising from the practice does not exceed 1 person-Sv per year.

In circumstances where the criteria specified above are not satisfied due solely to adventitious exposure to natural sources of radiation, practices other than those specifically involving work with radiation may be exempted, as determined by the appropriate authority. In the case of exposure to radon, a practice may be exempted provided that it can be demonstrated that exposures are not expected to exceed the action levels for intervention given in Annex C.
References


Annex A - Glossary of terms

Absorbed dose
the energy absorbed per unit mass by matter from ionizing radiation which impinges upon it (see Annex B).

Accident
an unintended event which causes, or has the potential to cause, employees or members of the public to be exposed to radiation from which the individual doses or collective doses received do not lie within the range of variation which is acceptable for normal operation. An accident may result from human error, equipment failure or other mishap; it may require emergency action to save life or to safeguard health, property or the environment; it requires investigation of its causes and consequences and, possibly, corrective action within the program for control of radiation; and it may require remedial action to mitigate its consequences.

Action level
an intervention level applied to exposure to radiation; when a public exposure action level is consistently exceeded, remedial action to reduce exposure should be considered; when an occupational exposure action level is consistently exceeded within a practice, a program of radiation protection should apply to that practice.

Activity
the measure of quantity of radioactive materials (see Annex B), except when used in the term 'human activity'.

ALARA
an acronym for 'as low as reasonably achievable', used in the context of optimization.

ALI
Annual Limit on Intake (see below).

Alpha particle
a charged particle, consisting of two protons and two neutrons, emitted by the nucleus of a radionuclide during radioactive decay (α-decay).

Annual Limit on Intake
that quantity of a radionuclide which, taken into the body during one year, would lead to a committed effective dose equal to the occupational annual limit on effective dose.

Approval
a written agreement by the appropriate authority that a plan or proposal meets the radiation protection requirements of the Recommendations.

Approved
when applied to a plan or proposal, one which has received approval from the appropriate authority.
Appropriate authority
a statutory or regulatory authority having responsibility for implementing radiation control legislation or any other regulatory instrument which makes use of or refers to the Recommendations.

Authorization
a written agreement by the appropriate authority that a proposal may be put into effect.

Beta particle
an electron or positron emitted by the nucleus of a radionuclide during radioactive decay (β-decay).

Code of practice for radiation protection
a document prescribing specific requirements for radiation protection in a particular application.

Collective effective dose
a measure of the total radiation exposure of a group of people which is obtained by summing their individual effective doses (see Annex B).

Collective equivalent dose
a measure of the total radiation exposure of a specific organ type or tissue type in a group of people which is obtained by summing the equivalent doses received by those individual organs or tissues of the people exposed (see Annex B).

Committed Effective Dose
the effective dose which a person is committed to receive from an intake of a radioactive material (see Annex B).

Committed Equivalent Dose
the equivalent dose which an organ or tissue is committed to receive from an intake of radioactive material (see Annex B).

Constraint
either dose constraint in the case of exposures anticipated to be received, or risk constraint in the case of potential exposures (see dose constraint and risk constraint).

Controlled area
an area to which access is subject to control and in which employees are required to follow specific procedures aimed at controlling exposure to radiation.

Critical group
a group of members of the public comprising individuals who are relatively homogeneous with regard to age, diet and those behavioural characteristics that affect the doses received and who receive the highest radiation doses from a particular practice.

Deterministic effect
an effect, such as partial loss of function of an organ or tissue, caused by radiation and manifest only above some threshold of dose, the severity of the effect depending upon the dose received.
Detriment
a measure, or measures, of harm caused by exposure to radiation and usually taken to mean health detriment; it has no single definition, but can be taken to be an attribute or a collection of attributes which measure harm, such as attributable probability of death and reduction of life expectancy.

Dose
a generic term which may mean absorbed dose, equivalent dose or effective dose depending on context.

Dose constraint
a prospective restriction on anticipated dose, primarily intended to be used to discard undesirable options in an optimization calculation.

in occupational exposure, a dose constraint may be used to restrict the options considered in the design of the working environment for a particular category of employee.

in medical exposure, a dose constraint for volunteers in medical research may be used to restrict the options considered in the design of an experimental protocol.

in public exposure, a dose constraint may be used to restrict the exposure of the critical group from a particular source of radiation.

