Regulations under the *Mines Regulation Ordinance*

I, JOHN ARMSTRONG ENGLAND, the Administrator of the Northern Territory of Australia, having received the advice of the Administrator's Council, hereby make the following Regulations under the *Mines Regulation Ordinance.*

Dated this twenty-first day of June, 1978.

J. A. ENGLAND
Administrator

MINES (RADIATION PROTECTION) REGULATIONS

Citation

1. These Regulations may be cited as the Mines (Radiation Protection) Regulations.

Interpretation

2. (1) In these Regulations—

"Code" means the Code of Practice on Radiation Protection in the Mining and Milling of Radioactive Ores, first published by the Australian Department of Health in August, 1975, as it is set out in Schedule 1 and as amended from time to time by these Regulations;

"Director of Health" means the person for the time being holding, or performing the duties of, Commonwealth Director of Health for the Northern Territory;

"Director of Mines" means the Director of Mines within the meaning of the *Mining Ordinance* and includes a person appointed under that Ordinance as Acting Director of Mines.

(2) Words and expressions that are used in these Regulations have the meanings that they have in the *Mines Regulation Ordinance.*

(3) The expression—

"appropriate statutory authority" used in the Code in a provision specified in the first column of Schedule 2, in relation to the relevant requirement in that provision specified in short form in the second column of that Schedule opposite that provision, means, subject to sub-regulation (5), the person or persons specified in the third column of that Schedule opposite that provision;

"central health authority" used in the Code means the Director of Health.

(4) Subject to sub-regulation (2), words and expressions that are used in these Regulations have the meanings that they have in the Code.

(5) The Director of Health shall not exercise his powers under sections 3.4.1, 4.7.1 and 4.7.3 without prior consultation with the Director of Mines, and the Director of Mines shall not exercise his powers under sections 4.1.1, 4.6.1.2, 4.6.1.3, 4.6.1.4 and 4.7.2 without prior consultation with the Director of Health.

Application

3. These Regulations apply to all mines in the Territory.

Duties of manager

4. (1) Where the operations of a mine include the mining or milling of radioactive ores and the provisions of the Code apply in respect of that mining or milling, the manager of the mine shall—

*Notified in the *Northern Territory Government Gazette* on 30 June, 1978.

(a) ensure that the provisions of the Code are applied in the mine or mill;

(b) notify an inspector and the Director of Health in writing, prior to operation of the mine or mill and thereafter at intervals not exceeding 12 months, of the individual processes in the mine or mill that will involve exposure to radiation of employees and of members of the public in the neighbourhood of the mine or mill and of the equipment and procedures that will be used and the safety organization established to limit this radiation exposure in accordance with the requirements of the Code;

(c) make such submissions, applications, reports and notifications and furnish such information to the appropriate statutory authority as are required by the provisions of the Code;

(d) with respect to the mine or mill, designate one or more restricted areas and control access to and occupancy of these restricted areas and cause suitable notices to be posted identifying the boundaries of restricted areas;

(e) with respect to the mine or mill, designate and control access to work places and bring to the notice of the employees of the mine or mill the areas designated as work places;

(f) provide safe work places and safe working environment in the mine or mill;

(g) provide the facilities, plant and equipment required in the Code and ensure that they are in safe working condition;

(h) maintain and periodically inspect the facilities, plant and equipment provided to limit radiation exposure in restricted areas, work places and the neighbourhood of a mine or mill and record the maintenance carried out and results of the inspections;

(i) provide radiation protective equipment and establish working procedures that, taken together, limit the radiation exposure of employees throughout restricted areas and, in particular, throughout each work place in accordance with section 3.2 of the Code;

(j) ensure that only in the special circumstances envisaged by sections 4.4.5 and 4.4.6 of the Code are personal radiation protective equipment and special individual working procedures used to limit the radiation exposure of an employee;

(k) periodically assess the radiation protective equipment provided and the working procedures established to ensure they maintain their effectiveness in limiting radiation exposure;

(l) ensure that employees, especially those newly engaged, are properly instructed and periodically reinstructed at appropriate levels in the radiation hazards of their work and in the precautions necessary to limit radiation exposure of all persons and to avoid radiation accidents and injuries;

(m) ensure, with respect to each type of work place and working activity in that work place, that notices, embodying the specific working procedures necessary to comply with the provisions of section 4 of the Code, are posted in prominent positions in the mine or mill and that the notices are resistant to weather, dust and fumes likely to arise in the mine or mill and are in such languages as to ensure comprehension by all employees of the mine or mill;

(n) provide the necessary supervision to ensure that employees perform their work in accordance with the provisions of the Code;

(o) appoint a person to be the Radiation Safety Officer of the mine or mill, who is qualified in the principles and practices of radiation protection in the mining and milling of radioactive ores;

(p) ensure that the Radiation Safety Officer undertakes the measurements, investigations and assessments provided for in section 3 of the Code;

(q) appoint such support staff and provide such equipment and facilities as are necessary to ensure that the Radiation Safety Officer can undertake the measurements, investigations and assessments provided for in section 3 of the Code;

(r) appoint a person to be the Ventilation Officer of the mine or mill, who is so qualified in principles and practices of ventilation as to enable him to undertake the investigations and assessments required of him in the Code;

(s) ensure that the Ventilation Officer undertakes the measurements, investigations, assessments and supervision laid down for his accomplishment in section 4 of the Code;

(t) appoint such support staff and provide such equipment and facilities as are necessary to ensure that the Ventilation Officer can undertake the measurements, investigations, assessments and supervision required by him in section 4 of the Code;

(u) ensure that there is effective collaboration between the Radiation Safety Officer and the Ventilation Officer (when different persons are appointed to these positions) in the investigation and assessment of sources of airborne contamination in a mine or mill and of their control in accordance with section 4.6.1 of the Code;

(v) ensure that effective measures are taken to control these sources of airborne contamination;

(w) require that the results of all measurements, examinations, investigations and assessments performed in accordance with the requirements of the Code are promptly recorded in a register and that, where required in the Code, these results are brought to his attention;

(x) ensure that all work associated with sources of radiation, including the storage, disposal and dispersal of radioactive material, is so arranged and conducted as to afford the standard of radiation protection required in section 3 of the Code for employees and for members of the public in the neighbourhood of the mine or mill;

(y) take measures to ensure that the radiation exposure of these persons is reduced to the lowest practical level;

(z) ensure that each item of radiation protective equipment is examined to determine that it is in good working order when first put into service and subsequently at appropriate intervals, but, in any case, at intervals not exceeding 3 months;

(za) ensure that whenever an item of radiation protective equipment is modified, it is examined to determine that it is in good working order;

(zb) ensure that, whenever a working procedure is changed, each item of radiation protective equipment associated with, or required in, that procedure is examined to determine that it is in good working order;

(zc) ensure that each defect in a work place, facility, plant, equipment or working procedure is promptly investigated to determine whether or not the defect is likely to cause a radiation hazard;

(zd) ensure that each defect likely to lead to a radiation hazard is promptly remedied or the hazard is promptly brought under control and that normal occupancy of all work places and parts of restricted areas in which a radiation hazard may arise is discontinued until the defect is remedied or the radiation hazard is otherwise brought under control;

(ze) arrange for the examinations and investigations required in sections 2.2.23, 2.2.24, 2.2.25 and 2.2.26 of the Code to be performed by the Radiation Safety Officer in collaboration with, as necessary, the Ventilation Officer and for the results of the examinations and investigations to be recorded and promptly brought to his attention;

(zf) provide to an employee, upon his request, the results of assessments required in sections 3.7.4 and 3.7.5 of the Code of his quarterly, annual and progressive annual radiation doses, radon daughter intakes and thoron daughter intakes;

(zg) make arrangements for the health surveillance of employees provided for in section 5 of the Code;

(zh) ensure that an employee, if transferred in accordance with section 5.7.2 of the Code, does not resume his regular work until he has been declared medically fit for that work by the medical practitioner; and

(zi) arrange for transfer of records as provided for in sections 3 and 5 of the Code.

Penalty: 100 dollars.

(2) The Radiation Safety Officer of a mine or mill may be the same person as the Ventilation Officer of that mine or mill.

Duties of employees

5. Where the operations of a mine include the mining or milling of radioactive ores and the provisions of the Code apply in respect of that mining or milling, the employees of the mine shall—

(a) acquaint themselves with and obey all notices displayed in their work places and places they occupy and all instructions issued to them to protect their safety and the safety of others;

(b) refrain from any careless or reckless practice or action likely to result in a radiation hazard for themselves or others;

(c) if they are employees who exercise supervision in accordance with section 2.2.13 of the Code, ensure that the employees they supervise perform their work in accordance with the provisions of the Code;

(d) examine their work places and the plant and equipment they are to use and report forthwith to their supervisor any defect of which they are aware and which they believe is likely to cause a radiation hazard or contribute to one arising;

(e) if they are employees who exercise supervision in accordance with section 2.2.13 of the Code, promptly assess each defect reported to them and, if they believe it likely to cause a radiation hazard or contribute to one arising, report the defect forthwith to the manager;

(f) use in a proper manner all radiation protective equipment furnished for their use;

(g) use, in a manner required by the manager, devices or equipment furnished to them to assess their personal radiation exposure;

(h) not, except for the purpose of inspection, maintenance, repair, modification or replacement, interfere with, remove, alter, displace or render ineffective any radiation protective equipment provided to protect the employee or other persons or interfere with any method, process or working procedure adopted to minimize radiation exposure;

(i) not eat, drink or smoke in areas where the contamination levels may exceed the levels in the Table set out in section 3.11.1 of the Code;

(j) not smoke in underground mines;

(k) following occupancy of work places, wash thoroughly their hands and faces before eating and drinking;

(l) when required by the manager, in accordance with section 3.11.2.2 or 3.11.2.3 of the Code, remove their work clothes in the change room provided for that purpose in accordance with section 4.4.3.1 of the Code, shower thoroughly in the wash room provided in accordance with section 4.4.3.2 of the Code and don their off-duty clothes in the change room provided in accordance with section 4.4.3.1;

(m) at the end of a work shift, and prior to leaving the mine site or mill site, if they have occupied work places during the shift, change their clothes and shower in the manner set out in paragraph (1);

(n) not, subject to sections 3.2.7 and 3.9 of the Code, undertake to receive a radiation dose, radon daughter intake or thoron daughter intake in excess of the limits given for planned special exposures in section 3.2.6 of the Code, except voluntarily to rescue a person, to prevent the exposure of a large number of persons to a radiation hazard or to protect a valuable installation;

(o) undergo all medical examinations and supplementary determinations as arranged by the manager for their health surveillance in accordance with section 5 of the Code; and

(p) when leaving the employment of one operator and taking up employment with another operator, accede to the request of the latter operator to authorize the transfer from the central health authority of a copy of the medical records of the employee as required in section 5.8.3 of the Code.

Penalty: 100 dollars.

SCHEDULE 1

Regulation 2

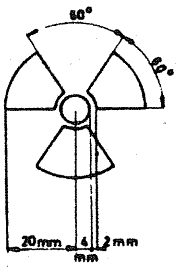
CODE OF PRACTICE

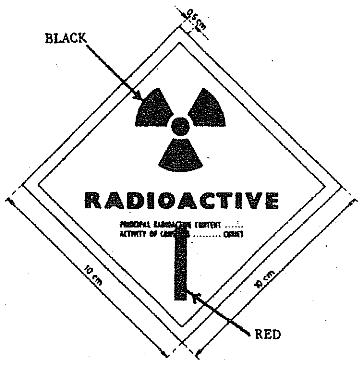
ON

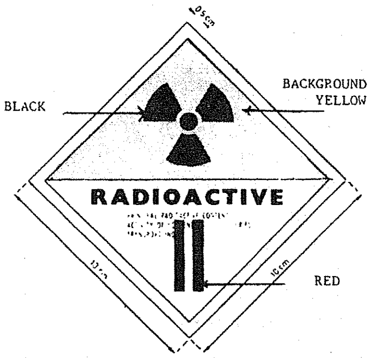
RADIATION PROTECTION IN THE

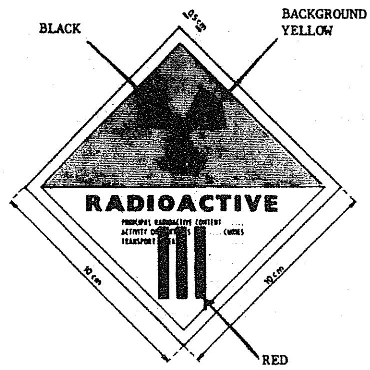
MINING AND MILLING OF RADIOACTIVE ORES

1975









AUSTRALIAN DEPARTMENT OF HEALTH

CANBERRA, A.C.T.

AUGUST, 1975

P.O. BOX 100,
WODEN, A.C.T.

Contents

Section 1

Introduction

Words which are defined in Appendix I are given in italics where they first occur in this Code.

1.1 Scope of this Code

1.1.1 This Code relates solely to the means of providing protection against *radiation* in the mining and milling of *radioactive ores* in order to prevent or limit the radiation risk to the health of persons employed in these operations and of persons in the neighbourhood of *mines* and *mills*. This Code is a guide to safe practices to be followed by *operators* and *employees* engaged in the recovery and processing of radioactive ores and should be applied with sound judgment to specific situations. The provisions apply in particular to such mining operations as excavation, removal and storage of ores, and such milling operations as crushing, grinding, sorting, flotation and other physical concentrating processes, as well as to the production of *concentrates* by chemical means. In addition these provisions relate to the management of all *radioactive materials* produced as waste and effluent in these operations and processes. With the exception of *uranium*, this Code does not specify standards or procedures to limit hazards due to chemical toxicity of materials encountered in mining and milling operations.

1.1.2 The provisions of this Code do not apply to:

(a) a mine that extracts radioactive ores containing less than 0.02 per cent by weight of uranium and less than 0.05 per cent by weight of *thorium* and that has not within it at any time or any place a *radon daughter concentration* in excess of 0.33 *Working Level* (WL), nor

(b) a mill that produces ore concentrates or intermediate products that at no stage of milling contain more than 0.05 per cent by weight of uranium and more than 0.05 per cent by weight of thorium.

1.2 Need for dose limitations

Man has always lived in an environment in which he has been exposed to background radiation of low intensity. This radiation comes from natural sources, including cosmic rays and radioactive material in the body of man and in the environment. Radiation doses greatly exceeding those normally received from natural sources are known to cause harm and, in particular, to increase the risk of cancer. It is not known, however, if harmful effects continue to be induced at low doses and low dose rates comparable to those associated with background radiation. Because of the lack of this knowledge, it is cautiously assumed that any exposure to radiation may entail some risk and that the risk is proportional to the dose received, down to the lowest dose. On the basis of this assumption, it is possible to associate any exposure to radiation with an estimate of the risk of inducing harmful effects. Thus, the levels of radiation dose to persons undertaking work with radiation and radioactive materials can be chosen so that the risks to them are small compared with other occupational risks. Furthermore, levels of radiation dose to members of the public in the neighbourhood of an operation involving radiation and radioactive material can be chosen so that the risks to them are small compared with the risks to which they are exposed in everday life. These levels of dose chosen to limit risks form a set of dose limitations. Dose limitations are applied in operations involving radiation and radioactive materials to ensure that the upper limits of the risks to health of the exposed persons and of society are appropriately small. In addition, dose limitations permit operational control of procedures so that the resulting radiation doses to persons are as low as practical and unnecessary radiation exposure is avoided.

1.3 Radiation protection standards

In general, dose limitations are applied by measurement of exposure rates. In the case of radioactive material which enters the body (in particular by inhalation or ingestion) the control of radiation doses is achieved by control of the *contamination* in air and water and on surfaces. Control of such contamination is achieved by setting permissible *concentrations* of *contaminants* in air and water and working limits for contamination on surfaces. In the special case of exposure of lung tissue to alpha-particle radiation from inhaled *radon daughters* or *thoron daughters* deposited in the lungs, the calculation of the dose delivered is uncertain. In this case, neither a dose limitation nor a permissible concentration in air is set and limitations are placed instead on the *radon daughter intake* and *thoron daughter intake* in a calendar year. The basic dose limitations, the permissible concentrations in air and water and the radon daughter intakes and thoron daughter intakes form a body of limits known as radiation protection standards. These are laid down in 3.2. Working limits for contamination on surfaces are given in 3.11.1.

1.4 Possibility of radiation injury

Unless adequate protective measures are taken in the mining and milling of radioactive ores, it is possible that the radiation protection standards will be exceeded. When radiation protection standards are exceeded by a large factor in a single exposure or a number of exposures over a short period of time or are exceeded over a long period, injury may result. The possible causes of injury requiring consideration in the mining and milling of radioactive ores are as follows:

1.4.1 Excessive inhalation of radon daughters or thoron daughters may result in lung cancer. Lung cancer is a serious risk in *uranium mines* where ventilation is inadequate or mining practices inappropriate.

1.4.2 Long-lived radioactive material which enters the body by inhalation or ingestion and becomes lodged there in excessive amounts may, in time, cause injury. This is usually a risk only in mills.

1.4.3 Sufficiently large doses of gamma radiation from external sources accumulated over all or part of a person's working life may give rise to injury. This is usually not a serious risk in mines or mills.

1.5 Persons

Two categories of persons are considered in this Code when radiation protection standards and requirements for radiation surveillance are laid down:

(a) employees who work in a *restricted area*,

(b) members of the public in the neighbourhood of a mine or mill.

1.6 Protective measures required in this Code

This Code outlines requirements for the following protective measures:

(a) allocation of responsibility for all safety procedures and for the provision and maintenance of all safety equipment,

(b) design, construction, testing and maintenance of installed and personal *radiation protective equipment*,

(c) design and development of mines, design and siting of mills and management of contaminated wastes and effluents from mining and milling of radioactive ores,

(d) consistent and informed use of suitable radiation measuring instruments and personal monitors to detect and assess potential *radiation hazards* and to assess personal doses,

(e) formulation of comprehensive working rules and emergency procedures,

(f) the initial and continued instruction of all persons involved in the mining and milling of radioactive ores,

(g) surveillance of the health of persons engaged in the mining and milling of radioactive ores, and

(h) recording and keeping of all relevant data.

1.7 Special meanings for 'shall' and 'should'

The words 'shall' and 'should', where used in this Code, have special meanings. 'Shall' indicates that the particular requirement is considered essential to ensure protection against radiation. 'Should' indicates a procedure or precaution which is to be applied, whenever practical, to reduce a radiation risk to the minimum.

Section 2

Responsibilities

2.1 Allocation of responsibilities

Both the operator and the employees of the operator have responsibilities to limit radiation exposure, arising in the mining or milling of radioactive ores, to employees and to members of the public in the neighbourhood of the mine or mill. As the responsibilities of the operator may, in practice, be vested in the *manager*, the responsibilities of the operator in applying this Code are referred to in 2.2 as being the responsibilities of the manager. The responsibilities of employees in application of this Code are given in 2.3.

2.2 Responsibilities of the manager

2.2.1 The manager shall ensure that the provisions of this Code are applied in the mine or mill for which he is responsible.

2.2.2 The manager shall notify the appropriate Statutory Authority in writing, prior to operation of the mine or mill and thereafter at intervals not exceeding 12 months, of the individual processes in the mine or mill that will involve exposure to radiation of employees and of members of the public in the neighbourhood of the mine or mill and of the equipment and procedures that will be used and the safety organization established to limit this radiation exposure in accordance with the requirements of this Code.

2.2.3 The manager shall make such notifications to the appropriate Statutory Authority as are required by the provisions of this Code.

2.2.4 The manager shall, with respect to the mine or mill, designate one or more restricted areas and control access to and occupancy of these restricted areas. He shall cause suitable notices to be posted identifying the boundaries of restricted areas.

2.2.5 The manager shall, with respect to the mine or mill, designate and control access to *work places*. He shall bring to the notice of the employees of the mine or mill the areas designated as work places.

2.2.6 The manager shall provide safe work places and a safe working environment in the mine or mill.

2.2.7 The manager shall provide the facilities, plant and equipment required in this Code and shall ensure that they are in safe working condition.

2.2.8 The manager shall maintain and periodically inspect the facilities, plant and equipment provided to limit radiation exposure in restricted areas, work places and the neighbourhood of a mine or mill. He shall record the maintenance carried out and the results of the inspections.

2.2.9 The manager shall provide radiation protective equipment and establish working procedures that, taken together, limit the radiation exposure of employees throughout restricted areas and, in particular, throughout each work place in accordance with 3.2. Only in special circumstances shall personal radiation protective equipment and special individual working procedures be used to limit the radiation exposure of an employee (see 4.4.5 and 4.4.6).

2.2.10 The manager shall periodically assess the radiation protective equipment provided and the working procedures established to ensure they maintain their effectiveness in limiting radiation exposure.

2.2.11 The manager shall ensure that employees, especially those newly engaged, are properly instructed in the radiation hazards of their work and in the precautions necessary to limit radiation exposure of all persons and to avoid radiation accidents and injuries. He shall ensure that reinstruction of employees is undertaken at appropriate intervals.

2.2.12 The manager shall ensure, with respect to each type of work place and working activity in that work place, that notices, embodying the specific working procedures necessary to comply with the provisions of Section 4 of this Code, are posted in prominent positions in the mine or mill. These notices shall be resistant to weather, dust and fumes likely to arise in the mine or mill. The notices shall be in such languages as to ensure comprehension by all employees of the mine or mill.

2.2.13 The manager shall provide the necessary supervision to ensure that employees perform their work in accordance with the provisions of this Code.

2.2.14 The manager shall appoint a person as Radiation Safety Officer of the mine or mill. The person so appointed shall be qualified in the principles and practices of radiation protection in the mining and milling of radioactive ores. The Radiation Safety Officer may also be the Ventilation Officer (see 2.2.17).

2.2.15 The manager shall ensure that the Radiation Safety Officer undertakes the measurements, investigations and assessments provided for in Section 3 of this Code.

2.2.16 The manager shall appoint such support staff and provide such equipment and facilities as are necessary to ensure that the Radiation Safety Officer can undertake the measurements, investigations and assessments provided for in Section 3 of this Code.

