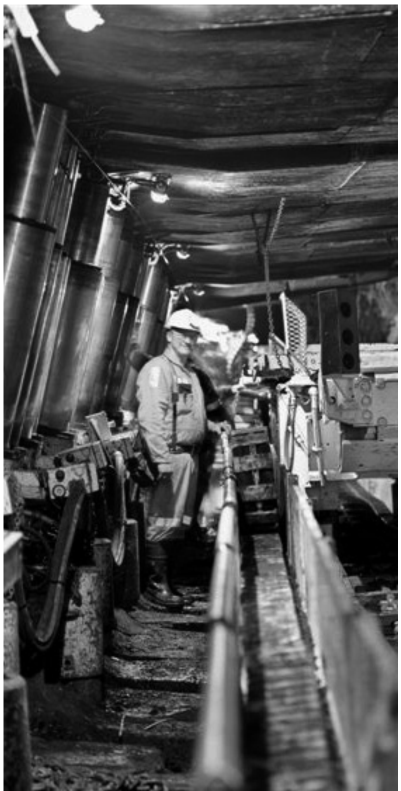
DRAFT

Code of Practice

MANAGING NATURALLY OCCURRING RADIOACTIVE MATERIALS IN MINING



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FOREWORD

This Code of Practice on managing naturally occurring radioactive materials in mining is an approved code of practice under section 274 of the *Work Health and Safety Act* (the WHS Act).

An approved code of practice is a practical guide to achieving the standards of health, safety and welfare required under the WHS Act and the Work Health and Safety Regulations (the WHS Regulations).

A code of practice applies to anyone who has a duty of care in the circumstances described in the code. In most cases, following an approved code of practice would achieve compliance with the health and safety duties in the WHS Act, in relation to the subject matter of the code. Like regulations, codes of practice deal with particular issues and do not cover all hazards or risks which may arise. The health and safety duties require duty holders to consider all risks associated with work, not only those for which regulations and codes of practice exist.

Codes of practice are admissible in court proceedings under the WHS Act and Regulations. Courts may regard a code of practice as evidence of what is known about a hazard, risk or control and may rely on the code in determining what is reasonably practicable in the circumstances to which the code relates.

Compliance with the WHS Act and Regulations may be achieved by following another method, such as a technical or an industry standard, if it provides an equivalent or higher standard of work health and safety than the code.

An inspector may refer to an approved code of practice when issuing an improvement or prohibition notice.

This Code has been developed by Safe Work Australia in conjunction with the National Mine Safety Framework Steering Group as a model code of practice under the Council of Australian Governments' *Inter-Governmental Agreement for Regulatory and Operational Reform in Occupational Health and Safety* for adoption by the Commonwealth, state and territory governments.

A draft of this Code was released for public consultation on *[to be completed]* and was endorsed by the Select Council on Workplace Relations on [*to be completed*].

SCOPE & APPLICATION

This Code applies to all types of work and all workplaces covered by the WHS Act including mining workplaces that are permanent, fixed, mobile, temporary or remote and where NORMs associated with mining are encountered.

This Code has been developed to assist the person conducting a business or undertaking to ensure that workplaces where naturally occurring radioactive materials (NORMs) associated with mining occur (whether in situ or when persons are exploring for minerals that contain NORMs, or handling, processing, storing or transporting minerals that contain NORMs) are without risks to health and safety and that facilities provided for the welfare of workers and health surveillance are adequate.

This Code complements *Code of Practice: Health Monitoring in Mining*, which is aimed at giving information in relation to health risks not covered in other codes.

Interaction with the other radiation protection legislation

This Code aligns the WHS standards governing mining with the system of radiation protection as recommended by the International Commission on Radiological Protection

(ICRP), International Atomic Energy Agency (IAEA) and the Australian Radiation Protection and Nuclear Safety (ARPANSA). In the event of any conflict between this Code and that of the ARPANSA legislation, the latter will take precedence. ARPANSA has also published the *Code of Practice and Safety Guide: Radiation and Radioactive Waste Management in Mining and Mineral Processing (Radiation Protection Series Booklet 9)* to support its legislation.

This Code applies to the control of occupational and public radiation exposures and the management of radioactive waste generated at all stages of mining and mineral processing from exploration to final site rehabilitation. It is not aimed at addressing risks associated with sealed sources of radiation. Further guidance on this issue can be found at the ARPANSA website at www.arpansa.gov.au.

This Code may apply to the mining and processing of other materials where products or wastes arising from these operations require management because the radionuclides they contain may cause harm to humans or to the environment. Many wastes arising from operations to which this Code applies will, in addition to their radionuclide content contain other contaminants that can be harmful to human health. While this Code does not address these matters, due regard for such other contaminants must be made in developing a system for management of radioactive materials and their waste.

In line with ARPANSA's *Radiation Protection Series Booklet 9*, the relevant regulatory authority may grant exemptions from the provisions of this Code either for the whole operation or for specified parts of the operation.

Who should use this Code?

You should use this Code if you have duties to ensure health and safety of workers and other persons under the WHS Act and Regulations, for example, a mine operator. This Code can also be used by managers, workers and their health and safety representatives to ensure that safeguards against exposure to NORMs in mining are devised, implemented and maintained as suitable and sufficient.

How to use this code of practice

This Code includes references to both mandatory and non-mandatory actions. The references to legal requirements contained in the WHS Act and Regulations (highlighted in text boxes in this Code) are not exhaustive and are included for context only.

The words 'must', 'requires' or 'mandatory' indicate that legal requirements exist, which must be complied with. The word 'should' indicates a recommended course of action, while 'may' indicates an optional course of action.

Throughout the WHS Act and its Regulations and this Code, there is reference to the term 'so far as is reasonably practicable', which relies on risk assessment to select suitable and sufficient control to proportionately prevent realisation of the risk. This term is broadly equivalent to the stricter term 'as low as reasonably practicable (ALARP), which is generally used in the radiation industry, to select the best control.

1. INTRODUCTION

1.1 What are naturally occurring radioactive materials?

Naturally occurring radioactive materials (NORMs) are materials containing no significant amounts of radionuclides other than naturally occurring radionuclides, disturbed or altered from natural settings, or present in technologically enhanced concentrations above background radiation levels due to human activities that may result in a relative increase in radiation exposures and risks to the public and the environment.

1.2 Who has duties to manage naturally occurring radioactive materials?

Under the WHS Act, all persons who conduct a business or undertaking have a duty of care to ensure, so far as is reasonably practicable, that workers and other persons are not put at risk from work carried out as part of the business or undertaking.

The WHS Regulations identifies ionising radiation as a principal mining hazard. To effectively control the risks, the mine operator must follow a *risk management process* and prepare and implement a hazard management plan which is included in the work health and safety management system (WHSMS). This Code provides guidance to help the mine operator meet this duty.

Other specific legislation including the *Australian Radiation Protection and Nuclear Safety Act 1998* (ARPANSA Act) and its Regulations also has requirements to protect the health of people and to protect the environment from the harmful effects of radiation. The content of the principal mining hazard management plan must take into account these requirements.

General guidance on the risk management process is available in the *Code of Practice: How to Manage Work Health and Safety Risks.* Further guidance to develop a WHSMS is available in the *Code of Practice: Work Health and Safety Management System*.