Effective dose
a measure of dose which takes into account both the type of radiation involved and the radiological sensitivities of the organs and tissues irradiated (see Annex B).

Electron
an elementary particle of mass $9.11 \times 10^{-31}$ kg having a single negative charge.

Employee
a person who works for an employer within an operation.

Employer
an operator who or which engages people to work within an operation; the term employer includes a self-employed person.

Equivalent dose
a measure of dose in organs and tissues which takes into account the type of radiation involved (see Annex B).

Excluded exposure
in the context of occupational exposure, the component of exposure which arises from natural background radiation, provided that any relevant action level, or levels, for the workplace are not exceeded and that the appropriate authority does not prohibit its exclusion.

Exclusion
in the context of assessing radiation exposure, the deliberate omission of a specified component, or components, of total exposure to radiation.

Exemption
the deliberate omission of a practice from regulatory control, or from some aspects of regulatory control, by the appropriate authority.
Exposure

either: the circumstance of being exposed to radiation,
or: a defined dosimetric quantity now no longer used for radiation protection purposes.
(The context in which the word is used should avoid ambiguity.)

Gamma ray

ionizing electromagnetic radiation emitted by a radionuclide during radioactive decay or during a nuclear (isomeric) transition.

Guidance level for medical exposure

a reference level of dose or of administered activity likely to be appropriate for average-sized patients undergoing medical diagnosis or treatment.

Half life

in relation to radioactive decay, the time required for the quantity of a radionuclide to decrease to one half of its initial value.

Incident

an event which causes, or has the potential to cause, abnormal exposure of employees or of members of the public and which requires investigation of its causes and consequences and may require corrective action within the program for control of radiation, but which is not of such scale as to be classified as an accident.

Intervention

action taken to decrease exposures to radiation which arise from existing situations.

Intervention level

a reference level of an environmental or dosimetric quantity, such as absorbed dose rate; if measured values of that quantity are found to consistently exceed the intervention level, remedial action should be considered.

Investigation level

a reference level of an environmental or dosimetric quantity, such as absorbed dose rate; if measured values of that quantity are found to consistently exceed the investigation level, the cause or implications of the situation should be investigated.

Ion

an atom in a charged state following ionization.

Ionization

the process by which one or more electrons are removed from, or sometimes added to, an atom leaving the atom in a charged state.

Ionizing radiation

radiation which is capable of causing ionization, either directly (for example: for radiation in the form of gamma rays and charged particles) or, indirectly (for example: for radiation in the form of neutrons).

Justification

the notion that human activities which lead to exposure to radiation should be justified, before they are permitted to take place, by showing that they are likely to do more good than harm.

Recommendations for limiting exposure to ionizing radiation (1995)

(Guidance note [NOHSC:3022(1995)])
Licence
a written authorization issued to an operator which allows the operator to carry out an operation legally.

Limitation
the requirement that radiation doses and risks should not exceed a value regarded as unacceptable.

Medical exposure
exposure of a person to radiation received as a patient undergoing medical diagnosis or therapy, or as a volunteer in medical research, or non-occupational exposure received as a consequence of assisting an exposed patient.

Muon
an elementary particle of mass $1.88 \times 10^{-28}$ kg having some properties similar to the electron; muons form a major component of cosmic radiation.

Neutron
an elementary particle of mass $1.675 \times 10^{-27}$ kg having some properties similar to the proton but carrying no charge; neutrons are constituents of all nuclei except for the stable isotope of hydrogen.

Occupational exposure
exposure of a person to radiation which occurs in the course of that person's work and which is not excluded exposure.

Operation
an instance of a practice; a particular human activity which may result in exposure to ionizing radiation and to which a program of radiation protection applies.

Operator
any person or entity responsible for an operation which may lead to exposure to ionizing radiation.

Optimization
the process of maximising the net benefit arising from human activities which lead to exposure to radiation.

Positron
an elementary particle of mass $9.11 \times 10^{-31}$ kg having a single positive charge; the anti-particle of the electron.

Practice
a type of human activity; in a radiological context, a human activity which may result in exposure to ionizing radiation and to which a system of radiation protection applies.

Program of radiation protection
an instance of a system of radiation protection, designed for a particular operation.

Proton
an elementary particle of mass $1.673 \times 10^{-27}$ kg having a single positive charge; protons are constituents of all nuclei.

