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Australian Government

**Australian Radiation Protection
and Nuclear Safety Agency**

CODE OF PRACTICE & SAFETY GUIDE

Radiation Protection and Radioactive Waste Management in Mining and Mineral Processing



RADIATION PROTECTION SERIES No. 9

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.



Australian Government

Australian Radiation Protection and Nuclear Safety Agency

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**Radiation Protection and
Radioactive Waste Management
in Mining and Mineral Processing
(2005)**

Radiation Protection Series Publication No. 9

August 2005

This publication was approved by the Radiation Health Committee on 22 July 2005,
and on 5 August 2005 the Radiation Health & Safety Advisory Council
advised the CEO to adopt the Code of Practice and Safety Guide.

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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 August 2005

Foreword

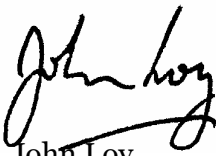
This Code of Practice and Safety Guide was prepared under the provisions of the ARPANS legislation in consultation with industry, unions, and the Governments of the States and Territories. It is an amalgamation and extensive revision of the *Code of Practice on Radiation Protection in the Mining and Milling of Radioactive Ores 1987* (CoA 1987) and the *Code of Practice on the Management of Radioactive Wastes from the Mining and Milling of Radioactive Ores 1982* (CoA 1982). It has been necessary to publish new versions of these Codes, as there have been major changes in radiation protection philosophy and standards since the publication of the earlier Codes. In particular, the International Commission on Radiological Protection (ICRP) has released revised recommendations (ICRP 1991) and subsequent guidance on a number of relevant matters, and the International Atomic Energy Agency (IAEA) has published its new Basic Safety Standards (IAEA 1996).

The Code provides for radiation protection in mining and mineral processing industries and for protection of human health and the environment from the effects of radioactive waste from mining and mineral processing.

Publication of the Code is intended to foster uniform high standards of radiation protection and radioactive waste management in mining and mineral processing throughout Australia. While requirements for regulation of mining are generally applied through the different State and Territory jurisdictions, this Code has been written to allow adoption into regulatory instruments (such as conditions on licences or mining tenements) which are common to all jurisdictions.

This Code of Practice and Safety Guide was prepared under the direction of the Radiation Health Committee. A draft was prepared by a group consisting of representatives of Commonwealth, State and Territory regulatory authorities, and of the uranium and mineral sands mining and mineral-processing industries. The draft was released for comment, and comments received were considered in preparing this document.

The *Code of Practice and Safety Guide for Radiation Protection and Radioactive Waste Management in Mining and Mineral Processing* (the 'Mining Code') was approved by the Radiation Health Committee on 20 July 2005. The Radiation Health and Safety Advisory Council advised the CEO to adopt the Code of Practice and Safety Guide on 5 August 2005.



John Loy
CEO of ARPANSA

31 August 2005

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1. Introduction

1.1 BACKGROUND

- 1.1.1 The *Environment Protection (Nuclear Codes) Act 1978* authorised the development of Codes of Practice regulating nuclear activities in Australia, in consultation with the States and Territories. This Act is now repealed. Three codes were published:
- *Code of Practice on Radiation Protection in the Mining and Milling of Radioactive Ores 1987* (CoA 1987) (the ‘Health Code’), which was an extensive revision of the earlier *Code of Practice on Radiation Protection in the Mining and Milling of Radioactive Ores 1980*;
 - *Code of Practice on the Management of Radioactive Waste from the Mining and Milling of Radioactive Ores 1982* (CoA 1982) (the ‘Waste Code’); and
 - *Code of Practice for the Safe Transport of Radioactive Substances, 1990* (CoA 1990), a revision of the 1982 Code of the same title (the ‘Transport Code’).
- 1.1.2 The Health and Waste Codes defined the objectives, scope and application and specified the responsibilities of owners, operators and managers for radiation protection of employees and members of the public, and for the management of radioactive waste, respectively. Further detail on the technical requirements for the application of these Codes was provided through guidelines. Fourteen guidelines were published for the Health Code (CoA 1987) and seven guidelines were published for the Waste Code (CoA 1982). These guidelines are now obsolete and there is no intention to review them.
- 1.1.3 This Code of Practice and Safety Guide supersedes the Health and Waste Codes. There have been major changes in recent years in radiation protection and waste management philosophies and standards. The International Commission on Radiological Protection (ICRP) has released revised recommendations (ICRP 1991) and subsequent guidance on a number of relevant matters, and the International Atomic Energy Agency (IAEA) has published its Basic Safety Standards (IAEA 1996). There has also been an emerging recognition in radiation protection of the employer’s ‘duty of care’ and ultimate ownership of occupational risks, while working in cooperation with the employees and the regulator rather than within a prescriptive enforcement regime.
- 1.1.4 There have also been developments in radioactive waste management since the publication of the Waste Code. IAEA *Safety Series No. 111-F* (IAEA 1995) discusses the principles of radioactive waste management, while IAEA *Safety Standards Series No. WS-G-1.2* (IAEA 2002) discusses the specific case of radioactive waste management in mining and milling. Other references on radioactive

waste management are IAEA Safety Standards Series No. RS-G-1.6 (IAEA 2004a), RS-G-1.7 (IAEA 2004b) and WS-R-3 (IAEA 2003).

- 1.1.5 In 1998 drafting groups were set up by the Nuclear Codes Committee to revise both the Health and Waste Codes. In 1999, as a result of the new *Australian Radiation Protection and Nuclear Safety Act 1998 (ARPANS Act)*, this work was continued by the Radiation Health Committee.

1.2 STRUCTURE

This publication consists of:

- a *Code of Practice* for the mining and mineral processing industries which sets out the mandatory requirements necessary for the control of occupational and public radiation exposures; and the management of radioactive waste arising from these industries. Schedule 1 specifies additional requirements that form part of the Code of Practice, and is therefore part of the material that may be referenced by regulatory authorities
- a *Safety Guide* which provides further information and guidance to assist in meeting the objectives and requirements of the Code of Practice, and in particular in the development of a radiation management plan and a radioactive waste management plan
- annexes that provide information supplementary to the requirements embodied in the Code. Annexes provide material that will help in interpretation of the Code, and background information relevant to the development of the Code.

1.3 PURPOSE

- 1.3.1 The purpose of this Code and Safety Guide is to provide a uniform framework for radiation protection in the mining and mineral processing industries, and for the safe management of radioactive waste arising from mining and mineral processing. The objectives in developing the Code include:
- encouraging the application of uniform standards in the mining and mineral processing industries for the radiation protection of employees and the public and in the management of radioactive waste, consistent with current international standards and by use of appropriate best-practicable technology;
 - fostering uniform outcomes in radiation protection and the management of radioactive waste in the mining and processing industries; and
 - providing an appropriate legal framework, including the clear allocation of responsibilities and provision for independent regulatory audit and inspection.
- 1.3.2 It is intended that the Code of Practice can be incorporated into regulatory instruments, such as conditions attached to licences or mining tenements as appropriate.

1.4 SCOPE

- 1.4.1 The Code addresses the regulatory and organisational aspects for the control of occupational and public radiation exposures in the mining and mineral processing industries, and for the management of radioactive waste generated in those industries. It describes the system of radiation protection to be applied in operations of the mining and mineral processing industries, and to waste generated by them, and identifies the roles of the various stakeholders.
- 1.4.2 Radioactive waste will most usually arise from the mining and processing of uranium and thorium ores, and of mineral sands. However, the Code may also be applicable to the mining and processing of other materials where the wastes arising from these operations require management because the radionuclides they contain may cause harm to humans or to the environment.
- 1.4.3 Many wastes arising from operations to which the Code applies will, in addition to their radionuclide content, contain other contaminants that can be harmful to human health or the environment. While the Code does not address these matters, due regard for such other contaminants must be made in developing a system for management of radioactive materials and their waste.
- 1.4.4 This document reflects the information contained in *Recommendations for Limiting Exposure to Ionizing Radiation* and *National Standard for Limiting Occupational Exposure to Ionizing Radiation, Radiation Protection Series Publication No. 1 (2002)* (ARPANSA 2002/NOHSC 2002).
- 1.4.5 Wherever practicable, all radioactive waste generated on a mine or mineral processing site should be managed and disposed of according to the provisions of the Code. However there are other national codes of practice relevant to various aspects of radioactive waste management and disposal. The *Code of Practice for the near surface disposal of radioactive waste in Australia (1992)* (NHMRC 1992) provides the basis for the near-surface disposal of solid radioactive waste including waste arising from processing of minerals remote from any mine site and where disposal at the mine site is inappropriate. The *Code of Practice for the Disposal of Radioactive Wastes by the User (1985)* (NHMRC 1985) provides for small amounts of solid, liquid or gaseous radioactive waste below defined limits to be disposed of by the user to an urban land-fill waste tip, or discharged to the sewerage system or into the air.

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Australian Radiation Protection and Nuclear Safety Agency

CODE OF PRACTICE

**Radiation Protection and
Radioactive Waste Management
in Mining and Mineral Processing
(2005)**

Radiation Protection Series Publication No. 9

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2. Code of Practice

2.1 CITATION

This *Code of Practice* may be cited as the *Code of Practice for Radiation Protection and Radioactive Waste Management in Mining and Mineral Processing (2005)* (short title: the 'Mining Code').

2.2 OBJECTIVE

The objective of this Code is to provide a regulatory framework to manage the protection of workers, members of the public and the environment from harmful effects of radiation exposures arising from mining or mineral processing and from the waste resulting from these activities both now and in the future.

