



RECOMMENDATIONS
& NATIONAL STANDARD

**Recommendations for Limiting
Exposure to Ionizing Radiation (1995)
(Guidance Note [NOHSC:3022(1995)])
and
National Standard for Limiting
Occupational Exposure to Ionizing
Radiation
[NOHSC:1013(1995)]**

Republished March 2002

RADIATION PROTECTION SERIES No. 1

Radiation Protection Series

The ***Radiation Protection Series*** is published by the Australian Radiation Protection and Nuclear Safety Agency (ARPANSA) to promote practices which protect human health and the environment from the possible harmful effects of radiation. ARPANSA is assisted in this task by its Radiation Health and Safety Advisory Council, which reviews the publication program for the ***Series*** and endorses documents for publication, and by its Radiation Health Committee, which oversees the preparation of draft documents and recommends publication.

There are four categories of publication in the ***Series***:

Radiation Protection Standards set fundamental requirements for safety. They are prescriptive in style and may be referenced by regulatory instruments in State, Territory or Commonwealth jurisdictions. They may contain key procedural requirements regarded as essential for best international practice in radiation protection, and fundamental quantitative requirements, such as exposure limits.

Codes of Practice are also prescriptive in style and may be referenced by regulations or conditions of licence. They contain practice-specific requirements that must be satisfied to ensure an acceptable level of safety in dealings involving exposure to radiation. Requirements are expressed in 'must' statements.

Recommendations provide guidance on fundamental principles for radiation protection. They are written in an explanatory and non-regulatory style and describe the basic concepts and objectives of best international practice. Where there are related **Radiation Protection Standards** and **Codes of Practice**, they are based on the fundamental principles in the **Recommendations**.

Safety Guides provide practice-specific guidance on achieving the requirements set out in **Radiation Protection Standards** and **Codes of Practice**. They are non-prescriptive in style, but may recommend good practices. Guidance is expressed in 'should' statements, indicating that the measures recommended, or equivalent alternatives, are normally necessary in order to comply with the requirements of the **Radiation Protection Standards** and **Codes of Practice**.

In many cases, for practical convenience, prescriptive and guidance documents which are related to each other may be published together. A **Code of Practice** and a corresponding **Safety Guide** may be published within a single set of covers.

All publications in the Radiation Protection Series are informed by public comment during drafting, and Radiation Protection Standards and Codes of Practice, which may serve a regulatory function, are subject to a process of regulatory review. Further information on these consultation processes may be obtained by contacting ARPANSA.

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exposure to ionizing
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National standard for limiting
occupational exposure
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Radiation Protection Series Publication No. 1

Republished March 2002

This publication is identical with the NHMRC's
Radiation Health Series No. 39 (1995)
apart from the material referred to in the Foreword.
It has been retitled as Radiation Protection Series No. 1
to reflect the discontinuation of the Radiation Health Series

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The mission of ARPANSA is to provide the scientific expertise and infrastructure necessary to support the objective of the ARPANS Act – to protect the health and safety of people, and to protect the environment, from the harmful effects of radiation.

Published by the Chief Executive Officer of ARPANSA in March 2002.

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 and, formerly, published radiation protection recommendations in its *Radiation Health Series*.

The Australian Radiation Protection and Nuclear Safety Agency (ARPANSA) is a Commonwealth Government agency within the Health portfolio charged with responsibility for protecting the health and safety of people and the environment from the harmful effects of radiation. Under the *Australian Radiation Protection and Nuclear Safety Act 1998* (the ARPANS Act), the CEO of ARPANSA has, among other functions, a responsibility for promoting uniformity of radiation protection and nuclear safety policy and practices across jurisdictions of the Commonwealth, the States and the Territories, and for providing advice on radiation protection and nuclear safety matters.

The Radiation Health Committee, established under the ARPANS Act, has responsibilities inter alia to advise the CEO of ARPANSA and to develop policies and prepare draft publications, including codes and standards, related to radiation protection. Radiation Health Committee members include radiation control officers from each State and Territory, independent experts and a person represent the interests of the general public.

The National Occupational Health and Safety Commission (NOHSC) 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.

The *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.

The *Recommendations* and the *Standard* were originally published jointly by NHMRC and NOHSC in 1995 as Publication No. 39 in the NHMRC *Radiation Health Series*. The NHMRC has discontinued its *Radiation Health Series* and the *Recommendations* and the *Standard* are now re-published as Publication No. 1 in the ARPANSA *Radiation Protection Series*, following a recommendation of the Radiation Health Committee and by agreement between ARPANSA and NOHSC. Except as indicated in the paragraph below, the text of *Radiation Protection Series No. 1* is identical with that of the former Radiation Health Series No. 39. As appropriate, a reference to NHMRC in either the *Recommendations* or the *Standard* should now be taken as a reference to ARPANSA.