Principal mining hazard management plan for NORMs

A principal mining hazard management plan must be developed for NORMs. Where an existing mine already deals with radionuclides and a radiation management plan is in place, that plan may be recognised to be sufficient, however, the mine operator should ensure that plan contains the appropriate information that is required in a principal mining hazard management plan.

The level of detail to be included in a principal mining hazard management plan for NORMs largely depends on the degree of potential radiation exposure, which has been estimated or identified, and the expected difficulty of controlling it.

Drilling, handling, extracting, storing, transporting and processing of ore samples that contain uranium or thorium mineralization has the potential to expose workers to a radiation hazard. Therefore, persons conducting a business or undertaking at an exploration, mining or processing site must ensure identify hazard, assess the risks and implement adequate control measures to protect all from exposure to radiation. For example, where no ionising radiation hazards are present whatsoever, a brief written principal mining hazard management plan for NORMs requires a simple statement indicating the reasons for holding this view must be done. If there is no principal mining hazard management plan for NORMs, it will be taken to signify that ionising radiation hazards have not been considered at all by the mining operation.

The principal mining hazard management plan for NORMs for an initial greenfield exploration project would not be expected to contain as much detail as one for an advanced mining and processing project. As such, a principal mining hazard management plan for

NORMs may need to be developed for new exploration activities and a separate one for established mining operations (including associated processing).

Consultation

When managing risks, the mine operator must consult with workers and other persons at the mine including other persons conducting a business or undertaking. Further guidance on consultation, cooperation and coordination can be found in the *Code of Practice: Work Health and Safety Consultation, Co-operation and Co-ordination.*

2. IDENTIFYING HAZARDS AND ASSESSING RISKS

2.1 Identifying hazards

The first step is to identify all hazards in the mine, including NORMs present in the ore body to be mined. The next is to determine the potential and actual exposure levels for all workers, who may come in contact with these NORMs.

Some selective leaching and mineral concentration processes may also concentrate undesired contaminants as well as NORMs. Hazardous contaminants should be tested for throughout the process to identify whether workers could be exposed to elevated concentrations. Exposure may occur through inhalation, ingestion (from contaminating food or drink) or absorption through the skin. The rate and amount of contaminant taken up by the body depends on factors including:

- size and nature of the contaminant
- atmospheric conditions
- breathing rate of the worker
- whether a respirator is worn
- whether the chemical can enter the body via routes other than breathing, for example, absorption invasion, injection or ingestion, and
- individual differences for example, personal hygiene habits, age, gender and fitness level.

2.2 Assessing the risks

Regulation 9.2.11 of the WHS Regulations require that when conducting a risk assessment for the purposes of preparing a principal mining hazard management plan, the mine operator must use investigation and analysis methods that are appropriate to the principal hazard being considered. The mine operator must also consider the principal mining hazard individually as well as cumulatively with other hazards at the mine.

The risk assessment must:

- state the likelihood of the principal mining hazard causing or contributing to any harm to the health and safety of any person, and the severity of the harm
- describe the investigation and analysis methods used in the assessment
- describe all control measures considered to control risks associated with the principal mining hazard, and
- state reasons for deciding which risk control measure to implement.

Assessing the risks will help the mine operator take the correct action to eliminate the risk or where this is not reasonably practicable, minimise the risks from ionising radiation. When undertaking a risk assessment to determine control measures, the following factors as outlined in Schedule 9.2 of the WHS Regulations must be considered:

- the potential sources of ionising radiation from both natural and manufactured sources including from dust, air, water, ore and waste from mining and drilling operations, stack emissions, ventilation system emissions, surface contamination, core and sample storage, monitoring equipment
- the type of radiation (alpha, beta or gamma)
- the levels of radiation including background radiation, and
- the potential for length of exposure.

When assessing the risks, the mine operator should also consider the following factors:

- the type and scope of radiation work undertaken

- identification of the sources and pathways of radiation exposure
- equipment, facilities, and systems of work for controlling radiation sources including optimisation of radiation protection by design, and optimisation of radiation protection by use of best practicable technology
- all relevant control measures including classification and demarcation of radiation work areas, working conditions and work systems
- the appointment of a competent site radiation safety officer
- a site monitoring program for radiation, which adequately assesses, records and reports site radiation exposures
- a personal monitoring program for radiation, which adequately assesses, records and
- reports personal radiation exposures
- the transport, handling and storage of radiation sources, and
- training of all persons at risk of exposure to radiation.

3. CONTROLLING THE RISKS

Note: This chapter is aligned with the ARPANSA principles that can be found in the *Code of Practice and Safety Guide: Radiation and Radioactive Waste Management in Mining and Mineral Processing (Radiation Protection Series Booklet 9).*

The International Commission on Radiological Protection (ICRP) has set some control principles in relation to all sources of ionizing radiation regardless of size and origin. However, it is recognised that all sources and exposures cannot be treated in the same way and with the same level of resources. The following applies the general system of radiation protection to mining operations.

The ICRP has defined two concepts to delineate the extent of radiological protection control for regulatory purposes:

- exclusion of certain exposure situations from legislation because they cannot be controlled by any reasonable means (for example, potassium_40 in the body or exposure to cosmic radiation at sea level), and
- exemption from some or all radiological protection legislation for situations where such controls are felt to be unwarranted (for example, very low levels of radioactivity in building materials).

There are three categories of radiation exposure:

- occupational
- public, and
- medical.

The ICRP recommends that ‘no attempt be made to add the exposures to the same individual from the different categories of exposure for regulatory purposes’.

This Code primarily deals with the control of occupational exposures.

3.1 Hierarchy of control

When controlling risks, the mine operator must firstly look to eliminate the risk. If this is not reasonably practicable, minimise the risk so far as is reasonably practicable.

The specific control measures for radiological protection are set out below and are listed in a hierarchy (i.e. most effective to least effective):

- *Eliminate the risks* - Any decision that alters the radiation exposure situation should do more good than harm, i.e. justification. This applies to all exposure situations.
- *Minimise through engineering controls* – for example, optimisation of protection – The likelihood of incurring exposures, the number of people exposed, and the magnitude of their individual doses should all be kept so far as is reasonably practicable, taking into account economic and societal factors. This applies to all exposure situations and is embedded within the concept of workplace risk assessment.
- *Minimise through administrative controls* - for example, dose limitation – The total dose to any individual from regulated sources in planned exposure situations other than medical exposure of patients should not exceed the appropriate limits recommended by the Commission. This is individual related and applies in planned exposure situations only.

The appropriate upper bound for optimising protection with regard to a particular activity or plan will vary according to a number of factors including the overall benefit to society conferred by that activity, the cost and practicability of protection options, and the benefit received by those incurring the exposure. The ICRP recommends that the national authorities set appropriate reference levels for specific activities.

The principle of optimisation of radiation protection is a cornerstone of the international system for radiation protection and is the key driver for ensuring that radiation doses are not just maintained below standards, but are kept to the lowest feasible level throughout the life cycle of a practice involving radioactive materials. This principle is commonly referred to as the 'as low as reasonably practicable (ALARP) principle'. The ALARP principle takes economic and social factors into account and therefore broadly equates to 'so far as is reasonably practicable' used in the WHS Act which allows for the application of controls by the process of risk assessment.