2.2.17 The manager shall appoint a person as Ventilation Officer of the mine or mill. The person so appointed shall be qualified in principles and practices of ventilation that enable him to undertake the investigations and assessments required of him in this Code. The Ventilation Officer may also be the Radiation Safety Officer (see 2.2.14).

2.2.18 The manager shall ensure that the Ventilation Officer undertakes the measurements, investigations, assessments and supervision laid down for his accomplishment in Section 4 of this Code.

2.2.19 The manager shall appoint such support staff and provide such equipment and facilities as are necessary to ensure that the Ventilation Officer can undertake the measurements, investigations, assessments and supervision required by him in Section 4 of this Code.

2.2.20 The manager shall ensure that there is effective collaboration between the Radiation Safety Officer and the Ventilation Officer (when different persons are appointed to these positions) in the investigation and assessment of sources of *airborne contamination* in a mine or mill and of their control (see 4.6.1). He shall ensure that effective measures are taken to control these sources of airborne contamination.

2.2.21 The manager shall require that the results of all measurements, examinations, investigations and assessments performed in accordance with the requirements of this Code are promptly recorded in a register. He shall ensure that, where required in this Code, these results are brought to his attention.

2.2.22 The manager shall ensure that all work associated with sources of radiation, including the storage, disposal and dispersal of radioactive material is so arranged and conducted as to afford the standard of radiation protection required in Section 3 of this Code for employees and for members of the public in the neighbourhood of the mine or mill. Furthermore, he shall take measures to ensure that the radiation exposure of these persons is reduced to the lowest practical level.

2.2.23 The manager shall ensure that each item of radiation protective equipment is examined to determine that it is in good working order when first put into service and subsequently at appropriate intervals, but in any case, at intervals not exceeding 3 months.

2.2.24 Whenever an item of radiation protective equipment is modified, the manager shall ensure that it is examined to determine that it is in good working order.

2.2.25 Whenever a working procedure is changed, the manager shall ensure that each item of radiation protective equipment associated with, or required in, that procedure is examined to determine that it is in good working order.

2.2.26 The manager shall ensure that each defect in a work place, facility, plant, equipment or working procedure is promptly investigated to determine whether or not the defect is likely to cause a radiation hazard.

2.2.27 The manager shall ensure that each defect likely to lead to a radiation hazard is promptly remedied or the hazard is promptly brought under control and that normal occupancy of all work places and parts of restricted areas in which a radiation hazard may arise is discontinued until the defect is remedied or the radiation hazard is otherwise brought under control.

2.2.28 The manager shall arrange for the examinations and investigations required in 2.2.23, 2.2.24, 2.2.25 and 2.2.26 to be performed by the Radiation Safety Officer in collaboration, as necessary, with the Ventilation Officer and that the results of the examinations and investigations are recorded and promptly brought to his attention.

2.2.29 The manager shall provide to an employee, upon his request, the results of assessments required in 3.7.4 and 3.7.5 of his quarterly, annual and progressive annual radiation doses, radon daughter intakes and thoron daughter intakes.

2.2.30 The manager shall make arrangements for the health surveillance of employees provided for in Section 5 of this Code.

2.2.31 The manager shall ensure that an employee, if transferred in accordance with 5.7.2, does not resume his regular work until he has been declared medically fit for that work by the medical practitioner.

2.2.32 The manager shall arrange for transfer of records as provided for in Sections 3 and 5 of this Code.

2.3 Responsibilities of employees

2.3.1 Employees shall acquaint themselves with and obey all notices displayed in their work places and places they occupy and all instructions issued to them to protect their safety and the safety of others.

2.3.2 Employees shall refrain from any careless or reckless practice or action likely to result in a radiation hazard for themselves or others.

2.3.3 Employees who exercise supervision in accordance with 2.2.13 shall ensure that the employees they supervise perform their work in accordance with the provisions of this Code.

2.3.4 Employees shall examine their work places and the plant and equipment they are to use and shall report forthwith to their supervisor any defect of which they are aware and which they believe is likely to cause a radiation hazard or contribute to one arising.

2.3.5 Employees who exercise supervision in accordance with 2.2.13 shall promptly assess each defect reported to them and, if they believe it likely to cause a radiation hazard or contribute to one arising shall report the defect forthwith to the manager.

2.3.6 Employees shall use in a proper manner all radiation protective equipment furnished for their use.

2.3.7 Employees shall use, in a manner required by the manager, devices or equipment furnished to them to assess their personal radiation exposure.

2.3.8 Except for the purpose of inspection, maintenance, repair, modification or replacement, no employee shall interfere with, remove, alter, displace or render ineffective any radiation protective equipment provided to protect the employee or other persons or interfere with any method, process or working procedure adopted to minimize radiation exposure.

2.3.9 Employees shall not eat, drink or smoke in areas where the contamination levels may exceed the levels in Table 3.11.1.

2.3.10 Employees should not smoke in underground mines.

2.3.11 Following occupancy of work places, employees shall wash thoroughly their hands and faces before eating and drinking.

2.3.12 When required by the manager, in accordance with 3.11.2.2 and 3.11.2.3, employees shall remove their work clothes in the change room provided for that purpose (see 4.4.3.1), shower thoroughly in the wash room (see 4.4.3.2) and don their off-duty clothes in the change room provided for that purpose (see 4.4.3.1).

2.3.13 At the end of a work shift, and prior to leaving the mine site or mill site, employees who have occupied work places should change their clothes and shower in the manner set out in 2.3.12.

2.3.14 No employee shall undertake to receive a radiation dose, radon daughter intake or thoron daughter intake in excess of the limits given for planned special exposures in 3.2.6 except voluntarily to rescue a person, to prevent the exposure of a large number of persons to a radiation hazard or to protect a valuable installation (see also 3.2.7 and 3.9).

2.3.15 Employees shall undergo all medical examinations and supplementary determinations as arranged by the manager for their health surveillance in accordance with Section 5 of this Code.

2.3.16 When an employee leaves the employment of one operator and takes up employment with another operator, the employee shall accede to the request of the latter operator to authorize the transfer from the central health authority of a copy of the medical records of the employee as required in 5.8.3.

Section 3

Radiation surveillance and protective action

3.1 Responsibility for radiation surveillance and protective action

The manager is responsible (see 2.2.15) for ensuring that the Radiation Safety Officer undertakes the radiation measurements, investigations and assessments required in this Section. These requirements are thus the duties of the Radiation Safety Officer. The manager is responsible (see 2.2.9) for ensuring that the requirements for protective action in this Section are met. The requirements of this Section, together with the other requirements of this Code, are intended to ensure that the recommended radiation protection standards (see 1.3) are not exceeded. However, attention is drawn to the responsibility of the manager to ensure that radiation exposure of persons is reduced to the lowest practical level (see 2.2.22).

3.2 Radiation protection standards

The radiation protection standards set out below are based on the principles given in Appendix II which also gives explanatory information. In assessing the radiation dose to any organ or tissue of a person so as to apply these radiation protection standards, account shall be taken of the doses contributed by external and internal sources of radiation. Different radiation protection standards are set for 2 categories of exposed persons (see 1.5). The radiation protection standards for members of the public shall be applied to the critical groups of persons (see 3. 5.1(b)) in the neighbourhood of a mine or mill and not applied to the whole of the population.

3.2.1 *Radiation doses excluded from dose determinations*

When radiation doses to persons are determined in order to apply the radiation protection standards set out in this Code, the following radiation doses are not to be taken into account:

(a) radiation doses received as a result of radiological examinations, radiotherapeutic treatments or nuclear medicine investigations,

(b) doses due to natural radiation other than those arising from the mining and milling of radioactive ores,

(c) doses to lung tissue caused by alpha-particle radiation from inhaled radon daughters or thoron daughters (but see 3.2.5), nor

(d) doses received by employees outside restricted areas.

3.2.2 *Maximum permissible doses for an employee*

The dose limitations specified for employees are termed maximum permissible doses (see Appendix II, II.2). They apply to the doses received by employees, both at their work places and elsewhere in restricted areas. The maximum permissible doses are expressed in terms of the quantity *Dose Equivalent*, the unit of which is the *rem*.

3.2.2.1 The maximum permissible doses that may be accumulated by an employee in a calendar year are given in the following table:

TABLE 3.2.2.1: ANNUAL MAXIMUM PERMISSIBLE DOSES FOR AN EMPLOYEE

Organ or tissue	*Annual maximum permissible dose (rem)*
Gonads, red bone-marrow, whole body	5
Skin, bone, thyroid	30
Hands and forearms, feet and ankles	75
Any other single organ	15

3.2.2.2 The maximum permissible doses that may be accumulated by an employee in a quarter of a calendar year are given in the following table:

TABLE 3.2.2.2: QUARTERLY MAXIMUM PERMISSIBLE DOSES FOR AN EMPLOYEE

Organ or tissue	*Quarterly maximum permissible dose (rem)*
Gonads, red bone-marrow, whole body	3
Skin, bone, thyroid	15
Hands and forearms, feet and ankles	40
Any other single organ	8
Abdomen of a fertile woman	1.3

3.2.2.3 In the special case of exposure of a pregnant employee, the dose to the foetus shall not exceed 1 rem as a result of the mother's employment in the period between the recognition of her pregnancy and the birth of her child.

3.2.3 *Dose limits for members of the public*

The dose limitations specified for members of the public are termed dose limits. The dose limits for doses accumulated in a calendar year by a member of the public in the neighbourhood of a mine or mill are given in the following table:

TABLE 3.2.3: ANNUAL DOSE LIMITS FOR A MEMBER OF THE PUBLIC

Organ or tissue	*Annual dose limit (rem)*
Gonads, red bone-marrow, whole body	0.5
Skin, bone, thyroid	3
Hands and forearms, feet and ankles	7.5
Any other single organ	1.5

3.2.4 *Maximum permissible concentrations of radioactive materials other than radon daughters and thoron daughters*

As stated in 1.3, the radiation dose received by persons due to incorporation into their bodies of contamination in the air inhaled and water ingested by them is limited in practice by controlling the concentrations of radioactive materials in the air and water. The maximum permissible concentrations in air and water for major contaminants (other than radon daughters and thoron daughters) present in mining and milling radioactive ores are given in Tables 3.2.4.1 and 3.2.4.2. If, after taking account of the provisions of 3.2.1, it is found that the sole source of radiation dose to a person is contamination of air and water, the permissible concentrations set out in Tables 3.2.4.1 and 3.2.4.2, may be used directly as the method of control. The permissible concentrations given in these Tables may also be used to estimate radiation doses that would arise from other concentrations of contaminants. Thus, if there are additional sources of radiation, other than contamination of air or water, to which a person is exposed, appropriate contamination levels in air and water may be estimated to restrict the total doses received to the appropriate limit given in Tables 3.2.2.1, 3.2.2.2 and 3.2.3. The concentrations in Tables 3.2.4.1 and

3.2.4.2 are given on the basis that each contaminant listed is present alone. When mixtures of contaminants occur in air or water, it is necessary to derive appropriate modified limits based on the maximum permissible concentrations in these Tables. Rules for determining such limits are given in Appendix III, III.10.1. Justifying and explanatory notes regarding these Tables are given in Appendix II, II.3. The special case of radon daughters and thoron daughters is considered separately in 3.2.5.

3.2.4.1 The maximum permissible concentrations in air inhaled and water ingested for an employee exposed continuously in his employment for 40 hours per week, 50 weeks per year, are given in the following table:

TABLE 3.2.4.1: MAXIMUM PERMISSIBLE CONCENTRATIONS FOR AN EMPLOYEE EXPOSED DURING WORKING HOURS ONLY (40 HOURS/WEEK)

Contaminant	*Maximum permissible concentration*	
	In air (Ci/m^3)	*In water* (Ci/m^3)
Uranium (soluble)	10^{-10}*	4×10^{-5}*
Uranium (insoluble)	10^{-10}*	10^{-3}*
Thorium (soluble)	6×10^{-11}	6×10^{-5}
Thorium (insoluble)	6×10^{-11}	6×10^{-4}
Thorium–230 (soluble)	2×10^{-12}	5×10^{-5}
Thorium–230 (insoluble)	10^{-11}	9×10^{-4}
Radium–228 (soluble)	7×10^{-11}	8×10^{-7}
Radium–228 (insoluble)	4×10^{-11}	7×10^{-4}
Radium–226 (soluble)	3×10^{-11}	4×10^{-7}
Radium–226 (insoluble)	2×10^{-7}	9×10^{-4}
Radium–224 (soluble)	5×10^{-9}	7×10^{-5}
Radium–224 (insoluble)	7×10^{-10}	2×10^{-4}
Radon–220 alone	6×10^{-6}**	10^{-3}**
Radon–222 alone	3×10^{-6}**	5×10^{-4}**
Lead–210 (soluble)	10^{-10}	4×10^{-6}
Lead–210 (insoluble)	2×10^{-10}	5×10^{-3}

* See Appendix II, II.3.4 and II.3.5
** With no daughter products present

3.2.4.2 The maximum permissible concentrations in air inhaled and water ingested by a member of the public in the neighbourhood of a mine or mill exposed continuously for 168 hours per week are given in the following table:

TABLE 3.2.4.2: MAXIMUM PERMISSIBLE CONCENTRATIONS FOR A MEMBER OF THE PUBLIC

Contaminant	*Maximum permissible concentration*	
	In air (Ci/m^3)	*In water* (Ci/m^3)
Uranium (soluble)	5×10^{-12}*	10^{-6}*
Uranium (insoluble)	4×10^{-12}*	4×10^{-5}*
Thorium (soluble)	2×10^{-12}	2×10^{-6}
Thorium (insoluble)	2×10^{-12}	2×10^{-5}
Thorium–230 (soluble)	8×10^{-14}	2×10^{-6}
Thorium–230 (insoluble)	3×10^{-13}	3×10^{-5}
Radium–228 (soluble)	2×10^{-12}	3×10^{-8}
Radium–228 (insoluble)	10^{-12}	3×10^{-5}
Radium–226 (soluble)	10^{-12}	10^{-8}
Radium–226 (insoluble)	6×10^{-9}	3×10^{-5}
Radium–224 (soluble)	2×10^{-10}	2×10^{-6}
Radium–224 (insoluble)	2×10^{-11}	5×10^{-6}
Radon–220 alone	2×10^{-7}**	3×10^{-5}**
Radon–222 alone	10^{-7}**	2×10^{-5}**
Lead–210 (soluble)	4×10^{-12}	10^{-7}
Lead–210 (insoluble)	8×10^{-12}	2×10^{-4}

* See Appendix II, II.3.4 and II.3.5
** With no daughter products present

3.2.5 *Permissible intakes of radon daughters and thoron daughters*

In the special case of exposure of a person to inhaled radon daughters and thoron daughters (Appendix II, II.1.3), radiation protection is achieved by limiting the intake of these contaminants. In this regard, permissible radon daughter intakes and thoron daughter intakes are given below for employees and for members of the public in the neighbourhood of a mine or mill. These are expressed in terms of *Working Level Months* (WLM).

3.2.5.1 Permissible Radon Daughter Intakes. In a calendar year, the permissible radon daughter intake is 4 WLM for employees and 0.4 WLM for members of the public in the neighbourhood of a mine or mill. In a quarter of a calendar year, the permissible radon daughter intake for employees is 2 WLM.

3.2.5.2 Permissible Thoron Daughter Intakes. In a calendar year, the permissible thoron daughter intake is 40 WLM for employees and 4 WLM for members of the public in the neighbourhood of a mine or mill. In a quarter of a calendar year, the permissible thoron daughter intake for employees is 20 WLM.

3.2.6 *Planned special exposures of an employee*

Planned special exposures of an employee to doses in excess of the limits given in Table 3.2.2.2, or the quarterly limits given in 3.2.5 may be permitted, subject to the conditions given in 3.8. The maximum radiation doses or radon daughter intake or thoron daughter intake for an employee which are permissible in a planned special exposure are as follows:

3.2.6.1 In a planned special exposure:

(a) the maximum dose may be twice the relevant annual maximum permissible dose given in Table 3.2.2.1, and

(b) the maximum radon daughter intake or maximum thoron daughter intake may be twice the relevant annual limit given in 3.2.5.

3.2.6.2 In a number of planned special exposures in the lifetime of an employee:

(a) the total dose received may be 5 times the relevant annual maximum permissible dose given in Table 3.2.2.1, and

(b) the total radon daughter intake or total thoron daughter intake may be 5 times the relevant annual limit given in 3.2.5.

3.2.7 *Emergency and accidental radiation exposures*

Subject to the conditions given in 3.9, a person may undertake to receive voluntarily in emergency operations during or immediately after an accident a radiation dose, radon daughter intake or thoron daughter intake in excess of the appropriate limit for planned special exposures given in 3.2.6.1. A dose limitation is not specified for such an exposure, which is permissible only if it is to be received in rescuing a person, in preventing the exposure of a large number of persons to a radiation hazard or in saving a valuable installation.

3.3 Radiation monitoring equipment

The radiation monitoring equipment to be provided by the manager (see 2.2.16) to ensure that the Radiation Safety Officer can undertake the measurements, investigations and assessments required in this Section includes equipment meeting the following requirements (see Appendix III for appropriate specifications):

3.3.1 *Air sampling equipment*

3.3.1.1 Portable, self-powered, air samplers suitable for sampling long-lived alpha-emitting airborne contamination and short-lived alpha-emitting airborne radon daughters and thoron daughters shall be provided. These air samplers shall be suitable for carriage into and operation in mines and mills. They shall be provided in good working condition and proper calibration in sufficient numbers (but not less than 2) to carry out all routine sampling and foreseeable emergency sampling, at each mine and each mill.

3.3.1.2 Personal, battery-operated air samplers suitable for carriage on the person and operation in mines and mills shall be provided in good working condition and proper calibration in sufficient numbers at each mine and each mill to carry out the monitoring of personal exposure of long-lived alpha-emitting airborne contamination required in 3.7.

3.3.2 *Portable scalers or ratemeters*

Portable, battery-operated, alpha-particle detectors with scalers or ratemeters shall be provided at each mine and mill in sufficient numbers (but not less than 2) in good working condition and proper calibration, to carry out the assessments of *radon daughter concentration* and *thoron daughter concentration* required in 3.4, 3.5 and 3.6 and the assessment of long-lived alpha-emitting contaminants required in 3.4 and 3.5.

3.3.3 *Exposure-rate monitors*

Portable, battery-operated, energy-independent gamma ray exposure-rate monitors shall be provided at each mine and mill, in good working condition and in proper calibration, in sufficient numbers (but not less than 2) to carry out the exposure-rate measurements required in 3.4 and 3.5 at each mine and each mill. These monitors shall provide discrimination against beta rays.

3.3.4 *Surface contamination monitors*

Portable, battery-operated, contamination monitors suitable for monitoring long-lived alpha-emitting *radionuclides* in uranium ores, thorium ores and concentrates of those ores shall be provided in good working condition and proper calibration in sufficient numbers to carry out the surface contamination monitoring required in 3.11.

3.3.5 *Personal gamma exposure monitors*

Personal integrating radiation monitors shall be provided to carry out the monitoring of external gamma radiation exposure of each employee required in 3.7.

3.3.6 *Personal radon daughter monitors*

Personal integrating monitors suitable for monitoring individual radon daughter intake of employees shall be provided in good working condition and proper calibration in sufficient numbers to meet the requirements of 3.7 when such monitors are available and proven for use in mines.

3.4 Monitoring, radiation assessments and classification of employees

To establish the potential hazard from external radiation and from contamination, the Radiation Safety Officer at each mine and mill shall carry out the following monitoring and classification procedures:

3.4.1 At the intervals stated in 3.4.4, 3.4.5 and 3.4.6 the Radiation Safety Officer shall monitor all areas of the mine and mill that are likely to be occupied. In monitoring, the Radiation Safety Officer shall use appropriate instruments and measurement techniques and apply sampling procedures approved by the appropriate Statutory Authority. For each place which is likely to be occupied in each area monitored, the Radiation Safety Officer shall:

(a) assess the radiation doses from external radiation (but not from radon daughters and thoron daughters) that would be received by employees occupying that place full-time,

(b) determine the average concentrations and variation of concentrations, over a working shift, of contaminants (other than radon daughters and thoron daughters) in air and water applying statistical tests approved by the appropriate Statutory Authority,

(c) determine the average concentrations and variation of concentrations, over a working shift, of radon daughters and thoron daughters in air, applying statistical tests approved by the appropriate Statutory Authority, and

(d) determine the average level of surface contamination on accessible surfaces.

3.4.2 At intervals not exceeding 3 months and using the monitoring results most recently determined in accordance with 3.4.1, the Radiation Safety Officer shall establish for each employee the likely radiation dose to that employee in one year (other than doses to lung tissue due to exposure to alpha radiation from inhaled radon daughters or thoron daughters), taking account of the areas in which he will work and the time he will spend in each area. The Radiation Safety Officer shall then classify each employee as belonging to one of the following groups:

(a) the group of employees likely to receive radiation doses in excess of three-tenths of the doses given in Table 3.2.2.1,

(b) the group of employees unlikely to receive radiation doses in excess of three-tenths of the dose limits given in Table 3.2.2.1.

3.4.3 At intervals not exceeding 3 months and using the monitoring results most recently determined in accordance with 3.4.1, the Radiation Safety Officer shall establish for each employee the likely radon daughter intake and thoron daughter intake by that employee in one year, taking account of the areas in which he will work and the time he will spend in each area. The Radiation Safety Officer shall then classify each employee as belonging to one of the following groups:

(a) the group of employees likely to receive a radon daughter intake or a thoron daughter intake in excess of three-tenths of the appropriate annual limit given in 3.2.5, or

(b) the group of employees unlikely to receive a radon daughter intake or a thoron daughter intake in excess of three-tenths of the appropriate annual limit given in 3.2.5.

3.4.4 The Radiation Safety Officer shall monitor as required in 3.4.1 (a) and 3.4.1 (b) at intervals not exceeding one month in each area where an employee classified in the group designated in 3.4.2 (a) may work.

3.4.5 The Radiation Safety Officer shall monitor as required in 3.4.1 (c) at intervals not exceeding one week in each area where an employee classified in the group designated in 3.4.3 (a) may work.