Since 1995 there has been further discussion by health authorities and by the Radiation Health Committee about the use of the 'exceptional circumstances' provision referred to in Section 2.5 and Note 3 of Schedule A of the *Recommendations* and in Note 2 of Schedule 1 of the *Standard*. This provision was intended to give some flexibility in approach in the mining industry and in developing new medical procedures, without compromising long term safety. However, the provision has not been taken up within Australian jurisdictions and the Radiation Health Committee now believes that such flexibility is neither required nor desirable. The Radiation Health Committee recommends that Australian jurisdictions should not make use of the provision, and a footnote to that effect has been included in Schedule A of the *Recommendations* and Schedule 1 of the *Standard*.

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Recommendations for limiting
exposure to ionizing
radiation (1995)
(Guidance note
[NOHSC:3022(1995)])

Radiation Protection Series Publication No. 1

(These Recommendations supersede the NHMRC's Recommended
radiation protection standards for individuals exposed to
ionising radiation, 1980)

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Preface

The National Health and Medical Research Council (NHMRC) recognises 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 ionising 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 60² superseding ICRP Publication 26³, 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 development of codes of practice and guidelines, and revision of existing *Radiation 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 60², 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 R . 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 factors¹
(from ICRP Publication 60)

Type and energy range ²	Radiation weighting factor, w_R
Photons, all energies	1
Electrons and muons, all energies ³	1
Neutrons ⁴ , energy <10 keV	5
10 keV to 100 keV	10
> 100 keV to 2 MeV	20
> 2 MeV to 20 MeV	10
> 20 MeV	5
Protons, other than recoil protons, energy >2 MeV	5
Alpha particles, fission fragments, heavy nuclei	20

- 1 All values relate to the radiation incident on the body or, for internal sources, emitted from the source.
- 2 The choice of values for other radiations is discussed in 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, **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 **detriment** resulting from the exposure to radiation is represented by a **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 *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 **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 **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 factors¹
(from ICRP Publication 60)

Tissue or organ	Tissue weighting factor, w_T
Gonads	0.20
Bone marrow (red)	0.12
Colon	0.12
Lung	0.12
Stomach	0.12
Bladder	0.05
Breast	0.05
Liver	0.05
Oesophagus	0.05
Thyroid	0.05
Skin	0.01
Bone surface	0.01
Remainder	0.05 ^{2,3}

- 1 The values have been developed 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 60². 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 60².

- No practice involving exposures to radiation should be adopted unless it produces sufficient benefit to the exposed individuals or to society to offset the radiation detriment it causes. (The justification of a practice.)
- 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 60², 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 maximised.”

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 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 foetus 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 foetus 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 limit¹ 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 document⁴ 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 mammography⁵, 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 NHMRC⁶ 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 of 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 recommended⁷ 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 dosimeters 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^{8,9} 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 persons¹⁰. 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.

**Recommendations
Limiting exposure to ionizing radiation**

Schedule A - Dose limits

The dose limits for ionizing radiation shall be as follows:

Application	Dose limit ¹	
	Occupational	Public
Effective dose	20 mSv per year, averaged over a period of 5 consecutive calendar years ^{2,3}	1 mSv in a year ⁴
Annual equivalent dose in the lens of the eye	150 mSv	15 mSv
the skin ⁵	500 mSv	50 mSv
the hands and feet	500 mSv	-

- 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 50 mSv in any single year. In addition, when a pregnancy is declared by a female employee, the embryo or foetus 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 50 mSv 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 20 mSv per year average applies shall not exceed 10 consecutive years and the effective dose shall not exceed 50 mSv 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 1 mSv per year.
- 5 The equivalent dose limit for the skin applies to the dose averaged over any 1 cm² area of skin, regardless of the total area exposed.

* In 2001, the Radiation Health Committee advised that the provision for exceptional circumstances was not recommended for use in Australia (see Foreword).

**Recommendations
Limiting exposure to ionizing radiation**

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.

**Recommendations
Limiting exposure to ionizing radiation**

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**Recommendations
Limiting exposure to ionizing radiation**

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 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 9.11×10^{-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.

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 1.88×10^{-28} kg having some properties similar to the electron; muons form a major component of cosmic radiation.