2.3 APPLICATION

- 2.3.1 The provisions of this Code apply to the mining and processing of ores for the production of uranium or thorium concentrates, and the separation of heavy minerals from mineral sands ore.
- 2.3.2 The relevant regulatory authority (see Annex A) may direct that this Code be applied, in whole or part, to other mining and mineral processing operations that have the potential to produce significant occupational radiation exposures, or to generate waste having the potential to cause a significant increase in the radiological exposure of members of the public or the environment and which would therefore require specific management. These operations may include:
- (a) the mining and processing of other minerals that adventitiously contain uranium or thorium or their decay products; and
 - (b) processes which lead to the production of waste not usually regarded as radioactive, but which contains naturally occurring radionuclides.
- 2.3.3 This Code applies to the control of occupational and public radiation exposures, and the management of radioactive waste generated, at all stages of mining and mineral processing from exploration to final site rehabilitation.
- 2.3.4 This Code applies to new operations, those established prior to its implementation, operations which are temporarily suspended, and such others as designated by the relevant regulatory authority.
- 2.3.5 This Code is not intended to be applied to the management of introduced radioactive sources used for process control, analysis or investigative purposes, or x-ray apparatus that might be used in an operation to which this Code applies.

2.4 EXEMPTIONS

In the application of this Code the relevant regulatory authority may grant exemptions from provisions of this Code, either for the whole operation, or for specified parts of the operation, where it is satisfied that:

- (a) the source of radiation exposure is inherently safe; and
- (b) doses to members of the public and workers from the operation are acceptably low; and
- (c) the collective effective dose to members of the public arising from the exempted parts of the operation does not exceed 1 person-Sv per year.

2.5 INTERPRETATION

2.5.1 In this Code, unless the contrary intention appears, a reference to a Clause is a reference to the relevant Clause of this Code; and a reference to a Schedule, or part thereof, is a reference to the relevant Schedule, or part thereof, of this Code.

2.5.2 Each of the terms set out in this Code has the meaning given in the Glossary together with any amplification stated in this Code.

2.5.3 Where the term 'must' appears in this Code, this indicates that the particular requirement is mandatory.

2.5.4 The ALARA principle has the meaning stated in Clause 117 of International Commission on Radiological Protection (ICRP) Publication 60 (ICRP 1991, p.29, Item 4.3.2). The broad aim is to ensure that the magnitude of the individual doses, the number of people exposed, and the likelihood of incurring exposures where these are not certain to be received, are all kept as low as reasonably achievable, economic and social factors being taken into account.

2.5.5 In this Code, 'radioactive waste' means material that contains or is contaminated with radionuclides at concentrations or activities greater than levels established by the relevant regulatory authority, and for which no use is foreseen.

2.5.6 In this Code 'best practicable technology' is that technology available from time to time, and relevant to the project in question, which produces the minimum occupational doses, member-of-public doses both now and in the future, and environmental detriment that can be reasonably achieved, economic and social factors taken into account.

2.6 RADIATION PROTECTION STANDARDS

2.6.1 This Code is to be interpreted in accord with the *Recommendations for Limiting Exposure to Ionizing Radiation* and *National Standard for Limiting Occupational Exposure to Ionizing Radiation, Radiation Protection Series Publication No.1 (2002)* (ARPANSA 2002/NOHSC 2002). The relevant dose limits are given

in Schedule 1, which is derived from ARPANSA's *Recommendations for Limiting Exposure to Ionizing Radiation (2002)*.

- 2.6.2 All operations subject to this Code must be managed in such a way that any radiation doses to workers or members of the public arising from the operation must not exceed the relevant limits specified in Schedule 1. The relevant regulatory authority may impose dose constraints, discharge limits or other requirements on an operation in order to ensure adequate levels of radiation protection. Additional information on the health effects and standards for control of exposure to ionizing radiation are given in Annex B.

2.7 RADIATION MANAGEMENT PLAN

- 2.7.1 Before the commencement of any stage of an operation to which this Code applies, a Radiation Management Plan (RMP) for that stage must be devised and presented to the relevant regulatory authority for approval. The Plan must be directed towards meeting the objectives of this Code and must be in accordance with best practicable technology and take into account the potential dose delivery pathways.
- 2.7.2 The Radiation Management Plan must include a description of the operations to which it applies, and the measures that are intended to be taken to control the exposure of employees and members of the public to radiation at or from the practice including:
- (a) demonstrated access to appropriate professional expertise in radiation protection;
 - (b) a plan for monitoring radiation exposure and for assessing the doses received by exposed employees;
 - (c) the provision of appropriate equipment, staffing, facilities and operational procedures;
 - (d) details of induction and training courses;
 - (e) record keeping and reporting;
 - (f) a plan for dealing with incidents, accidents and emergencies involving exposure to radiation; and
 - (g) a system of periodic assessment and review of the adequacy and effectiveness of procedures instituted under the Radiation Management Plan to ensure currency and to facilitate a process of continual improvement.

2.8 RADIOACTIVE WASTE MANAGEMENT PLAN

- 2.8.1 A Radioactive Waste Management Plan (RWMP) must be developed to provide for the proper management of radioactive waste arising from the operations. Before the commencement of any stage of an operation, a RWMP for that stage must be presented to the relevant regulatory authority (see Annex A) for approval. The Plan must be directed towards meeting the objectives of this Code and must be in

accordance with best practicable technology and take into account the potential dose delivery pathways.

- 2.8.2 The Radioactive Waste Management Plan must provide for the proper management of radioactive waste arising from the operation and will include:
- (a) an outline of the processes generating waste, and a description of the waste generated;
 - (b) a description of the environment into which the waste will be discharged or disposed, including the baseline radiological characteristics;
 - (c) a description of the proposed system for waste management including the facilities and procedures involved in the handling, treatment, storage and disposal of radioactive waste;
 - (d) prediction of environmental concentrations of radionuclides and radiation doses to people from the proposed waste management practices, including demonstration that the radiation protection requirements of this Code will be met both now and in the future as determined by the relevant regulatory authority;
 - (e) a program for monitoring the concentration of radionuclides in the environment and assessment of radiation doses to members of the public arising from the waste management practices;
 - (f) contingency plans for dealing with accidental releases, or circumstances which might lead to uncontrolled releases of radioactive waste, to the environment;
 - (g) a schedule for reporting on the operation and results of monitoring and assessments required by this plan;
 - (h) a plan for decommissioning the operation and the associated waste management facilities and rehabilitating the site; and
 - (i) a system of periodic assessment and review of the adequacy and effectiveness of procedures instituted under the Radioactive Waste Management Plan to ensure currency and to take account of potential improvements consistent with best practicable technology.

2.9 APPROVALS AND AUTHORISATIONS

- 2.9.1 Prior to the commencement of any stage of an operation to which this Code applies, the operator must obtain approval for the Radiation Management Plan and the Radioactive Waste Management Plan appropriate for the proposed activities at that stage.
- 2.9.2 An operator must not commence construction of any part of a mine, processing plant or waste management facility to which this Code applies without authorisation from the relevant regulatory authority (see Annex A).

- 2.9.3 An operator must not commence operation of any part of a mine, processing plant or waste management facility to which this Code applies without authorisation from the relevant regulatory authority.
- 2.9.4 An operator must not commence decommissioning or rehabilitation of any part of a mine, processing plant or waste management facility to which this Code applies without authorisation from the relevant regulatory authority.
- 2.9.5 The relevant regulatory authority must be informed of any proposal for significant changes to an operation to which an approved Radiation Management Plan or Radioactive Waste Management Plan applies. The relevant regulatory authority may, on receipt of such notification, direct that a new Radiation Management Plan and/or Radioactive Waste Management Plan or part thereof must be submitted, and that those changes must not be brought into operation without authorisation.
- 2.9.6 The operator must review the Radiation Management Plan and the Radioactive Waste Management Plan, and submit any revised plans for approval, at intervals determined by the relevant regulatory authority.
- 2.9.7 Radioactive material, above exemption limits defined by the relevant regulatory authority, must not be removed from or brought into any operation to which this Code applies without authorisation from the regulatory authority.

2.10 RESPONSIBILITIES

2.10.1 Operator/Employer

The operator and employer must:

- (a) ensure that the workplace and work procedures are designed, constructed, and operated so as to keep exposures to ionizing radiation as low as reasonably achievable, economic and social factors being taken into account, and below the limits set in Schedule 1;
- (b) ensure that waste is managed by means of best practicable technology, and that exposures to ionizing radiation resulting from waste are as low as reasonably achievable, economic and social factors being taken into account;
- (c) obtain all necessary approvals and authorisations from the relevant regulatory authority (see Annex A) prior to commencing the operational aspects to which they apply;
- (d) ensure that appropriate expertise in the fields of radiation protection and radioactive waste management is available, and appoint a Radiation Safety Officer who has qualifications and experience acceptable to the relevant regulatory authority;
- (e) construct and operate all facilities in accordance with the approved RMP and RWMP, and any other requirements of this Code;

- (f) ensure that sufficient resources are available to allow the requirements of the RMP and the RWMP to be fully implemented;
- (g) notify the relevant regulatory authority promptly of any changes in operation, or operating conditions or other matters which are likely to significantly increase radiation exposures to workers or members of the public, or requirements for the management of radioactive waste, and which are not provided for in approvals or authorisations;
- (h) report any unauthorised effluent discharges to the relevant regulatory authority;
- (i) investigate promptly any defect, due to design or malfunction discovered in plant equipment or working procedures which is likely to significantly increase radiation exposures to workers or members of the public, or endanger the security of waste management facilities, and record the results of such an investigation;
- (j) ensure that any defect referred to above is promptly remedied, and the situation resulting from the defect is brought under control;
- (k) undertake ongoing reviews of the RMP and RWMP as determined by the relevant regulatory authority and revise them as required;
- (l) ensure that all employees are, upon commencing work, properly instructed in the radiation aspects of their work, and in the precautions necessary to control their exposure to radiation, and to avoid radiation accidents, and that reinstruction of employees is undertaken at appropriate intervals;
- (m) ensure that employees are properly supervised in the performance of their work to ensure that they act in accordance with approvals and authorisations, and the requirements of this Code;
- (n) keep records of results of all measurements, monitoring and assessments required by this Code or by approvals or authorisations;
- (o) provide employees with copies of their dose records on request, and at termination of their employment; and
- (p) encourage employees to inform the employer when they are pregnant, and when so informed, take steps to limit the exposure of the fetus as required in Schedule 1.