3.4.6 The Radiation Safety Officer shall monitor as required in 3.4.1 (d) at intervals not exceeding one week in meal rooms, offices, recreation rooms, change rooms and wash rooms (see 3.11.2.1) and at intervals not exceeding one month in all other occupied areas (see 3.11.2.2).

3.4.7 When a planned special exposure is to be undertaken (see 3.2.6 and 3.8), the Radiation Safety Officer shall make appropriate complete radiation surveys in each area where the planned special exposure is to be undertaken. He shall assess for each employee to be exposed:

(a) the anticipated and actual radiation doses during the planned special exposure,

(b) the anticipated and actual intakes of radioactive materials (other than radon daughters and thoron daughters),

(c) the anticipated and actual dose commitments, i.e. the total doses that will be delivered to the body organs or tissues receiving the greatest doses in relation to the maximum permissible doses as a result of the intakes referred to in 3.4.7 (b), and

(d) the anticipated and actual radon daughter intake and thoron daughter intake.

3.4.8 After an emergency exposure or accidental exposure (see 3.2.7 and 3.9), the Radiation Safety Officer shall make appropriate complete radiation surveys and assess for each person exposed:

(a) the radiation doses received during the emergency exposure or accidental exposure,

(b) the intakes of radioactive materials (other than radon daughters and thoron daughters),

(c) the dose commitments, as referred to in 3.4.7 (c), and

(d) the radon daughter intake and thoron daughter intake.

3.4.9 The Radiation Safety Officer shall record the results of the monitoring, undertaken in accordance with 3.4.1, 3.4.4, 3.4.5, 3.4.6, 3.4.7 and 3.4.8 and all the criteria taken into account in making assessments and classifications in accordance with 3.4.2, 3.4.3, 3.4.7 and 3.4.8, such as anticipated occupancy, degree of personal protection, estimated doses and dose-rates, estimated exposures to radon daughters and thoron daughters in WLM, rate of production, ore grades and types and presence, magnitude and disturbance of sources of *radon* and *thoron.*

3.4.10 The Radiation Safety Officer shall record radiation doses, dose commitments, radon daughter intakes and thoron daughter intakes resulting from planned special exposures with those received in noımal employment.

3.4.11 The Radiation Safety Officer shall record radiation doses, dose commitments, radon daughter intakes and thoron daughter intakes resulting from emergency exposures or accidental exposures together, but separately from those received in normal employment.

3.5 Monitoring and radiation assessment for members of the public

Responsibility for ensuring control of doses to members of the public in the neighbourhood of a mine or mill rests with the operator (see 4.1 and 4.7).

3.5.1 In the design stage of a mine or mill, when performing the assessment required in 4.7.3, the operator shall ensure that:

(a) the factors which influence the dose to members of the public in the neighbourhood are assessed,

(b) the groups in the public that are likely to be exposed to the highest doses due to the operation of the mine or mill (the critical groups) are determined, and

(c) the mean doses which may be received by the organs and tissues of the critical groups and the mean radon daughter intakes and mean thoron daughter intakes of the critical groups due to the operations of the mine or mill are determined in relation to potential rates of emission and discharge of contaminants.

3.5.2 Following the appointment of the manager and commencement of operations, responsibility for control of doses to members of the public in the neighbourhood of each mine and mill in practice rests with the manager (see 2.2.22). To meet the responsibility, the manager shall ensure that the Radiation Safety Officer carries out the following monitoring and assessment duties:

3.5.2.1 The Radiation Safety Officer shall monitor releases and emissions from tailings dams, overburden and waste rock dumps and ore stockpiles and discharges of contaminated wastes and effluents. In monitoring, he shall use appropriate instruments and measurement techniques and apply sampling procedures and statistical tests approved by the appropriate Statutory Authority.

3.5.2.2 Following monitoring, the Radiation Safety Officer shall determine whether or not discharge limits approved in accordance with 4.7 are met and whether or not the manager's responsibility given in 2.2.22 is being met. To this end, he shall reassess the mean doses, radon daughter intakes and thoron daughter intakes referred to in 3.5.1 (c) and redetermine the critical groups referred to in 3.5.1 (b) at intervals approved by the appropriate Statutory Authority. The assessment referred to in 3.5.1 shall be made available to the Radiation Safety Officer.

3.5.3 The dose limits for members of the public in the neighbourhood of a mine or mill shall be deemed not to have been exceeded if the mean doses to the organs and tissues of the critical groups referred to in 3.5.1 (b) and evaluated by the means outlined therein do not exceed the appropriate limits given in 3.2.3.

3.5.4 The permissible radon daughter intake and permissible thoron daughter intake for a member of the public in the neighbourhood of a mine or mill shall be deemed not to have been exceeded if the mean radon daughter intakes and mean thoron daughter intakes of the critical groups referred to in 3.5.1 (b) and evaluated by the means outlined therein do not exceed the appropriate limits for a member of the public given in 3.2.5.

3.6 Detection and measurement of radon sources in mines

The Radiation Safety Officer at each mine shall carry out the following monitoring and assessments to detect all significant radon sources, to advise the manager on the removal or control of such sources, to reduce variations in radon daughter levels to which employees are exposed, to reduce the requirement for ventilation and variations in that requirement and to reduce the need for personal protective equipment. These requirements are particularly important in underground mines.

3.6.1 The Radiation Safety Officer shall determine:

(a) the location of all significant sources of radon including heaps of broken ore, rock faults, bulkheads of sealed-off areas, mine water and ore faces,

(b) the rate of emanation of all significant sources of radon,

(c) the location of all potential sources of radon which may be released during mining operations such as blasting and removal of heaps of broken ore and the *activity* of radon which may be released.

3.6.2 The Radiation Safety Officer shall assess the contribution of all radon sources to the concentration of radon daughters in all areas occupied by employees. He shall then determine whether or not any of the sources of radon will make a contribution likely to result in:

(a) an employee receiving a radon daughter intake in excess of the relevant limits given in 3.2.5,

(b) a need to reassess the requirements for ventilation, or

(c) personal protective equipment for employees becoming necessary.

3.6.3 The Radiation Safety Officer shall inform the manager when his assessments and determinations made under 3.6.2 indicate that to ensure no employee receives a radon daughter intake in excess of the relevant limits given in 3.2.5, it will be necessary to:

(a) remove a source of radon from the mine,

(b) reduce the emanation of radon (e.g. by reducing pressure within sealed-off areas or reducing the volume of underground openings),

(c) cause employees to temporarily vacate the mine (e.g. during blasting),

(d) improve or increase ventilation, or

(e) provide employees with personal protective clothing and equipment.

3.6.4 The measurements, assessments and determinations required in 3.6.1 and 3.6.2 shall be carried out on a continual basis and each potential or actual source of radon shall be resurveyed at intervals not exceeding one month. The Radiation Safety Officer shall record these measurements, assessments and determinations.

3.7 Personal monitoring and dose assessment

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

3.7.1 Each employee classified as belonging to the group designated in 3.4.2(a) shall be subjected to personal radiation monitoring for external radiation exposure, internal radiation exposure and exposure to uranium.

3.7.2 Each employee classified as belonging to the group designated in 3.4.3(a) shall be subjected to personal monitoring to determine his radon daughter intake and thoron daughter intake.

3.7.3 The personal monitoring requirements of 3.7.1 for external radiation exposure shall be carried out by direct monitoring of employees (e.g. using film badge monitors or thermoluminescent monitors). The personal monitoring requirements of 3.7.1 and 3.7.2 for internal radiation exposure and for exposure to uranium shall be carried out by direct monitoring (e.g. using personal integrating radon daughter monitors, see 3.3.6) or by indirect monitoring. In using indirect monitoring methods, the Radiation Safety Officer shall use appropriate instruments and measurement techniques and apply sampling procedures and statistical tests approved by the appropriate Statutory Authority.

3.7.4 The Radiation Safety Officer shall use the results of personal monitoring carried out in accordance with 3.7.1 to assess the quarterly and annual radiation doses to the whole body and to all organs and tissues (other than lung tissue doses due to alpha-particle radiation from inhaled radon daughters and thoron daughters) of each employee so monitored. The quarterly dose assessments shall be made at the end of each calendar quarter, at which time the progressive annual dose assessment shall be updated.

3.7.5 The Radiation Safety Officer shall assess the quarterly and annual radon daughter intakes and thoron daughter intakes of each employee for whom personal monitoring results are available (see 3.7.2). The quarterly assessments shall be made at the end of each calendar quarter at which time the progressive annual assessment shall be updated.

3.8 Conditions for planned special exposures

Planned special exposures in accordance with 3.2.6 are permitted subject to the following conditions:

3.8.1 The manager shall inform the appropriate Statutory Authority of any intention to apply the provisions of 3.2.6 and shall report in full the anticipated doses, intakes of radioactive materials (other than radon daughters and thoron daughters), dose commitments and radon daughter intakes and thoron daughter intakes.

3.8.2 Planned special exposures shall be undertaken only after careful planning and after the completion of associated radiation surveys and then only when alternative techniques which do not involve such exposures of employees are unavailable or impractical. Planned special exposures shall be reserved for special, infrequent circumstances and shall not be applied to overcome shortcomings in routine procedures.

3.8.3 A planned special exposure of an employee shall not be permitted:

(a) if the intended dose to the body, the gonads or red bone-marrow will cause the accumulated dose to exceed the amount for that person determined by the formula 5(N-18) rem, where N is the age in years of the employee,

(b) if the employee has received in the previous 12 months a single radiation exposure or intake of radioactive material (other than radon daughters and thoron daughters) such that the dose received or to be received as a result of the intake of radioactive material is in excess of the appropriate quarterly limit in Table 3.2.2.2,

(c) if the employee has received in the previous 12 months a single radon daughter intake or thoron daughter intake in excess of the appropriate quarterly limit given in 3.2.5,

(d) if the employee has previously received emergency or accidental radiation doses in excess of 5 times the appropriate annual limit given in Table 3.2.2.1,

(e) if the employee has previously received emergency or accidental radon daughter intakes or thoron daughter intakes in excess of 5 times the appropriate annual limit given in 3.2.5, or

(f) if the employee is a fertile woman.

3.8.4 Any radiation doses, radon daughter intakes or thoron daughter intakes in excess of the limits recommended in 3.2.2 and 3.2.5, received by an employee as a result of planned special exposures, shall not constitute a reason for excluding that employee from his usual occupation.

3.9 Conditions for emergency and accidental radiation exposures

The following conditions apply to emergency exposures undertaken voluntarily and accidental exposures received involuntarily:

3.9.1 Persons likely to be called on in an emergency to receive exposures in accordance with the provisions of 3.2.7 shall be well-informed of the risks involved in accepting higher levels of radiation exposure.

3.9.2 The manager shall make a full report to the appropriate Statutory Authority immediately after each emergency in which emergency exposures were voluntarily received and shall, as soon as practical thereafter, provide assessments to the appropriate Statutory Authority of all emergency and accidental radiation doses, intakes of radioactive materials (including radon daughter intakes and thoron daughter intakes) and dose commitments which were received or incurred during the emergency.

3.9.3 The manager shall make a full report to the appropriate Statutory Authority immediately after receiving an assessment of an accidental exposure received involuntarily in which is received or incurred a radiation dose in excess of the appropriate quarterly limit given in 3.2.2.2 or a radon daughter intake or a thoron daughter intake in excess of the appropriate quarterly limit given in 3.2.5 or a dose commitment due to intake of radioactive material (other than radon daughters or thoron daughters) in excess of the appropriate quarterly limit given in 3.2.2.2.

3.9.4 The manager shall ensure that the requirements for medical examinations given in 2.2.30 and 5.5.2 are met in regard to each employee who receives emergency exposure or accidental exposure. Attention is drawn in this regard to provisions of 5.7.

3.10 Protective action in the presence of airborne contamination

In order to limit doses received by employees due to inhalation of airborne contamination, it is necessary to exercise control of the concentrations of contaminants. While some flexibility is essential in normal operations, persistent high concentrations will prejudice continued operation. Protective action to be taken in the presence of high concentrations of airborne contaminants is set down in this sub-section. This is framed in terms of Protective Action Levels specified for each contaminant.

3.10.1 The Protective Action Levels for airborne contaminants are given in the following table:

TABLE 3.10.1: PROTECTIVE ACTION LEVELS FOR AIRBORNE CONTAMINATION

Contaminant	*Protective action level*
Radon daughters	0.33 WL
Thoron daughters	3.3 WL
Contaminants listed in Table 3.2.4.1	Maximum permissible concentrations in air listed in column 2 of Table 3.2.4.1.

3.10.2 If an average concentration of a contaminant in air (measured in accordance with the monitoring requirements of 3.4.1) at an occupied place of a mine or mill, when multiplied by the fraction of the working time that the place is occupied and expressed as a multiple of the relevant Protective Action Level, exceed unity, the Radiation Safety Officer shall report this occurrence and the multiple obtained to the manager. The manager shall ensure that the protective action given in Table 3.10.2 is taken, according to the multiple of the Protective Action Level which is reported to him.

TABLE 3.10.2: PROTECTIVE ACTION AGAINST AIRBORNE CONTAMINATION

Multiple of relevant protective action level	*Protective action*
Greater than 1 and up to 3	Carry out a survey, determine the cause of a concentration of this magnitude and carry out necessary corrective action as soon as practicable. All operations may continue.
Greater than 3 and up to 10	(i) Suspend normal operations in the work place where a concentration of this magnitude has been measured. (ii) Determine corrective action necessary to reduce the concentration sufficiently to ensure that permissible doses and maximum permissible radon intakes and maximum permissible thoron intakes are not exceeded during normal operations. (iii) Implement corrective action before resuming normal operations.
Greater than 10	(i) Suspend all operations in the work place where a concentration of this magnitude has been measured, vacate the work place and inform the appropriate Statutory Authority of the measured concentration and the action taken and to be taken. (ii) Determine corrective action necessary to reduce the concentration sufficiently to ensure that permissible doses and maximum permissible radon intakes and maximum permissible thoron intakes are not exceeded. Persons who enter the area to determine corrective action shall wear respirators. (iii) Perform necessary corrective action. Respirators shall be worn by persons carrying out protective action and by persons who enter the area to check the effectiveness of protective action. (iv) Inform the appropriate Statutory Authority on resuming normal operations.

3.11 Protective action in the presence of contamination of surfaces

In order to protect employees from the risks of ingestion and inhalation of loose contamination on surfaces in restricted areas of mines and mills, some protective action is required. To formulate such protective action it is necessary to select working limits for surface contamination by alpha-emitting radionuclides.

3.11.1 *Working limits for surface contamination in restricted areas*

The working limits for surface contamination given in Table 3.11.1 shall be applied in carrying out the protective action in this sub-section.

TABLE 3.11.1: WORKING LIMITS FOR SURFACE CONTAMINATION BY ALPHA-EMITTING RADIONUCLIDES IN RESTRICTED AREAS

Type of surface	*Working limit* (Ci/m^2)
Skin	10^{-7}
Accessible surfaces in meal rooms, offices, recreation rooms, change rooms and wash rooms	10^{-6}
Accessible surfaces of occupied areas in mines and mills other than meal rooms, offices, recreation rooms, change rooms and wash rooms	10^{-5}
Clothing	10^{-5}

3.11.2 *Protective action*

The Radiation Safety Officer shall be responsible to ensure that the following protective action is carried out:

3.11.2.1 Meal rooms, offices, recreation rooms, change rooms and wash rooms in restricted areas shall be cleaned daily to remove contamination incorporated in ore dust, concentrate dust and tailings dust from all accessible surfaces. Each week, following cleaning, the accessible surfaces shall be monitored for contamination. If the level of surface contamination, confirmed by a repeat measurement, exceeds the appropriate limit given in Table 3.11.1, the contaminated surfaces shall be cleaned thoroughly and monitored again (and, if necessary, further cleaned and monitored) until the level of contamination no longer exceeds the appropriate limit.

3.11.2.2 Each month the Radiation Safety Officer shall undertake a survey of levels of contamination on accessible surfaces in work places and other occupied areas except in meal rooms, offices, recreation rooms, change rooms and wash rooms in mines and mills. The Radiation Safety Officer shall report promptly to the manager the results of each survey. If the level of surface contamination in any occupied area exceeds the appropriate level given in Table 3.11.1:

(a) the manager shall require employees who enter the area during a work shift to change their clothes and shower in the manner set out in 2.3.12 at the end of that work shift and prior to leaving the mine site or mill site, and

(b) the Radiation Safety Officer shall recommend to the manager additional appropriate protective action.

3.11.2.3 In the event of spillage of uranium or thorium concentrates, the Radiation Safety Officer shall be immediately notified. The clean-up operation shall be carried out following procedures established by the Radiation Safety Officer. Special care shall be taken to avoid dispersing the spilled material. Respirators and protective clothing shall be provided for use where appropriate (see 4.4.5 and 4.4.6). The manager shall require employees engaged in the clean-up operation to change their clothes and shower in the manner set out in 2.3.12 at completion of the operation.

3.12 Records of dose assessments, radioactive intake and contaminant measurements

3.12.1 The Radiation Safety Officer shall retain during the term of employment of an employee all records which are relevant to the assessment of radiation doses, of the radon daughter intakes and of the thoron daughter intakes of that employee. Such records shall be properly documented for future reference and shall include the quarterly and annual assessments of doses to the whole body and to all organs and tissues (other than lung tissues doses due to alpha-particle radiation from inhaled radon daughters and thoron daughters) required in 3.7.4 and of the radon daughter intakes and thoron daughter intakes required in 3.7.5.

3.12.2 The Radiation Safety Officer shall retain all records of measurements made of exposure-rates and of concentrations of contaminants in air and in water. Such records shall be properly documented for future reference. Summaries of these measurements shall be compiled annually.

3.12.3 At the termination of employment of an employee, the manager shall arrange for the records specified in 3.12.1 for that employee to be transferred to the central health authority for retention for 50 years.

3.12.4 The manager shall arrange for copies of the summaries of the records of measurements specified in 3.12.2 to be forwarded annually to the central health authority for retention for 50 years.

3.12.5 When an employee leaves the employment of one operator and takes up employment with another operator, the latter operator shall request the employee to authorize in accordance with 5.8.3 the transfer from the central health authority of a copy of the quarterly and annual assessment of the doses and of the radon daughter intakes and thoron daughter intakes referred to in 3.12.1 received by that employee during all previous employments.

Section 4

Facilities, equipment and procedures

4.1 Initial planning for a mine or mill

4.1.1 In the initial planning of a mine or mill, and pending the appointment of a manager, the operator shall take into consideration the basic facilities and equipment to be provided and the working procedures to be adopted to ensure that the radiation protection standards set down in 3.2 for employees and for members of the public in the neighbourhood of a mine or mill are not exceeded. The dose received by the critical groups (see 3.5.1(b)) of the public will, in practice, be kept within the limits specified by controlling the discharge of contaminated waste and effluent to the environment. Approval for such discharges shall be obtained by the operator from the appropriate Statutory Authority in advance.

4.1.2 Following appointment of a manager and before commencement of operations, the responsibility for the design and development of the mine or mill, the provision of facilities to limit exposure to employees and to members of the public in the neighbourhood of the mine or mill to the requirements of this Code, and the seeking of approvals, where required, from the appropriate Statutory Authority rests with the manager.

4.1.3 A guide, to be used in conjunction with this Section, is given in Appendix IV on the control of radon and radon daughters in mines, on the use of respiratory protective devices to control personal exposure to inhaled radon daughters and on appropriate methods of control and management of contaminated waste and effluent.

4.2 Mine design and development

4.2.1 If a mine is under consideration for development of an orebody, full account shall be taken of the need to control radon and thoron release from underground openings, broken ore and water in the mine and the need to provide ventilation suitable to control radon daughters, thoron daughters and airborne contamination in the mine air. Assessments shall be made of the need to control exposure to radon daughters and thoron daughters at an early stage of design and development of the mine so that the requirements of this Code are met.

4.2.2 The ventilation requirements in underground uranium mines may be different in character and magnitude from those in other underground mines. Provision shall be made at an early stage of design of an underground uranium mine for ventilation shafts and airways, sufficient in size and number, to conduct air to and from occupied areas so as to control the concentration of radon daughters and thoron daughters in these areas throughout the life of the mine.

4.2.3 Open-cut uranium mines are less likely than underground uranium mines to present hazards from radon daughters, thoron daughters and other airborne contamination and from radon and thoron released from *contaminated water*. Nevertheless, assessments shall be made of the need to control exposure to radon daughters and thoron daughters in these mines.

4.2.4 Long-lived alpha-emitting airborne contamination arises in many of the mining operations. The control of dust to protect employees against non-radioactive dust hazards is generally sufficient to reduce the concentrations of airborne contaminations below the appropriate levels in 3.2.4.1. The design and development of a mine, taken in conjunction with the working procedures adopted, shall be such that the dust concentrations do not exceed limits specified by legislation or, in the absence of legislation, established safe limits.

4.2.5 The design, development and operation of a mine shall be such that the wearing of respirators or protective clothing by employees is necessary only in special circumstances (see 4.4.5 and 4.4.6).

4.2.6 In developing an underground mine, unworked, worked-out and abandoned areas which give rise to radon or thoron in occupied areas shall be segregated by sealing off from the occupied areas or by backfilling with material which is not a significant radon source. In sealing off an area, all cracks and porosity shall be properly sealed and consideration shall be given to the need to maintain the sealed-off area under negative pressure. If an area is sealed-off, backfilling with material which is a significant radon source (e.g. mill tailings) may be used (see 4.7.2).

4.2.7 Fixed work stations shall not be located in exhaust airways or in areas of high external radiation.

4.3 Siting and design of mills

4.3.1 *Siting*

Whenever a site for a mill is chosen, the choice shall be made so as to ensure that run-off of rain water and ground water from the mill environs to the mill, tailings storage and disposal areas and ore stockpiles will be controlled so as to limit the dispersal of contaminated material (see also 4.7). In meeting this requirement consideration shall be given to the likely meteorological conditions during the lifetime of the mill, the topography of the environs of the proposed mill and the elevation and route of all water courses in the environs of the proposed mill (see Appendix IV).