Neutron

an elementary particle of mass 1.675×10^{-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 9.11×10^{-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 1.673×10^{-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.

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 , is a measure of the radiation exposure in a population given by the expression:

$$S = \int_0^{\infty} E \frac{dN}{dE} dE \quad \text{or} \quad S = \sum_i \bar{E}_i N_i$$

where $(dN/dE)dE$ is the number of individuals who receive an effective dose between E and $E+dE$ and where \bar{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:

$$S_T = \int_0^{\infty} H_T \frac{dN}{dH_T} dH_T \quad \text{or} \quad S_T = \sum_i \bar{H}_{T,i} N_i$$

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 $\bar{H}_{T,i}$.

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 τ 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:

$$H_T(\tau) = \int_{t_0}^{t_0+\tau} \dot{H}_T(t) dt$$

where $\dot{H}_T(t)$ is the relevant equivalent dose rate in organ or tissue T at time t and τ 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:

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

where $D_{T,R}$ 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

Application	Action level
(a) Radon concentration in dwellings ¹	200 Bq m ⁻³
(b) Radon concentration in workplaces ²	1000 Bq m ⁻³

- 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.

**Recommendations
Limiting exposure to ionizing radiation**

Annex D - Advisory authorities

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

COMMONWEALTH STATE/TERRITORY	CONTACT
Commonwealth	Director, Regulatory Branch ARPANSA PO Box 655 Miranda NSW 1490 Email: arpansa@health.gov.au Tel: (02) 9545 8333 Fax: (02) 9545 8348
Australian Capital Territory	Secretary, ACT Radiation Council Department of Health, Housing and Community Care GPO Box 825 Canberra ACT 2601 Email: radiation.safety@act.gov.au Tel: (02) 6207 6946 Fax: (02) 6207 6966
New South Wales	Director, Radiation Control Section NSW Environment Protection Authority PO Box A290 Sydney South NSW 1232 Email: info@epa.nsw.gov.au Tel: (02) 9995 5000 Fax: (02) 9995 6603
Northern Territory	Manager, Radiation Health Radiation Health Section Department of Health & Community Services GPO Box 40596 Casuarina NT 0811 Email: envirohealth@nt.gov.au Tel: (08) 8999 2939 Fax: (08) 8999 2530
Queensland	Director, Radiation Health Department of Health 450 Gregory Terrace Fortitude Valley QLD 4006 Email: radiation_health@health.qld.gov.au Tel: (07) 3406 8000 Fax: (07) 3406 8030
South Australia	Manager, Radiation Section Department of Human Services PO Box 6 Rundle Mall Adelaide SA 5000 Email: radiation@dhs.sa.gov.au Tel: (08) 8130 0700 Fax: (08) 8130 0777
Tasmania	Senior Health Physicist Department of Health & Human Services GPO Box 125B Hobart TAS 7001 Email: health.physics@dchs.tas.gov.au Tel: (03) 6222 7256 Fax: (03) 6222 7257
Victoria	Manager, Radiation Safety Unit Department of Human Services GPO Box 4057 Melbourne VIC 3001 Email: radiation.safety@dhs.vic.gov.au Tel: (03) 9637 4167 Fax: (03) 9637 4508
Western Australia	The Secretary Radiological Council Locked Bag 2006 Nedlands WA 6009 Email: radiation.health@health.wa.gov.au Tel: (08) 9346 2260 Fax: (08) 9381 1423

Annex D was correct at the time of printing but is subject to change from time to time. For the most up to date list, the reader is advised to consult the ARPANSA web site, www.arpansa.gov.au.

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Supplement

Part 1 - Recommended guidance levels for medical exposures¹

Application ²	Guidance level
Mammography: mean glandular dose per single image ³	2.0 mGy

- 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.
- 3 Using an anti-scatter grid. A detailed recommendation is contained in the Report of the 111th Session of the National Health and Medical Research Council, June 1991.

Part 2 - Recommended dose constraints for volunteers in medical research¹

Application	Dose constraint^{2,3}
Adult volunteers in biomedical research: cumulative effective dose	
- in any year	5 mSv
- over 5 years ⁴	10 mSv
Children exposed in biomedical research: cumulative effective dose to age 18 years ⁴	5 mSv

- 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*.