2.10.2 Employees

Employees who may be exposed to radiation, or perform duties which may affect the radiation exposure of others, must to the extent to which they are capable, comply with all reasonable measures to control and assess exposure to radiation, or to manage radioactive waste. The employee must:

- (a) follow radiation protection and waste management practices specified in approvals or authorisations, and other regulatory requirements;
- (b) comply with the legitimate instructions of the employer, or the employer's agents;
- (c) participate in training programs required under this Code, and make proper use of such training;

- (d) make proper use of plant and equipment supplied for radiation protection, or for the monitoring or assessment of radiation exposures;
- (e) not engage in any careless or reckless action which might result in unnecessary radiation exposure to themselves or others, or compromise the management of radioactive waste;
- (f) report to the employer any defects of which they become aware, in plant equipment or procedures, which may compromise radiation protection or the management of radioactive waste;
- (g) report all incidents or accidents to the employer; and
- (h) advise the employer of previous employment involving occupational exposure to radiation, and cooperate in obtaining records of such previous exposure.

Female employees are encouraged to notify their employer if they become pregnant.

Schedule 1

ARPANSA'S *RECOMMENDATIONS FOR LIMITING EXPOSURE TO IONIZING RADIATION (2002)* – DOSE LIMITS

Application	Dose Limits ¹	
	Occupational	Public
Effective dose	20 mSv per year, averaged over a period of 5 consecutive calendar years ²	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 fetus should be afforded the same level of protection as required for members of the public.
3. (DELETED)
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.

NOTE 1: The above dose limits table has been directly extracted from ARPANSA's *Recommendations for limiting exposure to ionizing radiation (1995)*, [republished as RPS 1 in 2002]. However, as the RHC now advises that the exceptional circumstances clause is not recommended for use in Australia, note 3 of the table in RPS 1 has been deleted from this Code.

NOTE 2: Exposure to radiation from natural sources is generally excluded from occupational or public 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. Medical exposure includes 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. Dose limits do not apply to exposures from natural sources, except as described above, or to medical exposures.



Australian Government

Australian Radiation Protection and Nuclear Safety Agency

SAFETY GUIDE

**Radiation Protection and
Radioactive Waste Management
in Mining and Mineral Processing
(2005)**

Radiation Protection Series Publication No. 9

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3. Safety Guide

3.1 CITATION

This Safety Guide may be cited as the *Safety Guide for Radiation Protection and Radioactive Waste Management in Mining and Mineral Processing (2005)*.

3.2 INTRODUCTION

The purpose of this Safety Guide is to assist in the interpretation and implementation of the *Code of Practice for Radiation Protection and Radioactive Waste Management in Mining and Mineral Processing* (referred to throughout as ‘the Code’), and in achieving compliance with its requirements. The information within this Safety Guide is intended to be advisory only, and does not form part of the requirements of the Code.

Radiation exposures arise in the mining and mineral processing industries through three principal pathways: external gamma radiation from ores, concentrates and the like; inhalation of dusts containing long-lived alpha-emitting radionuclides; and inhalation of the short-lived decay products of radon. In the past, inhalation of radon decay products in poorly ventilated underground mines led to exposures greatly in excess of current limits, and was associated with a high incidence of lung cancer. There is consequently a need to adopt careful radiological control measures in mining and mineral processing operations involving radioactive ores, in order to protect those involved and to meet dose limits.

Significant radiation exposures can also arise in the mining and processing of ores not generally considered radioactive, and from precipitates, scales, etc. that may accumulate in recovery of oil or natural gas. Such exposures can lead to doses in excess of the limits for members of the public, and radiological control measures may thus be required.

Mining and mineral processing of radioactive ores generally leads to the generation of large volumes of radioactive waste. The most important are uranium mill tailings and monazite wastes from mineral sand mining. These have the potential to generate radiation doses significantly in excess of the dose limit for members of the public if they are not managed appropriately. Wastes from other mining or mineral processing operations, including the recovery of oil or natural gas, can also result in significant exposures if not managed properly.

3.3 OBJECTIVES

3.3.1 Radiation Protection

The objective of radiation protection is to ensure that there is no unacceptable health risk to people, both workers and members of the public, from the operations to which the Code applies.

3.3.2 Radioactive Waste Management

The objective of radioactive waste management is to ensure that there is no unacceptable health risk to people, both now and in the future, and no long-term unacceptable detriment to the environment from the waste so managed, and without imposing undue burdens on future generations.

The ICRP notes that 'Waste management and disposal are an integral part of the practice generating the waste. It is wrong to regard them as a free-standing practice, needing its own justification. The waste management and disposal operations should therefore be included in the justification of the practice' (ICRP 2000).

3.4 APPLICATION

3.4.1 Operations

The provisions of the Code are intended to apply to the control of occupational and public radiation exposures, and to the management of radioactive waste, arising from any stage of operation in the mining and mineral processing industries in Australia. The major activities covered will be those involved in mining and processing to produce uranium or thorium concentrates, the separation of heavy minerals such as ilmenite, leucoxene, rutile, monazite and zircon from mineral sands ore, and further processing of these minerals.

The provisions of the Code may also be applied to other mining or mineral processing facilities where significant quantities of uranium and thorium and their decay products occur in the minerals or appear in waste streams. This may include the mining and processing of phosphate ores, tin, tantalum, and other non-ferrous ores, coal, and oil and gas extraction.

3.4.2 Criteria for Application

The criteria on which the relevant regulatory authority may decide to require operations to comply with the Code will depend *inter alia* on potential doses to workers and to members of the public. Operations would generally be brought under the regulatory framework of the Code where doses to workers are expected to exceed the public limits, and doses to the critical group are likely to exceed some tens of microsieverts.

All mines may contain substantial concentrations of radon in the air. In determining whether the Code should be applied, note should be taken of Annex C of Radiation Protection Series Publication No. 1 (ARPANSA 2002/NOHSC 2002), which recommends that a program of radiation protection is not required where the long-term average concentration of radon-222 does not exceed 1000 Bq/m³.

3.4.3 Stages of Operation

The stages of mining and processing are drilling and exploratory excavation, development and construction, production, temporary cessation of operations, final decommissioning, and site rehabilitation.

The Code is not intended to be applied to exploration in areas where the presence of radioactive mineralisation has not been identified. Once radioactive mineralisation has been identified, consideration needs to be given to core storage and sample preparation activities, and the handling of any waste arising.

3.4.4 Existing Operations

It is intended that the Code would be applied to operations that are in existence at the time that the Code is adopted. In some cases the operation may need to be brought into compliance over a timescale to be determined by the relevant regulatory authority.

The Code is not intended to be applied to operations that have been decommissioned or abandoned prior to the adoption of the Code. Nevertheless, aspects of the Code may be applied to such sites, as determined by the relevant regulatory authority – refer section 3.6.3, *Intervention*.

3.4.5 Application of Other Codes

The Code is not intended to apply to sources of radiation which are used in operations, but for which other Codes or requirements are applicable. Examples include sealed sources used in radiation gauges, industrial radiography and the like, unsealed sources used for tracer studies, or x-ray apparatus used for analysis (XRF).

The Code is intended to apply to the management and disposal of all radioactive wastes generated by operations to which the Code applies. This includes on-site disposal of tailings and other bulk waste, operational wastes, contaminated clothing, plant or equipment, and residues arising from clean-up.

However, there may be situations where the use of the Code may not be appropriate or practicable. These cases include sites where this Code has not been applied, or where disposal at the mine site is inappropriate or impracticable. In these cases, the *Code of Practice for the Near Surface Disposal of Radioactive Waste in Australia (1992)* (NHMRC 1992) ('near-surface disposal Code') provides an alternative disposal regime.

The near-surface disposal Code expressly states that it is not intended to apply to the of specific types of waste covered by other Commonwealth codes of practice, such as the *Code of Practice on the Management of Radioactive Waste from the Mining and Milling of Radioactive Ores 1982* (CoA 1982), which this Code supersedes.

Situations where the near-surface disposal Code may be applied at the discretion of the relevant regulatory authority include disposal of contaminated plant and equipment resulting from handling or processing of naturally occurring materials that contain radioactive contaminants in low but non-trivial amounts (for example, gypsum, phosphate, natural gas and crude oil). The near-surface disposal Code may also be applied to waste arising from processing of minerals remote from any mine site and where disposal at the mine site is inappropriate.

In some instances of processing of materials (such as phosphate ores, tin, tantalum and other non-ferrous ores, coal, and oil and gas extraction) where this Code is not applied, the *Code of Practice for the Disposal of Radioactive Wastes by the User (1985)* (NHMRC 1985) ('user disposal Code') may have application. The user disposal Code provides for small amounts of low-level solid radioactive waste below defined limits, including that containing uranium or thorium, to be disposed of by the user to an urban land-fill waste tip. Gaseous or liquid wastes below specified limits may be discharged into the air or to the sewerage system in accordance with provisions of the user disposal Code.