Public exposure
exposure of a person, or persons, to radiation which is neither occupational nor medical exposure.
Recommendations for limiting exposure to ionizing radiation (1995)
(Guidance note [NOHSC:3022(1995)])

Radiation
electromagnetic waves or quanta, and atomic or sub-atomic particles, propagated through space or through a material medium.

Radiation weighting factor
a factor which modifies absorbed dose in an organ or tissue to yield equivalent dose and which is determined by the type and energy of the radiation to which the organ or tissue is exposed (see Annex B).

Radioactive decay
the spontaneous transformation of the nucleus of an atom into another state, accompanied by the emission of radiation; for a quantity of such atoms, the expectation value of the number of atoms present decreases exponentially with time.

Radioactive material
material which spontaneously emits ionizing radiation as a consequence of radioactive decay.

Radionuclide
a species of atomic nucleus which undergoes radioactive decay.

Radon
used generically, all isotopes of the element radon, having atomic number 86, but typically used to refer to the radioactive gas radon-222.

Radon progeny
the short-lived products of the radioactive decay of radon, namely polonium-218, lead-214, bismuth-214, and polonium-214.

Risk constraint
a restriction applied to potential exposure (see dose constraint).

Specific activity
the activity of a radionuclide per unit mass of the element, or the activity of a radioactive material per unit mass of that material.

Stochastic effect
an effect known to occur sometimes as a consequence of exposure to radiation, but which may or may not be expressed in a particular exposed person, the likelihood of the effect occurring being a function of the dose received.

Supervised area
an area in which working conditions are kept under review but in which special procedures to control exposure to radiation are not normally necessary.

System of radiation protection
a generic process of radiation risk management designed to limit the health risks arising from exposure to radiation to acceptable levels in a manner which takes economic and social considerations into account.

Thoron
the radioactive gas radon-220.

Thoron progeny
the short-lived products of the radioactive decay of thoron, namely polonium-216, lead-212, bismuth-212, polonium-212, and thallium-208.
**Tissue weighting factor**

A factor which modifies equivalent dose in an organ or tissue to yield effective dose and which is the partial contribution from the organ or tissue to the total detriment resulting from uniform irradiation of the whole body (see Annex B).

**X-ray**

Ionizing electromagnetic radiation emitted during the transition of an atomic electron to a lower energy state or during the rapid deceleration of a charged particle.
Annex B - Quantities used in radiation protection

Absorbed dose
Absorbed dose, \( D \), is defined by the expression:

\[
D = \frac{dE}{dm}
\]

where \( dE \) is the mean energy imparted by ionizing radiation to matter of mass \( dm \).

The unit of absorbed dose is joule per kilogram (J kg\(^{-1}\)) with the special name gray (Gy).

Activity
Activity, \( A \), is a measure of the amount of a radioactive material given by:

\[
A = \frac{dN}{dt}
\]

where \( dN \) is the expectation value of the number of spontaneous nuclear transitions which take place in the time interval \( dt \). The unit of activity is s\(^{-1}\) with the special name becquerel (Bq).

Collective effective dose
Collective effective dose, \( S_T \), is a measure of the radiation exposure in a population given by the expression:

\[
S_T = \int_0^\infty E \, \frac{dN}{dE} \, dE \quad \text{or} \quad S_T = \sum_i \overline{E_i} N_i
\]

where \( (dN/dE)dE \) is the number of individuals who receive an effective dose between \( E \) and \( E+dE \) and where \( \overline{E_i} \) is the mean effective dose to the population subgroup \( i \) consisting of \( N_i \) individuals.

Collective equivalent dose
Collective equivalent dose, \( S_T \), is a measure of the total radiation exposure of a specific organ type or tissue type in a group of \( N \) individuals given by the expression:

\[
S_T = \int_0^\infty H_T \, \frac{dN}{dH_T} \, dH_T \quad \text{or} \quad S_T = \sum_i H_{T,i} N_i
\]

where \( (dN/dH_T)dH_T \) is the number of individuals receiving an equivalent dose in organ or tissue \( T \) between \( H_T \) and \( H_T+dH_T \), and where \( N_i \) is the number of individuals in population subgroup \( i \) receiving mean organ or tissue equivalent dose \( \overline{H_T} i \).
Committed effective dose
Committed effective dose, \( E(\tau) \), is the effective dose which an individual is committed to receive from an intake of radioactive material over the period subsequent to that intake and is given by the expression:

\[
E(\tau) = \sum_T w_T H_T(\tau)
\]

where \( \tau \) is the period over which the integral of the equivalent dose rate for organ or tissue \( T \) is made to obtain the committed equivalent dose \( H_T(\tau) \). For adults, an integration period of 50 years is assumed; for children, the integration period is taken to age 70.