4.3.2 *Design*

4.3.2.1 Ventilation and Dust Control. The control of dust to protect employees against non-radioactive dust hazards is generally sufficient to reduce the concentrations of airborne contaminations below the appropriate levels in 3.2.4.1. The design of a mill, taken in conjunction with the working procedures adopted shall be such that the dust concentrations do not exceed limits specified by legislation or, in the absence of legislation, established safe limits. Recognized methods of dust control, such as wetting down of the ore, and use of local air extraction systems shall be employed to ensure protection against airborne contamination during physical separation processes such as ore crushing and screening, at transfer points and during the processes of drying and packing the final product.

4.3.2.2 Final Product Section. The final product drying and packing processes shall be isolated from the remainder of the mill. The design shall be such that these processes, including sampling, are carried out by automatic or semi-automatic operations so as to avoid manual handling of the products and to avoid the wearing of protective clothing or respirators by employees, except in special circumstances (see 4.4.5 and 4.4.6).

4.4 Facilities and equipment in mines and mills

The manager of a mine or mill shall ensure that facilities and equipment are supplied in accordance with the following requirements:

4.4.1 *General radiation protection requirements*

4.4.1.1 All radiation protective equipment shall be suitable for the purpose for which it is intended, shall provide protection and should be convenient to use.

4.4.1.2 Radiation protective equipment and procedures of the type intended to provide protection throughout an area shall be used in preference to personal protective equipment.

4.4.2 *Drinking and washing water*

Water supplied to a mine or mill for drinking and washing shall not have a concentration of a contaminant in excess of the appropriate limit given in Table 3.2.4.1.

4.4.3 *Meal rooms, change rooms, wash rooms and recreation rooms*

Meal rooms, change rooms and wash rooms shall be provided for the use of all employees at each mine and mill. These rooms shall be situated in at least one restricted area but they shall not be situated in work places. Recreation rooms, if provided, shall not be situated in work places. Requirements for cleaning and radiation monitoring of meal rooms, change rooms, wash rooms and recreation rooms are given in 3.11. These rooms shall satisfy the following requirements:

4.4.3.1 At least one change room for donning and removing off-duty clothes and a separate change room for donning and removing work clothes shall be provided in at least one restricted area. There shall be a step-over barrier between these 2 rooms.

4.4.3.2 At least one wash room, separate from the change rooms, shall be provided. It shall include showers and drying facilities (see also 2.3.12 and 2.3.13).

4.4.3.3 Change rooms and wash rooms shall be so constructed as to ensure that waste water is carried away from the wash rooms and cannot enter the change rooms.

4.4.3.4 They shall be constructed of materials that are easy to clean and that will withstand cleaning without rapid deterioration of their surface finishes.

4.4.3.5 Meal rooms shall include personal washing facilities.

4.4.4 *Residential quarters*

Residential quarters shall not be sited in restricted areas.

4.4.5 *Clothing*

4.4.5.1 Work clothes, removed in the change room provided for that purpose (see 4.4.3.1), shall be laundered at least once each week within a restricted area.

4.4.5.2 The following protective clothing shall be provided for each employee when engaged in decontamination activities, in cleaning up a spill of concentrate of uranium or thorium (see 3.11.2.3), where manual operations with concentrates or uranium or thorium take place or where recommended by the Radiation Safety Officer (see 3.11.2.2):

(a) overalls or tight-closing boiler suits,

(b) head coverings,

(c) gloves,

(d) footwear.

4.4.5.3 The manager shall arrange for protective clothing to be cleaned in a restricted area after each use.

4.4.6 *Respirators*

4.4.6.1 Respirators shall be provided in accordance with 4.4.6.4 for each employee:

(a) when engaged in decontamination activities,

(b) in cleaning up a spill of concentrate of uranium or thorium (see 3.11.2.3),

(c) in manual operations with concentrates of uranium or thorium,

(d) in taking the protective action referred to in 3.10, or

(e) when engaged in special activities which may result in a radon daughter intake or a thoron daughter intake in excess of the quarterly limits given in 3.2.5 (see 3.6.3 and 4.6.1.5.2).

4.4.6.2 Dust respirators shall comply with the requirements of the Australian Standard Specification for Respiratory Protective Devices AS1716–1975 and shall be worn and maintained in accordance with the requirements of the Australian Standard Code of Practice for Respiratory Protection AS1715–1975. Class M filters shall be worn with half-face pieces and Class H filters with full-face pieces.

4.4.6.3 Positive pressure, powered dust respirators shall comply with the requirements of British Standard Specification for Positive Pressure, Powered Dust Respirators, BS4558–1970.

4.4.6.4 Prior to the use of respirators a well-planned respiratory protective programme shall be instituted and this shall include:

(a) air sampling and other surveys sufficient to identify the hazard, to evaluate individual exposures and to permit selection of respirators to afford necessary protection,

(b) a written policy statement by the manager on respirator usage,

(c) written procedures to ensure proper selection, supervision and training of personnel using respirators,

(d) written procedures to ensure satisfactory individual fitting of respirators, and

(e) written procedures to provide for cleaning, inspection, repair and storage of respirators.

4.5 Control of sources of radon and thoron

The following measures shall be undertaken to control, in mines and mills, sources of radon and thoron and the release of radon and thoron from such sources.

4.5.1 *Contaminated underground water*

Underground water may be contaminated with radon or thoron dissolved under pressure within the ground, Upon entry of such water into underground openings, release of much of the dissolved radon and thoron to the air occurs. The consequent growth of radon daughters or thoron daughters in the mine air may lead to a radiation hazard in underground mines, but is less likely to cause a hazard in open-cut mines. Where such a hazard arises, the water shall be confined, close to its point of entry into the mine, in sealed channels or pipes and conveyed, with as few transfer points as practical, out of the mine.

4.5.2 *Changes in mine conditions and mining procedures*

In order to meet the requirements of 2.2.22 with regard to airborne radon daughters and thoron daughters, the effects of all changes in mine conditions and mining procedures on the radon, thoron, radon daughter and thoron daughter concentrations shall be assessed. Where assessment reveals a need to alter the mining practices, ventilation, radiation protective equipment or working procedures in use to meet the requirements of 2.2.22, the necessary alterations shall be instituted, recorded and reported promptly to the appropriate Statutory Authority. Changes which may result in an immediate variation in the concentrations of radon, thoron, radon daughters and thoron daughters include extension of the mine, changes in the pressure differentials in the mine, changes in the type, grade or porosity of the ore worked, changes in the location or quantity of the ore stored underground and loosening of the air doors and bulkheads.

4.5.3 *Broken material stored in mines*

Careful attention shall be paid to the release of radon and thoron from broken ore stored in the mine. In particular, broken uranium ores release radon continuously from stationary heaps and larger short-term releases can occur when a heap is moved. In order to meet the requirements of 2.2.22 with regard to airborne radon daughters and thoron daughters, the need to limit the quantity of broken ore stored underground and in open cuts, to limit the duration of its storage, to change the location of such stores and to choose the times for their movement shall be continually assessed.

4.5.4 *Segregated areas*

The manager shall ensure that airtight barriers used to segregate unworked, worked-out or abandoned areas of a mine (see 4.2.6) are installed and removed only at his direction and under conditions specified by him.

4.6 Control of exposure to dust and airborne contamination

The following requirements for ventiliation, equipment and procedures are laid down to ensure control of exposure to dust and airborne contamination as required in 4.2.4 and 4.3.2.1.

4.6.1 *Ventilation*

4.6.1.1 Sufficient air shall be provided at all times to each work place to ensure that the exposure of any employee to dust will not exceed the established safe limits (see 4.2.4 and 4.3.2.1) and to ensure, in conjunction with the measures required in 4.5, that no employee receives a radon daughter intake or thoron daughter intake in excess of the appropriate limits given in 3.2.5 (however see 4.4.6).

4.6.1.2 In each underground mine, the requirements of 4.6.1.1 shall be met by provision of a ventilation system. Prior to installation of the initial ventilation system, the operator shall arrange for the ventilation requirements to be assessed and the system designed by a person or persons qualified in the principles of design and operation of such systems in underground mines and familiar with the special requirements of underground uranium mines. Prior to installation of this system, the operator shall submit the design in detail for approval to the appropriate Statutory Authority. After commencement of operations, the ventilation requirements shall be assessed by the Ventilation Officer in collaboration with the Radiation Safety Officer. Where assessments reveal a need for further ventilation or alterations to the ventilation, the ventilation system shall be redesigned promptly and the proposed variations shall be submitted for approval to the appropriate Statutory Authority. The ventilation system shall meet the following requirements:

4.6.1.2.1 It shall provide a supply of air for breathing by employees in each work place.

4.6.1.2.2 It shall be so arranged that contaminated air in the vicinity of each employee in each work place is promptly removed.

4.6.1.2.3 It shall use supply airways or ducts or both that are suitable to so limit the increase in contamination of the supplied air during passage to the work place as to ensure that the requirements of 4.6.1.1 are met.

4.6.1.2.4 Its air inlet shall be so positioned as to provide an air supply meeting the requirements of 4.6.1.1 at all times and under all meteorological conditions which occur at the mine.

4.6.1.3 For each open-cut mine, prior to preliminary excavations and commencement of production, the operator shall arrange for the need for ventilation, and if needed its requirements, to be assessed by a person or persons qualified in the principles of design and operation of ventilation of open-cut mines and mining vehicles and familiar with the special requirements for open-cut mines for radioactive ores.

Where assessments reveal a need for ventilation, a supply of air for breathing shall be provided under positive pressure. Prior to providing this air supply, the proposals for ventilation shall be submitted for approval to the appropriate Statutory Authority. Following commencement of operations, the ventilation requirements shall be assessed by the Ventilation Officer in collaboration with the Radiation Safety Officer. Where assessments reveal a need for further ventilation or alterations to the ventilation, the ventilation shall be redesigned promptly and the proposed variations shall be submitted for approval to the appropriate Statutory Authority.

4.6.1.4 In each mill, the requirements of 4.6.1.1 shall be met by provision of local air extraction systems. Prior to installation of the initial systems, the operator shall arrange for their requirements to be assessed by a person or persons qualified in the principles of local air extraction systems. Prior to installation of these systems, the operator shall submit the design in detail for approval to the appropriate Statutory Authority. The requirements for subsequent air extraction systems or for variations in the initial systems shall be assessed by the Ventilation Officer in collaboration with the Radiation Safety Officer. The design for subsequent systems and proposals for variations in the initial systems shall be submitted for approval to the appropriate Statutory Authority.

4.6.1.5 Ventilation Procedures. In mines and mills the procedures to be adopted for ventilation and air extraction systems shall include the following:

4.6.1.5.1 The operation of all ventilation and air extraction systems shall be supervised by the Ventilation Officer. The Ventilation Officer in collaboration with the Radiation Safety Officer shall assess the effectiveness of the systems upon installation, routinely thereafter at intervals not exceeding 3 months in mines and at least weekly for local air extraction systems in mills and, in addition, after each significant modification of a system. They shall record the results of these assessments and report them promptly to the manager, together with a detailed description of the system in operation during the assessment.

4.6.1.5.2 On receiving notice of stoppage of any part of a ventilation or air extraction system the manager shall take immediate action to ensure the safety of persons either by restoring ventilation, by providing auxiliary ventilation, by evacuating persons or by providing them with appropriate personal protective equipment (see 4.4.5 and 4.4.6).

4.6.1.5.3 The main ventilation system of a mine or mine sector shall be operated continuously, or for a length of time prior to entry of persons sufficient to provide protection against airborne contamination. The ventilation system of a mine shall be turned off only with the authority of the manager.

4.6.1.5.4 Following a suspension of activities in a mine for a period of 16 hours or more during which the ventilation system has not operated, or has operated at a reduced level, the manager shall specify the conditions under which the mine may be re-entered.

4.6.2 *Dust control*

4.6.2.1 Rock Drilling. The following requirements for equipment and procedures to be used to control dust in rock drilling shall be met:

4.6.2.1.1 All rock drilling in underground mines shall be done with equipment that uses water to clear the drill cuttings from the borehole to suppress dust.

4.6.2.1.2 In open-cut mines, drilling should be done in accordance with requirements for underground mines given in 4.6.2.1.1. If dry drilling is used, the dust produced shall be collected so that the requirements of 4.2.4 are met.

4.6.2.1.3 Where pneumatic drills are used, the raising of dust by the exhaust air shall be prevented.

4.6.2.2 Blasting. The following requirements for equipment and procedures to be used to control dust in blasting shall be met:

4.6.2.2.1 Dust from blasting in underground mines shall be removed by mechanical ventilation.

4.6.2.2.2 The times and procedures used for blasting shall be so chosen as to reduce to a minimum the number of persons exposed to the dust produced.

4.6.2.2.3 The manager shall ensure that employees responsible for blasting have received instruction in the dust risks involved.

4.6.2.3 Transport. The following requirements shall be met with respect to the equipment and procedures for transport of ores:

4.6.2.3.1 The formation and dispersal of dust shall be limited at all stages of transport to the requirements of this Code, taking into consideration:

(a) the design and use of transfer, loading and discharge systems and their components,

(b) The design and use of transport equipment,

(c) the need for each transfer point.

4.6.2.3.2 Transport systems and transport routes shall be properly maintained and dust shall be consolidated or cleaned from them regularly.

4.6.2.3.3 Spillage occurring during transport shall be regularly collected and removed.

4.6.2.3.4 Transport shall be arranged so as to avoid the accumulation of material at transfer points.

4.6.2.3.5 Material transported shall be protected from exposure to high velocity air currents or winds.

4.6.2.4 Suppression of Deposited Dust.

4.6.2.4.1 Water or other agents shall be used to prevent deposited dust from becoming airborne, and shall be applied as often as necessary to consolidate the dust.

4.6.2.4.2 The manager shall ensure that employees responsible for watering and spraying have received instruction in these techniques.

4.6.2.4.3 Water used for consolidating dust shall not be applied with such force as to raise dust.

4.7 Management of contaminated waste and effluent

4.7.1 Contaminated waste and effluent from mines and mills shall be so managed as to ensure that the radiation protection standards specified for employees in 3.2.2 and 3.2.5 are maintained. The release of contaminated waste and effluent into *unrestricted areas* shall be so controlled to limit the exposures to members of the public in the neighbourhood of the mine or mill as a result of dispersion of the contaminated material in the environment to levels not exceeding the limits specified in 3.2.3 and the relevant parts of 3.2.5 or such lower limits as are prescribed with respect to that release of contaminated waste and effluent by the appropriate Statutory Authority. Additional information on the management of such waste and effluent is given in Appendix IV.

4.7.2 Overburden and waste rock dumps and tailings dams in disposal and storage areas shall be so placed, formed and stabilized as to ensure the maximum practical containment of their contents under all likely meteorological conditions, having particular regard to seasonal changes and the possibility of leaching of radioactive materials from the dumps and dams. Contaminated waste and effluent that is released from dumps and dams shall be collected and contained separately to the extent necessary to ensure that the limits approved in accordance with 4.7.3 are not exceeded. Consideration shall be given to the placement of overburden, waste rock and tailings in unworked, worked-out or abandoned areas of mines (see 4.2.6) and account shall be taken of the environmental effects of such action. The proposals for design and long-term management of overburden and waste rock dumps and of tailings dams shall be submitted for approval to the appropriate Statutory Authority.

4.7.3 The manager shall make a detailed safety assessment with respect to the release of contaminated airborne and liquid effluents into unrestricted areas (see 3.5). The assessment shall determine the rates of releases that will ensure the requirements of 4.7.1 are met. He shall make an application to the appropriate Statutory Authority for approval of the rates of release of contaminants that may be permitted in wastes and effluent released to the environment.

4.8 Transport of radioactive concentrates

4.8.1 Radioactive concentrates shall be packed in containers for transport and labelled in accordance with the requirements of the appropriate regulations and with the International Atomic Energy Agency's regulations for the transport of radioactive materials.

4.8.2 The containers used for transport shall be of a type approved by the appropriate Statutory Authority.

Section 5

Health surveillance

5.1 Need for health surveillance

It is important that the health of persons seeking employment or employed in the mining and milling of radioactive ores be assessed to determine whether or not they are fit for the tasks for which they seek employment or on which they are employed. The requirements of this Code for health surveillance are given below. Attention is drawn to the requirements of all relevant legislation which may impose requirements additional to the following.

5.2 Type and extent of health surveillance

The health surveillance of employees engaged in the mining and milling of radioactive ores shall meet the requirements of general occupational medical practice and shall include the additional medical examinations required in 5.4, 5.5 and 5.8 and the supplementary determinations specified in 5.6. A guide to the type and scope of medical examination for such employees is given in Appendix V.

5.3 Arrangements for medical examinations and supplementary determinations

5.3.1 The manager shall make adequate arrangements for all pre-employment medical examinations (see 5.4), medical examinations during employment (see 5.5), and supplementary determinations (see 5.6) required in this Code and shall ensure that these examinations and determinations are carried out. These examinations and determinations shall be without expense to the employee.

5.3.2 The manager shall make adequate arrangements for all terminal medical examinations (see 5.8), without expense to the employee.

5.4 Pre-employment medical examinations

Except as prescribed in 5.8.2 each person seeking employment in the mining or milling of radioactive ores on duties which have been assessed by the Radiation Safety Officer as likely to give rise to doses to organs and tissues of that person in excess of three-tenths of the maximum permissible doses specified in Table 3.2.2.1 or a radon daughter intake or thoron daughter intake in excess of three-tenths of the appropriate limit given in 3.2.5 shall undergo a medical examination within a period of 4 weeks prior to, or within a period of 4 weeks immediately after the date of commencing such duties. This medical examination shall include direct radiographic examination of the chest using X-ray film. Because in general, the mining and milling of radioactive ores is carried out in remote areas and because it is possible that an employee may transfer from one type of duty to another involving a change in potential exposure levels, all other persons seeking employment in this industry should undergo this type of pre-employment medical examination.

5.5 Medical examinations during employment

5.5.1 Additional medical examinations of all employees employed on duties that have been assessed by the Radiation Safety Officer as likely to give rise to doses to organs and tissues of such employees in excess of three-tenths of the maximum permissible doses specified in Table 3.2.2.1 or a radon daughter intake or thoron daughter intake in excess of three-tenths of the appropriate limit given in 3.2.5 shall be carried out at intervals not exceeding 12 months. The frequency and extent of examinations shall be determined by the medical practitioner, taking account of the conditions of work and the general health of the employee, particularly any recent reported illness or injury. A direct radiographic examination of the chest using X-ray film of these employees shall be carried out annually, or more frequently if considered essential by the medical practitioner.

5.5.2 Medical examinations shall be carried out on employees who, in an emergency operation or as a result of accidental exposure, receive a radiation dose, dose commitment or radon daughter intake or thoron daughter intake in excess of the levels given in 3.2.6.1. Supplementary determination shall also be carried out when considered appropriate.

5.6 Supplementary determinations

5.6.1 In a mill for the production of chemical concentrates of uranium, measurements of the uranium content of the urine shall be made in the case of each employee whose duties have been assessed by the Radiation Safety Officer as likely to give rise to exposure to airborne uranium concentrations in excess of three-tenths of the maximum permissible concentration specified in Table 3.2.4.1. These measurements shall be made at intervals determined by the medical practitioner who makes the examination required in 5.5.1 of that employee, but in any case at intervals not exceeding 12 months. Check determinations should be made in the case of other employees engaged in the mill as determined by the Radiation Safety Officer in consultation with the medical pratitioner.

5.6.2 In a mill for the production of chemical concentrates of thorium, estimates of the internal contamination by thorium shall be made in the case of each employee whose duties have been assessed by the Radiation Safety Officer as likely to give rise to exposure to airborne thorium concentrations in excess of three-tenths of the maximum permissible concentration specified in Table 3.2.4.1. These estimates may be made by determining the radium-228 content of urine. Measurements and the subsequent estimates shall be made at intervals determined by the medical practitioner who makes the examination required in 5.5.1 of that employee, but in any case at intervals not exceeding 12 months. Check determinations should be made in the case of other employees engaged in the mill as determined by the Radiation Safety Officer in consultation with the medical practitioner.

5.6.3 The medical practitioner shall make available to the Radiation Safety Officer the results of the supplementary determinations made under 5.6.1 and 5.6.2.

5.6.4 Where the results of the supplementary determinations, made under 5.6.1 and 5.6.2, of an employee are not in accordance with the employment history of that employee, the manager and the Statutory Authority shall be immediately informed.

5.7 Recommendations of medical practitioner

5.7.1 Following his examination of an employee in accordance with 5.5 and supplementary determinations 5.6 the medical practitioner shall inform the manager when, in his opinion the manager ought to act to reduce any radiation hazard to the health of that person.

5.7.2 The medical practitioner may recommend in regard to the employee examined in accordance with 5.5 and supplementary determinations 5.6 transfer from his regular work for a specified period.

5.8 Medical examination upon termination of employment

5.8.1 Each employee who has been employed by the operator for a period of not less than 6 months shall undergo a terminal medical examination and supplementary determination (see 5.6) by a medical practitioner on termination of his employment.

5.8.2 If an employee who has been medically examined in accordance with 5.8.1 seeks similar employment with another operator the medical practitioner engaged by the latter operator may accept the report of the terminal medical examination, in lieu of the pre-employment examination required in 5.4 or part thereof, provided a period of not more than 8 weeks has elapsed since the terminal medical examination was performed.

5.8.3 When an employee leaves the employment of one operator and takes up employment with another operator, the latter operator shall request the employee to authorize the transfer of a copy of his medical records from the central health authority (see 5.9.2) to the medical practitioner acting on behalf of the latter operator.

5.9 Medical records

5.9.1 The Manager shall arrange for medical records to be maintained for each employee. These shall contain the original reports of all medical examinations and medical laboratory tests carried out in accordance with this Code whilst employed by the operator. The records shall include the originals of all radiographic films.

5.9.2 At the termination of employment of an employee, the manager shall arrange for the medical records of the employee, including those of the terminal examination to be transferred to the central health authority for retention for 50 years.

5.9.3 Records should be maintained in a form standardized at the national level when such a form becomes available. A suggested format for use in the interim is included in Appendix V.