3.5 EXEMPTIONS

3.5.1 Exemptions of Whole Operation

International Basic Safety Standards (BSS), Safety Series No. 115 (IAEA 1996) gives guidance on the general principles for exemption of practices, including:

- the radiation risks to individuals caused by the exempted practice be sufficiently low as to be of no regulatory concern;
- the collective radiological impact of the exempted practice be sufficiently low as not to warrant regulatory control under the prevailing circumstances; and
- the exempted practice is inherently safe with no appreciable likelihood of scenarios that could lead to a failure to meet the above criteria.

IAEA Safety Standards Series No. RS-G-1.7 (IAEA 2004b), *Application of the Concepts of Exclusion, Exemption and Clearance*, sets exclusion levels for naturally occurring radioactivity in bulk materials at 1 Bq/g head-of-chain activity for the uranium and thorium decay chain radionuclides. These values are at the upper end of the world-wide distribution for naturally occurring radioactivity in soils. The activity concentration of 1 Bq/g is currently the internationally-accepted level for defining the scope of regulation for naturally occurring materials containing uranium or thorium.

A potential source of radiation exposure, such as an ore or mineral concentrate, could be considered inherently safe if low probability events involving accidents or misuse are extremely unlikely to produce significant health impacts. For example, a source could be considered inherently safe if no conceivable situation arising from such a low probability event would be likely to result in an individual dose above a millisievert.

Ores or mineral concentrates with head-of-chain uranium or thorium activity concentrations less than 1 Bq/g would generally be considered inherently safe (IAEA 2004b). Naturally occurring materials of higher activity concentrations may also be assessed, on a case-by-case basis, as inherently safe by the relevant regulatory authority (for example, if the source radionuclides are insoluble or immobile).

If the activity concentration (head-of-chain or individual activity concentration for radionuclides of natural origin) exceeds 1 Bq/g, the relevant

regulatory authority should decide on the extent to which the Code should be applied, using a graded approach proportionate to the risk. Where the activity concentrations exceed 1 Bq/g by up to ten times, the IAEA suggest, in Safety Standards Series No. RS-G-1.7 (IAEA 2004b), that the regulatory authority may decide that the optimum regulatory option is not to apply the Code.

IAEA Safety Standards Series No. RS-G-1.7 (IAEA 2004b) also recommends that where the relevant regulatory authority determines that regulatory controls should be applied, the stringency of the regulatory requirements should be commensurate with the level of radiological risk involved. The minimum requirement is that such practices be notified to the relevant regulatory authority.

Exemptions may also be granted on the basis that radiation protection is optimised as determined by an assessment agreed between the operator and the relevant regulatory authority. Such an exemption may be subject to monitoring and reporting conditions to ensure that the basis for the exemption remains in place.

The magnitude of doses in comparison with the limits in Schedule 1 should also be considered. In general, exemption can be considered if the average effective dose arising from the exempted operation to members of the public is less than 10 microsieverts per annum. For workers, exemption can be considered if conditions in areas in which the exemption applies are such that it is unlikely that any worker will receive a dose arising from the operation greater than one millisievert per annum.

3.5.2 Partial Exemptions

The relevant regulatory authority may decide that the exemption criteria are met within a part of an operation which falls generally within the scope of the Code. Exemption of that part of the operation from compliance with the Code could then be given. Alternatively for example, exemption from the requirement to prepare a Radiation Management Plan could be granted, but a Radioactive Waste Management Plan might still be required. Such an exemption could be given subject to conditions (such as monitoring) to ensure that the criteria continue to be met.

3.6 RADIATION SAFETY STANDARDS

3.6.1 System of Radiation Protection

The Radiation Safety Standards imposed by the Code are those set out in Radiation Protection Series Publication No. 1 (ARPANSA 2002/NOHSC 2002). These in turn are based on the 'System of Radiation Protection' recommended by the International Commission on Radiological Protection (ICRP) in its Publication 60 (ICRP 1991).

3.6.2 Practices

The ICRP uses the term ‘practice’ for an activity which causes (or has the potential to cause) an increase in the overall exposure to radiation. Activities to which the Code applies will generally be ‘practices’.

For continuing and proposed practices, the system of radiation protection is based on the following general principles, referred to in abbreviated form as ‘justification’, ‘optimisation’, and ‘limitation’:

- 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 ‘optimisation’ of protection); and
- 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 to 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).

3.6.3 Intervention

The ICRP uses the term ‘intervention’ to describe activities that decrease the overall exposure from existing sources of radiation. The rehabilitation of an abandoned uranium tailings dam is an example of an ‘intervention’. The criteria on which it is decided that intervention is required are generally not the same as those applying to radiation protection in a ‘practice’. In particular, the dose limits for members of the public for exposure from practices may not be directly relevant in determining if intervention is required; in fact the ICRP recommends that intervention would not generally be justified unless the individual doses averted by the intervention were significantly above the annual dose limit for a member of the public. As the Code is principally concerned with ‘practices’ its requirements may not be directly applicable to ‘interventions’.

However, the requirements of the Code may be applicable to the operation of intervention, for example for controlling the radiation doses to the workers.

3.6.4 Exceptional and Special Circumstances

Radiation Protection Series (RPS) Publication No. 1 (ARPANSA 2002/NOHSC 2002) allowed the relevant regulatory authority, in exceptional circumstances, to grant a temporary relaxation of the occupational dose limitation requirements. However, the Radiation Health Committee has now advised that this relaxation is not recommended. Such a relaxation should not be required in properly managed and optimised operations to which the Code applies.

RPS Publication No. 1 (ARPANSA 2002/NOHSC 2002) also allows, in special circumstances, that the dose limit to members of the public could be relaxed, provided that the average over a five year period does not exceed 1 mSv per annum. Again, in a properly managed and optimised operation to which the Code applies, such a relaxation should not be required.

3.6.5 Critical Group

The critical group is defined in the Glossary. RPS Publication No. 1 (ARPANSA 2002/NOHSC 2002) also recommends that in evaluating compliance with the limit on effective dose to members of the public, the effective dose to the critical group should be assessed. The monitoring program should be designed to collect sufficient data to allow such an assessment to be made.

3.6.6 Radiological Protection of the Environment

For the purposes of the Code it is assumed that by achieving adequate protection of human health, an acceptable level of protection will be afforded to the environment. However, this assumption may not be valid in all circumstances and specific additional control measures may be required.

3.6.7 Dose Constraints

Dose constraints for particular categories of employee should be used when appropriate. For employees not directly involved in work with radiation, a dose constraint should be adopted which would normally be related to the public effective dose limit specified in Schedule 1.

Dose constraints applied to the critical group, through modelling of the exposure pathway, imply restrictions at the source (ie. discharge limits).

3.7 APPROVALS AND AUTHORISATIONS

The Code specifies that approval must be received from the relevant regulatory authority (see Annex A) for the Radiation Management Plan and the Radioactive Waste Management Plan prior to the commencement of any stage of an operation to which the Code applies. Authorisation for the construction, and for operation, is also required. It is also likely that other legislative measures have requirements for approvals or authorisations.

The requirements and administrative procedures for obtaining approvals and authorisations will be determined by the relevant regulatory authority, and

should be made clear to the operator in a timely manner. Some aspects of an approval procedure that might be adopted are discussed below.

3.7.1 Consultation

In order to ensure that the plans developed by the operator are consistent with the requirements of the relevant regulatory authority, and to allow prompt and efficient evaluation of the plans, it is important that there be continuing consultation between the operator and the relevant regulatory authority(ies). It is unlikely that an optimum design for facilities will be achieved unless requirements for radiation protection and waste management are included in the initial specifications. Consultation will allow all parties to be clear on the requirements and constraints that should be considered.

3.7.2 Authorisation to Construct

At the completion of the engineering design phase of a project, it is in the interests of all parties that there be an understanding that the proposed facilities will be acceptable. The operator needs to have confidence that, provided facilities are built and function as designed and all other operational requirements are met, the relevant regulatory authority will be able to grant authorisation to operate; while the regulator can have confidence that all relevant requirements have been addressed in the design.

This assurance is provided by the formal ‘authorisation to construct’, as required in Section 2.9 of the Code.

An application for authorisation to construct would be expected to contain the following information:

(a) *Mining and Processing Facilities*

The application for construction approval should include the following:

- (i) plans of the proposed mine or processing plant and an outline of the equipment to be constructed or installed and its function;
- (ii) an outline of the operational procedures for the mine or processing plant; and
- (iii) an outline of the Radiation Management Plan for the operation of the proposed mine or processing plant, including details of the engineering controls that will be put in place.

(b) *Waste Management Facilities*

It would be expected that the RWMP for the operation should be approved prior to the commencement of construction of waste management facilities; however, some details, for example monitoring locations and frequencies, might not be finalised.

In addition, other information may be required, such as:

- further engineering detail on the actual construction of facilities;

- schedules and timetables for construction; and
- quality assurance procedures in place during construction.

3.7.3 Authorisation to Operate

Authorisation is required for the commencement of operation of a mine, mill, or waste disposal facility. In seeking such authorisation, the operator would be expected to demonstrate that the facility has been constructed in accordance with authorisations, and that all plant, equipment and procedures required by the approved Radiation Management Plan and Radioactive Waste Management Plan are in place and operational.

Authorisation to operate may be given in stages, with an initial commissioning phase where monitoring inspection etc. is relatively intensive. Once it has been determined that the operation has stabilised within design parameters, then the operator might request a reduction in monitoring and inspection to a level appropriate to routine operation. The results obtained during the commissioning phase would be used to determine ongoing monitoring and inspection requirements.