Committed equivalent dose
Committed equivalent dose, \( H_T(\tau) \), is the equivalent dose which would be received by an organ or tissue from an intake of radioactive material over the period subsequent to that intake and is given by the expression:

\[
H_T(\tau) = \int_0^{\tau+t} H_T(t) \, dt
\]

where \( H_T(t) \) is the relevant equivalent dose rate in organ or tissue \( T \) at time \( t \) and \( \tau \) is the period over which the integration is made. For adults, an integration period of 50 years is assumed; for children, the integration period is taken to age 70.

Effective dose
Effective dose, \( E \), is the sum of weighted equivalent doses in all organs and tissues of the body. It is given by the expression:

\[
E = \sum_T w_T H_T
\]

where \( H_T \) is the equivalent dose in organ or tissue \( T \) and \( w_T \) is the weighting factor for that organ or tissue. The unit of effective dose is the same as for equivalent dose, J kg\(^{-1}\), with the special name sievert (Sv).

Equivalent dose
Equivalent dose, \( H \), is a weighted dose in an organ or tissue, with the radiation weighting factor(s) determined by the type and energy of the radiation to which the organ or tissue is exposed. The equivalent dose \( H_T \) in organ or tissue \( T \) is given by the expression:

\[
H_T = \sum_R w_R D_{TR}
\]

where \( D_{TR} \) is the absorbed dose averaged over the organ or tissue \( T \) due to radiation \( R \) and \( w_R \) is the radiation weighting factor for that radiation. The unit of equivalent dose is the same as for absorbed dose, J kg\(^{-1}\), with the special name sievert (Sv).

Radiation weighting factor
A radiation weighting factor, \( w_R \), is a modifying factor which is applied to an organ or tissue absorbed dose to yield equivalent dose and which depends on the type and energy of the radiation to which the organ or tissue is exposed (see 'equivalent dose' in this Glossary of terms and Table 1).

Tissue weighting factor
A tissue weighting factor, \( w_T \), is a modifying factor which is applied to an organ or tissue equivalent dose to yield a component of effective dose and which depends on the organ or tissue irradiated (see 'effective dose' in this Glossary of terms and Table 2).
Annex C

Recommended action levels for radon-222 concentration in air

<table>
<thead>
<tr>
<th>Application</th>
<th>Action level</th>
</tr>
</thead>
<tbody>
<tr>
<td>(a) Radon concentration in dwellings(^1)</td>
<td>200 Bq m(^{-3})</td>
</tr>
<tr>
<td>(b) Radon concentration in workplaces(^2)</td>
<td>1000 Bq m(^{-3})</td>
</tr>
</tbody>
</table>

1. If measured values are found to consistently exceed this level, consideration should be given to possible remedial action within the context of optimization.

2. If measured long-term average values are found to exceed this level, and are not reduced below this level by intervention, the workplace should be subject to a program of radiation protection.
Annex D - Advisory authorities

Advice and assistance from the relevant statutory authority may be sought by contacting the following offices:

Australian Capital Territory

ACT Health
Radiation Safety Section
GPO Box 825
Canberra ACT 2601

Tel: (06) 2472899
Fax: (06) 257 3503

South Australia

South Australian Health Commission
Radiation Protection Branch
PO Box 6, Rundle Mall
Adelaide SA 5000

Tel: (08) 2266520
Fax: (08) 226 6255

New South Wales

Environment Protection Authority
Radiation Control Section
PO Box 136
Regents Park NSW 2143

Tel: (02) 7955014
Fax: (02) 6494470

Tasmania

Department of Community and Health Services
Health Physics Branch
GPO Box 125B
Hobart TAS 7001

Tel: (002) 33 6421
Fax: (002) 310735

Northern Territory

Department of Health and Community Services
Radiation Health Branch
GPO Box 40596
Casuarina NT 0811

Tel: (089) 892983
Fax: (089) 892700

Victoria

Department of Health and Community Services
Radiation Safety Section
GPO Box 4057
Melbourne VIC 3001