The use of risk management to develop a suitably detailed plan for the identification, control and monitoring of radiation exposure and the management of radioactive wastes is necessary to coordinate the system of radiation protection. This is documented in the principal mining hazard management plan for NORMs for an exploration, mining and / or processing operation; see later sections for details on the requirements for these.

One of the most effective ways to control radiation risks is to 'engineer out' radiation hazards to the greatest extent feasible. Administrative controls should only be used to control residual risk when all other control measures have been utilised.

3.2 Minimising the risks

Principles of best practicable technology

The person controlling a business or undertaking at a mining operation should be able to demonstrate that the operation is employing the best practicable technology that it is reasonably practicable to use and that radiation doses to workers received as a result of that operation, so far as is reasonably practicable.

The preparation of a formal principal mining hazard management plan for NORMs is intended to document how best practicable technology has been incorporated into the design and operation of the mine and / or processing plant, and also the procedures that have been adopted to ensure the radiation exposure of persons employed at, or affected by, the mine are not just below the relevant dose limit, so far as is reasonably practicable.

It is considered that if a company is able to demonstrate that they are complying with their *approved* radiation management plan, then that should suffice as an indication that the doses received are at an acceptable level. However, it should be noted that all radiation management plans are required to be reviewed within two years of commencement of each operation and subsequently at intervals designated by the regulator, typically every two years. This review interval will be more frequent if the risk assessment process determines this to be the case.

Principles of radiation design

Optimisation commences in the design stage of an exploration, mining or processing operation. At the design stage, cost-benefit analysis is required to achieve a balanced design, which is not only optimised for radiation protection, but all other health, safety and welfare requirements.

Once the detailed engineering design of a process has been finalised, it is often quite expensive to retro-fit radiation control equipment, such as ventilation ducting for dust control and the associated infrastructure. For this reason, specification of radiation protection standards to be achieved in operations is important at the initial design stages.

In design, optimisation can be facilitated by:

- specifying radiation protection design criteria, usually in terms of contamination levels or dose rates at some fraction of derived limits

- specifying engineering control features, such as dust extraction or suppression equipment, shielding, layout of plant, automation of processes
- undertaking formal hazard assessments, for example, hazard and operability (HAZOP) studies at various stages of design
- ensuring design engineers are aware of relevant radiation protection measures through appropriate training and instruction, and
- applying the hierarchy of risk control principles (*i.e*. preference to elimination and control of hazards rather than use of operational procedures and PPE to achieve exposure control).

Although it may be possible to carry out minor modifications to plant and equipment following completion of the detailed design phase, post-design stage optimisation may be restricted to the implementation of operational procedures, including the adherence to any dose constraints that may be imposed on an operation.

The underlying principles of radiation protection in design are summarised below (from best to worst) and should be considered in the design of new facilities:

CONTROL	RATIONALE
Source shielding	Maximise containment, minimise release
Distance	Maximise distance
Time	Minimise exposure and intake time
Source reduction	Minimise production and use of radioactive materials
Optimal technology	Choose best practicable technology
Housekeeping	Minimise spillages and surface contamination
Dilution and blending	Minimise concentration, maximise dilution
Personal barrier	Minimise entry into the body by providing appropriate PPE and washing facilities
Education	Maximise knowledge through training
Limit other exposures	Minimise exposures to other agents

3.3 Administrative processes for optimisation

If a residual risk still exists after implementing best practicable technology and reviewing the design, administrative processes can be used for optimisation. These include:

- classification of working conditions and workplaces
- application of dose constraints to certain work categories
- implementation of investigation and reporting levels, and
- formulation, distribution and implementation of safe work procedures for identified critical tasks and provision of awareness training to all workers.

The classification of working conditions and workplaces and the implementation of investigation and reporting levels where contamination of the workplace cannot be `engineered out' of the operations are discussed in the following sections.

Classifying work conditions

- Classification of controlled areas
  One administrative method of achieving optimisation involves identifying and delineating areas of higher contamination levels or dose rates in the workplace with designated controlled area warning signs. There are two such areas that the ICRP and ARPANSA recommend should be invoked in premises that use or handle radioactive materials, namely, controlled and supervised areas. Such designated areas are accompanied by suitable radiation safety rules or procedures specified by management.

  If there is an area in a mine in which exposure conditions are such that an worker could receive in excess of 5 mSv in a year, then that area is to be declared a controlled area. This dose of 5 mSv may be received from one or a combination of radioactive sources; for example, either internal exposure or external exposure or both. Note that even if no workers are anticipated to work in the particular controlled area for a full twelve month period, control is still required to be established for that area if the potential for exposure exists.

- Controlled area work procedures
  Each responsible person at the mine must ensure that each worker working in a controlled area has received appropriate instructions about the nature of the radiation hazard in the area. These instructions should be in the form of clearly defined written procedures, which explain what is necessary for any worker working in the area to reduce, as much as practicable, any identified hazard associated with a set task.

  The defined tasks would be for routine operations, as well as for tasks that are only performed at infrequent times during a year (for example, major maintenance overhauls). It is important to describe procedures for infrequently performed tasks, as personnel may change during the period (for example, use of contractors) and people, over time, may forget the manner in which tasks were performed to result in the lowest exposure.

  Detailed work practices and procedures need to be developed to ensure that the effective control over radioactive material is established and lowest practicable exposure levels are being maintained.

  These procedures should be reviewed periodically for their effectiveness as well as audited for their actual application in practice.

- Requirements should be established for activities such as the movement, storage, processing and packaging of radioactive materials, and waste management. Work practices and, particularly good housekeeping measures are required to prevent unnecessary exposure to, and dispersion, of radioactive materials. Procedures should be provided in relation to spillage clean up, including the control measures to be used (for example, water, vacuuming), and the preventative maintenance of control equipment such as filters and dust collector. The procedures should also specify any personal protective clothing or apparatus that may be necessary to perform the task in a safe manner.

  All written procedures for controlled areas should also be part of the radiation management plan and must be readily available to, and understood by, all personnel involved.

- Controlled area work practices
  The practices that are adopted in controlled areas would be specific to each operation but should involve good hygiene practices as follows:
  1. Areas where it is possible for designated workers to eat, drink and smoke should be clearly delineated and these areas should not be part of a controlled area
  2. Facilities to wash personnel's hands and faces before leaving a controlled area should be provided. In most circumstances, general showering facilities may be necessary, (which are not the same as emergency shower facilities), and
  3. Contaminated clothing should not be allowed to leave controlled areas. It will be necessary to provide laundering facilities. Disposable clothing or easily cleaned clothing like waterproof garments would be required for those tasks where clothing may become contaminated if the potential for personal contamination cannot be engineered out of a task.

- Classification of restricted areas
  There may be work areas in some mining and / or processing operations where the potential for exposure of workers may be a significant fraction of the annual dose limit, say, in excess of 15 mSv in a year. In these cases it may be beneficial to further categorise these areas as restricted areas. A restricted area would then be a part of a controlled area where access is stringently controlled and marked clearly with designated restricted area warning signs; time spent in the area is minimised; and all work practices and procedures are carried out by experienced personnel possibly under supervision, either remotely or directly.

  In the mining and processing of minerals involving naturally occurring radioactive materials, restricted areas would only be anticipated where there is substantial concentration of thorium and uranium bearing materials; typically when thorium exceeds 0.3% (3,000 ppm) and uranium concentrations exceed 0.13% (1,300ppm.).