ARPANSA Radiation Protection Series Publications

ARPANSA has taken over responsibility for the administration of the former NHMRC Radiation Health Series of publications and for the codes developed under the *Environment Protection (Nuclear Codes) Act 1978*. The publications are being progressively reviewed and republished as part of the *Radiation Protection Series*. Current publications in the Radiation Protection Series are:

- RPS 1. Recommendations for Limiting Exposure to Ionizing Radiation (1995) and National Standard for Limiting Occupational Exposure to Ionizing Radiation (republished 2002)
- RPS 2. Code of Practice for the Safe Transport of Radioactive Material (2001)

Those publications from the NHMRC Radiation Health Series and the Environment Protection (Nuclear Codes) Act Series that are still current are:

Radiation Health Series

- RHS 2. Code of practice for the design of laboratories using radioactive substances for medical purposes (1980)
- RHS 3. Code of practice for the safe use of ionizing radiation in veterinary radiology: Parts 1 and 2 (1982)
- RHS 4. Code of practice for the safe use of radiation gauges (1982)
- RHS 5. Recommendations relating to the discharge of patients undergoing treatment with radioactive substances (1983)
- RHS 8. Code of nursing practice for staff exposed to ionizing radiation (1984)
- RHS 9. Code of practice for protection against ionizing radiation emitted from X-ray analysis equipment (1984)
- RHS 10. Code of practice for safe use of ionizing radiation in veterinary radiology: part 3-radiotherapy (1984)
- RHS 11. Code of practice for the safe use of soil density and moisture gauges containing radioactive sources (1984)
- RHS 12. Administration of ionizing radiation to human subjects in medical research (1984)
- RHS 13. Code of practice for the disposal of radioactive wastes by the user (1985)
- RHS 14. Recommendations for minimising radiological hazards to patients (1985)
- RHS 15. Code of practice for the safe use of microwave diathermy units (1985)
- RHS 16. Code of practice for the safe use of short wave (radiofrequency) diathermy units (1985)
- RHS 17. Procedure for testing microwave leakage from microwave ovens (1985)
- RHS 18. Code of practice for the safe handling of corpses containing radioactive materials (1986)
- RHS 19. Code of practice for the safe use of ionizing radiation in secondary schools (1986)

**Radiation
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No. 1**

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- RHS 20. Code of practice for radiation protection in dentistry (1987)
- RHS 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)
- RHS 22. Statement on enclosed X-ray equipment for special applications (1987)
- RHS 23. Code of practice for the control and safe handling of radioactive sources used for therapeutic purposes (1988)
- RHS 24. Code of practice for the design and safe operation of non-medical irradiation facilities (1988)
- RHS 25. Recommendations for ionization chamber smoke detectors for commercial and industrial fire protection systems (1988)
- RHS 26. Policy on stable iodine prophylaxis following nuclear reactor accidents (1989)
- RHS 28. Code of practice for the safe use of sealed radioactive sources in bore-hole logging (1989)
- RHS 29. Occupational standard for exposure to ultraviolet radiation (1989)
- RHS 30. Interim guidelines on limits of exposure to 50/60Hz electric and magnetic fields (1989)
- RHS 31. Code of practice for the safe use of industrial radiography equipment (1989)
- RHS 32. Intervention in emergency situations involving radiation exposure (1990)
- RHS 34. Safety guidelines for magnetic resonance diagnostic facilities (1991)
- RHS 35. Code of practice for the near-surface disposal of radioactive waste in Australia (1992)
- RHS 36. Code of practice for the safe use of lasers in schools (1995)
- RHS 37. Code of practice for the safe use of lasers in the entertainment industry (1995)
- RHS 38. Recommended limits on radioactive contamination on surfaces in laboratories (1995)

Environment Protection (Nuclear Codes) Act Series

Code of Practice on the Management of Radioactive Wastes from the Mining and Milling of Radioactive Ores 1982

Code of Practice on Radiation Protection in the Mining and Milling of Radioactive Ores 1987



National standard for
limiting occupational exposure
to ionizing radiation
[NOHSC:1013(1995)]

June 1995

The National Occupational Health and Safety Commission has declared a *National standard for limiting occupational exposure to ionizing radiation.*

National Standards declared by the National Commission under s.38(1) of the *National Occupational Health and Safety Commission Act 1985* (Cwlth) are documents which prescribe preventive action to avert occupational deaths, injuries and diseases. Most national standards deal with the elimination/reduction or management of specific workplace hazards. In appropriate circumstances, national standards may take the form of national model regulations.