Appendix I

Definitions

I.1 **Absorbed dose**

The absorbed dose (D) is the quotient of ΔE by Δm, where ΔE is the energy imparted by ionizing radiation (see I.16) to the matter in a volume element and Δm is the mass of the matter in that element, i.e.:

$$D = \frac{\Delta E}{\Delta m}.$$

The special unit of absorbed dose is the rad.

$$1 \text{ rad} = 0.01 \text{J/kg} = 100 \text{ erg/g}.$$

I.2 **Activity**

The activity (A) of a quantity of a radionuclide (see I.21) is the quotient of ΔN by Δt where ΔN is the number of nuclear transformations which occur in this quantity in time Δt, i.e.:

$$A = \frac{\Delta N}{\Delta t}.$$

The special unit of activity is the curie (Ci).

1 Ci = 3.7×10^{10} disintegrations per second (exactly).

I.3 **Airborne contamination**

Contamination (see I.8) forming part of, suspended in or carried by air.

I.4 **Concentrate**

The end-product of the processes of milling of a radioactive ore (see I.20).

I.5 **Concentration**

The mass or activity (see I.2) of a constituent substance per unit volume of air, water or other material.

I.6 **Contaminant**

A radionuclide (see I.21) which is a component of specified contamination (see I.8).

I.7 **Contaminated water**

Water having contamination (see I.8) in solution or suspension.

I.8 **Contamination**

Radioactive material (see I.19) in unsealed gaseous, liquid or particulate form in air, water or other substances or on surfaces.

I.9 **Daughter products**

Radionuclides (see I.21) which are formed as the result of radioactive decay of a specified radionuclide.

I.10 Dose equivalent

The dose equivalent (*DE*) is defined as the product of absorbed dose (*D*) (see I.1), quality factor (*QF*), absorbed dose distribution factor (*DF*), and other necessary modifying factors, i.e.:

$$DE = D \times QF \times DF \quad . \; . \; . \; . \; . \; .$$

The unit of dose equivalent is the 'rem'. The dose equivalent in rem is numerically equal to the absorbed dose in rad multiplied by the appropriate modifying factors.

I.11 Employee

A person of any classification or grade employed by the operator (see I.15) and engaged in activities for which he receives direct payment.

I.12 Manager

The person appointed by the operator (see I.15) of a mine (see I.14) or mill (see I.13) who is responsible for the technical and administrative direction of the mine or mill.

I.13 Mill

A facility used for physically concentrating radioactive ores (see I.20) or for producing concentrates (see I.4) of radioactive ores by chemical means, its associated administrations support and facilities for management of contaminated waste and effluent.

I.14 Mine

A facility engaged in the extraction (including excavation, removal and storage) of radioactive ores (see I.20), its associated administrative support and facilities for management of contaminated waste and effluent.

I.15 Operator

The person, company or authority on whose behalf a mine (see I.14) or mill (see I.13) for radioactive ores (see I.20) is managed.

I.16 Radiation

Ionizing radiation, that is, electromagnetic or corpuscular radiation capable of producing ions directly or indirectly in passage through matter.

I.17 Radiation hazard

A hazard to the health of a person due to radiation (see I.16).

I.18 Radiation protective equipment

Equipment intended for the protection of a person or persons against a radiation hazard (see I.17). It may be intended for wearing on the person to ensure individual protection in a hazardous area (personal protective equipment) or to provide protection throughout an area.

I.19 Radioactive material

A material which spontaneously emits radiation (see I.16).

I.20 Radioactive ore

An ore or mineral bearing uranium (see I.34) or thorium (see I.28) or their radioactive daughter products (see I.9).

I.21 Radionuclide

A species of radioactive atom having specified numbers of neutrons and protons in its nucleus.

I.22 Radon

The radioactive gas radon-222 (^{222}Rn).

I.23 Radon daughters

The short-lived radioactive products of decay of radon, (see I.22), viz. polonium-218 (^{218}Po or RaA, lead-214 (^{214}Pb or RaB), bismuth-214 (^{214}Bi or RaC) and polonium-214 (^{214}Po or RaC′).

I.24 Radon daughter concentration

The radon daughter (see I.23) concentration (C) in a volume element of air ΔV is the quotient of ΔE by ΔV, where ΔE is the total ultimate alpha-particle energy emission of the radon daughters in the volume element ΔV, i.e.:

$$C = \frac{\Delta E}{\Delta V}.$$

The special unit of radon daughter concentration is the Working Level (WL) (see I.37).

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

I.25 Radon daughter intake

The radon daughter intake of a person (S) is the sum, for all exposures of a person to inhaled radon daughters (see I.23) within a stated period T, of all products formed by multiplying the radon daughter concentration C_i (see I.24) in the air he breathed and the time t_i for which he breathed that concentration, i.e.:

$$S = \sum_{i=1}^{n} C_i t_i \text{ and } T = \sum_{i=1}^{n} t_i.$$

In practice, the radon daughter concentrations C_i may be known only as average concentrations $\overline{C}_i$ over fairly long periods t_i. Then S may be determined as the sum

$$S = \sum_{i=1}^{n} \overline{C}_i t_i.$$

The special unit of radon daughter intake is the Working Level Month (WLM) (see I.38).

$$1 \text{ WLM} = 170 \text{ WL. hour} = 8.0 \times 10^{10} \text{ MeV second/litre.}$$

I.26 Rem

The special unit of dose equivalent (see I.10).

I.27 Restricted area

An area, access to which is subject to control by the manager (see I.12) for purposes of protecting persons from exposure to radiation (see I.16) and radioactive materials (see I.19).

I.28 Thorium

The mixture of thorium-232 (^{232}Th) and thorium-228 (^{228}Th) in the proportion in which they occur naturally.

I.29 Thoron

The radioactive gas radon-220 (^{220}Rn).

I.30 Thoron daughters

The short-lived radioactive products of decay of thoron, (see I.29) viz. polonium-216 (^{216}Po or ThA), lead-212 (^{212}Pb or ThB), bismuth-212 (^{212}Bi or ThC), polonium-212 (^{212}Po or ThC′) and thallium-208 (^{208}Tl or ThC″).

I.31 Thoron daughter concentration

The thoron daughter (see I.30) concentration (C) in a volume element of air ΔV is the quotient of ΔE by ΔV, where ΔE is the total ultimate alpha-particle energy emission of the thoron daughters in the volume element ΔV, i.e.:

$$C = \frac{\Delta E}{\Delta V}.$$

The special unit of thoron daughter concentration is the Working Level (WL) (see I.37).

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

I.32 Thoron daughter intake

The thoron daughter intake of a person (S) is the sum, for all exposures of a person to inhaled thoron daughters (see I.30) within a stated period T, of all products formed by multiplying the thoron daughter concentration C_i (see I.31) in the air he breathed and the time t_i for which he breathed that concentration, i.e.:

$$S = \sum_{i=1}^{n} C_i t_i \text{ and } T = \sum_{i=1}^{n} t_i.$$

In practice, the thoron daughter concentrations C_i may be known only as average concentrations $\bar{C}_i$ over fairly long periods t_i. Then S may be determined as the sum

$$S = \sum_{i=1}^{n} \bar{C}_i t_i.$$

The special unit of thoron daughter intake is the Working Level Month (WLM) (see I.38).

1 WLM = 170 WL. hour = 8.0 x 10^{10} MeV second/litre.

I.33 Unrestricted area

An area access to which is not subject to control by the manager (see I.12) for purposes of protecting persons from exposure to radiation (see I.16) and radioactive materials (see I.19).

I.34 Uranium

The mixture of uranium-238 (^{238}U), uranium-235 (^{235}U) and uranium-234 (^{234}U) in the proportions in which they occur naturally.

I.35 Uranium mine

A mine (see I.14) from which uranium-bearing ores are extracted.

I.36 Work place

An area or region under the control of the manager (see I.12) in which work activities directly entailed in mining and milling of radioactive ores (see I.20) are carried out.

I.37 Working level

The special unit of radon daughter concentration and thoron daugther concentration (see I.24 and I.31). The abbreviation for 'Working Level' is 'WL'.

1 WL = 1.3 x 10^5 MeV/litre.

I.38 Working level month

The special unit of radon daughter intake and thoron daughter intake (see I.25 and I.32). The abbreviation for 'Working Level Month' is 'WLM'.

1 WLM = 170 WL. hour = 8.0 x 10^{10} MeV second/litre.

Appendix II

Principles, criteria and explanatory notes for the radiation protection standards

II.1 Principles underlying the determination of the radiation protection standards

While it has not been considered necessary to discuss in detail the basic concepts underlying the radiation protection standards, it is thought desirable to outline briefly here the principles which have been applied in drawing up the standards.

II.1.1 *The purpose in setting the radiation protection standards*

The aim of the radiation protection standards given in Section 3 of this Code is to prevent or limit the risk to a person of somatic injuries including leukaemia, lung cancer and other malignant diseases, and to reduce to the practical minimum the deterioration in the hereditary constitution of the population resulting from radiation-induced gene mutations. Fundamental to the standards is the concept of balancing the risks to a person and the public generally against the benefits which accrue to man through the use of radioactive substances and irradiating apparatus. The radiation protection standards are founded on the cautious assumption that any exposure to radiation may carry some risk of somatic and hereditary injuries. The further assumption is made that the risk of inducing disease or disability in a person increases linearly with the dose accumulated by him.

II.1.2 *Dose limitations*

In the present state of knowledge, the relationship between dose and effect is not known precisely. Further, it is not always possible to make quantitative evaluations of the benefits derived from a given practice involving the use of radiation. Nevertheless, there is a need to lay down for planning and operational purposes, dose limitations that can be applied in various conditions to safeguard persons. To fulfil this need dose limitations (maximum permissible doses for employees and dose limits for members of the public in the neighbourhood of a mine or mill) have been incorporated in the radiation protection standards.

II.1.3 *Doses related to organs and tissues*

II.1.3.1 Organs and tissues in the body of man are sensitive to radiation to varying degrees. Allowing for this variation in sensitivity, exposure of some organs and tissues to radiation can have more serious consequences than exposure of others. The organs and tissues at greatest risk are known as the critical organs and tissues and it is important to identify these organs and tissues and specify individual dose limitations for them. It must be appreciated that the direct measurement of radiation doses to organs and tissues is rarely practical. Therefore, the doses to the critical organs and tissues must, in practice, be derived by calculation.

II.1.3.2 Serious uncertainties exist in computing radiation dose to lung tissues from radon daughters inhaled in mine air and this prevents the setting of radiation protection standards for radon daughters in air in the same terms as for other contaminants and prevents the application of the basic dose limitations for lung. In seeking appropriate alternative radiation protection standards, epidemological data on lung cancer amongst underground miners have been studied. Only in recent times has it been possible to show a correlation between data on lung cancer in underground miners and the radon daughter intakes in their working life time. The radiation protection standards for radon daughters are therefore based on the radon daughter intake in the working life time of a miner and are expressed in terms of Working Level Months.

II.1.3.3 Inhalation of thoron daughters also leads to radiation dose to the lung with the possible induction of cancer of the lung. Investigations have been carried out to compare the doses to the lung from radon daughter intakes with those from thoron daughter intakes. These show that, under conditions of ventilation typical of mines and mills, the thoron daughter intake might be 10 times the radon daughter intake before resulting in the same dose to the lung. Accordingly the radiation protection standard for thoron daughter intake has been set in this Code at 10 times that for radon daughter intake.

II.2 Maximum permissible doses for employees

The maximum permissible doses recommended in the radiation protection standards are not maxima in the sense that an employee will inevitably incur serious injury if a dose is exceeded. However, as any exposure involves some degree of risk, any unnecessary exposure as a result of employment should be avoided and all doses should be kept as low as practical. The maximum permissible doses provide a basis for planning work procedures, for designing the in-built protection that is desirable, for assessing the efficiency of protective measures and practices and for determining the extent and nature of the health surveillance which should be applied to an employee. In assessing the radiation dose to any organ or tissue of an employee so as to apply the radiation protection standards, account shall be taken of the doses contributed by external and internal radiation sources (other than radon daughters and thoron daughters) resulting from the circumstances imposed by the occupation of the person. Doses received by an employee as a member of the public which do not result from his occupation shall not be included in the dose assessment.

II.3 Maximum permissible concentrations of contaminants in air and water

On the basis of the maximum permissible doses defined for organs and tissues in paragraph 3.2.2.1 of this Code, it is possible to derive by calculation maximum permissible burdens of specific radionuclides in the body and the critical organs and tissues which will not give rise to radiation doses in excess of the maximum permissible doses. It is then possible to derive maximum permissible concentrations in air and water for each radionuclide such that, on the basis of assumed conditions of inhalation and ingestion, the maximum permissible burdens will not be exceeded. The maximum permissible concentrations derived for this Code and given in paragraph 3.2.4 are based on the following assumptions:

II.3.1 The employee or member of the public in the neighbourhood of a mine or mill for whom the maximum permissible concentration is specified is assumed to be exposed continuously for the stated period per week to a constant concentration of the relevant contaminant throughout each year.

II.3.2 An employee consumes half his total water intake (in water and food) during his working hours and inhales half his total air intake during working hours.

II.3.3 The maximum permissible concentrations given for each radionuclide are based on the assumption that the critical organs or tissues for that radionuclide receive radiation doses only from the given radionuclide. If another inhaled or ingested radionuclide also irradiates the same critical organ or tissue, or a source of external radiation irradiates the same critical organ or tissue, the maximum permissible concentrations of each contaminant must be reduced accordingly.

II.3.4 The materials uranium and thorium are mixtures of radionuclides. The maximum permissible concentrations given for uranium and thorium in Tables 3.2.4.1 and 3.2.4.2 of this Code are expressed in curies per cubic metre of the total activity of the appropriate mixture of radionuclides. In the case of uranium, this mixture contains equal activities of uranium-238 and uranium-234. The activity of uranium-235 is not significant in setting maximum permissible concentrations. In the case of thorium, the mixture of radionuclides contains equal activities of thorium-232 and thorium-228.

II.3.5 The maximum permissible concentrations of natural uranium and of natural thorium given in Tables 3.2.4.1 and 3.2.4.2 of this Code may be expressed in mass units instead. The limits thus obtained are given in the following table:

TABLE II.3.5: MAXIMUM PERMISSIBLE CONCENTRATIONS FOR AN EMPLOYEE EXPOSED DURING WORKING HOURS ONLY (40 HOURS/WEEK) AND FOR A MEMBER OF THE PUBLIC

Contaminant	*Maximum permissible concentration*			
	Employee (40 hours/week)		*Member of public*	
	In air $\mu g/m^3$	*In water* mg/l	*In air* $\mu g/m^3$	*In water* mg/l
Uranium (soluble)	210	60	7	2
Uranium (insoluble)	180	1500	6	60
Thorium (soluble)	280	280	9	9
Thorium (insoluble)	280	280	9	90

Appendix III

Guide to the practice of measurements and assessments required for radiation surveillance

III.1 General

In Section 3 of this Code, requirements are laid down for measurements and assessments to be made for purposes of radiation surveillance. This Appendix sets out broad guidelines for good practice in carrying out the measurements and assessments required and refers to some of the more detailed literature which will be useful to persons undertaking such measurements and assessments. New developments and changing technology may lead to further refinements in this field. The measurements and assessments outlined in this Appendix should be carried out under the supervision of the Radiation Safety Officer (see paragraphs 2.2.15 and 2.2.16 of the Code).

III.2 Measurement of radon daughter concentration

The fundamental measurement required to determine the radiation hazard in uranium mines is that of radon daughter concentration. Because the radon daughters quickly attach to dust they may be readily collected and their activity determined. These operations can be carried out quickly in mines. However, because of the short half-lives of the radon daughters relative to the parent radon, the concentration of radon in air serves as an upper limit to the concentration of the daughters. Hence, radon measurements may be used in place of radon daughter measurements where facilities or a service are available for measurement of radon concentration in air (such measurements may also be required for engineering control—see III.11). In some mines in other countries, routine assessment of the radon daughter hazard is carried out by converting measurements of radon concentration to daughter concentration using an average conversion factor. The conversion factor is checked by periodical measurements of radon daughters and radon at the same time and location. If a conversion factor is not used, the measurement of radon concentration alone will over-estimate the daughter concentration in the normal non-equilibrium conditions in mines, introducing a significant error in assessment of the radon daughter intakes of employees and requiring an unnecessary and perhaps very costly additional degree of engineering control. However, this error is considerably less than the errors leading to underestimation which have occurred frequently in the past in assessment of radon daughter concentrations and even less than the errors in assessment which have occurred on some occasions due to such factors as insufficient or incorrectly applied measurement data.

III.2.1 *Evaluation of available measurement methods*

The measurement of radon daughter concentration is undertaken to allow an estimate to be made of the total alpha-particle energy that would be deposited in the superficial tissue of the lungs of persons breathing the sampled air. As the radon daughters emit alpha-particles having different energies and as they have different half-lives, the contribution to the total energy deposited from equal concentrations of each of the daughter products differs significantly. As the ratios of the concentrations of the radon daughter products to each other and to that of radon vary with ventilation conditions, an error in the assessment of total alpha energy deposited occurs if the concentrations of the individual daughters are not measured. It has been shown by a number of authors (Rolle[1], Kuznetz[2], Breslin[3]) that if appropriate sampling and counting procedures are adopted, the error introduced in not measuring the individual daughter concentrations can be reduced to an acceptable value. The methods proposed by these authors have become known as the Rolle method, Kuznetz method and modified Kuznetz method respectively. Methods have been developed for measurement of the individual daughter concentrations but these have not been used extensively in mines. The most common method, described by Tsivouglou *et al.*[4] is now known as the Tsivouglou method. Modified Tsivouglou methods have been described[5,6] subsequently that enhance the accuracy of the method. Unfortunately, the Tsivouglou method and modified Tsivouglou and modified Kuznetz methods require items of equipment and constraints on the performance of equipment additional to those required for the Rolle and Kuznetz methods. Recently, automatic instruments for monitoring radon daughters in mines have been devised and tested. These are more complicated than earlier equipment used for other methods but include all necessary equipment in a single box and present the measurement result directly in units of working level. They are thus named 'automatic working level meters' or a similar name. None of the models tested has proved satisfactory.

In absence of satisfactory automatic monitors, it is recommended that one of the proven methods requiring only simple equipment be used in mines and mills in Australia. Comparison of the 2 methods of this type (the Kuznetz and Rolle methods) indicates that the Rolle method is faster, more sensitive and more accurate than the Kuznetz method. The greater sensitivity of the Rolle method means that requirements for instrumentation can be relaxed if daughter concentrations of the order of 0.3 to 1 working level are to be measured and that if lower concentrations are to be measured, adequate sensitivity is inherent in the method. Hence Rolle's method is recommended for use.

III.2.2. *Rolle's method*

III.2.2.1 *Equipment.* The equipment required to use Rolle's method in mines includes a battery-operated air pump and filter holder and a battery-operated alpha-particle ratemeter (counter). The air pump or filter holder must have an air-flow meter to indicate flow-rate. It is useful if an adjustment to flow-rate can be made. The air pump must be of minimum weight (preferably less than 6 kg) and must have battery and pump capacity adequate to permit 100 minutes of sampling at 10 l/minute before recharging. A supply of membrane or glass-fibre filters is required of a size to fit the filter holder. Pore size of filters must be in the range 0.5 to 0.8 micrometres. An alphpa-particle source having long half-life is essential to calibrate the alpha ratemeter. The ratemeter efficiency must be known for alpha particles of the average energy of the radon daughters and the detector should have a response independent of energy. The ratemeter must have a variable time constant with selectable values between approximately 10 and 30 seconds. The ratemeter must be of minimum weight and have a stable and variable high tension supply. It is preferable that the ratemeter incorporate in the instrument case a sample holder adjacent to the detector. It must provide a scale for indication of high tension supplied to the detector and incorporate batteries having sufficient power capacity to allow operation for at least 8 hours continuously. The ratemeter must have a stable response when subjected to temperature, pressure and humidity variations likely to occur in the mines in which it will be used. Light-weight scalers that are suitable for determination of activity are also available. These may be used in place of a ratemeter with minor adaptation of the method outlined below.

III.2.2.2 *Method.* The air pump is used to draw a sample of air through the filter for a measured time. A short time later the count-rate on the filter paper is measured using the ratemeter. The timing of the ratemeter reading is critical to the accuracy of the Rolle method and typical times used are 10 minutes of sampling at 10 litre per minute followed by a delay of 6.6 minutes before the count-rate is determined. Approximation of 6.6 minutes as 7 minutes does not lead to greatly increased error. If a scaler is used in place of a ratemeter the delay period of 6.6 minutes should be reduced to 4.35 minutes and the counting period should be 5 minutes.

The calibration of the ratemeter (or scaler) must be determined frequently, using the alpha-particle source and preferably before or after each count-rate measurement.

The calculation of radon daughter concentration proceeds as follows:

III.2.2.2.1 Determine the activity on the filter paper:
Activity (disintegrations/min)

$$= \frac{\text{Count-rate (counts/min)}}{\text{Efficiency of the ratemeter}}$$

where the efficiency of the ratemeter is equal to the ratio of the number of disintegrations detected to the total number of disintegrations occurring. When count-rates are very low (for concentrations less than 0.1 WL) the count-rate to be used in this formula is the net count-rate after the background count-rate has been subtracted from the sample count-rate.

III.2.2.2.2 Determine sample volume:

$$\text{Volume (litre)} = \text{Sampling rate (litre/min)} \times \text{Sampling time (min)}$$

The sampling rate used in this formula must be the mean sampling flow-rate during air sampling.

III.2.2.2.3 Determine radon daughter concentration:
Radon daughter concentration (working level)

$$= \frac{\text{Activity (disintegrations/min)}}{213 \times \text{Sample volume (litre)}}$$

The factor 213 appearing in the denominator of this formula is the mean conversion factor for the sampling time of 10 minutes for all likely radon daughter ratios. It may be used without greatly increased error as an average value for sampling times between 1 and 20 minutes. Rolle[7] has given precise conversion factors and delay times for other combinations of sampling time and counting time when a scaler is used.