- Classification of supervised areas
  In accordance with the ARPANSA definition: "a supervised area is an area in which working conditions are kept under review, but in which special procedures to control exposure to radiation are not normally necessary". Members of the public are to be supervised and the dose constraint controlled.

  In practice, supervised areas are all of those areas on an exploration, mining or mineral processing site where it is possible for exposure conditions, either by internal or external exposure or both, to exceed member of the public limits based on an occupancy factor of 25%, or for approximately 40 hours per week exposure.

  Supervised areas should be clearly delineated and marked with designated supervised area warning signage, so that any member of the public (for example, a visitor) or a worker in a restricted occupation (for example, office and administration staff), is aware that the supervised area exists and that they are required to obey instructions whilst in these areas. The minimum constraint on these areas would require the responsible person to ensure that members of the public and relevant workers are restricted in the amount of time spent in supervised areas, assuming that access is deemed necessary.

  The use of supervised areas on an exploration / mining / processing site can be used to highlight areas of marginally elevated exposure levels (for example, stockpiles of radioactive minerals in a store producing elevated radiation levels on the other side of the store wall). As exposures to all personnel are to be kept as low as practicable, then knowledge of any elevated exposure levels can eliminate unnecessary exposure.

- Areas outside supervised areas
  The boundaries of supervised areas should not be confused with the site boundary, where it is required that exposure levels are such that, as a result of exploration, mining and / or processing operations, the member of the public limit should not be exceeded when based on 100% occupancy or exposure for 168 hours per week, *i.e.* a hypothetical person residing adjacent to the site lease will not receive in excess of 1 mSv per annum.

  As all areas of potential radiation exposure should be known and classified according to the exposure conditions, there should not be any surprise exposure conditions such that persons may receive doses in excess of the member of the public limit outside of supervised or controlled areas.

  Monitoring of areas outside of supervised or controlled areas could, therefore, be limited to area monitoring to determine levels of airborne radioactivity and to area gamma measurement utilising either thermoluminescent dosimetry or survey meters; *i.e.* it should not be necessary to conduct personal monitoring in these areas.

  Note: In the assessment of the internal exposure from airborne radioactivity outside of supervised or controlled areas, unless there is evidence to the contrary, the relevant dose conversion factor for the member of the public default aerial median aerodynamic diameter (AMAD) of 1 µm should be used.

Classification of workers and dose constraints

- Classification of designated workers
  One operational technique used to target radiation protection resources efficiently is the classification of workers. This is in recognition of the fact that radiation monitoring and protective efforts need to be directed to those groups of workers, who have the potential to receive a relatively higher radiation exposure in comparison to other groups of workers.

  An individual is to be classified as a designated worker if there is potential for the individual to receive an occupational dose in excess of 5 mSv per year. It is required that the number of designated workers be kept to the minimum necessary for the proper conduct of the operation.

  A person must be classified as either “designated” or “non-designated” workers before work by them commences. The `*a priori*' assignment of a worker as a designated worker is necessary as this group of workers requires personal monitoring, which will necessitate the planning of adequate resources and possibly work activities.

  Depending on the concentrations of radionuclides and processing conditions, some workers directly involved in the operation and maintenance of metallurgical plants processing radioactive materials may be classified as designated workers. Workers involved in work categories like: surface mining, concentration, transport, administration, general workshop duties and technical services are typically classified as non-designated workers, some of which have a dose constraint placed on them.

- Criteria for prediction of designated workers
  Practical experience has indicated that an assignment of a worker as a designated worker based on the previous year's work category assessments has become increasingly difficult, because of complicating factors such as:
  - a consistent reduction, through optimisation measures, of the annual effective dose received by workers, and

- an increased used of `multi-skilling' personnel in the mining and mineral processing industry, which means that workers spend times in several work categories throughout the reporting year.

  The following criteria can be utilised for classifying designated workers for subsequent reporting years:

  - If an worker received an effective dose approaching 5 mSv in the previous year, and is likely to undertake the same work patterns in the coming year
  - If an existing worker or a new worker is to work, in the coming year, in conditions where other workers received a dose approaching 5 mSv in the previous year
  - Where a worker is required to work for a considerable proportion of their annual working hours in an area where the absorbed dose rate arising from gamma radiation is 2.5 microsievert per hour (μSv/h) or more
  - Where a worker is required to work for a considerable proportion of their annual working hours in a work category that was assessed from the previous year's monitoring program, as being exposed to a mean airborne alpha activity concentration equivalent to or in excess of one quarter of the derived airborne concentration (DAC), or
  - Any combination of the above criteria which may result in the annual effective dose approaching 5 mSv.

- <u>Dose constraint for office, support and services staff</u>
  The WHS Regulations defines mining operations to include areas where radioactive materials would not normally be encountered or handled, such as offices, warehouses and service buildings.

  The occupational dose limit (20 mSv per year averaged over 5 years) is applicable to all workers, including external contractors & visitors. However, such workers should be constrained to receive radiation doses much less than the occupational dose limit. A dose constraint of 1 milliSievert (mSv) per year averaged over 5 years, could be applied to individuals employed in work categories where work practices do not involve the direct handling, or use, of radioactive materials. This includes – but is not limited to - workers and contractors in work categories involved in the operation of:
  - any support facilities on an exploration, mining and / or processing site, including administration offices, workshops and services buildings
  - residential and recreational facilities such as exploration / mining camp and the ground used for that purpose, where such facilities are located on the mine tenement and are used in connection with exploration and / or mining operations
  - environmental rehabilitation of an exploration, mining and / or processing site during production operations and after their completion, and
  - care, security and maintenance of mine and plant at the site undertaken during any period when production or development operations at the site are suspended.

Establishing triggers for action and control
The approved radiation management plan for the mine should contain a radiation monitoring program that requires, amongst other matters, the monitoring of personal contamination levels and external gamma doses. Due to the use of work category averages in dose assessment, any unusually high or low monitoring result may impact on the exposure estimates for all workers in the particular work category. Thus, the treatment of non-routine measurement results requires careful consideration.

The site radiation safety officer (RSO) is expected to have a detailed knowledge of the mean contamination levels and gamma exposures that each work category is normally exposed to. Thus, the RSO should be able to provide professional judgement to make an assessment as to whether any monitoring result appears unusual. An investigation should commence if the result is outside some pre-determined statistical bounds of the work category mean. The following will prove helpful in this regard and in reviewing any .assessment of risks.

- <u>Classifying an exposure result as a special exposure</u>
  If an investigation into an unusually or unexpectedly high monitoring result reveals that an exposure to an individual resulted from a task considered as 'non-routine', a view will need to be formed on whether that task will be repeated frequently in the remainder of the monitoring year. This requires careful consideration as it is possible that similar circumstances or work activities may occur during the year, but, due to the nature of the sampling regime, the task may not have been monitored previously. If it is considered that it is highly unlikely that the circumstances will occur again, then the elevated exposure should not be included in the work category average, and should be declared as a separate `special exposure' and assigned solely to those individual(s), who incurred the exposure.

  Similarly, if a known or planned task involving an unusual exposure within a work category, or across several work categories, may occur once or even several times in a monitoring period, the exposure received by those persons involved in the task could also be assigned as a personal special exposure. In this case, each individual involved will be monitored each time that task is performed.

