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DEPARTMENT OF MINES  
WESTERN AUSTRALIA

**CODE OF PRACTICE  
ON RADIATION PROTECTION  
IN THE MINING AND PROCESSING  
OF MINERAL SANDS (1982)**

**CODE OF PRACTICE ON RADIATION PROTECTION IN THE MINING  
AND PROCESSING OF MINERAL SANDS (1982)**

**PART I—PRELIMINARY**

**Title**

1. This Code of Practice on Radiation Protection in the Mining and Processing of Mineral Sands (1982) may be referred to as the Radiation Protection (Mineral Sands) Code (1982).

The intention is to develop, achieve and maintain the best practicable radiation safety practice for the mineral sands industry in Western Australia such that no person shall be exposed to radiation in excess of the National Health and Medical Research Council's "Recommended Radiation Protection Standards for Individuals Exposed to Ionising Radiation" (hereafter to be referred to as the NHMRC Recommendations) or as otherwise determined by the Radiological Council.

**Interpretation**

2. (1) In this Code, unless the contrary intentions appear—
  - (a) a reference to a Section is a reference to the relevant Section of this Code;
  - (b) a reference to a Schedule or part thereof is a reference to the relevant Schedule or part thereof of this Code.
- (2) Each of the terms set out in this Section have, in this Code, the meaning given in this Section.

*Appropriate Authority* means the authority having responsibility for enforcing the provisions of any legislation implementing any part or the whole of this Code. Insofar as this Code is implemented under the provisions of the Radiation Safety Act, the appropriate authority shall be the Radiological Council established under that Act.

*Approval* means approval in writing from the appropriate authority.

*Contaminant* means the radionuclide which is a component of specified contamination.

*Contamination* means radioactive material in unsealed gaseous liquid or particulate form in air, water or other substances or on surfaces.

*Contractor* means a person or organisation, other than an employee of the operator, who is employed to perform work on that area of the mine or processing site that falls within the application of this Code.

*Controlled Area* means an area or region where radiation levels could exceed 3/10ths of any of the derived limits given in Schedules 5(a), 7(a) and 9(a).

*Derived Limit* means a limit used in radiation protection which is derived from the limits given in the radiation protection standards by a defined model of the situation and is such that its application will ensure that these limits will not be exceeded. (For example, the derived limit for a situation which is occupied by a designated employee for 40 hours a week for 50 weeks of the year would be 2.5 millirem per hour which is derived from the annual limit of 5 rems.)

*Designated Employee* means any person who regularly works in a controlled area, or any person who works in any other area or region and is assessed by the Radiation Safety Officer as likely to receive a radiation dose equivalent in excess of the limits given in Schedule 2.

*Direct Monitoring* means the measurement of radiation exposure using a personal monitoring device (for example, film badge, personal dosimeter).

*Dose Assessment* means an estimate of personal exposure using information from direct or indirect monitoring and knowledge of work habits and duration of exposure.

*Employee* means a person of any classification or grade employed by the operator or engaged in activities in those areas of the mine or processing plant that fall within the application of this Code.

*Environment* means the area beyond the boundaries of the mine or processing site and shall include air, surface water and underground water which may traverse the boundaries.

*Exposure* means the circumstance of being exposed to radiation beyond normal background levels.

*External Exposure* means exposure to radiation from sources of radiation external to the body.

*Indirect Monitoring* means the use of data from radiation surveys, contamination measurements and a knowledge of work habits and occupancy to assess radiation exposure.

*Inspector* means a person appointed as an inspector by the Department of Mines, as provided under Section 8 of the Mines Regulation Act 1946-1974.

*Internal Exposure* means exposure to radiation from radioactive material taken into the body.

*Manager* means the person responsible for the administration and direction at the mine or processing site as defined in the Mines Regulation Act 1946-1974 and its regulations.

*Medical Examination* means an examination performed on an employee by a registered medical practitioner to determine the fitness of the employee to undertake the work required.

*Members of the Public* means all persons other than employees or employees of contractors when working at the mine.

*Mine* means a facility engaged in the extraction, including excavation, removal, storage and processing of mineral sands, as defined in Section 4 of the Mines Regulation Act 1946-1974, and includes its associated administrative support facilities and the facilities for management of waste and effluent.

*Mineral Sands* means any naturally concentrated heavy minerals including ilmenite, rutile, leucoxene, zircon, monazite, xenotime, kyanite, garnet, staurolite, or any other notifiable product.

*Mining* means operations to recover mineral sands as defined in Section 4 of the Mines Regulation Act 1946-1974.

*Monitoring Programme* means a programme of measurements and assessments of radiation levels and personal radiation exposures.

*Natural Radiation* means the naturally occurring level of radiation at a particular locality.

*Notifiable Product* means a product which gives rise to conditions which fall within the application of this Code.