3.7.4 Cessation of Operations

Cessation of operations constitutes a ‘significant change’ under Clause 2.9.5 of the Code, and the relevant regulatory authority (see Annex A) should be notified. The operator should continue all relevant monitoring, inspection and rehabilitation programs until approval to discontinue is received from the relevant regulatory authority.

(a) *Temporary Cessation*

Changes to the RMP and RWMP may be required when operations cease. The relevant regulatory authority will need to be assured that appropriate care and maintenance procedures, monitoring and inspection (particularly of waste management facilities), and other requirements are in place to ensure that the site remains in an acceptable condition, and that deterioration, which might prejudice reopening or final rehabilitation, does not occur.

(b) *Permanent Closure*

Prior to permanent closure of all or part of an operation, plans for decommissioning and rehabilitation will need to be updated or prepared, and submitted for approval. Such plans will form part of the relevant RMP and RWMPs. Again, the relevant regulatory authority will require assurance that the site remains in an acceptable condition until rehabilitation is complete, and that deterioration which might prejudice final rehabilitation does not occur.

3.7.5 Authorisation to Rehabilitate

The waste management plan should contain proposals for rehabilitation of the project as a whole and for individual components (for example tailings

dams reaching their capacity). On decommissioning, these plans will need to be updated and engineering detail finalised.

Inappropriate attempts at rehabilitation may prejudice the ability to attain an acceptable final state. For this reason, rehabilitation operations should not be attempted without authorisation.

An application for authorisation to rehabilitate should include the following information:

- the condition of the site to be rehabilitated, including the facilities and waste to be rehabilitated, levels of contamination, and quantities of waste;
- details of rehabilitation measures to be undertaken;
- management of waste generated during rehabilitation;
- the anticipated final state of the site after rehabilitation, including estimates of the levels of residual contamination;
- details on ongoing monitoring and surveillance that will be required after rehabilitation; and
- contingency plans, and plans for remediation of any defects in the rehabilitation that may become apparent.

At the conclusion of the rehabilitation, the operator may wish to relinquish responsibility for the site. Generally the requirements and conditions for this step will be set in legislation. However, in respect of matters covered by the Code, requirements and responsibilities for continuing monitoring and surveillance of the site, and of any remedial work that may become necessary, will need to be determined. Any land use restrictions that may be necessary, and the administrative mechanisms that will implement them, will also need to be determined.

3.7.6 Variations

Variations to operational procedures, changes in equipment in the mine or processing plant, or to the scope or output of the project that may increase exposure of employees or members of the public, constitute ‘significant changes’ which require notification to the relevant regulatory authority under Clause 2.9.5 of the Code.

3.8 RADIATION MANAGEMENT PLAN

The Code requires the development and implementation of a Radiation Management Plan (RMP) by the operator, with periodic review, evaluation and modification as necessary to ensure continued adequacy of resources, and continued effectiveness and relevance, thus facilitating continuous improvement.

The purpose of the Radiation Management Plan is to control the exposure of employees and members of the public to radiation at or from the practice by the inclusion of measures that are relevant to the degree of risk.

To facilitate this process, it is essential that the Radiation Management Plan provides for continuous feedback to management, workers and front-line supervisors as to the continued effectiveness of control systems, and that the data it generates are reviewed and responded to in the same manner as other management information.

Further guidance can be obtained by reference to relevant Australian and international standards (see Bibliography).

3.8.1 Development of Plan

(a) *Sources of Exposure*

The RMP should contain sufficient information to allow all significant exposure sources and pathways to be identified. This should include plans of the mine or processing plant, descriptions of the equipment to be used and processes involved, and estimates of the radionuclide concentrations in process streams.

(b) *Control Measures*

The RMP needs to identify the measures that will be implemented to control radiation exposures. These may include provision of engineering controls such as ventilation, dust or fume control measures, and shielding. Other controls such as occupancy limitation (for example by use of Controlled and Supervised Areas), warning signs and labels, personal hygiene facilities and provision and use of personal protection where necessary should also be addressed. Measures to ensure that workers are adequately supervised in their duties will be required.

Control of doses to members of the public is achieved principally by controlling discharges of waste, and this will be addressed in the RWMP. These aspects of the two plans will need to be developed in conjunction.

Where radioactive materials are to be transported off site (for example product or samples for analysis or testing), procedures need to be developed to control such movement. Procedures also need to be developed to ensure that contaminated equipment or materials are not inadvertently transported from a site.

(c) *Monitoring*

Details of the plan to monitor radiation should be submitted. There are three main aims for monitoring, which should be addressed:

- demonstration of compliance with regulatory limits, etc;
- determination of doses received by individuals or groups; and
- provision of information on the effectiveness of engineering and procedural control measures.

Different monitoring techniques may be required to achieve these aims.

The plan needs to provide information on the monitoring techniques to be used, and schedules of monitoring frequencies. Monitoring plans need to be flexible enough to respond to changing circumstances.

The intensity of monitoring should be matched to the exposures potentially received. It is common practice to 'designate' employees who are likely to receive significant doses (for example, greater than 5 mSv per annum). Such designated employees are then monitored more intensively (including, where appropriate, personal monitoring), and their doses are assessed individually. Non-designated employees will then be monitored less intensively, and their doses assessed as an average of their relevant workgroup(s).

Investigation levels which, if exceeded by monitoring results, trigger investigations or actions may be set as part of the RMP.

Surface contamination monitoring is not useful for personal dose calculations nor is it directly useful in assessment of the effectiveness of engineering controls. However, it is the prime method of assessing housekeeping standards (procedural control issues), and is useful in checking of equipment prior to maintenance. Surface contamination checks are also crucial for control over release of potentially contaminated equipment from site (gatehouse control). For these reasons, surface contamination monitoring will usually be an integral component of the overall monitoring plan.

(d) ***Dose Estimates***

Estimates of the exposures or doses that will arise from the operation will need to be provided in order to judge the adequacy of the proposed control measures. These estimates may be made from empirical data, from modelling or from experience in similar operations.

The RMP will need to include methods for the calculation of doses from the monitoring results, and these methods should be acceptable to the relevant regulatory authority. These calculations require the use of 'dose conversion factors', which are based on the radionuclides involved, and their physical and chemical forms (ie. particle size and solubility). Tables of these factors are provided in Tables II-III and II-IV of International Basic Safety Standards (BSS), Safety Series No. 115 (IAEA 1996).

Table 1 provides dose conversion factors that may be used as default values for inhalation of the mixtures of radionuclides commonly found in operations to which the Code applies. Column 2 gives values based on an AMAD of 1 μm and these values are unlikely to underestimate the doses arising from monitored exposures. ICRP Publication 66 (ICRP 1994b) and IAEA Safety Standards Series No. RS-G-1.6 (IAEA 2004a) recommend the use of a 5 μm AMAD as the most appropriate particle size in the workplace and the derived values are shown in column 3. Other factors such as dissolution behaviour of

inhaled particulates in the lung, departure from equilibrium and loss of radon from dust samples may also need to be considered. If more accurate dose assessments are required, dose conversion factors appropriate to the operation can be used. Monitoring to determine the relevant parameters may be required, and the plan should provide for such monitoring if required.

Dose conversion factors for radon decay products are given in Table 2.

Different factors are generally required for the assessment of doses to members of the public.

Non-radiological parameters such as occupancy times, and the use and effectiveness of personal protection may also need to be monitored.

Table 1. Dose conversion factors for mixtures of inhaled radionuclides¹

Mixture	Factors for Inhalation ² (mSv/αdps)	
	1 μm AMAD	5 μm AMAD
Uranium dusts³		
Ore dust ⁴	7.2×10^{-3}	3.5×10^{-3}
Product dust ⁵	7.9×10^{-3}	6.2×10^{-3}
Tailings dust ⁵	6.7×10^{-3}	2.6×10^{-3}
Thorium dust		
Th-232 series	1.1×10^{-2}	8.0×10^{-3}

- Notes:
1. The values tabulated are derived from IAEA Basic Safety Standard No. 115 (IAEA 1996) for the longest pulmonary retention class. The values quoted are applicable to adults.
 2. αdps means the number of alpha-particle disintegrations per second of the mixture. It is assumed that no loss of radon occurs.
 3. It is assumed that 0.72% by mass of natural uranium is U-235.
 4. Secular equilibrium is assumed.
 5. Greater than 90% uranium extraction to product is assumed, with greater than 90% rejection of thorium, radium and decay products to tailings.

Table 2. Dose conversion factors for inhaled radon decay products^{1,2}

Radionuclides	Factor (mSv/mJ)	Factor (mSv/mJ.h.m ⁻³)
Radon-222 decay products	1.2	1.4
Radon-220 decay products	0.39	0.48

- Notes:
1. The values tabulated are derived from IAEA RS-G-1.6 (IAEA 2004a), for adult workers.
 2. A breathing rate of 1.2 m³/h is assumed.

(e) ***Education and Training***

Appropriate education and training in the radiation aspects of the operation need to be provided to all workers. The training needs to be directed towards understanding the measures that should be taken to reduce radiation exposure, and needs to include job specific training. Additional training for supervisors needs to be supplied.

Education and training needs to be continuing, and measures to evaluate the effectiveness of the training should be included.

Induction and training programs should be documented and employee participation should be recorded.

(f) ***Reporting and Record Keeping***

The RMP needs to include provisions for reporting the results of the monitoring program, and related information. Reports will be required for the relevant regulatory authority, management, and for the workers, both as individuals and as a group, at least on a twelve-monthly basis. Operational requirements may require more frequent reporting and analysis to management. Requirements for reporting operational matters such as incidents or accidents should also be developed.