  An immediate review of the risk management system should follow concentrating on how exposure was not satisfactorily identified, assessed for risk and controlled before exposure occurred.

  Where an exploration, mining and / or processing operation is implementing a specific campaign, where the exposure conditions are anticipated to be significantly different than usual (for example, obtaining exploration samples with relatively high concentrations of radionuclides, re-processing radioactive tailings, cleaning of large processing vessels or pipe-work from radioactive scale and sludge), alternative arrangements for handling the monitoring data may be made. For example, a special work category sub-group may be established for the period of the campaign, rather than declaring a series of special exposures.

  Consideration will also need to be given to variations in dose assessment parameters, such as particle size or different ratio of radionuclide decay series, as a result of the campaign.

  Note: This method of dose assessment by declaration of special work category sub-groups is more suitable if exposures are going to occur for a large group of persons over an extended period, rather than a small group. The technique of assessment by special exposures is more useful for small groups of individuals involved in short term exposures.

- <u>Handling of special exposures</u>
  If a routine monitoring program result appears unusual or, following statistical analysis, the result is significantly different from what is normally expected, then the circumstances of the particular exposure should be investigated. If the investigation confirms that the exposure circumstances comply with the conditions for a special exposure (as outlined above) then:
  - The result can be recorded in the site's radiation exposure register as a special exposure for the individual(s) concerned, along with the details of its

occurrence. (*Note*: The dose arising from this exposure is calculated separately from the individual's routine work category assessment, and is added to the dose assessment at the end of the reporting period.)
  - The regulator must be notified in writing of any special exposures including the resultant dose or exposure and the conditions under which it was received, and
  - All special exposures should be specifically highlighted in the organisation's annual occupational radiation monitoring report and any interim reports.

- Investigation levels
  The numerical value of a monitoring result determines whether an investigation into the exposure is necessary. Investigation and reporting levels have been identified for such radiation parameters as:
  - Area Gamma Dose Rate
  - Personal External Dose
  - Personal Internal Dose
  - Airborne Radioactivity
  - Airborne Dust
  - Radon / Thoron in Air
  - Radionuclides in Water
  - Stack Emissions
  - Surface Contamination.

Developing procedures and awareness

- Safe work procedures
  These should be written and reviewed periodically for their effectiveness, as well as audited for their actual application in practice. These written work procedures should be referenced in the radiation management plan (see next section), and must be readily available to, and understood by, all personnel involved.

  Requirements should be established for activities such as the movement, storage, processing and packaging of radioactive materials, and waste management. Work practices and good housekeeping measures are necessary to prevent unnecessary exposure to, and dispersion, of radioactive materials. Procedures should be provided in relation to spillage clean up, including the control measures to be used (for example, water, vacuuming), and the preventative maintenance of control equipment such as filters and dust collectors.

- Training
  All workers who may be exposed to radiation should be provided with information on the risks associated with radiation exposure, detailed description of sources and pathways of radiation exposure, and safe working methods. The detailed information for a particular mining / processing site should be included in the education and training program.

  Several units of competency are available from the Government Skills Australia web site at www.governmentskills.com.au that can be used to create training programs for radiation workers.

4. PRINCIPAL MINING HAZARD MANAGEMENT PLAN FOR EXPLORATION

Persons conducting a business or undertaking at a mining exploration operation must ensure that adequate measures are taken to control the exposure of workers and other persons (including members of the public) to radiation at or from the mining exploration operation that handles NORMs. They must consider the protection of the health and safety of workers and the protection of the environment at all stages in the design, planning, construction and operation of the facility.

It is important that best practicable technology is incorporated into the design of facilities at a mining exploration site. For example, the location of radioactive mineral stockpiles, tailing's storage facilities and exhaust stacks in relation to regularly or temporarily-occupied workplaces and critical groups of the members of the public have a significant effect on the radiation exposure of the different groups of people and on the most effective manner in which operational procedures are carried out.

The level of detail included in the principal mining hazard management plan for exploration depends on the degree of potential radiation exposure, which has been estimated or identified, and the expected difficulty of controlling it. The principal mining hazard management plan for uranium exploration would be more comprehensive than those prepared for a mineral sands exploration, which in turn would be more comprehensive than those prepared for other mineral exploration operations

Radiation monitoring is required during drilling and sample preparation in exploration as this is where the workers could have the greatest radiation exposure. The results of the monitoring must be reported to the workers.

There are four main radiation exposure pathways that require some form of control:

1. direct gamma irradiation from radiation-emitting materials (for example, core samples, sludges and drill cuttings). This is significant where long periods of time are spent close to large deposits of high grade ore
2. inhalation of airborne radionuclides (airborne dust containing uranium and / or thorium)
3. radon decay products (inhalation of radon / thoron decay progeny or daughters), and
4. ingestion of radionuclides in the dust on hands. This can be transferred to mouth while eating or smoking.

To actively control exposure to radioactivity requires:

- thorough preparation and planning
- dust minimisation and dust suppression through the application of water and, if necessary, use of respiratory protection
- good housekeeping and personal hygiene practices, and
- effective monitoring and recording systems.

4.1 Considerations when developing a principal mining hazard management plan

Natural and induced disequilibrium

The radiation safety officer and the geologist should be aware of three main possible sources of disequilibrium that may lead to serious errors in the estimation of the grade of the ore. These should be considered in advance of exploration activities:

<u>Natural disequilibrium</u>: Uranium and thorium in ores may be mobile as a result of periodic fluctuations in the elevation of the groundwater table caused by changes in the climatic conditions. Radium may be leached or mobilized and hence removed from uranium mineralization, reducing the amount of gamma emitting ^{214}Bi and affecting gamma-radiation surveys.

The natural disequilibrium in an ore deposit can take place in a number of ways:

1. Uranium and / or thorium may be freshly deposited from the groundwater so that insufficient time has lapsed for the in-growth of radium-226 and / or radium-228 and their daughter gamma-emitting isotopes (bismuth-214 and / or thallium-208), and.
2. Uranium and / or thorium may have been leached from the original ore material, leaving behind unsupported radium_226 and/or radium_228.

In the first case, if a field `scintillometer' is used for core logging and / or grade control the measured uranium / thorium concentration will be low, whereas in the second case the uranium / thorium concentration will be high. These factors may have serious implications for the estimation of the ore resource and, subsequently, for grade control during mining (for example, in bulk grade determination of ore on trucks and the use of radiometric sorting methods).

Induced disequilibrium: This may occur during percussion drilling and is caused by the `degassing' of radon. The induced disequilibrium in the process of exploration for uranium minerals is brought about by the loss of radon-222 during percussion drilling. This causes an apparent lowering of the uranium concentration due to a decrease in gamma-ray activity. By the nature of the drilling operation, compressed air is forced into the hole and blows out the pulp with the simultaneous loss of radon-222. This causes severe disequilibrium between the gamma-emitting isotopes lead-214 and bismuth-214 and their longer-lived parent radium-226.

The degree of radon loss will depend on many factors, for example, the pressure of air from the compressor, the friability and porosity of the ore, the mineralogy and radon exhalation rate from a particular mineral. Therefore, each geological environment will have its own radon escape characteristics. The measurements are required in each case but it could be assumed that during the percussion drilling operation 70% of radon gas is blown away and that the remaining 30% is retained in the sample.