*Operator* means any person, government or other entity that conducts or carries on operations for the mining and/or processing of mineral sands.

*Personal Monitoring* means the use of personal monitoring devices and/or personal dose assessment to determine the exposure of individuals to ionising radiation.

*Positional Monitoring* means the measurement of levels of radiation or contamination at specific positions in the mine or processing plant.

*Processing Operation* means all physical and chemical processes applied to mineral sands.

*Processing Plant* means a facility used for processing mineral sands, its associated administrative support facilities and facilities for management of contaminated waste and effluent.

*Processing Site* means a site where a processing operation is conducted away from the mine site.

*Product* means any material resulting from processing operations and includes useful materials, waste materials and tailings.

*Radiation* means ionising radiation, that is, electromagnetic or corpuscular radiation capable of producing ions directly or indirectly in passage through matter.

*Radioactive Material* means material which spontaneously emits radiation.

*Radiation Protective Equipment* means equipment intended for the protection of a person or persons against radiation or contamination. It may be intended to ensure individual protection or to provide protection throughout an area.

*Radiation Safety Officer* means a person with qualifications and experience approved by the appropriate authority who is appointed by the Manager for the mine or processing plant.

*Tailings* means waste and reject materials resulting from processing operations.

### **Application**

3. The purpose of this Code is the prevention, limitation or minimisation of radiation exposure to persons in all stages of mineral sands mining or processing operations, and subsequent to these operations, where the derived limits quoted in Schedules 5(c), 6(c), 7(c) or 9(c) may be exceeded.

This Code will apply from 1st September 1982.

### **Exemptions**

4. An operator may apply for exemption from all or part of these provisions if he can demonstrate to the appropriate authority that in a specific area of a mine or processing plant the total annual dose equivalent arising from both external and internal exposure cannot reasonably exceed the annual dose limits given in Schedules 2 or 4.

It is incumbent on the operator to produce the evidence required for the appropriate authority to decide on the scope or extent of any exemption.

The appropriate authority may declare any mining or processing operation as falling within the scope of the Code and require operation of those mining or processing works to comply with the Code.

#### **Notifications**

5. Notification to the appropriate authority is required before commencing or making significant changes to those operations that come within the application of this Code.

Notifications are required for:

- (1) all operations prior to the commencement of mining and processing operations; and
- (2) significant changes to operations

where the derived limits quoted in Schedules 5(c), 6(c), 7(c) or 9(c) may be exceeded.

Details shall include relevant information on:

- (1) the plant process;
- (2) input and products;
- (3) effluent both liquid and gaseous;
- (4) all products, both useful and waste generated by the plant

and such additional relevant information as is requested by the appropriate authority.

## **PART II—DUTIES AND RESPONSIBILITIES**

### **Operator and Manager**

6. (1) The operator and manager of the mine or processing plant shall be responsible for ensuring that the provisions of this Code are applied in the mine or processing plant.
- (2) Where a contractor is employed, his responsibility shall be to the manager or to the operator. It is the operator or manager's responsibility to ensure that contractors, sub-contractors and their employees comply with this Code.
- (3) The operator and manager shall ensure that:
- (a) all exposures are kept as low as reasonably practicable;
  - (b) the exposure of employees and of members of the public to radiation resulting from the operations of the mine or concentration plant does not exceed those levels specified in Schedules 1, 2, 3 and 4;
  - (c) such notifications are made to the appropriate authority as are required by the provisions of this Code or by the direction of the appropriate authority;
  - (d) all employees, before commencing work and periodically thereafter, are properly instructed in the precautions necessary to limit their exposure to radiation;
  - (e) supervision is provided to ensure that employees perform their work in accordance with the provision of this Code;