III.2.3 *Assessment of error in measured radon daughter concentration*

Rolle[1] has assessed the error in the Rolle method and compared it favourably with the error in the Kuznetz and Tsivouglou methods. The sources of error are largely common to these 3 methods and include both random errors and systematic errors. The random errors occur due to the statistical nature of the radiation detection process and to averaging over all possible radon daughter ratios. Rolle gives a typical total random error for his method in the ± 10 to ± 27 per cent with a possible maximum of ± 34 per cent and indicates that use of a Kuznetz method would increase this error significantly. Loysen[8] has estimated errors in the Kuznetz method but has included conversion factor errors as systematic errors, rather than as random errors. If these are added to the random errors given by Loysen, the total error ranges between −76 per cent and + 81 per cent. This is not directly comparable to Rolle's assessment as Rolle determined his error for 4 per cent standard deviation in counting and Loysen considered errors for a wide range of WL values. But the size of the errors estimated by these authors, under best conditions, indicated how greatly in error measurements may be if best conditions are not attained. Loysen indicates additional errors which may then occur, especially errors due to air leakage in the sampling system. To these random errors must be added several systematic errors listed by these authors. Rolle[7] has considered the reduction of error using a scaler for measurement of activity on the filter. Groer[9] has considered error in the Kuznetz method, with particular reference to use of a scaler. Groer concludes that in the majority of cases the Kuznetz method underestimates the radon daughter concentration, especially for 'young' air (i.e. air containing radon daughters greatly out of equilibrium with the parent radon).

III.3 Measurement of thoron daughter concentration

The measurement of thoron daughter concentration reduces to a measurement of ThB (^{212}Pb). Although not an alpha-emitter, ThB has a long half-life relative to the other thoron daughters and leads to alpha decay by its decay products ThC (^{212}Bi) and ThC′ (^{212}Po). Due to its long half-life, ThB is responsible for a minimum of 92 per cent of all alpha-particle energy from thoron daughters contributing to lung dose and under typical conditions of equilibrium, probably 97 per cent.

III.3.1 *Equipment and procedure for recommended method*

ThB can be determined by collecting it on a filter paper along with any ThC present. The ThB may be determined by measuring the activity as soon as possible after cessation of sampling and again 5 hours later (Duggan[10] has described the equations for this method). However, after 5 hours the ThC and ThC′ will have grown and almost attained equilibrium with ThB (Rock[11]). The build-up and decay of the daughters after 5 hours does not lead to significant error for counting periods up to 1 hour. Use of a scaler to determine the activity over such long counting periods is usually necessary due to the low activity then present. The ThB activity is taken as equal to the activity of ThC plus ThC′, i.e. the total alpha-particle activity on the filter. The determination is simply made as follows:

III.3.1.1 Determine the net count due to ThC plus ThC′:
Net count (ThC + ThC′) = Total count
−Background count where the background count has been determined for the same time as the sample count.

III.3.1.2 Determine the count rate due to ThC and ThC′:

$$\text{Count rate (counts per minute)} = \frac{\text{Net count}}{\text{Counting time (minutes)}}$$

III.3.1.3 Determine the ThC plus ThC′ disintegration rate:

$$\text{Disintegration rate (disintegrations/minute)} = \frac{\text{Count rate (counts/minute)}}{\text{Efficiency of the ratemeter}}$$

where the efficiency of the ratemeter is equal to the ratio of the number of disintegrations detected to the total number of disintegrations occurring.

If the efficiency of the detector has been determined for radon daughters, this may be used in this formula with sufficient accuracy, as the alpha-particle energies are not greatly different.

III.3.1.4 Determine the ThB concentration in air:

ThB concentration (disintegrations/minute-litre)

$$= \frac{\text{Disintegration rate of ThB (disintegrations/minute)}}{\text{Sample volume (litres)}}$$

where Sample volume = Sampling rate (l/min) x Sampling time (min)

and the sampling rate used is the average during the sampling time.

III.3.1.5 Determine the thoron daughter concentration:

Thoron daughter concentration (WL)

= 0.068 x ThB disintegration rate (disintegration/min)

where 0.068 is the appropriate conversion factor 5 hours after sampling. Rock[11] gives a graph of conversion factors to be used when counting the activity in the period 5 to 17 hours after sample collection. A second advantage in delaying the count is to ensure the decay of radon daughters, as these would contribute strongly to the count-rate nearer the end of the sampling time. It is clear that if both radon daughters and thoron daughters are present in mine or mill air, sequential counts of the same filter sample must be taken to distinguish the 2 contaminants and the contribution of each to the total Working Level is calculated separately. Rock gives a good guide to procedures.

III.3.2 *Assessment of error in measured thoron daughter concentration*

No assessment of total error for thoron daughter determinations is presently available but the assessment proceeds on the same lines as those of radon daughters. The errors would differ in that the random counting error may be greater for thoron daughters due to the long delay before counting and working level conversion will be less in error due to the essentially single contribution by ThB.

III.4 Personal monitoring for radon daughter intake

Numerous personal monitors for radon daughter intake have been constructed and tested. None has proved satisfactory in tests under working conditions in mines. The principle of all these monitors is the integration of the effect on a suitable minimizing of alpha-particle emissions from radon daughters. Detectors that have been tested include solid thermoluminescent discs and cellulose nitrate film. Daughter products, representative of the breathed atmosphere, are collected either by exposing the detector in the mine atmosphere close to the miner's head (e.g. on his hat) or by pumping air from the breathing zone to the detector. A further refinement has been to collect the radon daughters on a filter close to the detector. This has advantages of increasing the sensitivity of the system (as the radon daughters are held close to the detector until they decay) and of minimizing response of the detector to alpha particles from radon. The monitors employing this refinement use small battery-operated pumps. The monitors not employing this refinement are subject to varying response in mines because of the varying radon level encountered.

An extensive test of such monitors (White[12]) revealed that none of the monitors constructed to that time was satisfactory. Some were moderately satisfactory in tests under laboratory conditions but all showed severe deficiencies under working conditions. Some of the difficulties were due to pump imperfections and could be removed if an improved, reliable pump were to become available.

Both the thermoluminescent discs and cellulose nitrate films require elaborate counting equipment for readout and some sophistication in counting techniques. But both types of detector are small and light in weight and may be used in the sampling head for periods in excess of one month. They thus lend themselves to incorporation in a monitoring service provided by a central laboratory such as the film badge and thermoluminescent dosemeter services already provided in Australia. The response of the detectors is not directly in units of WLM but in terms of number of tracks or electric charge. This must be converted to units of WLM at a measurement laboratory that has a suitable facility for calibration of the responses of the personal monitors using standard atmospheres for radon daughters. The perfection and introduction of personal radon daughter monitors is desirable because this would provide the best opportunity for determining the radon daughter intake of each employee.

III.5 Assessment of radon daughter intake and thoron daughter intake of employees

When the radon daughter concentrations in occupied areas are measured (see III.2) and personal radon daughter monitors are not used, it is essential to also record the times of occupancy of each employee in the areas he enters during the working day, accounting for all of his time on the site. Both the radon daughter concentrations measured and the time spent in the area should be tabulated for each employee against the areas entered. This can be conveniently done on a daily or weekly basis. On the same tabulation form, the products 'radon daughter concentration (WL) x occupancy time (hours)' can be calculated and entered against each area listed. These products give radon daughter intakes in units of WL.hour and these can be summed to give the total intake for a day or week and converted to the recommended units of WLM by dividing the total by 170.

Quarterly and annual radon daughter intakes can then be calculated as the sum of daily or weekly totals. An important distinction must be made between 2 types of radon daughter concentration monitoring programmes when assessment of personal intakes is made using the measured concentrations. Monitoring programmes may be undertaken to assist engineering control of radon daughters (so called 'environmental surveys') or directly to determine intake of radon daughters of employees. In the latter case the location, frequency and repetition of measurements can be planned to give measurements making possible an accurate assessment of each employee's intake. The frequency of measurements will be much greater than for 'environmental surveys' and the location of measurements may be quite different. 'Environmental survey' results are therefore of limited use in assessing personal intakes and often lead to large inaccuracies in the assessments.

If personal radon daughter monitors are used, the assessment of individual exposure is simplified. Each detector (the thermoluminescent disc or the film) can be worn for a long period before replacement is needed. Results advised from the measurement laboratory, reported in WLM, may be readily summed for each employee.

III.6 Measurement of gamma radiation

III.6.1 *Area exposure-rate monitors*

4 different types of area exposure-rate monitor are readily available. The types differ basically in the detector used: ionization chambers, proportional chambers, geiger tubes and scintillators. The energies of gamma rays emitted from radioactive ores are generally high and all the types of monitor referred to above will give accurate results. On the basis of ruggedness, cost and simplicity, geiger monitors offering best available energy independence and ion-chamber monitors of minimum size and weight are recommended for use.

Additional features that gamma monitors for use in mining and milling of radioactive ores must have include the following:

(a) a measurement range of at least 1 to 200 millirad per hour (or 1 to 200 milliroentgen per hour),

(b) total measurement uncertainty not exceeding $\pm$ 25 per cent (this should include uncertainty due to energy dependence) for gamma rays having energies from 0.1 million electron volts to 2 million electron volts,

(c) a response to radiation fields of greater intensity than its maximum reading that ensures an off-scale reading at the higher end of its maximum range,
(d) calibration in units of dose-rate e.g. millirad per hour or of exposure-rate, e.g. milliroentgen per hour, and
(e) a battery supply consisting of readily available dry cells (e.g. 1.5 volt torch cells) or rechargeable cells with an accessory or built-in battery charger.

III.6.2 *Personal monitoring of employees*

Personal exposure of employees to gamma radiation can be monitored by small devices worn by each employee. These devices include pocket dosemeters of the quartz-fibre electrometer type, film badges and thermoluminescent monitors. In view of the relative advantages and disadvantages of the various types of monitor, thermoluminescent monitors are recommended for use in the measurement of personal exposure of employees in mines and mills. These monitors have good stability in hostile environments and are suitable for long term integration of doses. In using monitors, care must be taken not to expose them to excessively high temperatures. Furthermore, with film badge and pocket dosemeters, special precautions must be taken to avoid the effects of humidity.

III.7 Measurement of airborne particulate contaminants, other than radon daughters and thoron daughters

Airborne particulate contamination can be measured by counting the activity of the residue left on a filter paper through which contaminated air has been drawn. This method is usually performed in 2 separate stages with 2 separate pieces of equipment. An air sampler is used to draw contaminated air through a filter paper. This sampler is usually portable and powered by rechargeable batteries. The equipment described in III.2.2 is suitable. The filter paper is removed from the sampler and checked with a ratemeter or scaler for contamination. This may be a quick on-site check if a portable contamination monitor is used. A more accurate count may be made using a more sophisticated portable or laboratory scaler which can integrate the counts over an extended period of time.

In mining and milling radioactive ores, the principal airborne contaminants (other than radon daughters and thoron daughters) are the long-lived alpha-emitting radionuclides of uranium, thorium and radium. These and the shorter-lived contaminants are usually attached to dust or aerosols and may be collected by filter paper sampling. The sources of error in filter paper sampling are as described in III.2.3 except for the correction factor errors that occur when determining radon daughter concentration.

III.8 Measurement of contamination in water and solid materials

A portable contamination monitor, similar to that described in III.7 for checking filter papers, may be used for measurement of contamination in water and solid materials. However, greater sensitivity is obtained if samples are assessed using a laboratory counting system. The samples may then be prepared in a uniform manner and counted with equipment having greater sensitivity and discrimination and reduced background radiation. Such a system will allow measurement of lower activities with greater reliability than can be obtained with a portable ratemeter. Use of a laboratory counting system is necessary when routine sampling of a body of water or a tailings heap is instituted to detect changes in contamination levels. Again, it is necessary to know which radioactive material is to be counted in order to know the type of detector to use (alpha, beta and gamma radiations of different energies will be counted with different efficiencies by the same detector).

Detectors with very thin windows (of the order of 1 milligram per square centimetre) are essential to detect alpha particles and are desirable for the efficient detection of beta particles. Such detectors can also be used to count gamma rays. The detectors principally used are geiger tubes, scintillation detectors and proportional counters.

III.9 Measurement of surface contamination

III.9.1 *Equipment and procedures for measuring surface contamination*

Surface contamination is most easily detected using a portable ratemeter, powered by dry cells or rechargeable batteries similar to that described in III.7. If it is necessary to use such a monitor in an area with high gamma radiation background, the ratemeter should incorporate a detector, sensitive to alpha particles, that discriminates well against gamma rays. The contamination can then be located more precisely because alpha particles travel only short distances in air. Such a detector (e.g., an appropriate scintillation detector) also allows measurements of greater sensitivity. Most portable ratemeters have a slow response time on their more sensitive ranges, hence monitoring should be performed slowly so that the instrument has time to respond to radiation from a spot of contamination. If a probe having a large sensitive area is used, large surfaces can be monitored in a reasonable time, even though the probe must be moved slowly. Care should be taken when monitoring not to contaminate the probe which at best would cause an unwarranted increase in background and at worst would lead to erroneous conclusions regarding the monitoring results. If the background level is too high to make a reading in a given area, a swab of the surface should be taken with a piece of cloth or absorbent paper. The swab should then be taken to a lower background area and monitored for contamination. The swab may be dry or may be soaked in water, alcohol or another solvent to ensure more efficient removal of surface contamination. This method will not detect fixed contamination. However contamination that is fixed to a surface presents much less hazard than loose contamination which may be inhaled or ingested.

III.9.2 *Assessment of surface contamination levels*

When measurements of surface contamination are made with a typical portable contamination monitor having an alpha scintillation probe with a sensitive area of approximately 50 square centimetres, the permissible levels of contamination of 10^{-7}, 10^{-6} and 10^{-5} Ci/m^2 given in paragraph 3.11.1 of the Code correspond to count rates of roughly 4, 40 and 400 counts per second on the meter. Readings obtained in counts/second can thus be readily converted to units of Ci/m^2 for comparison to the permissible levels by dividing by 4×10^7. It is essential to check the literature of the manufacturer of the monitor to ensure that this conversion factor applies and advisable to have the detector calibrated using distributed alpha sources of known activity and alpha energy appropriate to the radionuclides to be monitored.

III.10 Assessment of permissible concentrations for discontinuous exposure and exposure to multiple radiation sources

III.10.1 *Adjustment of maximum permissible concentrations where 2 or more contaminants irradiate an organ or tissue*

When 2 or more contaminants irradiate a single organ or tissue, the maximum permissible concentrations given in paragraph 3.2.4 of this Code no longer apply as each contaminant inhaled or ingested at the maximum permissible level will lead to the exposed person receiving the maximum permissible dose to that organ or tissue. The levels given in paragraph 3.2.4 of the Code must be reduced by the rule for mixtures as follows.

If C_1, C_2, C_3, etc. are the actual concentrations of the different contaminants and P_1, P_2, P_3, etc. are the corresponding maximum permissible limits given in paragraph 3.2.4. of this Code, concentrations C_1, C_2, C_3, etc. must be reduced until the sum of the new ratios C_1/P_1, C_2/P_2, C_3/P_3, etc. is equal to unity.

To achieve this, the concentration of each contaminant may be reduced either independently of or proportionately to the other contaminants present. In the latter case the proportion can be calculated by forming the sum

$$\frac{C_1}{P_1} + \frac{C_2}{P_2} + \frac{C_3}{P_3} + \ldots\ldots\ldots = n,$$ where C_1, C_2, C_3 etc.

are the actual measured concentrations before reduction. The levels to which each concentration must be reduced can then be determined by dividing C_1, C_2, C_3 etc. by 'n'.

If an assessment of the ratios shows that one contaminant in particular can be reduced to negligible levels independently of the others, the sum of the remaining ratios may then be less than unity. If this is not so, the concentration of one or more of the remaining contaminants must be reduced accordingly.

III.10.2 *Adjustment of maximum permissible concentrations where an organ or tissue receives external and internal radiation*

As in III.10.1, the rule for mixtures may be invoked and applied. However, the external radiation exposure of employees may be difficult to reduce. Then, if the ratio $\frac{E}{D}$ for employees is less than unity where D is the permissible dose for radiation and E the external radiation dose in the same period, the sum of the similar ratios for all contaminants also leading to radiation exposure must be reduced to $1-\frac{E}{D}$ using the method of mixtures described in III.10.1 with unity replaced by $1-\frac{E}{D}$.

Lung dose due to inhalation of radon daughters and thoron daughters cannot be apportioned in this way (see paragraph 3.2.5 of this Code).

III.10.3 *Adjustment of maximum permissible concentrations for discontinuous exposure and exposure of employees outside working hours*

When employees are exposed to contaminants regularly for periods less than 40 hours per week, the maximum permissible concentrations given in Table 3.2.4.1 of the Code may be increased by an appropriate factor. If the regular exposure period is t hours per week, the permissible concentrations given in paragraph 3.2.4 of the Code may be increased by the factor $\frac{40}{t}$. However, it is important to realize that the permissible concentrations given in Table 3.2.4.1 of the Code are based on breathing rates and food and water intake applicable to working hours only.

When workers are exposed outside working hours their exposure are limited by provisions of this Code to the limits applicable to members of the public whilst they are in unrestricted areas.

III.11 Radon and thoron measurements

III.11.1 *Need for radon measurements in mines*

Radon measurements may be undertaken for estimation of radon daughters (see III.2.1). If extensive air cleaning is used to remove radon daughters, radon is left as the significant source of hazard and its measurement may then be necessary to estimate the radiation hazard. However, the most important need for radon measurements is in determining, on a continuing basis, the sources of radon emanation into mines and in assessing the control of these sources. The availability of such data has proved to be most important in controlling the radon daughter hazard in mines and in significantly reducing ventilation costs.

III.11.2 *Techniques for measurement of radon in mines*

Techniques used for measurement of radon concentration in air may be either direct methods of measurement or indirect methods. The former methods involve the direct collection of a sample of the radon or an air sample of known volume containing the radon and the direct determination of the radon content in the sample. The latter methods involve sampling the air through a filter that removes all radon daughters present in the air, allowing the radon only to pass through. A second filter is used to collect the radon daughters forming from decay of radon as it passes through a long delay tube. From the activity on the second filter, the time of travel of the air through the tube and the decay constants of the radionuclides involved together with an estimate of the diffusion of radon daughters to the walls of the tube, an accurate estimate of the concentration of radon in air can be made. This method is known as the two-filter method. Both methods are useful and reliable techniques. The two-filter method allows measurements to be completed in the mine but involves careful attention to technique to prevent spurious results. Its sensitivity is good, although not as good as the direct methods of measurement. Direct methods also allow large numbers of samples to be taken in a short time, with the analysis being performed at a later time in some of these methods.

III.11.2.1 *Direct Methods of Measurement.* The sample collected may be an air sample or a sample of radon extracted from the air. When air samples are taken the air may be collected directly in the measurement chamber (e.g. an alpha scintillation flask) or in a sealed vessel for transfer to the measurement chamber. The sealed vessels may be pre-evacuated and opened to atmosphere for sampling or filled by pumping. Metal vessels (standard butane cylinders) and glass vessels are used successfully. The gas in the vessels must be transferred volumetrically to the counting chamber. This can be achieved by flushing with gas or water or by using a gas transfer (peristaltic) pump, depending on the volume of the measurement chamber. The measurement chamber may be an air ionization chamber, proportional counter or alpha scintillation counter. All of these measurement techniques require expensive laboratory equipment and experienced operators. They are more economically set up in a central laboratory offering a measurement service. Because of the high efficiency of the counting systems used, the radon samples may be counted several days after collection, thus allowing time for their transport. For samples having higher concentrations measurements may be made up to several weeks after sampling.

As an alternative, samples of radon extracted from the air may be collected on activated charcoal. Small volumes of charcoal may be used, so again many samples may be taken in a mine and analysis made at a distant laboratory. The collection of radon on charcoal is dependent on a number of factors, so careful standardization of the collection method is necessary. Due to the methods of sampling and detection, the lower limit of detection is not so low as for methods where air samples are collected.

Air samples may also be collected and analysed instantaneously using a monitor with flow-through ionization chamber to give a continuous readout of the concentration level in the contaminated air drawn through the chamber. Relatively sophisticated and delicate equipment is needed and must be carried to the site of the measurement. The sources of error in these flow-through ionization chambers are similar to those described in III.2.3 for the filter paper sampling method, except that errors associated with the filter paper are absent. In their stead, however another error occurs and this results from prior contamination of the chamber, usually by long-lived radioactive materials. This contamination increases the background of the chamber and, if severe, must be removed by cleaning. Such contamination may lead to a reduction of sensitivity and the monitors must be provided with a gamma compensation chamber and ionization chambers which are readily demountable for cleaning. The monitors must provide efficient particle filters at the inlet to make accurate radioactive gas measurements.

These monitors are therefore heavy and expensive, usually requiring mains power, but with these qualifications are useful and effective devices having a lower limit of detection approaching that of the activated charcoal sampling method.

III.11.2.2 *Indirect Methods of Measurement.* The two-filter method employing 2 filters in series at the ends of a long delay tube will be discussed. This method, as described by Thomas and Le Clare[13] for radon determination has been thoroughly tested in mines and its practical difficulties largely overcome. Requirements for the method are as for the Rolle method (see III.2.2) with the addition of a tube and second filter. However, use of a low-background portable scaler instead of a ratemeter is required. The sensitivity depends markedly on the background of the scaler. The sensitivity of the method for radon depends on measuring the activity on the second (outlet) filter immediately after sampling. The sensitivity and accuracy also depend on preventing contamination of the outlet filter by radon daughters not formed in the air between the filters. Great care must be taken to prevent such contamination. The method allows the immediate assessment of radon concentration. By measuring the activity on the inlet filter, the radon daughters can be determined also, allowing the radon-to-radon-daughter ratio to be determined.