Records of monitoring results, dose assessments including calculation methods, and related information should be retained in a form that will allow them to be retrieved. Such records should normally be retained for a period of at least 30 years. They should not be destroyed without consulting the relevant regulatory authority (see Annex A), and appropriate measures for their management should be put in place should the project close.

3.8.2 Implementation of Plan

(a) ***Personnel and Resources***

The RMP needs to include commitments to provide adequate staff, with appropriate qualification and experience, and with sufficient resources, to properly implement the requirements of the plan, and other

requirements of the Code. Radiation protection staff need access to continuing training and professional development.

(b) ***Integration into Operation***

The plan needs to demonstrate that it is integrated into other Occupational Health and Safety (OH&S) management and the management of the operation as a whole. This includes ensuring that radiation issues will be considered in planning of any changes or development of the operation, and that the results of monitoring are made available promptly to management, in particular so that corrective measures are taken as required in a timely fashion.

3.8.3 Quality Assurance

A quality assurance program which is compliant with Australian Standards (see Bibliography) should be implemented, including traceability of all radiation measurements to Australian metrological standards where possible.

(a) ***Calibration***

The RMP should include measures for calibration of equipment used in monitoring, including where appropriate, traceability to Australian standards. Schedules for calibration should be included, which are appropriate to the type of equipment and the conditions under which it is used.

(b) ***Auditing***

A system of auditing of the performance of the RMP should be implemented. This may include both internal and external auditing.

3.8.4 Review and Assessment

The continual review and assessment is essential in achieving continual improvement of radiation protection, and should be addressed in the RMP. This may include review of doses, including trends over time, for both the operation as a whole and for smaller areas or workgroups, review of the monitoring plan to ensure that monitoring frequencies and techniques remain appropriate, and review of administrative procedures and work practices.

3.8.5 Accidents and Incidents

All radiological accidents should be reported without delay to the relevant regulatory authority (see Annex A). The relevant regulatory authority should be advised as soon as is practicable of the cause of the incident or accident, its consequences (including radiation doses arising) and the steps taken to remedy the situation and to prevent a recurrence.

In the event of an accident which causes or which may lead to significant doses of radiation or significant contamination of persons with radioactive materials, and following any immediate first aid and medical assistance

provided, the relevant regulatory authority should be consulted without delay for advice on the medical management of those exposed. Appropriate counselling should be provided to the persons affected.

Corrective measures should be taken, as necessary, to bring an accident under control and to prevent a recurrence.

All radiological incidents and resulting doses received should be recorded and reported as required by the relevant regulatory authority. The relevant regulatory authority should be advised of the cause of the incident, its consequences and the steps taken to remedy the situation and to prevent a recurrence.

3.9 RADIOACTIVE WASTE MANAGEMENT PLAN

The Radioactive Waste Management Plan (RWMP) is an integral part of a project and should be addressed from the inception of project planning. It should be based on best practicable technology. The RWMP includes a description of the facilities and resources, and the procedures such as operating instructions, and monitoring program. It should also include the conceptual decommissioning and rehabilitation plan, and the proposed final deposition of waste.

The RWMP should be developed in conjunction with the Radiation Management Plan and with the overall project environmental management plan.

The RWMP should be developed and updated as the project progresses through the various stages of the operation (including temporary suspension of operation, if applicable) and to be able to cope with any foreseeable contingency. The RWMP should be revised if circumstances change significantly or if indicated by the results of monitoring and surveillance programs. All changes to the RWMP need to be approved by the relevant regulatory authority.

The establishment of 'baseline' conditions is an important part of the development of a RWMP. A monitoring program designed to evaluate baseline conditions should be developed in conjunction with the relevant regulatory authority. It is important that it be commenced early enough to allow seasonal variations in pre-existing conditions to be evaluated prior to commencement of the project. These 'baseline' conditions should be established prior to any collection of significant amounts of radioactive material through ground disturbance exercises. These conditions will probably have to be established whilst the RWMP is being developed.

The RWMP should address such monitoring as is needed to verify the effectiveness of engineering design, to validate models and predictions, and to demonstrate compliance with discharge limits and operational discharge procedures.

All relevant employees should be acquainted with the approved RWMP in particular the reasoning behind the containment policy and the requirements

for allowing discharges to take place. Any fluctuations from normal operating conditions should be assessed for their effect on the approved RWMP.

3.9.1 Development of Plan

In order that a Plan which is acceptable to the relevant regulatory authority is developed in a timely and efficient manner, it is important that the relevant regulatory authority be made aware of all relevant information. Prior to seeking approvals (or authorisation) for a RWMP, the operator should consult with the relevant regulatory authority with respect to the waste to be generated, possible management strategies, and the potential effects of this waste on members of the public (critical group assessment) and the environment. As the project develops, consultation with the relevant regulatory authority should continue. The operator should inform the relevant regulatory authority of matters that it considers may significantly affect the current or future management of the waste, or the potential for appropriate rehabilitation.

The identification of potential, past, and future impacts on the environment are aspects to be considered in devising the monitoring program for the RWMP.

In developing the RWMP all relevant pathways for dispersion of radionuclides and for radiation exposure should be considered. The assessment should include the optimisation of handling, treatment, storage, and disposal of radioactive waste. The following elements, although not exhaustive, are given as a guide for information that may be relevant to some operations for inclusion in the RWMP:

- outline of the operation and the processes generating waste;
- characterisation of waste including nature of material (chemical, physical and radiological), contaminants, and quantities and rate of production;
- characterisation of the environment: climate, terrain (geomorphology), soils and vegetation, and hydrology;
- heritage (social and cultural), and land use (present, potential and future);
- waste management facilities and practices, waste conditioning, and containment including siting, design and construction, and operation;
- outline of proposed decommissioning concepts and the final disposition of wastes;
- discharges: form (liquid, solid, and gaseous), receiving environment, discharge and release criteria;
- contingency measures: natural events, incidents, equipment failures, and operational failures;
- initial impact (safety) assessment;
- monitoring, surveillance and reporting: personnel and monitoring equipment, and geotechnical monitoring;

- assessment and review of integrity of the facility;
- environmental monitoring: assessment of doses, environmental impacts, reporting; and
- post-operational practices: temporary suspension of operations, decommissioning, closure, decontamination, rehabilitation, monitoring, (long term) surveillance and reporting, records management, and institutional control and land use.

Throughout the operational stage the plans for decommissioning should be further developed in consultation with the relevant regulatory authority. Decommissioning proposals should be reviewed whenever there is a significant change in the operation or of the waste management system, and at other intervals determined by the relevant regulatory authority.

The operational plan should include contingency plans to cover the cases of early shutdown or temporary suspension of operations. These contingency plans should address the continuation of all measures required to safeguard the integrity of the containment facility.

In accordance with best practicable technology, factors to consider in developing the RWMP in order to minimise the environmental detriment include:

- the level of effluent control achieved and the extent to which environmental pollution and degradation are prevented in similar mining, milling and mineral processing operations anywhere in the world;
- the total cost of the application or adoption of that technology relative to the environmental protection to be achieved by its application or adoption;
- evidence of detriment, or lack of detriment, to the environment after the commencement of the project in question;
- the physical location of the project in question; and
- the age of equipment and facilities in use on the project in question and their relative effectiveness in reducing environmental pollution and degradation; and social factors including possible adverse social effects of introducing new technology.

3.9.2 Implementation of Plan

(a) *Commissioning*

The operator should be capable of demonstrating to the relevant regulatory authority that the facility has been constructed in accordance with the approved design, and that operational procedures including monitoring are in place prior to commissioning any waste management facility. The relevant regulatory authority could approve operation for a restricted period of commissioning. An approved monitoring and surveillance program would be required in this commissioning stage.

(b) ***Routine Operation***

Where the relevant regulatory authority is satisfied that the RWMP can be operated within its design parameters, then approval permitting routine operation may be issued. An approved monitoring and surveillance program would be required for routine operations.

(c) ***Variations***

The operator would be expected to inform the relevant regulatory authority of:

- any changes to the operation which may alter the nature or quantity of waste generated;
- any proposal to change the waste containment system; and
- any unanticipated circumstances that may lead to a variation in the performance of the approved RWMP.

The relevant regulatory authority would determine whether these changes require approval of modifications to the approved Waste Management System. These changes would not normally be put into effect until any required approval has been issued.

If it is necessary to temporarily suspend operations, the contingency plans referred to previously should be brought into effect. If the suspension continues for more than 12 months the RWMP should be reviewed. During such reviews the decommissioning plan would also be reviewed.

(d) ***Decommissioning and Rehabilitation***

The operator should not commence operations for decommissioning or rehabilitating any waste management facility except in accordance with provisions of the approved waste management system. The relevant regulatory authority would determine when the decommissioning phase has been completed.

3.9.3 Quality Assurance

A quality assurance program should be included in the Radioactive Waste Management Plan. It should cover the civil engineering and geotechnical aspects of the containment system; the operation of the system; the appropriateness, scope and frequency of the monitoring programs; and the accuracy and traceability to Australian Standards wherever appropriate of sample analyses arising from the monitoring programs.

Further guidance can be obtained by reference to relevant Australian Standards (see Bibliography).

3.9.4 Reporting and Record Keeping

An annual report on the performance of the Radioactive Waste Management Plan should be prepared for submission to the relevant regulatory authority. This report should analyse and present the results of the monitoring program for the previous year, including assessment of doses and environmental impacts.

3.9.5 Review and Assessment

During the operational phase the operator should continue to assess the performance of the Radioactive Waste Management Plan in conjunction with the relevant regulatory authority. The Plan should be reviewed at a frequency determined by the relevant regulatory authority with a view to continuous improvement, and the operator may formulate an improved monitoring program based on the previous results and any foreshadowed changes.