- (f) the adequacy and effectiveness of the working procedures instituted to limit exposure to radiation of persons are assessed at intervals not exceeding six months;
- (g) situations, incidents or procedures, not otherwise covered by the normal good housekeeping of the mine or processing plant and giving rise to radiation levels that are in excess of those reasonably practicable under normal operating conditions, shall be promptly remedied, recorded and reported to the appropriate authority;
- (h) boundaries of controlled areas are delineated and brought to the attention of employees of the mine or processing plant;
- (i) access to and occupancy of controlled areas is controlled;
- (j) in every controlled area legible notices specifying the procedures necessary to comply with the provisions of this Code are posted and maintained as approved by the appropriate authority;
- (k) eating, drinking and smoking are not permitted in controlled areas;
- (l) a monitoring program is carried out in accordance with Part IV;
- (m) corrective measures are taken to ensure that where the derived limits specified in Schedules 5(c), 6(c), 7(c) or 9(c) may be exceeded, these shall not lead to the basic radiation protection standards specified in Schedules 1, 2, 3 and 4 being exceeded whilst ensuring that all radiation exposures are kept as low as reasonably achievable;
- (n) inspectors from the appropriate authority are afforded the right of access and reasonable opportunity to examine equipment, working procedures and records required to be held by the operator or manager under this Code;
- (o) the results of all measurements and assessments performed in accordance with the requirements of this Code are:
  - (i) promptly recorded in a register and retained until such time as determined by the appropriate authority;
  - (ii) brought to the attention of the manager where required by the provisions of this Code or the appropriate authority;
  - (iii) supplied to the appropriate authority on request; and
  - (iv) made available to an employee on request where they pertain to that employee's working conditions;
- (p) a Radiation Safety Officer with qualifications and experience approved by the appropriate authority is appointed for the mine or processing plant. The person appointed shall be responsible to the manager for radiation protection in the mine or processing plant and for carrying out the monitoring requirements given in Part IV of this Code;
- (q) monitoring equipment and facilities are made available and used to ensure compliance with the provisions of this Code;
- (r) for each designated employee:
  - (i) measurements and assessments to determine the annual and cumulative dose equivalent and radon and thoron daughter exposures are made in accordance with Part IV; (see also 12(3))
  - (ii) the results are recorded and retained in a form acceptable to the appropriate authority;

- (s) a pregnant designated employee about whom notification under Section 7(10) has been received is not employed in a controlled area;
- (t) showers and changerooms are provided in accordance with the Mines Regulation Act;
- (u) monazite and xenotime products are stored in a controlled area specifically designated for that purpose and approved by the appropriate authority;
- (v) final monazite and xenotime products are handled by procedures designed to keep exposures as low as reasonably practicable and which are approved by the appropriate authority;
- (w) health surveillance of employees is carried out in accordance with Part V of this Code.

**Employee**

7. (1) An employee shall inform the manager of all previous employment as a designated employee or designated radiation worker during which he may have been exposed to radiation.
- (2) An employee shall obey all notices displayed in accordance with the Code and obey all instructions relating to radiation protection of himself and others.
- (3) An employee shall not engage in any careless or reckless practice or action likely to result in radiation levels in excess of those given in Schedules 2 or 4 being exceeded for himself or others.
- (4) An employee shall report forthwith to his supervisor situations, incidents or procedures not otherwise covered by the normal good housekeeping of the mine or processing plant of which he is aware and which he believes is likely to give rise to radiation levels that are above those that are reasonably achievable under normal operating conditions.
- (5) An employee who exercises supervision in accordance with Section 6(3)(e) shall promptly assess each circumstance reported to him and if he believes it likely to give rise to radiation levels that are in excess of those reasonably achievable under normal operating conditions, shall report the circumstances forthwith to the manager, or Radiation Safety Officer.
- (6) An employee shall use in the manner instructed by the manager, all radiation protective equipment furnished for his use.
- (7) An employee shall use in the manner instructed by the manager, devices or equipment furnished to him to assess his dose equivalent, and radon and thoron daughter exposure.
- (8) Except for the purposes of inspection, maintenance, repair, modification or replacement, an employee shall not interfere with, remove, alter, displace or render ineffective any radiation protective equipment provided to protect employees or other persons or interfere with any method, process or working procedure adopted to minimise exposure to radiation.
- (9) Within any controlled area, an employee shall not eat, drink or smoke except in locations specified for such purpose. Such locations shall meet the requirements of Schedule 8(b).

- (10) A designated employee who becomes pregnant, or believes that she is pregnant, shall, as soon as practicable, notify the manager so that the requirements of Section 6(3) (s) are met.
- (11) A designated employee shall undergo all medical examinations as arranged by the manager for health surveillance in accordance with the provisions of the Code.

### **PART III—RADIATION STANDARDS AND LIMITS**

#### **Basic Radiation Protection Standards**

8. For the purposes of this Code, the basic radiation protection standards shall be as follows:
  - (1) the dose equivalent limits for radiation received by an employee as a consequence of employment are given in Schedule 1;
  - (2) the dose equivalent limits for members of the public exposed as a consequence of the operation of a mine or processing plant are given in Schedule 2;
  - (3) the radon and thoron daughter exposure limits for an employee in the course of employment are given in Schedule 3;
  - (4) the radon and thoron daughter exposure limits for members of the public exposed as a consequence of the operation of a mine or processing plant are given in Schedule 4.

Exclusions from the requirements for meeting these standards are given in Section 9.

#### **Doses Excluded from Basic Radiation Standards**

9. For the purposes of this Code, the following shall not be taken into account in assessing compliance with the basic radiation standards given in Section 8:
  - (1) doses due to natural radiation other than those arising from the mining and processing of mineral sands;
  - (2) doses received as a result of radiological examinations, radiotherapeutic procedures or nuclear medical investigations.