The expectation of the Commonwealth Government and the National Commission is that national standards will be suitable for adoption by Commonwealth, State and Territory governments. Such action will increase uniformity in the regulation of occupational health and safety throughout Australia and contribute to the enhanced efficiency of the Australian economy. It should be noted that National Commission documents are instruments of an advisory character, except where a law, other than the National Occupational Health and Safety Commission Act, or an instrument made under such a law, makes them mandatory. The application of any National Commission document in any particular State or Territory is the prerogative of that State or Territory.

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**Radiation
Protection
Series
No. 1**

**National Standard
Limiting occupational exposure to ionizing radiation**

Preface

This *National standard for limiting occupational exposure to ionizing radiation* will serve to identify the provisions which are to be made in the regulations of States, Territories and the Commonwealth for the control of occupational exposure to radiation. It is recognised that legislation, including regulations, may already exist which covers all or part of the scope of this *Standard*. It is also recognised that it may not be appropriate to take up this *Standard* verbatim because of differing legislative frameworks and drafting conventions in each State and Territory and in the Commonwealth. However, it is expected that the implementation of the provisions contained in this *Standard* will be nationally consistent. This *Standard* deals only with occupational health and safety matters related to exposure to ionizing radiation; the appropriate authority should be consulted about other radiation control requirements which may apply.

The complementary *Recommendations for limiting exposure to ionizing radiation (1995)* is a guidance note which describes the principles and practice on which this *Standard* is based and provides interpretive and reference material. Technical terms used in this *Standard* have the meaning given in the Glossary. It should be noted that one of the established principles of radiation protection is the concept of 'optimization' of exposure to ionizing radiation, that is, the requirement to keep exposures as low as reasonably achievable; economic and social factors being taken into account. This concept is compatible with occupational health and safety standards in other fields which require safety measures to be undertaken to an extent that is 'practicable'. Optimization of protection is also compatible with the concept of minimizing risk to health, used in other occupational health and safety contexts.

In applying the requirements of the *Standard* relating to pregnant employees, care should be taken to avoid unlawful discrimination on the basis of sex. Men and women may be treated differently for a legitimate reason, provided that it involves no less favourable treatment for one or the other.

The *Standard* and the *Recommendations* were developed by an Expert Working Group on behalf of both the National Occupational Health and Safety Commission (NOHSC) and the National Health and Medical Research Council (NHMRC), and were released for a three-month period of public comment from May to July 1994. Comments relating to occupational exposure and to the *Standard* were reviewed by a joint NHMRC/NOHSC Expert Review Group, and all the public comments together with the joint Expert Review Group report were reviewed by the Radiation Health Standing Committee of the NHMRC. 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 NOHSC with the recommendation that it be forwarded to the Council and to the National Commission.

The National Commission, having ensured that the public comment on the draft had been taken into account, now declares this *National standard for limiting occupational exposure to ionizing radiation* under s.38(1) of the National Occupational Health and Safety Commission Act 1985. The Standard is endorsed by the National Health and Medical Research Council. Adoption of this *Standard* will promote a consistent basis for the control of exposure to ionizing radiation in workplaces throughout Australia. The *Standard* will be subject to periodic review.

1. Citation

1.1 This Standard may be cited as the *National standard for limiting occupational exposure to ionizing radiation (1995)*.

2. Objective

2.1 The objectives of this *Standard* are to limit the risk to health arising from exposure to ionizing radiation in the workplace and to optimize radiation protection by setting common essential requirements for the control of exposure to radiation, including the specification of employer's duties and employee's duties.

3. Scope and application

3.1 This Standard shall apply to all workplaces in which employees are occupationally exposed, or in which there is a potential for occupational exposure, to ionizing radiation, unless exempted by the appropriate authority. A workplace may be exempted from implementing the measures required by this *Standard* if the exemption criteria given in **Schedule 2** are met.

3.2 When exposure to ionizing radiation occurs, or may occur, in a workplace to which the *Standard* has not been applied, the employees in that workplace shall be treated as members of the public for dose limitation purposes by the operator responsible for the operation which causes the exposure.

4. Interpretation

4.1 This *Standard* is based on the principles described in the *Recommendations for limiting exposure to ionizing radiation (1995)* and terms used in this *Standard* have the meaning given in the *Recommendations*. In addition, the words 'shall' and 'should' have a special meaning. 'Shall' indicates that the requirement to which it refers is considered to be mandatory. 'Should' indicates a recommendation - that is, a requirement that is to be applied as far as is practicable in the interests of reducing risk.