Minimum standards for radiation controls and monitoring

Persons conducting a business or undertaking at a mine should already have carried out a suitable and sufficient risk assessment, which will need to take account of any local hazards, including (but not limited to) exposure to airborne contaminants and co-operation between persons in control of a business or undertaking and utilising the ALARP principle. This should be done before any work activity begins and target elimination of the risk.

Regular risk assessments of exposure to airborne contaminants are recommended during each phase of all mining operations, including exploration, construction, surface and underground mining, processing, shutdowns, care and maintenance and rehabilitation activities.

- Restrict exposure to all by:
    - means of engineering controls (best practicable technology) and design features and in addition by the use of safety features and warning devices
    - in addition, providing safe administrative systems of work, (such as local rules incorporating safe distances, exposure time limitation & delineated areas and a contingency plan for reasonably foreseeable accidents)
    - good housekeeping procedures and resourcing of both secure encapsulation, labelling & storage of waste on site and the prevention of the spread of contamination on clothing or skin (contamination monitoring must be carried out to check work surfaces, desks, tables, and skin contamination levels), and
    - in addition, by the provision of adequate and appropriate personal protective equipment.
- At least one person on site will be a trained radiation safety officer.

- All workers and contractors must receive general training in radiation safety and be aware of the risks of working with radioactive materials and the above three steps, which can be used to eliminate or minimise their exposure.
- Regular maintenance (including appropriate storage of) and examination of all engineering and personal protective controls.
- A portable radiation monitoring device should be available on site at all times to monitor not only radiation levels in drill core / cuttings, but also in the workplace and in the environment.
- Dust monitoring should be conducted as inhalation is a major exposure pathway. A personal dust pump should be worn by a worker on the rig to allow the collection of dust for analysis. Both the monitoring and the analysis of collected samples should be carried out in accordance with this Code. Regular area monitoring should be conducted and data recorded in a log.
- Other than some short Greenfield campaigns, workers potentially exposed to radiation should wear a personal radiation monitoring badge or electronic dosimeter from an approved supplier of monitoring badges. For short duration Greenfield campaigns, the doses can be assessed by survey meter readings, if the initial risk assessment suggests exposures to radionuclides will be in line with the ALARP principle.

Dust is typically the greatest source of exposure and the ALARP principle demands dust suppression at source. Potential dust sources on a drilling rig when drilling dry or above the water-table include the: T-piece, splitter, cyclone (top vent), drill rods, and collar cutting. Water should be applied to prevent any form of contamination being made airborne.

The difference between drilling with and without injected water acting as a dust suppressant (for instance, the water captures the dust that would become airborne) is appreciable, control of the dust at source is always preferable to relying on personal protective equipment, such as masks, which is prone to failure, over-loading, improper wear.

Any clothing, plant or personal protective equipment should be cleaned and assessed for surface contamination prior to leaving site to ensure radioactive material is not being transported from the site. The resultant washings should report to a sump and be buried by at least 1 metre of clean fill at the end of campaign.

Ingestion of radioactive material can be prevented by maintaining proper levels of workplace and personal hygiene and by requiring washing of hands before meal breaks or smoking.

Gamma radiation does not generally require any active control measures as it can be monitored with a survey meter although an appropriately calibrated portable gamma survey meter should be used to identify any active samples.

A personal dosimeter (for example, a TLD badge) should be supplied for those workers with routine exposure to potentially radioactive ores. Dose results should be regularly provided to the wearer and a record should be kept of all worker doses. Such TLD badges should be stored suitably between uses and not be exposed to any unrepresentative radioactive source when not in use; a hook is usually allocated to each worker and each control badge. Alternatively, an electronic personal dosimeter may be used.

With a well designed principal mining hazard management plan and acceptable work practices doses, radiation exposures in mineral exploration are not expected to be significant, and should be well below the public limits.

Note: Some jurisdictions may require some of the above controls and monitoring to be reported to the Mines Inspectorate.

Core and sample storage

Radon gas will emanate from the uranium in core samples and drill cuttings. Radon gas does not require active control other than when in enclosed spaces where active ventilation will be required. Therefore, drill core / cuttings must be handled in a well-ventilated area nad, therefore, wooden or steel core stores containing significant amounts of mineralised core should be ventilated when workers are inside.

Where large quantities of radioactive material are being stored in an enclosed area, periodic measurements of the radon progeny levels would be required. Stores made of canvas (*i.e.* tents) generally have sufficient adventitious air to dilute any radon gas present, and therefore should not require ventilation *per se*.

- Cores should ideally be placed on a concrete floor which has been sealed and, where practicable, painted in a different colour to the core.
- The core should be covered with a roof leaving the sides open.
- The area should be secure.
- There should be a supply of water to hose down the floor to keep dust to a minimum.
- Run-off water should pour into a sump, which can be caught, and the sediment stored for future disposal.
- Signs should be placed around the area advising “no entry without authorisation”.
- The area should be located away from other work places.
- The general external dose rate should be measured in the area and used to calculate doses in order to keep personal doses as low as practicable.
- Core cutting must be undertaken using wet methods.

It should be noted that a core storage areas containing a significant amount of radioactive material may need to be registered with other radiation regulators.

Core and sample handling

Radioactive minerals emit various forms of radiation. If proper safeguards and precautions are followed, any hazards due to the radiation are minimised.

- Avoid handling samples wherever possible.
- Keep radioactive mineral samples in a closable (not sealable), but ventilated bag or container with a ventilated lid wherever possible. This helps to control small pieces that may break away during handling that will fall to the bottom, but allow any radioactive gases to slowly escape through the top. A boxed radioactive mineral keeps you from directly touching the specimen, which helps to minimise radiation exposure to your skin.
- If direct handling is necessary, wear gloves and always wash hands with soap and water after handling samples.
- Never store specimens, even the smallest of size, in an inhabited room.
- Where samples are stored in bags, these should be in good condition to contain debris.
- Store specimens in a well ventilated area.
- Never eat, drink, smoke, or sleep near samples.
- Clearly label all radioactive samples and:
  - never carry radioactive minerals on your person (for example, in your pocket)
  - don’t carry radioactive minerals open (for example, temporarily in a sealable bag), and
  - clean up small particles that may break away from using a type H vacuum cleaner and personal protective equipment (for example, P3 mask and disposable gloves).

Contaminated equipment
It is possible that some equipment items may become contaminated with radioactive material and operators should ensure all equipment has been thoroughly cleaned to remove loose material before leaving the site.

Surface contamination means the presence of a radioactive substance on a surface in quantities in excess of 0.4 Bq/cm^2 for beta and gamma emitters and low toxicity alpha emitters, or 0.04 Bq/cm^2 for all other alpha emitters. Low toxicity alpha emitters are natural uranium, natural thorium, ^{235}U, ^{238}U, ^{232}Th, ^{228}Th and ^{230}Th when contained in ores, physical or chemical concentrates; or alpha emitters with a half-life of less than 10 days.

The target levels for cleaning should be to background level.

It is necessary to ensure that material is dry before surface contamination readings are taken.

Waste management
A separate waste management plan, as required by ARPANSA, is not typically required for an exploration operation, and the management of radioactive waste forms a part of an overall radiation management plan for the site.