3.10 RESPONSIBILITIES

3.10.1 Operator

The operator is responsible for ensuring that the provisions of the Code are complied with. In addition the operator has a general duty of care in regard to a whole range of occupational health and safety issues, of which the radiation protection aspects of the Code form part. Compliance with the Code should demonstrate achievement of duty of care in radiation protection matters. In developing the RMP and RWMP, the operator should consider all other OH&S requirements and recognise the potential for conflicts in their control. Prioritisation of hazard control requirements will need to be made.

Similarly, the operator has a general duty to protect the environment in which he operates. Control of radionuclides and management of radioactive waste may constitute only one aspect of overall environmental protection environments.

The operator has the responsibility to appoint an appropriately qualified Radiation Safety Officer (RSO). The requirements will change depending on the scale of the operation and concomitant risks of radiation exposure. Normally, an RSO is expected to have a degree in physical sciences or equivalent and some years of experience in radiation protection, preferably in the mining industry. The RSO is responsible for advising the operator on all matters relating to radiation protection of employees, members of the public and the environment, and for implementing the radiation management plan.

In the event that an employee advises her employer that she is pregnant, the employer should discuss with the employee the probable dose that the employee will receive for the remainder of the pregnancy. If the dose to the employee is estimated to not exceed 1 mSv for the rest of the pregnancy, then no specific additional radiation protection measures are required (for example, change of duties).

There is a requirement in the Code on the operator to notify the relevant regulatory authority (see Annex A) of any changes which are likely to

significantly increase radiation exposures to workers or members of the public, or requirements for the management of radioactive waste. In deciding whether a change is significant, the operator will need to consider the magnitude of expected dose increase, number of people exposed, and duration. Examples include:

- major change in plant process or components; and
- change of the order of 30% or more in production capacity.

There may also be requirements to report such changes under other legislation.

3.10.2 Relevant Regulatory Authority

The relevant regulatory authority is responsible for ensuring that approved Radiation Management Plans and Radioactive Waste Management Plans are adequate to meet the objectives of the Code. In carrying out this responsibility, the relevant regulatory authority would be expected to:

- inform potential applicants of all approvals and authorisations that will be required at each stage of the project, and the administrative requirements for applications;
- provide the opportunity for operators or potential operators to consult with the relevant regulatory authority on matters relating to the Code;
- consider all relevant applications and proposals, submitted at each stage of the approval process;
- advise applicants promptly of decisions on applications, including reasons for the rejection of any applications;
- advise applicants on requirements for reporting of project activities, monitoring results, dose assessments, incidents and accidents, and other matters that may be required; and
- make arrangements for the long-term retention of records of radiation exposure and related matters.

The relevant regulatory authority is also responsible for auditing compliance with the objectives of the Code. This auditing may be carried out by the relevant regulatory authority themselves or by contracting an external auditor. In carrying out this function, the relevant regulatory authority would be expected to:

- communicate any concerns and requirements in relation to the system to the proponent and may require modifications to plans, criteria, standards and characteristics as deemed necessary; and
- determine the means of indemnifying the relevant regulatory authority against costs of surveillance, monitoring, premature closure and any rectification work which may become necessary.

The relevant regulatory authority also has responsibility to ensure that upon decommissioning of facilities to which the Code applies, appropriate administrative and other procedures are in place to ensure the long-term integrity of sites, particularly waste disposal sites.

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Glossary

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. An accident 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 the consequences.

Activity

the measure of quantity of radioactive materials, except when used in the term 'human activity'.

Activity median aerodynamic diameter (AMAD)

the diameter of a unit density sphere with the same terminal velocity in air as that of an aerosol particle whose activity is the median for the entire aerosol.

ALARA

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

Approval

a written agreement by the relevant regulatory authority that a plan or proposal meets the requirements of the Code.

AS/NZS

an Australian/New Zealand Standard jointly published by Standards Australia and Standards New Zealand.

Authorisation

the granting by a regulatory body of written permission for an operator or class of operators to perform specified activities.

Best practicable technology

that technology, from time to time relevant to a specific project, which enables radioactive waste or exposure to radiation to be managed so as to minimise radiological risks and detriment to people and the environment, having regard to:

- (a) the achievable levels of effluent control and the extent to which pollution and degradation of the environment is minimised or prevented in comparable mining operations elsewhere;
- (b) the cost of the application or adoption of that technology relative to the degree of radiological and environmental protection expected to be achieved by its application or adoption;
- (c) evidence of detriment or lack of detriment to the environment after the commencement of mining operations;
- (d) the location of the mine;

- (e) the age of the equipment and facilities in use for mining purposes and their relative effectiveness in achieving radiological and environmental protection; and
- (f) the potential long term hazards from the wastes.

Clearance

the removal of radioactive materials or objects within authorised practices from any further control by the relevant regulatory authority.

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.

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.

Disposal

the emplacement of waste in an approved, specified facility without intention of retrieval. Disposal may also include the approved direct discharge of effluent (eg. liquid or gaseous waste) into the environment with subsequent dispersion.

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 optimisation 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.

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 T .

The unit of effective dose is the same as for equivalent dose, $J\ kg^{-1}$, with the special name sievert (Sv).

Employee

a person who works for an employer within an operation including a contractor performing work on the project site on behalf of the owner/operator.

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.

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).

Exclusion

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

Exemption

a designation, by the relevant regulatory authority, for sources of radiation that are not subject to nuclear regulatory control because they present such a low radiological hazard; the deliberate omission of a practice from regulatory control, or from some aspects of regulatory control, by the relevant regulatory 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.)

IAEA

International Atomic Energy Agency; headquarters located in Vienna, Austria.

ICRP

the International Commission on Radiological Protection. It is an independent organisation that provides general guidance on radiation protection. The recommendations of the ICRP are not legally binding, but are generally followed by countries framing national regulatory requirements.

Incident

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

Intervention

an action intended to reduce or avert exposure or the likelihood of exposure to sources which are not part of a controlled practice or which are out of control as a consequence of an accident or other event.

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.

Institutional control

control of a waste site by an authority or institution designated under the law. This control may be active (monitoring, surveillance, remedial work), or passive (land use restrictions).

ISO

the International Organization for Standardization. It is a non-governmental organisation with a Central Secretariat in Geneva, Switzerland that coordinates a network of national standards institutes.

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 approval 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.

Mining and mineral processing

mining is all activities associated with the extraction of minerals from the ground.

Mineral processing is all activities associated with the processing of minerals to produce a physical or chemical concentrate, including hydrometallurgical and pyrometallurgical processing, and physical ore beneficiation.

NOHSC

the National Occupational Health and Safety Commission established by section 6 of the *National Occupational Health and Safety Commission Act 1985*.

Occupational exposure

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

OH&S

Occupational Health and Safety.

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 a mining or mineral processing operation which may lead to exposure to ionizing radiation.

Optimisation

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

Practice

any human activity that introduces additional sources of exposure or exposure pathways or extends exposure to additional people or modifies the network of exposure pathways from existing sources, so as to increase the *exposure* or the likelihood of exposure of people or the number of people exposed.

Public exposure

exposure incurred by members of the public from radiation sources, excluding any *occupational* or *medical exposure* and the normal local natural background radiation but including exposure from authorised *sources* and practices and from *intervention* situations.

Radiation

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

Radiation Safety Officer (RSO)

an individual technically competent in radiation protection matters relevant for a given type of practice who is designated by the operator or employer to oversee the application of the requirements of the Code.

Radioactive waste

radioactive waste means material that contains or is contaminated with radionuclides at concentrations or activities greater than clearance levels as established by the relevant regulatory authority, and for which no use is foreseen.

Relevant regulatory authority

the radiation protection authority or authorities designated, or otherwise recognised, for regulatory purposes in connection with protection and safety in mining and mineral processing. A list of regulatory authorities in Australia is included as Annex A.

Risk constraint

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

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.

Waste management system

includes all the facilities and procedures involved in the handling, treatment, storage and disposal of radioactive wastes.

Annex A

RADIATION PROTECTION AND REGULATORY AUTHORITIES

Table A1: Radiation Protection Authorities

Where advice or assistance is required from the relevant radiation protection authority, it may be obtained from the following officers:

COMMONWEALTH, STATE / TERRITORY	CONTACT
Commonwealth	Director, Regulatory Branch ARPANSA PO Box 655 Miranda NSW 1490 Email: info@arpansa.gov.au Tel: (02) 9541 8333 Fax: (02) 9541 8348
Australian Capital Territory	Manager Radiation Safety Radiation Safety Section ACT Health Locked Bag 5 Weston Creek ACT 2611 Email: radiation.safety@act.gov.au Tel: (02) 6207 6946 Fax: (02) 6207 6966
New South Wales	Director Radiation Control Department of Environment and Conservation PO Box A290 Sydney South NSW 1232 Email: radiation@environment.nsw.gov.au Tel: (02) 9995 5000 Fax: (02) 9995 6603
Northern Territory	Manager Radiation Protection Radiation Protection Section Department of Health and Community Services GPO Box 40596 Casuarina NT 0811 Email: envirohealth@nt.gov.au Tel: (08) 8922 7152 Fax: (08) 8922 7334
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	Director, Radiation Protection Division Environment Protection Authority PO Box 721 Kent Town SA 5071 Email: radiationprotection@state.sa.gov.au Tel: (08) 8130 0700 Fax: (08) 8130 0777
Tasmania	Senior Health Physicist Health Physics Branch Department of Health and Human Services GPO Box 125B Hobart TAS 7001 Email: health.physics@dhhs.tas.gov.au Tel: (03) 6222 7256 Fax: (03) 6222 7257
Victoria	Manager, Radiation Safety Program 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	Secretary, Radiological Council Locked Bag 2006 PO Nedlands WA 6009 Email: radiation.health@health.wa.gov.au Tel: (08) 9346 2260 Fax: (08) 9381 1423