5. Employers' duties

5.1 An employer shall ensure that a program of radiation protection is devised and implemented. In fulfilling this requirement, the employer shall:

- (a) ensure that, at the planning stage of an operation, 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, making use of dose constraints, where appropriate, for particular categories of employee, including employees not directly involved in work with radiation (see Chapter 7);
- (b) obtain all necessary approvals and authorizations for the practice from the appropriate authority (see Chapter 8);

- (c) appoint a Radiation Safety Officer, or Officers, as required by the appropriate authority;
- (d) provide for consultation with employees who may be exposed to radiation in their work, and with employees' representatives, where appropriate;
- (e) provide information to and appropriate induction and on-going training for employees who may be exposed to radiation in their work (see Chapter 9);
- (f) ensure that a plan for the control of exposure to radiation is developed, approved, implemented and regularly reviewed, and that the workforce is consulted in the planning and review process (see Chapter 10);
- (g) ensure that all necessary resources for implementing the plan for the control of exposure are provided, including personal protective equipment and radiation monitoring equipment;
- (h) ensure that a plan for monitoring exposure to radiation and for assessing radiation doses received by those exposed is developed, approved, implemented and regularly reviewed (see Chapter 11);
- (i) endeavour to ensure that exposure to radiation in the workplace is kept as low as reasonably achievable, economic and social factors being taken into account;
- (j) not employ persons under the age of 16 under conditions where they are directly involved in work with radiation;
- (k) demonstrate that the doses estimated to have been received by employees comply with the dose limits specified in **Schedule 1** (see Chapter 12);
- (l) demonstrate that, where a dose constraint has been adopted in the design of the working environment for employees not directly involved in work with radiation, the level of protection achieved is compatible with that constraint (see Chapter 12);
- (m) when an employee declares that she is pregnant, ensure that appropriate measures are taken to control her exposure so that doses which may be received by the foetus during the remainder of the pregnancy, while the employee is at work, are consistent with the public effective dose limit specified in **Schedule A** of the *Recommendations*;
- (n) when an employee reports a matter which may compromise radiation protection, as required in Subsection 6.1(g), ensure that appropriate action is taken to investigate and, if necessary, rectify the problem;
- (o) ensure that a plan for dealing with incidents, accidents and emergencies involving exposure to radiation is developed, approved, implemented and regularly reviewed, and that the workforce is consulted in the planning and review process (see Chapter 13);

- (p) inform the appropriate authority without delay of the occurrence of an incident or accident and, as soon as practicable, of its cause and consequences and of the steps taken to remedy the situation and to prevent a recurrence (see Chapter 13);
- (q) keep records relating to exposure of the workforce (see Chapter 14);
- (r) provide copies of an employee's dose records to the employee on request and on termination of employment; and
- (s) provide a periodic report to the appropriate authority, as required, evaluating the performance of the radiation protection program.

5.2 The employer may seek an exemption from some of these requirements, where they are not all appropriate in a particular circumstance, by making application to the appropriate authority.

6. Employees' duties

6.1 Employees who may be exposed to radiation in the workplace shall, to the extent that they are capable, comply with all reasonable measures to control and assess exposure to radiation in the workplace, including:

- (a) following the radiation protection practices specified in the plan for the control of exposure to radiation;
- (b) complying with the legitimate instructions of the employer, the Radiation Safety Officer or their agents, in relation to radiation protection;
- (c) participating in training related to radiation protection, as required;
- (d) making proper use of the training received to ensure their own health and safety and that of other persons;
- (e) making proper use of protective and monitoring equipment provided by the employer;
- (f) upon employment, providing to the employer, or assisting the employer in obtaining, details of their prior radiation exposure, as necessary; and
- (g) reporting to the employer, the Radiation Safety Officer or their agents any matter of which they are aware which may compromise radiation protection.

6.2 An employee who becomes pregnant should advise the employer as soon as practicable, so that appropriate measures may be taken to control her exposure and to provide the level of protection recommended in Subsection 5.1(m).

7. Planning and design

7.1 The employer shall ensure that the workplace and work procedures are designed to keep exposure to radiation as low as reasonably achievable and to keep doses received below the relevant dose limits. Dose constraints

for particular categories of employee should be used when appropriate. For employees not directly involved in work with radiation, a dose constraint shall be adopted which shall normally be related to the public effective dose limit specified in the *Recommendations*.

7.2 A program of radiation protection shall be devised which shall include:

- a plan for the control of exposure to radiation in the workplace;
- a plan for monitoring radiation exposure and for assessing the doses received by exposed employees; and
- a plan for dealing with incidents, accidents and emergencies involving exposure to radiation.