Calculations and corrections have been derived and tabulated in the publications referenced above. The corrections are derived to avoid the need to calibrate the two-filter sampler for each length and width of decay tube used. However, calibration is practical, given adequate laboratory facilities, if the method is standardized for a given tube size. Dimensions of 35 mm internal diameter and 500 mm length are practical dimensions for construction and use of a two-filter sampler using readily available filter heads. These dimensions are recommended as a standard. For them, a flow-rate of 10 litre/minute, a sampling time of 10 minutes, and counting time extending from 1 minute after sampling to 15 minutes after sampling, the following calculations are made to determine radon concentration:

Net count from filter

= Total count–(Background in 14 minutes)

Radon concentration (p*Ci*/l)

$$= \frac{0.481 \times \text{Net count from filter}}{\text{Efficiency of the scaler}}$$

where the efficiency of the scaler is equal to the ratio of the total number of disintegrations detected to the total number of disintegrations occurring.

(Thomas and Le Clare[13] suggested use of a tube 50 mm diameter. If this were used but all other parameters were unchanged from those assumed above, the factor in the above formula must be replaced by 0.198, indicating an improvement of sensitivity of approximately 2.4 fold.)

III.11.3 *Assessment of radon emanation rate in mines*

Thompkins and Cheng[14] have developed and tested in mines a suitable method for determining radon emanation from the walls, floor and ceiling of a mine opening. Kraner *et al.*[15] and Thompkins[16] have also indicated the use of such measurements and reported emanation rates measured in mines with ore of different grades and having porosities differing by 2 orders of magnitude. Measurements of this type assist decision making on mine development, particularly in regard to the location of airways and the need to close unused openings. They also assist in finding strong sources of radon in the walls of mines and, with other measurements and calculations, indicate the presence of other sources of radon such as bulkheads and heaps of broken ore. The method is not applicable to determining emanation rates from broken rock directly, but Thompkins[16] has described the development of laboratory methods for direct determination of radon emanation from rocks of different sizes and has indicated the increase in emanation rate when the ore is broken.

The method of determining radon emanation described by Thompkins and Cheng[14] first requires cutting a flat face into a mine surface and cementing a steel frame against it. A small chamber approximately 0.6 x 0.6 x 0.3 m is then connected to the frame and the metal-to-metal joint and the cemented joint are sealed with a good bitumastic compound. The chamber incorporates a sampling port with valve and an inlet valve on the opposite side of the chamber and is similar to chambers described by Kraner *et al.*[15] The chamber is initially flushed with compressed air for 20 minutes, the chamber valves closed and the time recorded. At this time and at intervals of several hours thereafter, several repeated samples of the chamber air are taken with the inlet valve opened simultaneously. The samples are taken by connecting evacuated flasks to the sampling valve and opening them to the chamber atmosphere. Measurement of the radon content of samples (see III.11.2) shows a steady increase of radon concentration in the chamber. The emanation rate is determined using the following formula:

$$J = \frac{\lambda V(C_2 - C_1 e^{-\lambda t})}{3600A\,(1 - e^{-\lambda t})}$$

where J = emanation rate (Ci/m^2. second)

V = chamber volume (litre)

A = area of rock surface sampled (m^2)

λ = decay constant of radon-222 (hour λ^{1})

C_1 and C_2 = measured radon concentrations (pCi/l)

t = time (hours) after measurement of C_1 until measurement of C_2

Thompkins and Cheng[14] report radon emanation rates in mines in Canada in the range 2×10^{-16} to 12×10^{-16} Ci/cm^2. second and calculate the small contribution to radon in the mines from such low emanation rates. The need for other than very slow changes of air in these mines to control the radon daughter hazard is due to other sources of radon, principally broken ore stored underground.

The radon emanation rates are reproducible for a given location but do not correlate with ore grade, as might be expected. However, other factors that influence the emanation rate are rock pressure, barometric pressure, temperature, rock porosity, geological nonconformities and ventilating air velocity.

The technique developed by Thompkins and Cheng[14] is subject to some errors but all major sources of error have been avoided by use of the technique and chamber described. In particular, leakage, prior contamination and build-up of resistance to emanation are avoided. Other methods of determining radon emanation, including measurement of build-up of radon in a slow airstream and in a closed-off section of mine, were found to be inadequate because of lack of sensitivity.

Methods of testing broken ore involve sampling radon build-up in a small sealed enclosure containing a sample of ore. Thompkins[16] has indicated the variation of measured emanation rates with ore grade, ore size and depth of ore heaps and the large increase in emanation rate measured when the ore is broken.

III.11.4 *Assessment of radon stored in ore bodies and broken ore*

The amount of radon stored in ore can be easily determined if the radium in the ore is known to be in equilibrium with the uranium or if the radium concentration in ore is known.

If ore is known to contain radium in equilibrium with the uranium, then the activity of radium is equal to the activity of uranium. The specific mass of radium (i.e. the mass of radium in gram per tonne of ore) must be known in this way or by direct assay. (Note that uranium forms 85 per cent of the mass of U_3O_8).

Then activity of radon in the ore (pCi/tonne)
= 10^{12} x specific mass of radium. If radium and uranium are in equilibrium, then the activity of radon in the ore (pCi/tonne)
= 2.91 x 10^5 x specific mass of uranium oxide (U_3O_8).
However, when the ore is broken not all this radon will be released. A measurement by Thompkins[16] in a mine indicated 5 per cent released on blasting. The remainder was trapped within the ore pieces and in the interstices in the ore heap. The radon trapped in the ore heap is now contained in a medium of relatively high porosity due to the many ore fractures. The interstices also provide small spaces into which more radon can emanate from the ore pieces. The radon concentration in the interstices therefore increases with time and the heap increasingly emanates radon, eventually at a rate far in excess of that from the unbroken ore. If the volume of the interstices and the surface area of the broken ore can be estimated (or the area/volume ratio can be estimated), the formula used in III.11.3 can be used to estimate the maximum growth of radon concentration in the interstices, based on the known emanation rate for the ore in the walls. It is more accurate, however, to use the emanation rate of pieces of ore of the appropriate size, if this is known. If the volume of the interstices can be estimated, the total radon content that can be released when the ore heap is moved can be determined. With the heap unmoved, the rate of emanation of radon from the heap into the mine will depend on the effective porosity of the broken ore. It will be much higher than the emanation rate of the rock but is best determined by measurement of typical sample ore heaps in the laboratory.

The effect of the emanation from an ore heap may be determined without knowledge of the radon content or emanation rate, by radon measurements in the air stream before and after the heap. The need to increase air supply or to move the heap can then be assessed. However, other sources of radon must also be taken into account, particularly the walls of the mine near the ore heap.

III.11.5 *Thoron measurements*

Thoron is a gas with very short half-life. It is not detected in air far from its parent radium-224. Unlike radon gas, it will not cause a hazard far from its source by being carried along by the prevailing air stream. Thorium-B (^{212}Pb) appears rapidly from decay of thoron close to its source and subsequent decay of its short-lived daughter thorium-A (^{216}Po). Thorium-B may be carried by the prevailing air stream to create a hazard at a distant place due to its long half-life. Thoron measurements may thus be of use in locating the sources of thorium-B in a mine or mill. Such measurement may be made very close to sources of thoron, provided the source is isolated from the prevailing air stream. The flow-through ionization chamber described in III.11.2.1 may be used for thoron measurement, using a correction for thoron decay in passing from its source into the detecting chamber. Alternatively, indirect methods of measurement similar to those described for radon-222 in III.11.2.2 have been developed (see Duggan[10], Hiller[17] and Thomas[18]).

III.12 Dose assessments for employees and members of the public

III.12.1 *Dose assessments for internal contamination of persons exposed to external radiation*

As the external radiation to all organs and tissues other than skin resulting from mining and milling radioactive ores is due to high energy gamma radiation, the exposure recorded on the personal monitors referred to in III.6.2 will be closely related to the dose to all organs and tissues other than skin due to external radiation. These measured personal exposures may be used directly to assess the dose of external radiation with sufficient accuracy. For skin, any significant exposure to beta rays should be included in the assessment of personal dose, but in mining and milling radioactive ores significant beta ray exposure is unlikely. The most likely sources of intense beta radiation are massive pitchblende and ore concentrates. The use of gloves is recommended in handling these materials. The material of the gloves and of containers for concentrate will reduce the beta ray dose-rates greatly. The surface dose-rate U_3O_8 is given as 203 m rad/hour[19] when attenuated by a thin absorber of 7 mg cm^{-2} which is approximately equivalent to the dead surface layer of the skin. This figure may be used to calculate beta doses received by persons whose skin is in contact with uranium chemical concentrate when the skin is unshielded by gloves or containers.

Where persons are exposed to external radiation and internal contamination, the total dose assessment is made as follows:

(a) If either of the rules described in III.10.2 is applied, the total dose to the relevant organ or tissue of the employee will be the maximum permissible dose,

(b) If the rules described in III.10.2 are not applied, the total dose to an organ or tissue is given by:

$$E + D \times \left(\frac{C_1}{P_1} + \frac{C_2}{P_2} + \frac{C_3}{P_3} + \ldots\ldots\ldots \right)$$

where E is the total external radiation dose,

D is the permissible dose,

C_1, C_2, C_3, etc. actual average concentrations of the relevant contaminants, and

P_1, P_2, P_3, etc. are the corresponding permissible concentrations for the relevant contaminants.

III.12.2 *Dose assessments for employees*

Dose assessments for employees are made in accordance with the provisions of III.12.1 (see also III.10.3). Where exposure-rates are measured (rather than exposures measured with personal monitors) doses must be assessed by estimating the total exposure time for each employee at each location occupied by him and forming the sum of the products of exposure-rate and exposure-time,

i.e. $t_1 \times D_1 + t_2 \times D_2 + t_3 \times D_3 +$ etc.

where t_1, t_2, t_3, etc. are the exposure times (hours) per week during which the employee occupies areas where the exposure rates (milliroentgen per hour) D_1, D_2, D_3, etc. have been measured.

III.12.3 *Dose assessments for members of the public*

Where members of the public are exposed to radiation and contamination, the methods of dose assessment given in III.12.1 are applicable. However, individual exposures measured with personal monitors are not generally available for members of the public. Further, it is not practical to assess doses for all members of the public in the neighbourhood of a mine or mill.

The general principle in this case is to select a group of persons representative of those members of the public likely to receive the highest dose. Assessment of the mean dose is then made for this group and this dose compared to the appropriate dose limit. It is important when selecting this group to do so on the basis of a full assessment of all sources of radiation exposure to the environment resulting from the operations at a particular mine or mill. Further guidance is given in references 20 and 21. It is, however, basic to the adoption of a set of dose limits for members of the public that the radiation doses actually received due to an operation involving sources of radiation are kept as low as reasonably achievable, economic and social considerations being taken into account (Reference 22).

III.12.4 *Dose assessment for planned special exposures*

It is important, for planned special exposures, that adequate radiation monitoring is carried out prior to and during the exposures. The maximum use of reliable personal monitors is desirable together with appropriate measurements of all radiation sources, including external radiation, airborne contamination (including radon and thoron, radon daughters and thoron daughters) and, if present in significant amounts, contamination in water and on surfaces. The assessment of total dose is then made in accordance with III.12.1 and III.12.2.

III.13 Removal of surface contamination

Surface contamination in excess of the limits given in paragraph 3.9.1 of the Code should be removed by collecting it and disposing of it as contaminated waste. It should not be removed by dispersing it. If the contamination is in loose powder form it should be collected gently onto a pan for removal. Traces remaining may be removed with a damp cloth. Contamination in liquid form should be absorbed with cloth or absorbent paper. Contamination of any kind should not be removed by dispersing it, e.g. by washing down the surface with large quantities of water. If clothing is found to be contaminated the item of clothing should be removed before any attempt is made to remove the contamination. If the contamination is not easily removed by light brushing the item may be laundered but the water used must be retained and monitored for possible contamination. If the water is contaminated it must be disposed of as liquid contaminated effluent. Skin contamination should be removed firstly by gentle brushing. If this is unsuccessful, washing and even scrubbing may be employed but scrubbing should not be so severe as to break the skin. For more detailed information on decontamination procedures reference should be made to 'Notes on Medical Procedures for Radiation Accidents and Radioactive Contamination' (Reference 23). Sections 4 and 5 of that publication give details of procedures with contamination accidents and decontamination technique respectively.

III.14 References

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Appendix IV

Guide to the control of exposure to radon daughters and contaminated wastes and effluents

IV.1 General

Guidelines are set out in this Appendix to assist operators and managers in providing the facilities, equipment and procedures required in Section 4 of this Code. Included are guidelines on:

(a) factors affecting radon emanation and its control in mines,
(b) factors affecting control of radon in mines and methods of control of radon daughters,
(c) the use of respiratory protective devices to control personal exposure to inhaled radon daughters, and
(d) procedures for control of exposure to contaminated wastes and effluents from mines and mills.

IV.2 Factors affecting radon emanation and its control

The radon emanation rate from radium-bearing minerals and ores, also known as the specific flux, is given the symbol *J*. Values of *J* are given in units of curie/square centimetre-second or other units having the same dimensions. Radon emanation rate and its variation and control are very significant factors in meeting the radiation protection standards of this Code in a mine (Schroeder and Evans[1]). The contribution to radon daughter concentration at a point in a tunnel due to emanation at rate *J* from tunnel surfaces of perimeter *P* and cross-sectional area *A* into air passing over such surfaces for time *t* is given by:

$$\frac{JPK}{1.85A} \times t^{1.85}$$

where *K* is a factor of proportionality which may be approximated by 0.023 in practical situations.

In addition to *J*, this formula indicates other quantities which, if varied, affect growth of radon daughter in mine air. These other quantities will be discussed in IV.3. At this point, factors affecting the radon emanation rate and its control will be discussed.

IV.2.1 *Factors not subject to control*

IV.2.1.1 *Porosity of ore and waste and barren rock.* Ore and waste and barren rock which bear radium are sources of radon gas and eventually of radon daughters in air. The porosity of these materials exerts a strong influence on their radon emanation rate, when they are exposed on surfaces of mine openings or as broken material in heaps underground. Porosity in underground uranium mines has been shown to range far over twenty-fold giving a range of a hundred-fold in radon emanation rates for ores of similar uranium and radon content (Thompkins[2]). Even an approximate determination of average porosity (pore space) of ore to be mined will give a valuable indication of the extent of control measures for radon daughters to meet the requirements of this Code and a guide to effects of pressure on radon emanation. A heap of broken ore has greater porosity than of unbroken ore and as a consequence a higher radon emanation rate.

IV.2.1.2 *Radium content of ore.* The ore grade (percentage U_3O_8) may be an indicator of likely emanation rate (in concert with porosity), but as disequilibrium between ^{238}U and ^{226}Ra is known to exist in some Australian ores, the ^{226}Ra contents of ore and waste and barren rock must be known if the radon emanation rate relative to other ores is to be estimated.

IV.2.1.3 *Radon concentration gradient.* Concentration of radon in ore and other rock depends on the radium content and the proximity of openings or rock fissures. Diffusion of radon towards regions of lower concentration, such as openings, leads to a concentration gradient (rate of change of concentration with distance through the rock). The concentration gradient may also be affected by air or rock pressures. The radon emanation rate at the surface of an opening depends directly on the radon concentration gradient close to the opening.

IV.2.1.4 *Rock fractures.* The number and extent of rock fractures, fault planes and fissures in ore and other rock that bears radium directly affects the radon emanation rate. Very small pieces of ore have been shown (Thompkins[2]) to have lower emanation rate than larger pieces. It has been speculated that a lack of microfractures in smaller pieces may be one cause of this effect. Emanation rate from ore faces increases after blasting, due to increased fracturing.

IV.2.1.5 *Atmospheric pressure.* Increase of atmospheric pressure reduces the flow of radon from highly porous ore and other rock that bears radium, thereby decreasing the emanation rate. Conversely, as atmospheric pressure falls, emanation rate from porous material increases, as does emanation rate from interstices in bulkheads or brattices intended to seal off mined-out areas. As wind and other airstreams result from pressure differentials, such air movement near radon sources will cause an increase in emanation rate.

IV.2.1.6 *Rock and water table pressures.* The mass of radon present in ores, whatever the radium content, is so small that the pressure exerted by the radon is insignificant. Pressures in rock due to stresses and due to force exerted by the water table increase the radon emanation rate.

IV.2.2 *Factors subject to control*

IV.2.2.1 *Water flow and water overlay.* Because flow of water through ore and other radium bearing rock towards openings may be more rapid than the radon diffusion process, such water flow may increase the radon emanation rate at the surface of the opening above that due to diffusion alone. Water flowing over or standing on mine surfaces will have a suppressive effect on radon emanation otherwise obtaining.

IV.2.2.2 *Classification of tailings.* Classification of tailings to remove slimes usually removes much of the radium in the tailings. Classification of tailings is a very useful procedure to thus reduce radon emanation and improve consolidation of fill if tailings are to be placed underground.

IV.2.2.3 *Consolidation of fill.* Consolidation of tailings placed as fill underground by settling and by use of cement leads to lower radon emanation rate. Over a range of cement content, emanation rate decreases with increase of cement content.

IV.3 Methods of control of radon emanation

Methods of control of radon emanation rate may be derived in considering the factors described in IV.2.2 above, as follows:

IV.3.1 *Mines in porous rock*

IV.3.1.1 Where water flow through an orebody in porous rock increases the radon emanation rate, water wells may be constructed at the periphery of the orebody to reduce or prevent this water flow.

IV.3.1.2 Construction of an exhaust airway around the periphery of an orebody and operation of that airway under reduced pressure relative to the mine openings in the orebody will drain radon away from the work places (Schroeder and Evans[2]).

All mines

IV.3.1.3 Operation of working stopes under high air pressure relative to the surrounding mine openings will reduce the radon emanation rate in the stopes.

IV.3.2 Exhaust airways may be constructed from worked-out areas segregated by bulkheads or brattices. These need only provide sufficient flow to place the air in the worked-out areas under low pressure relative to the air in the adjacent mine openings in order to reduce or eliminate the radon emanation ratio from cracks in the bulkhead or brattice. This technique is termed 'protective vacuum'. It will also overcome sudden increases in emanation rate from such cracks, due to variations in mine airflows or atmospheric pressure. Such cracks in bulkheads and brattices cannot be entirely avoided, depite best efforts at sealing.

IV.3.3 Tailings placed underground for filling of worked-out areas will contain radium, the source of radon emanation. However, the emanation rate may be reduced by classification of tailings to remove slimes, consolidation of tailings by compaction or mixing with cement and use of the exhausted bulkhead techniques detailed in IV.3.2 above.

IV.4 Control of radon

The control of the radon emanation rate from mine surfaces, bulkheads, brattices and ore heaps detailed in IV.3 makes a major contribution to the control of radon in mines, if implemented. Other factors which affect control of radon in mines and resultant control measures are as follows:

IV.4.1 *Other effects of pressure in mines*

IV.4.1.1 If pressure differences exist in 2 mine ventilation circuits separated by segregated mined-out areas, radon will flow from the segregated areas into the circuit of lower pressure. This can lead to a large rise in radon daughter concentration at a distant point in that air circuit.

IV.4.1.2 If ventilation to 2 adjoining stopes results in a pressure difference between the 2, radon migration to the stope of lower pressure may occur, leading to elevated radon daughter concentrations in such stopes.

IV.4.2 *Limitation of radon sources*

The number and extent of all radon sources in a mine determines, in part, the need for ventilation and the cost of other control procedures.

IV.4.2.1 Unless mined-out areas are placed under 'protective vacuum' or filled with barren rock or overburden, they must be considered as large sources of radon. In this case clean intake air should not be conducted past them.

IV.4.2.2 Broken ore is a major source of radon in mines, often of far greater importance than mine surfaces. Mining and milling practices which do not ensure rapid removal of broken ore from underground and avoidance of large ore stores underground will result in a severe economic penalty and technical difficulties in meeting the radiation protection standards of this Code.

IV.4.2.3 The extent of ore surface exposed in mining directly affects the importance of that surface as a radon source. This is clear from the units for radon emanation rate, which may be rearranged as curies per second per square centimetre. Thus mining practices which limit the surface area of exposed ore faces reduce the importance of those surfaces as a source of radon.

IV.5 Control of radon daughters

By control of radon emanation rate and the magnitude and extent of radon sources, as described in IV.3 and IV.4, a major contribution to limiting radon daughter concentration can be made. Other measures to control radon daughter concentration in occupied places in order to meet the radiation protection standards of this Code are as follows:

IV.5.1 *Ventilation*

The recognized method of ventilation in underground uranium mines of conducting fresh air under slight positive pressure to the work places, where it dilutes the contaminated air, followed by removal of the mixture is still of significance. However, improvements in detail can be made as follows:

IV.5.1.1 If mine development is planned to achieve complete separation of contaminated used air and fresh intake air, significant improvement in control of radon daughters occurs. Underground booster fans must be so used as to avoid recirculation.

IV.5.1.2 Control of radon daughters will be enhanced if mining is conducted towards the fresh air supply and exhaust is conducted through mined-out areas.

IV.5.1.3 A pressure gradient should be maintained in the ventilation system towards the exhaust portal or portals.

IV.5.1.4 Improvement of extraction of contaminated air by use of extraction raises and fans may allow alternative mining practices (e.g. 'blasthole' stoping) without exceeding the radiation protection standards of this Code.

IV.5.1.5 Following determination of radon emanation rates (Thompkins and Cheng[3] and Kraner, Schroeder and Evans[4]) and radon source locations, informed decisions may be made regarding:

(a) location of haulage ways in barren rock or ore,
(b) use of haulage and travelways as inlet airways,
(c) the maximum residence time of air in the mine without exceeding the radiation protection standards in this Code,
(d) the circulation of air through stopes in series.

IV.5.2 *Filtration*

Filtration of air to remove radon daughters is not a commonly accepted technique. However, in some mines it offers some economic incentive. The growth of radon daughter concentration in air from radon diffusing or emanating into the air is in proportion to residence time to the power 1.85, whereas the growth from a single radon source in a sealed volume is in proportion to residence time to the power 0.85 (Evans[5]).

IV.5.2.1 Although absolute filters are effective initially, they deteriorate rapidly underground due to water and other airborne materials. In addition, they are expensive.

IV.5.2.2 'Sera Foam' chips in wire frames and commercial electronic air cleaners operated at low speed are quite effective and reliable underground for removal of radon daughters. Capital cost and space underground are therefore the important considerations in evaluating filtration.