#### **Derived Limits**

10. Derived limits are established as an aid in conducting a radiation protection program. The basic radiation protection standards are the annual limits given in Schedules 1, 2, 3, 4. Derived limits are calculated from these annual limits using a model which normally assumes "worst case" situations, such that adherence to the derived limit will provide virtual certainty of compliance with the annual dose equivalent limits.

Derived limits are not used as mandatory limits for instantaneous exposure. It is recognised that short term exposure levels may exceed derived limits but that personal dose equivalents can be minimised by controlling the time of exposure. Hence failure to adhere to the derived limit will not necessarily imply a failure to achieve compliance with the basic radiation protection standards and may require only a more careful study of the circumstances.

11. For designated employees and for other employees the derived limits are based on exposure to radiation over a 40 hour working week. For members of the public, where such derived limits are given, the derived limits are based on exposure to radiation over a 168 hour week. For the purposes of this Code, the derived limits for the concentrations of radioactive materials in air and water and on surfaces and for absorbed dose rates in air shall be as detailed below:
- (1) the derived limits of concentrations of radioactive materials, other than radon daughters and thoron daughters, in air inhaled and in water for personal use by a designated employee in the course of employment are given in Schedules 5(a) and 6(a). The derived limits applicable at other times are the same as for members of the public (see Section 11(3));
  - (2) the derived limits of concentration of radioactive materials, other than radon daughters and thoron daughters, in air inhaled and in water for personal use by an employee, other than a designated employee, in the course of employment, are given in Schedules 5(b) and 6(b). The derived limits applicable at other times are the same as for members of the public (see Section 11(3));
  - (3) the derived limits of concentrations of radioactive materials, other than radon daughters and thoron daughters, in air inhaled and in water for personal use by members of the public who may be exposed continually as a consequence of the operation of a mine or processing plant are given in Schedules 5(c) and 6(c);
  - (4) the derived limits of radon daughter concentration and of thoron daughter concentration for a designated employee in the course of employment are given in Schedule 7(a). The derived limits applicable at other times are the same as for members of the public (see Section 11(6));
  - (5) the derived limits of radon daughter concentration and of thoron daughter concentration for an employee, other than a designated employee, in the course of employment are given in Schedule 7(b). The derived limits applicable at other times are the same as for members of the public (see Section 11(6));
  - (6) the derived limits of radon daughter concentration and of thoron daughter concentration for members of the public who may be exposed continually as a consequence of the operation of a mine or processing plant are given in Schedule 7(c);
  - (7) the derived limits of radioactive contamination on surfaces are given in Schedule 8;
  - (8) the derived limit for absorbed dose rate in air at positions occupied by a designated employee in the course of employment is given in Schedule 9(a);
  - (9) the derived limit for absorbed dose rate in air at positions occupied by an employee, other than a designated employee, in the course of employment, is given in Schedule 9(b);
  - (10) the derived limit for absorbed dose rate in air at positions occupied by members of the public is given in Schedule 9(c).

**Measurements and Assessments of Dose Equivalents, Radon Daughter Exposures and Thoron Daughter Exposures**

12. (1) Monitoring techniques, sampling procedures, monitoring frequency and statistical tests to be used and assessments of dose equivalents, radon daughter exposures and thoron daughter exposures of employees and of members of the public shall be carried out in a manner approved by the appropriate authority.

- (2) The results of all measurements, investigations and assessments shall be recorded together with all the criteria and assumptions used in arriving at these results.
- (3) The appropriate authority recognises that techniques for the measurement of thoron daughter exposure are not presently available. In the absence of available techniques to measure thoron daughter exposure, the appropriate authority withhold any requirement to make such measurements. When a method of measurement is approved by the appropriate authority, then this method will be implemented.

#### **PART IV—MONITORING**

13. A monitoring programme shall be carried out to:

- (1) Assess directly or indirectly personal dose equivalent of all employees and to identify those employees to be classified as designated employees.
- (2) Provide data to assist in ensuring no employee receives an annual dose equivalent in excess of the limits given in Schedules 1 and 3.
- (3) Provide data to assist in ensuring that no employee other than a designated employee receives an annual dose equivalent in excess of the limits given in Schedules 2 and 4.
- (4) Provide data to assist in ensuring that radiation exposure of employees and members of the public is kept as low as reasonably practicable.

14. *Positional Monitoring*—shall be carried out using methods approved by the appropriate authority to:

- (1) Delineate the boundaries of controlled areas.
- (2) Determine the contamination of surfaces, air and water.
- (3) Assist in the assessment of dose equivalents for all employees.

This monitoring shall be carried out at the commencement of operations and thereafter at periods not exceeding 12 months or after variations to operations that may result in changes in exposure to radiation of employees or members of the public.

15. The results of positional monitoring to delineate the boundaries of controlled areas shall be recorded and made available to the appropriate authority on request.