Table A2: Regulatory Authorities

The following organisations may regulate various radiological aspects of mining and mineral processing:

COMMONWEALTH, STATE / TERRITORY	CONTACT
Commonwealth	Director, Regulatory Branch ARPANSA PO Box 655 Miranda NSW 1490 Email: info@arpansa.gov.au Tel: (02) 9541 8333 Fax: (02) 9541 8348
Australian Capital Territory	Manager Radiation Safety Radiation Safety Section ACT Health Locked Bag 5 Weston Creek ACT 2611 Email: radiation.safety@act.gov.au Tel: (02) 6207 6946 Fax: (02) 6207 6966
New South Wales	Deputy Director-General, Mineral Resources NSW Department of Primary Industries PO Box 344 Hunter Region Mail Centre NSW 2310 Email: webcoord@minerals.nsw.gov.au Tel: (02) 4931 6666 Toll-free: 1300 763 122 Fax: (02) 4931 6790
Northern Territory	Chief Executive Officer Department of Business, Industry and Resource Development GPO Box 3000 Darwin NT 0801 Email: mineral.info@nt.gov.au Tel: (08) 8999 5204 Fax: (08) 8941 1284
Queensland	<i>For approval of mining leases:</i> Department of Natural Resources and Mines Bureau of Mining and Petroleum Mineral House GPO Box 2454 Brisbane QLD 4001 Email: mines@nrm.qld.gov.au Tel: (07) 3237 1435 Fax: (07) 3224 7768 <i>For all other radiological matters:</i> 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	Director, Radiation Protection Division Environment Protection Authority PO Box 721 Kent Town SA 5071 Email: radiationprotection@state.sa.gov.au Tel: (08) 8130 0700 Fax: (08) 8130 0777
Tasmania	Mineral Resources Tasmania Department of Infrastructure, Energy and Resources GPO Box 56 Rosny Park TAS 7018 Email: info@mrt.tas.gov.au Tel: (03) 6233 8377 Fax: (03) 6233 8338
Victoria	Manager, Radiation Safety Program 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	State Mining Engineer Resources Safety Division Department of Consumer and Employment Protection 100 Plain Street East Perth WA 6004 Email: ResourcesSafety@docep.wa.gov.au Tel: (08) 9222 3333 Fax: (08) 9325 2280

Please note: Tables A1 and A2 were correct at the time of printing but are 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). For after hours emergencies only, the police will provide the appropriate emergency contact number.

Annex B

HEALTH EFFECTS OF IONIZING RADIATION AND STANDARDS FOR CONTROL OF EXPOSURE

It is well known that high doses of ionizing radiation can cause harm, but there is continuing scientific uncertainty about effects at low doses. At levels of dose routinely encountered by members of the public and most present-day radiation workers, there is little or no epidemiological evidence of health effects. Radiation protection standards recognise that it is not possible to eliminate all radiation exposure, but they do provide for a system of control to avoid unnecessary exposure and to keep doses in the low dose range.

Extreme doses of radiation to the whole body (around 10 sievert* and above), received in a short period, cause so much damage to internal organs and tissues of the body that vital systems cease to function and death may result within days or weeks. Very high doses (between about 1 sievert and 10 sievert), received in a short period, kill large numbers of cells, which can impair the function of vital organs and systems. Acute health effects, such as nausea, vomiting, skin and deep tissue burns, and impairment of the body's ability to fight infection may result within hours, days or weeks. The extent of the damage increases with dose. However, 'deterministic' effects such as these are not observed at doses below certain thresholds. By limiting doses to levels below the thresholds, deterministic effects can be prevented entirely.

Doses below the thresholds for deterministic effects may cause cellular damage, but this does not necessarily lead to harm to the individual: the effects are probabilistic or 'stochastic' in nature. It is known that doses above about 100 millisievert, received in a short period, lead to an increased risk of developing cancer later in life. There is good epidemiological evidence – especially from studies of the survivors of the atomic bombings - that, for several types of cancer, the risk increases roughly linearly with dose, and that the risk factor averaged over all ages and cancer types is about 1 in 100 for every 100 millisievert of dose (i.e. 1 in 10,000 per millisievert).

At doses below about 100 millisievert, the evidence of harm is not clear-cut. While some studies indicate evidence of radiation-induced effects, epidemiological research has been unable to establish unequivocally that there are effects of statistical significance at doses below a few tens of millisieverts. Nevertheless, given that no threshold for stochastic effects has been demonstrated, and in order to be cautious in establishing health standards, the proportionality between risk and dose observed at higher doses is presumed to continue through all lower levels of dose to zero. This is called the linear, no-threshold (LNT) hypothesis and it is made for radiation protection purposes only.

There is evidence that a dose accumulated over a long period carries less risk than the same dose received over a short period. Except for accidents and medical exposures, doses are not normally received over short periods, so that it is appropriate in determining standards for the control of exposure to use a risk factor that takes this into account. While not well quantified, a reduction of the high-dose risk factor by a factor of two has been adopted internationally, so that for radiation protection purposes the risk of radiation-induced fatal cancer (the risk factor) is taken to be about 1 in 20,000 per millisievert of dose for the population as a whole.

* The sievert (Sv) is a unit of measurement of radiation dose (see ARPANSA's *Recommendations for limiting exposure to ionizing radiation (2002)*).

If the LNT hypothesis is correct, any dose carries some risk. Therefore, measures for control of exposure for stochastic effects seek to avoid all reasonably avoidable risk. This is called optimising protection. However, risk in this sense may often be assessed in terms of risk to a population, and may not ensure sufficient protection of the individual. Consequently, the optimisation approach is underpinned by applying dose limits that restrict the risk to individuals to an acceptable level. The fundamental regulatory philosophy is expressed in three principles, based on the recommendations of the International Commission on Radiological Protection (ICRP), which may be summarised as follows:

Justification: human activities that cause exposure to radiation may be permitted only if they do more good than harm;

Optimisation of protection: exposure to radiation from justified activities should be kept as low as reasonably achievable, social and economic factors being taken into account; and

Limitation of individual dose: doses must not exceed the prescribed dose limits.

Determining what is an acceptable risk for regulatory purposes is a complex value judgement. The ICRP reviewed a number of factors in developing its recommendations, which have in general been internationally endorsed, including by the World Health Organization, the International Labour Organisation and the International Atomic Energy Agency. Australia’s Radiation Health Committee, now established under the ARPANSA Act[†], has recommended that the international standards be adopted in Australia. The recommended dose limits are summarised as follows:

Limit on effective dose*

	For occupational exposure	For members of the public
To limit individual risk	20 mSv per year, averaged over 5 years*	1 mSv in a year*

*for details, see ARPANSA’s *Recommendations for limiting exposure to ionizing radiation (2002)*

In most situations, the requirements for limiting individual risk ensure that doses are below deterministic thresholds, but for cases where this does not apply, the recommended limits are as follows:

Annual limit on equivalent dose*

	For occupational exposure	For members of the public
To prevent deterministic effects		
in the lens of the eye	150 mSv	15 mSv
in the skin	500 mSv	50 mSv
	in the hands and feet 500 mSv	–

*For details, see ARPANSA’s *Recommendations for limiting exposure to ionizing radiation (2002)*

[†] The Australian Radiation Protection and Nuclear Safety Act (1998)

In the case of occupational exposure during pregnancy, the general principle is that the embryo or fetus should be afforded the same level of protection as is required for a member of the public. For medical workers, the ICRP recommends that there should be a reasonable assurance that fetal dose can be kept below 1 mGy* during the course of the pregnancy. This guidance may be generalised to cover all occupationally exposed pregnant workers by keeping the fetal dose below 1 mSv. A full explanation of radiation protection principles and of the recommended standards for Australia is given in ARPANSA/NOHSC Radiation Protection Series No. 1: *Recommendations for limiting exposure to ionizing radiation (1995)* and *National standard for limiting occupational exposure to ionizing radiation* (both republished in 2002).

* The gray (Gy) is a unit of radiation dose. For X-rays and gamma radiation, it is essentially equivalent to the sievert.

Annex C

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*. All of the Nuclear Codes have now been republished in the Radiation Protection Series.

All publications listed below are available in electronic format, and can be downloaded free of charge by visiting ARPANSA's website at www.arpansa.gov.au/codes.htm.

Radiation Protection Series publications are available for purchase directly from ARPANSA. Further information can be obtained by telephoning ARPANSA on 1800 022 333 (freecall within Australia) or (03) 9433 2211.

RADIATION PROTECTION SERIES

- 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)
- RPS 3. Radiation Protection Standard for Maximum Exposure Levels to Radiofrequency Fields – 3 kHz to 300 GHz (2002)
- RPS 4. Recommendations on the Discharge of Patients undergoing Treatment with Radioactive Substances (2002)
- RPS 5. Code of Practice and Safety Guide for Portable Density/Moisture Gauges Containing Radioactive Sources (2004)
- RPS 6. National Directory for Radiation Protection, Edition 1.0 (2004)
- RPS 7. Recommendations for Intervention in Emergency situations Involving Radiation Exposure (2004)
- RPS 8. Code of Practice for the Exposure of Humans to Ionizing Radiation for Medical Research Purposes (2005)
- RPS 9. Code of Practice and Safety Guide for Radiation Protection and Radioactive Waste Management in Mining and Mineral Processing (2005)

Those publications from the NHMRC Radiation Health 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 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 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 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)
- 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 28. Code of practice for the safe use of sealed radioactive sources in borehole 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 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)

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