Two types of waste are generated in the process of exploration: liquid and solid.

Liquid waste typically includes drilling mud, slurry from core cutting, and in some cases accidental release of groundwater containing elevated natural levels of radionuclides (such as uranium and radium). A good practice is to collect all of the above in mud pits, which then should be allowed to dry prior to being covered by at least one metre of compacted soil. Please note that if the material in the mud pit is not classified as radioactive, the surface soil will not need to be compacted and there will be no impediment for vegetation growth.

Solid waste typically includes surplus radioactive samples, contaminated PPE, equipment and containers, and, in some cases, samples returned from analytical laboratories:

- Drill cuttings and other collected materials that are classified as `radioactive' should be disposed down drill holes. The holes should then be capped either temporarily or permanently.
- Where this is a not possible, bulk cuttings or samples (*i.e.* from multiple drill holes) should be mixed with soil to reduce any artificial concentration of the material, and buried in mud pit / sumps with one metre of compacted soil cover. Please note that all samples should be removed from the sample bags prior to the mixing with soil and subsequent disposal.
- In situations when all samples (including those received from analytical laboratories) cannot be filled down drill holes and mud pits are not available, disposal of waste should be carried out in a purposefully constructed waste disposal pit.
- Drilling fluids should be controlled to prevent radiological contamination of surface soils. Where this contamination has taken place due to an accidental release the soil may also need to be removed and buried together with other solid waste.
- In situations where thorough radiation monitoring shows that empty sample bags, PPE and other materials have negligible contamination, they can be disposed of in landfill, after consultation with the appropriate authority. Where such materials are found to be contaminated, they typically cannot be disposed of without an approval from the appropriate authority. In these cases, the preparation and approval of a specific Radioactive Waste Management Plan (RWMP) may be necessary.
- On final closure, each site should be assessed to determine that radiation levels are not significantly elevated above background. Note: to do this, background monitoring

needs to be undertaken prior to any drilling. Ideally, drill sites must be returned to the original pre-exploration radiation levels.

4.2 Contents of the principal mining hazard management plan

There are 15 key elements of a principal mining hazard management plan for exploration. These include:

- Document format and cover sheet
- Scope
- Introduction
- Workforce information
- Critical group information
- Sources and pathways of radiation exposure
- Equipment and facilities for controlling radiation sources
- Institutional controls
- Worker training
- Radiation monitoring program
- Records management and reporting
- Dose assessment
- Transport of radioactive materials
- Waste management system
- Radiation safety resources

These elements are explained in more detail below.

Document format and cover sheet

The principal mining hazard management plan for exploration should be a `controlled' document, with each page dated, numbered as to version and clearly identified as 'controlled'. The cover sheet should include:

- the title of the document
- document identifier (unique reference number relevant to the operation)
- date of submission to the appropriate authority
- the name of the company and a particular operation, and
- signed endorsement by the site responsible person.

Scope

The principal mining hazard management plan for exploration should detail the specific operations and facilities described in the document, including the name and location of sites, the number of the lease, tenement or other interest and the name and address of the principal employer at the exploration company.

Introduction

The introduction should detail the history of the site and ownership (where necessary) and the reason a principal mining hazard management plan for exploration is required. List the exploration activities to be undertaken on the site, including a description of the type of drilling, the type of sampling to take place at the site, the expected duration of exploration operations and the critical project dates of the project, should be summarised. The site operations summary could be enhanced by the inclusion of a block diagram of broad functional activities, showing inter-relationships.

Workforce information

The number of persons who will be employed at the site should be detailed. This requires workforce stratification as a function of the work category and type of employer (company or contractor). It is also necessary to include the proposed shift roster system used on the site and the likely average annual working hours for workers.

Critical group information

Critical group is a group of members of the public comprising individuals who are relatively homogeneous with regard to age, diet and those behavioural characteristics that may affect the doses received and who are likely to receive the highest radiation doses from a particular operation. The likely critical groups of the public should be identified and the location of these groups shown on a suitable location plan. The size and demographics of the critical groups should also be briefly described. In some cases, identification of the critical group may not be possible due to the distance from the proposed site being too far for a group to receive any measurable radiation dose. However, even in such situations, there still exits a need for the operator to demonstrate that the impact of the operation on the local environment is minimal or negligible; and, in these cases a reference plant/animal may be selected for the study after the consultation with an appropriate authority. The flora / fauna selected should, in these cases, described in the principal mining hazard management plan for exploration.

Sources and pathways of radiation exposure

The principal mining hazard management plan for exploration should contain sufficient information to allow all significant exposure sources and pathways to be identified. This should include a map of the lease, descriptions of the equipment to be used and processes involved, and estimates of the radionuclides' concentrations. Estimates of the radiation levels to which various categories of workers and critical group(s) could be exposed should be provided, using appropriate exposure pathway models and/or contemporary experience. Suitable and sufficient scientific justification, including references where appropriate, should be provided for any models, assumptions or data used in the estimation process.

Equipment and facilities for controlling radiation sources

The principal mining hazard management plan for exploration – through the risk assessment process - should identify the measures that will be implemented to control radiation exposures including:

- the generation of dust should be minimised by the use of appropriate techniques, such as the use of water and the use of appropriate capture equipment
- where dust is generated, it should always be suppressed at the source
- care should be taken to avoid the re-suspension of dust as a result of equipment vibration, high air velocities & contact
- during maintenance operations, special care should be taken to control the occupational exposures that may arise from the build up of dust on internal and external surfaces of the equipment, and
- only when engineering methods of dust control do not achieve acceptable air quality in working areas should personal respiratory protection be used to control exposure of workers. It is also important to ensure that dust control is an integral part of an overall system of occupational hygiene. For example, some elements of the dust extraction / collection system may be a significant source of exposure of workers to unacceptable levels of noise.

Institutional controls

The principal mining hazard management plan for exploration should clearly show the assignment of responsibilities in regards to radiation protection and accountability for radioactive sources, the commitment of the organisation to maintain high levels of occupational health and safety should also be described. Where necessary, a specific radiation protection policy should also be developed.

The primary responsibility for the implementation of a principal mining hazard management plan for exploration is usually delegated to an appropriately trained and qualified radiation safety officer (RSO). Their requirements may change depending on the scale of operations and the levels of potential radiation exposure, but an exploration RSO will – as a minimum - have attended a radiation protection course relevant to the mineral industry, and had some experience in sampling of air contaminants and gamma-radiation measurements in the mining environment with another experienced RSO, keeping records of such training and accompaniment are vital to ensuring safety at the exploration site.

The main duties of the RSO are advising the management on the implementation of the principal mining hazard management plan for exploration and on all matters in relation to radiation protection of workers, public and the environment; the principal mining hazard management plan for exploration should clearly & explicitly describe these duties.

A description of the operational procedures and practices should be provided in the plan, including, among other issues:

- designation and control of supervised or controlled areas (for example, physical barriers, signs, special work permits)
- designation of workers according to the levels of radiation exposure.
- general housekeeping measures
- correct operation of control equipment, including preventative maintenance measures and schedules
- standard operating procedures for critical operations from a radiation protection perspective
- use of personal protective equipment, and
- inspection and auditing programs to ensure that correct work practices and procedures are being followed.