16. *Personal Monitoring and Dose Assessment*

Personal monitoring is monitoring undertaken to determine dose equivalent of individual persons. It may be performed by direct monitoring using individual monitors carried on the person or by indirect monitoring. In indirect monitoring, dose equivalent radon daughter exposure and thoron daughter exposure can be inferred from results of surveys of radiation, contamination and occupancy. The manager shall ensure that the following requirements for personal monitoring of employees and dose assessments are carried out using methods approved by the appropriate authority.

- (1) For designated employees, individual dose equivalents will be measured or otherwise assessed.
- (2) For designated employees, individual radon and thoron daughter exposures will be measured or otherwise assessed.
- (3) For employees other than designated employees dose equivalents will be assessed.
- (4) For employees other than designated employees radon and thoron daughter exposures will be assessed.

17. The results of the monitoring and assessment of personal annual dose equivalents for designated employees shall be reported to the appropriate authority annually.
18. The results of the assessment of annual dose equivalent for employees other than designated employees shall be recorded and supplied to the appropriate authority on request.
19. To ensure that radiation exposure is kept as low as reasonably achievable and to draw attention to any single measurements which if projected for a full year suggest that the annual dose equivalent limits given in Schedules 1 and 3 may be exceeded, pro-rata annual doses shall be calculated.  
 Personal monitoring measurements or assessments that exceed the pro-rata annual dose equivalent limits given in Schedules 1 and 3 shall be advised to the appropriate authority, provided that the measurements or assessments have been conducted over a period of at least 28 days, i.e. the appropriate authority shall be advised if:
 
$$E \times \frac{365}{d} > 50 \text{ millisieverts (5 000 millirems)}$$
 Where E = dose equivalent exposure recorded by measurement or assessment.  
 d = monitoring period in days, d > 28
20. Exemption from a particular type of monitoring may be granted by the appropriate authority if the operator can show that the derived limits given in Schedules 5(c), 6(c), 7(c), 8 or 9(c) cannot reasonably be exceeded

## **PART V—HEALTH SURVEILLANCE**

### **Health Surveillance of Radiation Workers**

21. The need for a medical examination both before and during employment should be based on the need to determine the fitness of an individual to undertake the work required but should not be based on possible exposure to ionising radiation. It is emphasised that the overriding philosophy is to minimise exposure.

The type and extent of the health surveillance for individual workers is essentially the same as in general occupational medical practice and accordingly would, in this case, be expected to include a comprehensive personal history including such aspects as previous radiation exposures. One objective of the examination would be the recognition of conditions or characteristics that may limit the type of work the individual should undertake.

The frequency of routine medical examinations should be determined by the general health of the individual, his personal exposure record and his conditions of work. Medical examinations must not be used to monitor the effectiveness of a radiation protection program.

### **Medical Examinations**

22. (1) Medical examinations shall be carried out on all employees as required by the appropriate authority or the manager.
- (2) Following any examination referred to in 23(1) the medical practitioner shall inform an employee, in writing, of the results of the examination.

### **Cost of Medical Examinations**

23. The operator shall meet the expenses of the medical examinations required.

## **PART VI—MANAGEMENT OF WASTES**

24. No water with contaminants in excess of the concentrations given in Schedule 6(c) shall be released to the environment without the approval of the appropriate authority.
25. Action shall be taken to limit the source of airborne contamination so that the concentration of contaminants in air released to the environment does not exceed the levels given in Schedule 5(c).
26. Action shall be taken to prevent the accumulation elsewhere than the mine or processing site of wind blown or other loose material which produces an absorbed dose rate above the natural background in excess of that given in Schedule (9c).  

In the event that material does accumulate elsewhere than the mine or processing site and produces an absorbed dose rate above the natural background in excess of half that given in Schedule 9(c) it shall be the responsibility of the operator and manager to:

  - (1) Notify the appropriate authority.
  - (2) Remedy the situation to the satisfaction of the appropriate authority.
27. Where notifiable products are buried on the mine or processing site, their location and depths shall be recorded and this information made available to the appropriate authority on request.

### **Disposal of Products and Tailings**

28. All products shall be transported in accordance with relevant State, Commonwealth and International regulations.
29. No notifiable product shall be disposed of to persons or otherwise within Western Australia elsewhere than the mine or processing site without the written approval of the appropriate authority.
30. No tailings shall be disposed of elsewhere than the mine or processing site without the written approval of the appropriate authority.

### **Rehabilitation of Sites**

31. When mining operations in a particular area cease, action shall be taken to restore average radiation levels over the area to:
  - (a) average levels which were measured before mining commenced, or
  - (b) levels approved by the appropriate authority having regard to estimated natural background levels in the vicinity of the ore body prior to mining.
32. When processing operations at a particular locality cease, action shall be taken to restore average radiation levels over the area to:
  - (a) average levels which were measured before processing commenced, or
  - (b) levels approved by the appropriate authority having regard to estimated natural background levels in the vicinity prior to processing.
33. Notification of intention to relinquish a mine or processing site shall be accompanied by a plan which indicates specific areas in which notifiable products have been buried and which shows the current radiation levels.