Tel: (03) 94127560
Fax: (03) 94127568
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# Supplement

## Part 1 - Recommended guidance levels for medical exposures

<table>
<thead>
<tr>
<th>Application</th>
<th>Guidance level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mammography: mean glandular dose per single image</td>
<td>2.0mGy</td>
</tr>
</tbody>
</table>

1. A guidance level for medical exposure indicates a dose which, on the basis of experience, would be expected to be typical for an average sized patient in normal circumstances for a particular medical procedure with current good practice. A guidance level is not a dose limit; it does not constitute a breach of the *Recommendations* if a guidance level is exceeded.

2. This supplement will be amended should it become desirable to recommend guidance levels for other applications.

Part 2 - Recommended dose constraints for volunteers R4 in medical research

<table>
<thead>
<tr>
<th>Application</th>
<th>Dose constraint$^{2,3}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adult volunteers in biomedical research:</td>
<td></td>
</tr>
<tr>
<td>cumulative effective dose</td>
<td></td>
</tr>
<tr>
<td>- in any year</td>
<td>5mSv</td>
</tr>
<tr>
<td>- over 5 years</td>
<td>10mSv</td>
</tr>
<tr>
<td>Children exposed in biomedical research:</td>
<td></td>
</tr>
<tr>
<td>cumulative effective dose to age 18 years$^{4}$</td>
<td>5mSv</td>
</tr>
</tbody>
</table>

1 A dose constraint for volunteers in medical research specifies a maximum dose with which it should be possible to comply in normal circumstances and it is intended to apply to volunteers who do not themselves benefit from the exposure. A dose constraint is not a dose limit; it does not constitute a breach of the Recommendations if a dose constraint is exceeded.

2 The dose constraint should apply to the sum over the relevant period of doses received from external exposure and the 50-year committed dose (to age 70 years for children) from intakes over the same period.

3 Any proposal to exceed these values should be referred to the appropriate authority.

4 See Section 2.6 of the Recommendations.
Radiation Health Series

No.1. Recommended radiation protection standards for individuals exposed to ionising radiation (1980) [Superseded by Radiation Health Series No.39]

No.2. Code of practice for the design of laboratories using radioactive substances for medical purposes (1980)


No.5. Recommendations relating to the discharge of patients undergoing treatment with radioactive substances (1983)

No.6. Code of practice on the safe use of lasers in secondary schools (1983) [Superseded by Radiation Health Series No.36]

No.7. Guidelines for the safe use of lasers in the entertainment industry (1983) [Superseded by Radiation Health Series No.37]


No.13. Code of practice for the disposal of radioactive wastes by the user (1985)

No.14. Recommendations for minimising radiological hazards to patients (1985)

No.15. Code of practice for the safe use of microwave diathermy units (1985)


No.17. Procedure for testing microwave leakage from microwave ovens (1985)

No.18. Code of practice for the safe handling of corpses containing radioactive materials (1986)


Recommendations for limiting exposure to ionizing radiation (1995)
(Guidance note [NOHSC:3022(1995)])
No.21. Revised statement on cabinet X-ray equipment for examination of letters, packages, baggage, freight and other articles for security, quality control and other purposes (1987)

No.22. Statement on enclosed X-ray equipment for special applications (1987)

No.23. Code of practice for the control and safe handling of radioactive sources used for therapeutic purposes (1988)


No.25. Recommendations for ionization chamber smoke detectors for commercial and industrial fire protection systems (1988)


No.27. Australia's radiation protection standards (1989) [Superseded by Radiation Health Series No.39]


No.30. Interim guidelines on limits of exposure to 50/60Hz electric and magnetic fields (1989)


No.32. Intervention in emergency situations involving radiation exposure (1990)

No.33. Interim statement on Australia's radiation protection standards (1991) [Superseded by Radiation Health Series No.39]

No.34. Safety guidelines for magnetic resonance diagnostic facilities (1991)


No.38. Recommended limits on radioactive contamination on surfaces in laboratories (1995)

No.39. Recommendations for limiting exposure to ionizing radiation (1995) and National standard for limiting occupational exposure to ionizing radiation

*Recommendations for limiting exposure to ionizing radiation (1995)*

*(Guidance note [NOHSC:3022(1995)])*