IV.5.2.3 The build-up of gamma ray activity on filters can pose a serious local radiation control problem. This is especially so where radon concentration in air is high, of the order of 500 picocuries/litre (Evans[5]). Such concentrations are not unlikely, even if radon daughter concentrations are kept within the radiation protection standards of this Code.

IV.5.2.4 Experiments on one mine have indicated that good reduction of radon daughter concentration can be obtained by operation of the filter fan without the filter. It is speculated that plate-out of unattached radon daughters on mine surfaces is the reason for this.

IV.6 Guide to the use of respiratory protective devices

Care must be exercised in the selection, use and maintenance of personal respiratory protective devices to ensure that the desired protection is achieved and all persons responsible for the issuance of this equipment should be familiar with *the Australian Standard Code of Practice for Respiratory Pressure* AS 1715–1975[6] and the *British Standard Specification for Positive Pressure, Powered Dust Respirators* BS4558: 1970[7]. The purpose of this part of this Appendix is to highlight some of the requirements for the use of respirators in mining and milling radioactive ores. Further references (8, 9) are given below.

IV.6.1 *Selection of respirators*

The atmospheric contaminants which are found in this industry are particulates in the form of dusts, fumes, mists and smokes which may be harmful in themselves or to which radon or thoron daughters are attached. No unique set of rules for the selection of respirators can be laid down and each particular use must be assessed individually in the light of the concentration of contaminant and the nature of the work to be performed. Selection will be made from a wide variety of devices, including the following:

IV.6.1.1 Air purifying devices:

Half facepiece dust respirators, (Section 3.3.4, AS1715),
Full facepiece dust respirators, (Section 3.3.4, AS1715),
Positive pressure, powered dust respirators. (BS4558).

IV.6.1.2 Air supplied devices:

Air-line respirators,
Half facepiece, (Section 2.4.3.3, AS1715),
Full facepiece, (Section 2.4.3.2., AS1715),
Hood or helmet. (Section 2.4.3.4, AS1715).

IV.6.2 *Air purifying devices*

Air purifying devices consist of a replaceable cartridge which is fitted to a rubber facepiece. The most common form is the facepiece type which, in mining and milling radioactive ores is used with a Class M cartridge complying with the Australian Standard. Some facepieces are capable of taking 2 filters in parallel and some employees prefer this configuration because of the lower breathing resistance.

IV.6.2.1 The limiting factor in protection afforded by a half facepiece respirator resides in its poor facial fit and when a protection factor greater than about 10 is required resort must be made to more efficient equipment. (Protection factor is defined in IV.6.4.) It must be noted, however, that the Australian Standard makes provision for the supply of several sizes of half facepieces and attention is drawn to Clause 4.2 of AS 1715-1975[6] concerning face fitting of respirators.

IV.6.2.2 Correctly fitted and well-maintained full facepiece dust respirators can give a protection factor of 100 but their use is severely restricted by the discomfort of the rubber moulding which covers the eyes, nose and mouth. The full facepiece ensures that the effectiveness of the facial seal is comparable with that of the Type H, high efficiency filtering medium with which it is used.

IV.6.2.3 Positive pressure powered dust respirators consist of a facepiece or hood provided with a battery powered blower which forces air through a filter cartridge. These devices and supplied air respirators are often to be preferred for lengthy periods of use because of the lower resistance to breathing they present relative to the cartridge types. Although these devices can give a greater protection factor than 100, prudence suggests that employees should be exposed to such high concentrations of atmospheric contaminants in special cases only and then under the strictest supervision.

IV.6.3 *Airline respirators*

IV.6.3.1 These respirators normally furnish respirable air from a compressor which draws its supply from an uncontaminated ambient atmosphere. The employees are restricted somewhat by the trailing air line but a convenient reticulation system with quick release plug-in air connectors can be designed to minimize this in some circumstances. Bulldozer and drivers of other mobile plant can be equipped with air line respirators furnished with air from large bottles resembling the commercially available 3.4 m^3 bottles of 'medical compressed air'.

IV.6.3.2 AS 1716-1975[6] distinguishes 2 methods of air supply, viz., the continuous flow type and demand flow type which, taken with the available facepieces and hoods, allows the selection of a respiratory protective system from a large number of combinations. A half facepiece with demand valve air flow will provide a protection factor of about 10 whilst a hood with continuous flow can give greater protection with greater comfort. It is unwise to use hoods in conditions requiring a protection factor greater than 100 because the design of the hood and the nature of the employee's work are limiting features. Hoods must be worn with a continuous air flow of not less than 120 litres per minute.

IV.6.4 *Protection factor*

The protection factor is a measure of the degree of protection which may be afforded by a respirator, defined as the ratio of the concentration of contaminant outside the respiratory protective equipment to that inside the equipment (usually inside the facepiece) under conditions of use. It is applied to the ambient airborne concentration to estimate the concentration inhaled by the wearer according to the following formula:

$$\text{Concentration inhaled} = \frac{\text{Ambient airborne concentration}}{\text{Protection factor}}$$

The concept of 'protection factor' is introduced only with reluctance as a guide to the protection which may be expected because a stated figure cannot be guaranteed under all circumstances. The stated figure of, say, 10 applies only for trained individuals wearing properly fitted respirators and maintained under supervision in a well-planned respiratory protective programme (see 4.4.6.4 of this Code).

IV.6.5 *Written procedures*

Australian Standard 1715-1975[6] and other publications (8,9) will assist managers in the preparation of the written procedures required in 4.4.6.4 of this Code. Consideration must be given to valve maintenance, particularly in hot environments, head harness, breathing tubes, regulators, hoses, compressed air quality, facial hair, spectacles, dentures and other aspects not obvious to persons inexperienced in the use of respirators.

IV.7 Principles underlying the control of wastes and potential pollutants from mining and milling operations

The distribution of natural resources is such that different orebodies are subject to differing environmental factors which impose differing constraints on the disposal of wastes and effluents from mining and milling operations. Although the general problems of waste disposal are common to all types of mining and milling operations, the mining and milling of radioactive ores poses a unique problem because the wastes and effluents may be both chemically toxic and radiotoxic.

Potential pollutants are produced at all stages in the mining and milling of radioactive ores. Thus, the primary object of the design, construction and methods of operation of the mine, the mill and the disposal system(s) should be that, during normal operation and all foreseeable emergency conditions, all process solutions, airborne dusts, and liquid and solid wastes and effluents will be contained. These wastes and effluents will contain a variety of pollutants depending on the type of ore and the milling processes used. The waste and effluent treatment which will be adopted will generally be determined more by the requirement to limit non-radioactive material (e.g. heavy metals), then by contamination as such.

However, in the event that radioactive materials, either dissolved or in solid form, are released into the surrounding water or air environment, stringent controls over the nature and amounts of discharged radionuclides should be observed. Moreover it should be noted that, as the optimum method for control of effluents depends both upon the climate and topography of the area concerned, the method chosen will vary from one facility to another.

This Code does not make detailed recommendations with respect to waste management practices. This Appendix outlines some of the problem areas and practices to which consideration should be given in the design, construction and operation of an acceptable waste management system. Further information is given in reference (10) listed below.

IV.7.1 *Airborne wastes*

Such wastes may include dusts fugitive from mining operations, overburden and waste rock dumps, ore stockpiles, tailings dams and transportation and ore handling operations. In addition, process effluents from milling operations may be released in gaseous or aerosol form as airborne wastes. Procedures should be adopted and equipment chosen, modified and located so that airborne wastes are minimized.

Airborne wastes can be minimized by the use of the following practices:

(a) Water spraying should be used to reduce severe dusty conditions arising from ore haulage operations, overburden and waste rock dumps, ore stockpiles and exposed tailings. Consideration should be given to the possibility of leaching pollutants if excessive water is used.

(b) Overburden and waste rock dumps and ore stockpiles may be covered with impervious materials or sprayed with organic membranes.

(c) Vegetative fixings of tailings and overburden and waste rock dumps is also effective.

(d) In the crushing, sampling and concentrate areas of a mill, an efficient dust collection and recovery system should be installed. Recovered dust should be recycled to the mill circuit.

(e) The ventilation exhaust from a mine or mill should be properly designed and managed.

IV.7.2 *Liquid wastes*

Liquid effluents from the mining and milling processes should be contained in an appropriate storage system above or below ground, in such a way that no adverse effect to the environment will result. If effective containment is practised, liquid effluents do not present an environmental problem. An investigation of the hydrological and geological conditions at, and in the neighbourhood of, the storage site should be made to determine if any action is necessary to protect ground water or water courses against pollution from percolate or drainage from the storage facility.

Alternatively, it is often possible to reduce the chemical toxicity or radiotoxicity of liquid effluents by physical or chemical treatment or by physical or chemical extraction procedures. Suitable procedures may exist which, if used on a large scale to treat effluents may permit such a reduction of the chemical toxicity and radiotoxicity that the treated effluent may be released in a controlled manner after monitoring for activity and other pollutants without harm to the environment. In this regard, consideration should be given to the neutralization of acidic or alkaline wastes and the clarification of liquid effluents. Precipitation of radium and heavy metals dissolved in liquid effluents is also important. Radium forms the major radiotoxic element in such waste. Physical methods include the use of settling ponds to precipitate fine solid matter in the liquid effluents.

Seepage from ponds, holding tanks and lines should be kept as low as practical. To this end, monitoring to detect and assess seepage is essential to indicate the need for corrective action. Seepage which cannot be prevented by practical means should be recycled or so treated that discharge can be made without harm to the environment.

The design and construction of the liquid effluent storage system should ensure that, during normal operation and all foreseeable emergency conditions, no overflow results.

IV.7.3 *Overburden heaps*

When locating, designing and constructing overburden and waste dumps, consideration should be given to the effects of water and wind erosion. In particular, extremes in the long-term weather pattern and the likely consequences of such extremes should be considered.

With regard to the effect of water, such as rain water, the possibility of formation of leaching agents able to leach pollutants from the dumps should be considered. If leaching or formation of potential pollutants may thus occur, the placement, construction and stabilization of dumps should be such as to prevent discharge of the potential pollutant. This may be achieved by provision of an outer layer of impervious material over and around the dumps. Alternatively, placement of an outer layer of cultivable soil of sufficient thickness to allow vegetation to be established and the establishment of thick vegetative cover may be found suitable. Provided suitable plant species are chosen and the cover is adequately thick to prevent seepage of pollutants at the base of the dump, this method may be environmentally more desirable. Further measures to reduce or eliminate the effects of surface water include the diversion of run-off waters away from dumps and backfill of overburden into mined-out areas. Where total prevention of seepage is not practical, seepage should be recycled and contained or so treated that discharge can be made without harm to the environment.

IV.7.4 *Tailings disposal*

The design, construction and location of tailings disposal areas should be such as to ensure that the contents are contained under all meteorological conditions, having regard to seasonal and long-term changes in the weather pattern, including projected extremes. The effects of erosion by water and wind should be carefully considered. The capacity of tailings disposal areas should be evaluated with regard to increased water volumes following rainfall, surface run-off from surrounding areas and surface evaporation. A 'design life' for each proposed disposal area should be established. Where seepage through a dam occurs at a level at which harm may be done to the environment, seepage should be recycled or treated to permit discharge.

IV.7.4.1 *Tailings dams.* The extent of seepage through tailings dams and the likelihood of failure of such dams, under conditions of rapid draw down and conditions of heavy and extended rainfall in excess of the highest recorded in the general climatic region, should be evaluated. The location, design and construction of tailings dams should be such as to prevent failure under these conditions and reduce seepage to a practical minimum. In addition an investigation of the hydrological and geological conditions at, and in the neighbourhood of the tailings dams should be made to determine if any action is necessary to protect ground water or water courses against pollution from percolate or drainage from the dams. Locations of tailings disposal areas in low lying depressions and the use of naturally occurring dams may lead to problems of excessive seepage, piping failure in the natural containment wall or loss of the dams by undermining due to flow through pervious layers in or below the dams. It may be found preferable to construct a properly engineered dam in a location having minimal catchment area. Such a dam will necessarily be constructed with an adequate cut-off curtain to lower the water flow in the soils underlying the tailings placement area, if natural formations are inadequate for this purpose. The dam will also include earth core, sand filter and overlying rip-rap to secure the dam and prevent erosion. The rise and fall of water behind the dam, including rise due to heavy rain, must be considered in designing the dam to prevent shear failure in the core.

IV.7.4.2 *Airborne wastes.* Airborne wastes which may arise from tailings disposal areas should be controlled (see IV.1.1). Radon emanation should receive particular evaluation and control.

IV.7.4.3 *Completed areas and regeneration.* When a tailings disposal area above ground has been filled to its practical limit, the area should be covered with soil and stabilized by vegetative fixation or by spraying with organic membranes as for overburden and waste rock dumps (see IV.1.3) or by covering with rip-rap. However, regeneration of the original vegetation of the area is desirable and should be undertaken if feasible.

IV.7.4.4 *Methods of control.* Additional particular methods of control which may be used in design and construction of tailings disposal areas include the following:

(a) diversion of surface run off,
(b) installation of settling ponds for dewatering tailings sands and slimes,
(c) precipitation of dissolved radium,
(d) installation of sumps and seepage collection dams,
(e) clarification and neutralization of seepage and prevention of overflow from tailings dams,
(f) reduction of radon diffusion from tailings sands by provision of water or soil cover,
(g) prevention of water erosion and reduction of seepage through sands, and
(h) backfilling of mined-out areas.

Each of the above methods should be assessed in relation to local environmental conditions.

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Appendix V

Guide to the type and scope of medical examinations

V.1 General

V.1.1 Medical examinations of employees are required by Section 5 of this Code. This Appendix gives a guide to the type and scope of such examinations. In this regard, the investigations usually made in good occupational medical practice are considered to be sufficient. Thus the usual anthropometric data (e.g. height, weight) and the results of examinations of the main organs and functions should be recorded, with special emphasis on respiratory system, blood and blood-forming organs, cardiovascular system, skin, liver and kidneys.

V.1.2 In paragraphs 5.4, 5.5.2, 5.6.1 and 5.6.2 of this Code, X-ray examination of the chest and supplementary determinations of urine are specified; however, it may be desirable to supplement these with other X-ray examinations and laboratory tests.

V.1.3 In the medical surveillance of employees engaged in mining and milling of radioactive ores, it is to be noted that there may be a risk of pneumoconiosis as well as radiation injury and that the former risk may be the greater.

V.2 Respiratory system

V.2.1 The examination of the respiratory system should include an X-ray examination of the chest by direct radiography, sputum cytology and respiratory function tests such as measurement of forced expiratory volume and vital capacity.

V.2.2 Examination of the mucous membranes of the mouth, nose and the pharyngolaryngeal region may reveal evidence of local irritation or other disorders due to contamination by dust.

V.3 Blood

V.3.1 The blood examination should include at least an estimation of the haemoglobin in grams per cent, a total and differential white cell count, examination of a stained blood film with note of any abnormal cells and an estimate of the number of platelets.

V.4 Skin

V.4.1 The skin should be examined for dermatoses which may increase its radiosensitivity. The hands and fingers should be examined for changes possibly due to chronic irradiation.

V.5 Pre-employment examination

V.5.1 The main purposes of this examination are:

(a) to determine the applicant's fitness to perform, without danger to himself or to others, the tasks on which he is seeking employment or is employed, and

(b) to establish a reference record for any subsequent changes in his health.

V.5.2 The examination should include a medical interview to establish the applicant's family, personal and occupational histories.

V.5.2.1 In establishing the family medical history the possibility of hereditary defects should be examined.

V.5.2.2 In establishing the personal medical history, attention should be given to any pre-existing disease that could have been due to radiation exposure or confused with radiation injury.

V.5.2.3 In establishing the occupational history, all previous exposures to radiation should be noted and a distinction made between exposures resulting from work with radiation sources and those received as a patient subject to radiological examinations, radiotherapeutic treatments and nuclear medicine investigations. Note is to be taken of previous exposures to non-radiation risks to the applicant, in particular his exposure to dust.

V.6 Periodical medical examination

The purpose of this examination is to assess continuing fitness and to detect effects due to hazardous working conditions. The type and scope of the periodical examination should be similar to the pre-employment examination but may not always need to be so extensive. The radiation exposure record of the employee should be referred to at the time of this periodical examination.

V.7 Medical examination at termination of employment and follow-up examination

The terminal medical examination should be similar in type and scope to that of the pre-employment examination. Depending on the result, it may be desirable to provide follow-up examination after employment has ceased e.g. for the detection of neoplasm of the lungs or evidence of pneumoconiosis.

V.8 Medical examinations following emergency or accidental radiation exposure

The medical examination following emergency or accidental radiation exposure should, in general, be similar in type and scope to the periodical medical examinations, but this may depend on the levels of radiation received or on the radon daughter intake or thoron daughter intake. These levels and intakes will also indicate the need for follow-up medical examinations and for supplementary determinations. Consideration should be given to the treatment and care[1] of the person following such exposure.

V.9 Form of medical records

A suggested format for medical records follows.

V.10 Reference

1. Australia, National Health and Medical Research Council. *Notes on medical procedure for radiation accidents and radioactive contamination.* Canberra, May 1968.

NO.

MEDICAL RECORD CARD

NAME:

(*Print surname*)

APPLICANT'S SIGNATURE:

DATE OF BIRTH: AGE:

DATE AND PLACE OF EXAMINATION:

ADDRESS:

BIRTHPLACE: M.S.W.

OCCUPATION:

OCCUPATIONAL HISTORY

Employer	*From year*	*To year*	*No. of years*	*Nature of work*

PREVIOUS HEALTH:

PRESENT HEALTH: SYMPTOMS AND DURATION:

FAMILY HISTORY:

T.B. CONTACT: SMOKING: ALCOHOL:

FINDINGS OF MEDICAL EXAMINATION

HEIGHT	WEIGHT	TEMP.	PULSE	B.P.	CHEST MEASUREMENTS MAX. MIN.	E.C.G.

BLOOD	URINE
Hb P.C.V.	S.G.
W.C.C.	Reaction (pH)
Neutrophils	Albumin
Lymphocytes	Sugar
Monocytes	Microscopic
Eosinophils	
Basophils	Uranium
Abnormal Cells	Radium 228
Platelets	....
E.S.R.	

VISION	L.	R.	Colour	HEARING	L.	R.
Uncorrected				Whisp. Voice	ft.	ft.
Corrected				db loss 4000cps		

RADIATION RECORD
Whole Body..
Local (specify)...
Working Level Months............................

RESPIRATORY FUNCTION	SPUTUM CYTOLOGY	CHEST X-RAY
FEV_1		
FVC		
PEFR		

PART OR SYSTEM	√=N	SPECIFIC FINDINGS–REFER TO ITEM NUMBER (DELETE PARTS NOT EXAMINED)	PART OR SYSTEM	√=N	SPECIFIC FINDINGS–REFER TO ITEM NUMBER (DELETE PARTS NOT EXAMINED)
1. General Appearance			14. Abdomen		
2. Eyes and pupils			15. Inguinal region		
3. Fundi			16. Reproductive organs		
4. Ears			17. Rectum and anus		
5. Nose			18. Spine		
6. Mouth			19. Upper extremities, Hands, Fingers		
7. Dental			20. Lower extremities		
8. Throat/Larynx			21. Haemopoietic system		
9. Neck			22. Lymphatic system		
10. Thorax			23. Skin		
11. Lungs			24. Central Nervous System		
12. Heart			25. Mental state		
13. Peripheral vessels			26. Others		

DIAGNOSIS	CLASSIFICATION
CERTIFICATE/REPORT	SIGNATURE OF MEDICAL EXAMINER

RE-EXAMINATION (1)

Date	*Locality*	*Work since last examination*	*Height*	*Weight*	*Temp.*	*Pulse*

B.P.	Chest	Vision	L	R	Hearing	L	R	E.C.G.
	Max.	Uncorrected			W.V.	ft	ft	
	Min.	Corrected			db loss 4000cps			

BLOOD

URINE

S.G. Albumin
Reaction (pH) Sugar
Microscopic

Uranium
Radium 228
....

RESP. FUNCTION

SPUTUM CYTOLOGY

CHEST X-RAY

ACCUMULATED RADIATION DOSE

Whole Body..
Local (specify)..
Working Level Months..

ILLNESS SINCE LAST EXAMINATION

SYMPTOMS AND DURATION

PHYSICAL EXAMINATION (SPECIFIC FINDINGS—REFER TO ITEM NUMBER)

MEDICAL EXAMINER

CLASSIFICATION

RE-EXAMINATION (2)

AS FOR RE-EXAMINATION (1)

RE-EXAMINATION (3)	RE-EXAMINATION (4)
AS FOR RE-EXAMINATION (1)	AS FOR RE-EXAMINATION (1)

SCHEDULE 2

Regulation 2

MEANING OF "APPROPRIATE STATUTORY AUTHORITY" IN THE CODE

Provision	Requirement	Meaning
2.2.2	Manager to notify	Director of Mines and Director of Health
3.4.1	Approval of sampling procedures	Director of Health
3.4.1(b)	Approval of tests	Director of Health
3.4.1(c)	Approval of tests	Director of Health
3.5.2.1	Approval of tests	Director of Health
3.5.2.2	Approval of intervals	Director of Health
3.7.3	Approval of tests	Director of Health
3.8.1	Manager to inform	Director of Health
3.9.2	Manager to report	Director of Mines and Director of Health
3.9.3	Manager to report	Director of Mines and Director of Health
3.10.2(i) and (iv)	Manager to inform where multiple of relevant protective action greater than 10	Director of Mines and Director of Health
4.1.1	Approval for discharges	Director of Mines
4.5.2	Manager to report	Director of Mines and Director of Health
4.6.1.2	Submission for approval	Director of Mines
4.6.1.3	Submission for approval	Director of Mines
4.6.1.4	Submission for approval	Director of Mines
4.7.1	Limits to be specified	Director of Health
4.7.2	Submission for approval	Director of Mines
4.7.3	Application for approval	Director of Health
4.8.2	Approval of containers	Director of Health
5.6.4	Whom to be informed	Director of Health