8. Approvals and authorizations

8.1 The employer shall obtain approvals and authorizations, as necessary, from the appropriate authority before putting into operation a practice which may expose employees to ionizing radiation and before varying operations within a practice in a manner which may significantly increase exposures to radiation.

9. Induction and training

9.1 The employer shall provide induction and on-going training to all employees who may be exposed to ionizing radiation in their work. The extent of training shall be consistent with the type and degree of risk associated with the proposed duties of the employee. Induction and training shall be carried out in a manner appropriate to the participating employees.

9.2 Induction and training programs shall be documented, and employee participation shall be recorded.

10. Control of exposure to radiation

10.1 The employer shall ensure that the plan for control of exposure to radiation in the workplace is based on a hierarchy of controls, including:

- avoidance of exposure, where practicable;
- isolation of sources of radiation, where practicable, through shielding, containment and remote handling techniques;
- engineering controls to reduce radiation levels and intakes of radioactive materials in the workplace;
- adoption of safe work practices, including work methods that make use of time, distance and shielding to minimize exposure; and
- where other means of controlling exposure are not practicable or not sufficient, the use of approved personal protective equipment.

10.2 Other measures should be used when appropriate, including:

- the designation of controlled areas and supervised areas;
- the use of appropriate signs and labels; and
- the use of investigation levels of exposure for specific categories of work.

11. Radiation monitoring and dose assessment

11.1 The employer shall ensure that a radiation monitoring program is designed, approved, implemented and regularly reviewed. The program shall provide for:

- identification of relevant sources of radiation exposure within a workplace;
- assessment of the radiation doses received by employees, including determination of parameters which affect the assessed dose, as required by the appropriate authority;
- detection of changes in the circumstances of exposure, as necessary; and
- acquisition of sufficient information on radiation exposure in the workplace to enable optimization measures to be adopted.

11.2 Dose assessments shall be made for all relevant employees, using the methodology approved by the appropriate authority.

12. Assessment of compliance with the *Standard*

12.1 To comply with this *Standard* the employer shall demonstrate that:

- all doses estimated to have been received by employees in the workplace are below the relevant limit in **Schedule 1**;
- where a dose constraint has been adopted in the design of the working environment for employees not directly involved in work with radiation, the level of protection achieved is compatible with that constraint;
- optimization of protection has been carried out, as required by the appropriate authority; and
- all other requirements of this *Standard* have been met.

13. Emergencies, accidents and incidents

13.1 In circumstances where exposure to high doses of radiation or severe contamination with radioactive materials might occur in the workplace, the employer shall ensure that comprehensive emergency plans are prepared, as required by the appropriate authority. The plans shall include provision for:

- availability of trained personnel and emergency equipment;
- specified procedures to bring the situation under control;
- assessment of doses received as a consequence of an incident or accident;
- access to appropriate medical care of overexposed persons; and
- acquisition of information for assessing the cause of the incident or accident.

13.2 All incidents and accidents shall be reported without delay to the appropriate authority. The appropriate authority shall be advised as soon as is practicable of the cause of the incident or accident, its consequences and the steps taken to remedy the situation and to prevent a recurrence.

13.3 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 shall be consulted without delay for advice on the medical management of those exposed. Appropriate counselling shall be provided to the persons affected.

13.4 Corrective measures shall be taken, as necessary, to bring an accident under control and to prevent a recurrence. Doses received by employees who volunteer to take part in emergency action to save lives or to bring an accident under control shall be restricted to ensure that deterministic effects are avoided; these doses shall be treated separately from the employees' normal occupational exposures. Once an accident has been brought under control, doses received during any further remedial work shall be treated as occupational exposure.

14. Record keeping

14.1 For all practices to which this Standard applies, the employer shall ensure that a record keeping system is implemented, as required by the appropriate authority. Records shall include the following, as appropriate:

- approvals and authorizations granted by the appropriate authority;
- specifications of the plans for control of radiation exposure in the workplace;
- specifications of the plans for radiation monitoring and dose assessment;
- specifications of the plans for dealing with emergencies and accidents;
- details of training courses and of participation by employees;

- doses assessed to have been received by employees who work directly with radiation and by other employees as required by the appropriate authority, including details of monitoring results and of dose calculation methods, as required by the appropriate authority; and
- details of incidents and accidents involving exposure to radiation and of corrective measures taken.