## GLOSSARY

*Absorbed dose (D)* is the quotient of  $\Delta E$  by  $\Delta m$ , where  $\Delta E$  is the energy imparted by ionising radiation to the matter in a volume element and  $\Delta m$  is the mass of the matter in that element

Absorbed dose is expressed as the energy absorbed per unit mass of matter exposed to radiation.

The unit of absorbed dose is one joule per kilogram and has the name gray (symbol Gy). This unit replaces the non-SI unit, the rad, where 1 gray = 100 rad.

*Activity (A)* of a quantity of a radionuclide is the quotient of  $\Delta N$  by  $\Delta t$  where  $\Delta N$  is the number of nuclear transformation which occur in this quantity in time  $\Delta t$ .

The unit of activity is one disintegration per second and has the name becquerel (symbol Bq). This unit replaces the non-SI unit, the curie (Ci) where 1 becquerel =  $2.703 \times 10^{-11}$  curie.

*Daughter products* means radionuclides which are formed as a result of radioactive decay of a specified radionuclide.

Dose equivalent (DE) is the product of absorbed dose (D), quality factor (Q) and absorbed dose distribution factor (DF).

The unit dose equivalent has the name sievert (symbol Sv), which is numerically equal to the absorbed dose in gray multiplied by the appropriate factors. This unit replaces the non-SI unit, the rem where 1 sievert = 100 rem.

For gamma radiation emitted by radioactive substances present in mineral sands, the quality factor (Q) and the absorbed dose distribution factor (DF) are close to unity so that the absorbed dose (D) and the dose equivalent (DE) may be taken as numerically equal.

*Radionuclide* means a species of radioactive atom having specified numbers of neutrons and protons in its nucleus.

*Radon* means the radioactive gas radon-222.

*Radon daughters* means the short-lived radioactive products of decay of radon, namely polonium-218 (radium A), lead-214 (radium B), bismuth-214 (radium C) and polonium-214 (radium C').

*Radon daughter concentration* means the quotient of  $\Delta E$  by  $\Delta V$ , where  $\Delta E$  is the sum of energies of the alpha particles emitted by the complete decay of the radon daughters in the volume element  $\Delta V$ .

*Radon daughter exposure* means the sum, for all exposures of a person to inhaled radon daughters within a stated period of time, of all products formed by multiplying the radon daughter concentration in the inhaled air and the time for which that concentration was inhaled.

*Thoron* means the radioactive gas radon-220.

*Thoron daughters* means the short-lived radioactive products of decay of thoron, namely, polonium-216 (thorium A), lead-212 (thorium B), bismuth-212 (thorium C), polonium-212 (thorium C) and thallium-208 (thorium C).

*Thoron daughter concentration* means the quotient of  $\Delta E$  by  $\Delta V$ , where  $\Delta E$  is the sum of energies of the alpha particles emitted by the complete decay of the thoron daughters in the volume element  $\Delta V$ .

*Thoron daughter exposure* means the sum, for all exposures of a person to inhaled thoron daughters within a stated period of time, of all products formed by multiplying the thoron daughter concentration in the inhaled air and the time for which that concentration was inhaled.

*Working level* means the concentration unit defined as any combination of radon daughters or thoron daughters in one litre of air such that the sum of energies of the alpha particles emitted by the complete decay of the daughters is  $1.3 \times 10^5$  MeV.

The abbreviation for "working level" is "WL".

1 WL =  $1.3 \times 10^5$  MeV/litre.

(Note: 1 "eV" or "electron volt" =  $1.6 \times 10^{-19}$  joules.)

*Working level month* means unit of exposure to radon daughters or thoron daughters.

The abbreviation for "working level month" is "WLM".

1 WLM =  $8.0 \times 10^{10}$  MeV second/litre.

(1 WLM is approximately equivalent to an exposure to 1 WL for a working month of 170 hours.)

## THE SCHEDULES

### ANNUAL LIMITS

#### Schedule 1

Dose equivalent limits for a designated employee exposed as a consequence of employment

Annual Whole Body Dose Equivalent 0.05 Sievert

NOTE: Where exposure is restricted to a part of the body, the procedures set out in the NHMRC Recommendations should be followed in consultation with the appropriate authority.

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#### Schedule 2

Dose equivalent limits for an employee, other than a designated employee and for members of the public

Annual Whole Body Dose Equivalent 0.005 Sievert

NOTE: Where exposure is restricted to a part of the body, the procedures set out in the NHMRC Recommendations should be followed in consultation with the appropriate authority.