14.2 Records shall be made available for inspection by the appropriate authority and shall be kept for a period of time specified by the appropriate authority. Records of doses assessed to have been received by an employee, including details of monitoring results and dose calculation methods, as required by the appropriate authority, shall be kept during the working life of the employee and afterwards for not less than 30 years after the last dose assessment and at least until the employee reaches, or would have reached, the age of 75 years. When an operation terminates, the employer shall pass to the appropriate authority the retained records of doses assessed to have been received by employees and any other records specified by the appropriate authority.

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Schedule 1

Occupational dose limits

Effective dose limit ¹	20 mSv per year, averaged over a period of 5 consecutive calendar years ^{2,3}
Effective dose limit in a single year ¹	50 mSv
Equivalent dose limit in the lens of the eye	150 mSv per year
in the skin ⁴	500 mSv per year
in the hands and feet	500 mSv per year

- 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 from intakes in the same period.
 - 2 Subject to any special limit set by the appropriate authority when it is satisfied that exceptional circumstances* exist, as specified in the *Recommendations*. 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 50 mSv 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 20 mSv per year average applies shall not exceed 10 consecutive years and the effective dose shall not exceed 50 mSv in any single year.
 - 3 When an employee declares that she is pregnant, the embryo or foetus should be afforded the same level of protection as required for members of the public, as specified in the *Recommendations*.
 - 4 The equivalent dose limit for the skin applies to the dose averaged over any 1 cm² area of skin, regardless of the total area exposed.
- * In 2001, the Radiation Health Committee advised that the provision for exceptional circumstances was not recommended for use in Australia (see Foreword).

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Schedule 2

Exemption criteria

General criterion

A practice may be exempted by the appropriate authority from implementing the measures required by this Standard provided that it can be demonstrated that individual occupational effective doses arising from the practice cannot reasonably be expected to exceed 1 mSv per year.

Criterion applicable to natural sources of radiation

In circumstances where the general criterion is 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 in the workplace, a practice may be exempted provided that it can be demonstrated that the action levels for intervention given in Annex C of the *Recommendations* are not expected to be exceeded.

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Relevant authorities

A. Authorities responsible for radiation control legislation.

COMMONWEALTH STATE/TERRITORY	CONTACT
Commonwealth	Director, Regulatory Branch ARPANSA PO Box 655 Miranda NSW 1490 Tel: (02) 9545 8333 Fax: (02) 9545 8348 Email: arpansa@health.gov.au
Australian Capital Territory	Secretary, ACT Radiation Council Department of Health, Housing and Community Care GPO Box 825 Canberra ACT 2601 Tel: (02) 6207 6946 Fax: (02) 6207 6966 Email: radiation.safety@act.gov.au
New South Wales	Director, Radiation Control Section NSW Environment Protection Authority PO Box A290 Sydney South NSW 1232 Tel: (02) 9995 5000 Fax: (02) 9995 6603 Email: info@epa.nsw.gov.au
Northern Territory	Manager, Radiation Health Radiation Health Section Department of Health & Community Services GPO Box 40596 Casuarina NT 0811 Tel: (08) 8999 2939 Fax: (08) 8999 2530 Email: envirohealth@nt.gov.au
Queensland	Director, Radiation Health Department of Health 450 Gregory Terrace Fortitude Valley QLD 4006 Tel: (07) 3406 8000 Fax: (07) 3406 8030 Email: radiation_health@health.qld.gov.au
South Australia	Manager, Radiation Section Department of Human Services PO Box 6 Rundle Mall Adelaide SA 5000 Tel: (08) 8130 0700 Fax: (08) 8130 0777 Email: radiation@dhs.sa.gov.au
Tasmania	Senior Health Physicist Department of Health & Human Services GPO Box 125B Hobart TAS 7001 Tel: (03) 6222 7256 Fax: (03) 6222 7257 Email: health.physics@dchs.tas.gov.au
Victoria	Manager, Radiation Safety Unit Department of Human Services GPO Box 4057 Melbourne VIC 3001 Tel: (03) 9637 4167 Fax: (03) 9637 4508 Email: radiation.safety@dhs.vic.gov.au
Western Australia	The Secretary Radiological Council Locked Bag 2006 Nedlands WA 6009 Tel: (08) 9346 2260 Fax: (08) 9381 1423 Email: radiation.health@health.wa.gov.au

The table above was correct at the time of printing but is subject to change from time to time. For the most up to date list, the reader is advised to consult the ARPANSA web site, www.arpansa.gov.au.

B. Authorities responsible for occupational health and safety legislation

An up to date list of jurisdictional authorities responsible for occupational health and safety legislation is available at the National Occupational Health and Safety Commission (NOHSC) website:

www.nohsc.gov.au

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