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#### Schedule 3

Annual limits for Radon Daughter exposure and Thoron Daughter exposure for a designated employee in the course of employment

Radon	....	....	....	....	4 WLM
Thoron	....	....	....	....	40 WLM

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#### Schedule 4

Annual limits for Radon Daughter exposure and Thoron Daughter exposure for an employee, other than a designated employee and for members of the public

Radon	....	....	....	....	0.4 WLM
Thoron	....	....	....	....	4 WLM

### Schedule 5

#### Derived limits of concentration of contaminants in air

Derived limits of concentration in units of becquerel/metre<sup>3</sup>

	5 (a) for a designated employee exposed in the course of employment (based on 40 hours/week exposure)	5 (b) for an employee, other than a designated employee, exposed in the course of employment (based on 40 hours/week exposure)	5 (c) for members of the public (based on 168 hours/week exposure)
(i) Contaminant	Bq/m <sup>3</sup>	Bq/m <sup>3</sup>	Bq/m <sup>3</sup>
Uranium (soluble)*	3.7	$3.7 \times 10^{-1}$	$1.9 \times 10^{-1}$
Uranium (insoluble)*	3.7	$3.7 \times 10^{-1}$	$1.5 \times 10^{-1}$
Thorium (soluble)*	2.2	$2.2 \times 10^{-1}$	$7.4 \times 10^{-2}$
Thorium (insoluble)*	2.2	$2.2 \times 10^{-1}$	$7.4 \times 10^{-2}$
Thorium-230 (soluble)	$7.4 \times 10^{-2}$	$7.4 \times 10^{-3}$	$3.0 \times 10^{-3}$
Thorium-230 (insoluble)	$3.7 \times 10^{-1}$	$3.7 \times 10^{-2}$	$1.1 \times 10^{-2}$
Radium-228 (soluble)	2.6	$2.6 \times 10^{-1}$	$7.4 \times 10^{-2}$
Radium-228 (insoluble)	1.5	$1.5 \times 10^{-1}$	$3.7 \times 10^{-2}$
Radium-226 (soluble)	1.1	$1.1 \times 10^{-1}$	$3.7 \times 10^{-2}$
Radium-226 (insoluble)	1.9	$1.9 \times 10^{-1}$	$7.4 \times 10^{-2}$
Radium-224 (soluble)	$1.9 \times 10^2$	$1.9 \times 10$	7.4
Radium-224 (insoluble)	$2.6 \times 10$	2.6	$7.4 \times 10^{-1}$
Radon-220 alone†	$2.2 \times 10^5$	$2.2 \times 10^4$	$7.4 \times 10^3$
Radon-222 alone†	$1.1 \times 10^5$	$1.1 \times 10^4$	$3.7 \times 10^3$
Lead-210 (soluble)	3.7	$3.7 \times 10^{-1}$	$1.5 \times 10^{-1}$
Lead-210 (insoluble)	7.4	$7.4 \times 10^{-1}$	$3.0 \times 10^{-1}$
(ii) Contaminant	ug/m <sup>3</sup>	ug/m <sup>3</sup>	ug/m <sup>3</sup>
Uranium (soluble)....	210	21	7
Uranium (insoluble)	180	18	6
Thorium (soluble)	280	28	9
Thorium (insoluble)	280	28	9

The inhalation of soluble uranium should not exceed 2.5 mg in one day.

The ingestion of soluble uranium should not exceed 150 mg over two days.

\* Expressed in mass units in Part (ii)

† With no daughter products present.

### Schedule 6

Derived limits of concentration of contaminants in water

Derived limits of concentration in units of becquerel/metre<sup>3</sup>

	6(a) for a designated employee exposed in the course of employment (based on 40 hours/week exposure)	6(b) for an employee, other than a designated employee, exposed in the course of employment (based on 40 hours/week exposure)	6(c) for members of the public (based on 168 hours/week exposure)
(i) Contaminant	Bq/m <sup>3</sup>	Bq/m <sup>3</sup>	Bq/m <sup>3</sup>
Uranium (soluble)*	1.5 x 10 <sup>6</sup>	1.5 x 10 <sup>5</sup>	3.7 x 10 <sup>4</sup>
Uranium (insoluble)*	3.7 x 10 <sup>7</sup>	3.7 x 10 <sup>6</sup>	1.5 x 10 <sup>6</sup>
Thorium (soluble)*	2.2 x 10 <sup>6</sup>	2.2 x 10 <sup>5</sup>	7.4 x 10 <sup>4</sup>
Thorium (insoluble)*	2.2 x 10 <sup>7</sup>	2.2 x 10 <sup>6</sup>	7.4 x 10 <sup>5</sup>
Thorium-230 (soluble)	1.9 x 10 <sup>6</sup>	1.9 x 10 <sup>5</sup>	7.4 x 10 <sup>4</sup>
Thorium-230 (insoluble)	3.3 x 10 <sup>7</sup>	3.3 x 10 <sup>6</sup>	1.1 x 10 <sup>6</sup>
Radium-228 (soluble)	3.0 x 10 <sup>4</sup>	3.0 x 10 <sup>3</sup>	1.1 x 10 <sup>3</sup>
Radium-228 (insoluble)	2.6 x 10 <sup>7</sup>	2.6 x 10 <sup>6</sup>	1.1 x 10 <sup>6</sup>
Radium-226 (soluble)	1.5 x 10 <sup>4</sup>	1.5 x 10 <sup>3</sup>	3.7 x 10 <sup>2</sup>
Radium-226 (insoluble)	3.3 x 10 <sup>7</sup>	3.3 x 10 <sup>6</sup>	1.1 x 10 <sup>6</sup>
Radium-224 (soluble)	2.6 x 10 <sup>6</sup>	2.6 x 10 <sup>5</sup>	7.4 x 10 <sup>4</sup>
Radium-224 (insoluble)	7.4 x 10 <sup>6</sup>	7.4 x 10 <sup>5</sup>	1.9 x 10 <sup>5</sup>
Radon-220 alone†	3.7 x 10 <sup>7</sup>	3.7 x 10 <sup>6</sup>	1.1 x 10 <sup>6</sup>
Radon-222 alone†	1.9 x 10 <sup>7</sup>	1.9 x 10 <sup>6</sup>	7.4 x 10 <sup>5</sup>
Lead-210 (soluble)	1.5 x 10 <sup>6</sup>	1.5 x 10 <sup>4</sup>	3.7 x 10 <sup>3</sup>
Lead-210 (insoluble)	1.9 x 10 <sup>8</sup>	1.9 x 10 <sup>7</sup>	7.4 x 10 <sup>6</sup>
(ii) Contaminant	mg/l	mg/l	mg/l
Uranium (soluble)	60	6	2
Uranium (insoluble)	1 500	150	60
Thorium (soluble)	280	28	9
Thorium (insoluble)	2 800	280	90

The inhalation of soluble uranium should not exceed 2.5 mg in one day.

The ingestion of soluble uranium should not exceed 150 mg over two days.

\* Expressed in mass units in Part (ii).

† With no daughter products present.

**Schedule 7**

**Derived limits of radon daughter concentration and of thoron daughter concentration**

<b>(a) For a designated employee in the course of employment (based on 40 hours/week exposure)</b>							
(i) Radon daughters	....	....	....	....	....	....	0.33 WL
(ii) Thoron daughters	....	....	....	....	....	....	3.3 WL
<b>(b) For an employee, other than a designated employee, in the course of employment (based on 40 hours/week exposure)</b>							
(i) Radon daughters	....	....	....	....	....	....	0.03 WL
(ii) Thoron daughters	....	....	....	....	....	....	0.33 WL
<b>(c) For members of the public (based on 168 hours/week exposure)</b>							
(i) Radon daughters	....	....	....	....	....	....	0.01 WL
(ii) Thoron daughters	....	....	....	....	....	....	0.1 WL

**Schedule 8**

**Derived limits of surface contamination by alpha-emitting radionuclides**

Type of surface	Derived limit in units of becquerel/metre <sup>2</sup> (limit in curies/metre <sup>2</sup> given in brackets)
(a) Accessible surfaces of occupied areas in mines and processing plants, other than meal rooms, offices, recreation rooms, change rooms and wash rooms.	3.7 x 10 <sup>5</sup> (10 <sup>-5</sup> )
(b) Accessible surfaces in meal rooms, offices, recreation rooms, changerooms and washrooms.	3.7 x 10 <sup>4</sup> (10 <sup>-6</sup> )
(c) Skin	3.7 x 10 <sup>3</sup> (10 <sup>-7</sup> )
(d) Clothing	3.7 x 10 <sup>5</sup> (10 <sup>-5</sup> )

**Schedule 9**

**Derived limits for absorbed dose rate in air at occupied positions**

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(a) For a designated employee in the course of employment (based on 40 hours/week exposure)	$2.5 \times 10^{-5}$ Gy/hour ( $2.5 \times 10^{-3}$ rad/hour)
(b) For an employee, other than a designated employee, in the course of employment (based on 40 hours/week exposure)	$2.5 \times 10^{-6}$ Gy/hour ( $2.5 \times 10^{-4}$ rad/hour)
(c) For members of the public (based on 168 hours/week exposure)	$6.0 \times 10^{-7}$ Gy/hour ( $6.0 \times 10^{-5}$ rad/hour)

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The above figures in Gy/hour may be taken as numerically equal to Sv/hour for gamma radiation (see glossary definition of dose equivalent).