It is usually appropriate for the boundaries of supervised areas to be marked with signs and any variance of this should be reasoned and documented in the risk assessment.

The primary reliance for radiation safety and control should be placed on properly designed facilities and engineered controls rather than on personal protective equipment. Dust (and radon / thoron) should usually be controlled in such a way that protective equipment is not necessary for routine tasks. However, there may be situations where engineered controls cannot reasonably be provided and the use of such equipment is necessary; the risk assessment must specifically justify this course of action. Circumstances where respiratory protection equipment may be needed is for emergencies and for repair and maintenance operations. All situations where personal protective equipment is required should be summarised, with details being provided of the location, task, reason for the need of protective equipment, its type, and expected frequency and duration of task. The procedures for proper fitting, training, cleaning, maintenance and inspection of personal protective equipment should also be summarised.

Personal hygiene rules should also be established and compliance with them should be continuously monitored and enforced. In the first aid procedures, special precautions in the cleaning of wounds of potentially radioactive material must be clearly described.

Worker training

All workers who may be exposed to radiation and all persons responsible for the implementation of the principal mining hazard management plan for exploration must receive appropriate training (*vide supra*). Senior management and workers in other departments (for example, public relations, human resources, administration) must also be provided with information on radiation-related risks and detailed description of sources and pathways of radiation exposure at relevant exploration sites. Workers whose work may impact on the levels of radiation exposure (designers, planners) must also be provided with relevant information.

Training programs must include relevant information and be provided in the principal mining hazard management plan for exploration:

- details of the induction program (for instance, training for new workers), including summary of topics covered, duration and context in relation to overall induction
- details of any worker's handbook used as part of the training or standard work practices (an informative radiation safety guide for mining and minerals processing workers in the uranium, mineral sands and rare earths sectors is now available from Australian Uranium Association website if no site or company specific handbook is available)
- details of periodic refresher training, including format, duration and frequency, with the triggers and actions to cause such, for example, targeted re-training in a subject of an incident investigation, failure of an in-situ inspection or audit
- details of any additional training given to the management personnel, for example responsible officer training, and
- the qualification and experience of the person(s) conducting the training (including the RSO).

The nature and extent of worker training is expected to vary with job requirements and responsibilities

Radiation monitoring program

The main aims of monitoring radiation levels in the workplace and in the environment are:

- to determine compliance with regulatory limits
- to determine radiation exposure of workers and members of general public
- to assess the impact of operations on the local environment
- to provide information on the effectiveness of control measures, and
- to assess whether doses are as low as practicable (for example, checking the effectiveness of control measures, studying specific tasks, identifying poor work practices, investigating incidents).

A detailed description of the radiation monitoring program should be provided in the principal mining hazard management plan for exploration and be based on an assessment of risk. In general, more frequent monitoring is required where levels are either higher and / or variable, less frequent monitoring is required where levels are low and relatively constant.

Surface contamination measurements are the main method of assessing housekeeping standards, and are always needed in the inspection of equipment prior to maintenance. Similarly, surface contamination monitoring is important in the control over the release of potentially contaminated equipment from site and, therefore, will usually be an integral component of the monitoring program.

The need for monitoring of radon / thoron concentrations is dependent on a particular site conditions.

The principal mining hazard management plan for exploration must include details of the quality assurance program for the radiation monitoring program, including the various actions, which are taken to assess the adequacy of equipment, instruments and procedures against established requirements, for example:

- quality and specifications of equipment and instruments
- training and experience of personnel using equipment and instruments
- verification of measurement procedures by the analysis of control samples and the use of standard methods for analysis (where applicable)
- frequency of calibration and maintenance of equipment and instruments
- details and frequency of independent audits
- the need for traceability of the results of monitoring programs to a National Standard, and

- the degree of documentation needed to demonstrate that the required standard of quality has been achieved and is maintained.

The samples such as filters from dust monitoring need to be kept for two years for the purpose of comparative analyses, if necessary.

Records management and reporting
The principal mining hazard management plan for exploration must list the type of records to be kept, their format and method of storage. Records of monitoring results, dose assessments (including calculation methods), and related information must be retained in an easily retrievable form and kept for a period of at least 30 years. The amount of records to be kept and their type will depend on the magnitude of potential radiation exposure on a particular site; the risk assessment would record definitive reasons for any lack of record retention. However, the principal mining hazard management plan for exploration would normally require the following records to be kept:

- information on radiological conditions at the particular site (external gamma-radiation surveys; airborne and waterborne radioactivity surveys, surface contamination surveys, inventory of radioactive materials, methods and locations for the disposal of radioactive wastes), and
- all documentation relevant to the implementation of the system of radiation protection on the site (safety assessments of whole operations and designs of relevant equipment; descriptions of unusual operational events, standard operating procedures and relevant company policies, descriptions of training programs, quality assurance data and reports of all external audits conducted on the site).

The principal mining hazard management plan for exploration should contain a requirement that the individual annual occupational exposure record includes the following:

- unique identification of the individual
- the exposure for the current year and, where available, for the relevant five-year period prior
- results of the measurements for the estimation of the external dose, and methods of assessment
- results of the measurements for the estimation of internal dose (result of personal dust and radon / thoron monitoring), and methods of assessment
- the allocated dose for lost or damaged monitors or samples
- any special radiation exposure assigned to the worker, and
- record of the formal declaration of pregnancy, any revocations of such declaration, and measures taken to ensure that dose to this worker is kept under 1 mSv over the remainder of the pregnancy.

Dose assessment
The principal mining hazard management plan for exploration should specify how the results of the monitoring program would be used in the assessment of doses of workers. It would include an estimate of the likely doses to be received by the various categories of workers, together with documentation of all assumptions used.

Transport of radioactive material
The principal mining hazard management plan for exploration should include a detailed description of procedures for transport of radioactive materials that includes:

- types of packaging (where applicable) and signposting
- details of mode of transport and containers
- number of workers involved in transport and their estimated exposure times and doses
- amounts and radioactivity content of transported materials, frequency of transport movements

- transport routes, where relevant, estimates of potential exposure of members of the general public and the environment in the course of normal operations and in case of transport accidents (specific emergency response procedures should also be developed)
- summary of operational procedures, particularly illustrating measures taken to ensure strict compliance with transport safety regulations.

Waste management system

Waste management systems should utilise the best practicable technology, be designed to minimise the release of radioactivity into the environment and utilise any available information (for example, prior geological studies) to inform decisions regarding controls. Wastes should be treated as though they contain deleterious levels of NORMs until there is evidence to the contrary.

Radiation safety resources

The principal mining hazard management plan for exploration would describe the management and reporting structure for the particular site, and the duties and qualifications of relevant personal and, in particular, the radiation safety officer. The principal mining hazard management plan for exploration would also include a clear commitment to provide adequate staff with appropriate qualifications and experience to advise the management on all aspects of radiation protection on the site and execute the plan.

The principal mining hazard management plan for exploration should also list the monitoring equipment and support facilities, including:

- the make and model of the equipment
- the purpose of the particular instrument and its suitability for the particular purpose
- calibration methods and frequency, and traceability to a National Standard, and
- maintenance and replacement schedule.

The principal mining hazard management plan for exploration should be adequately resourced so as to give effect to the it intent and content.

Once developed, the principal mining hazard management plan for exploration should be fully implemented, monitored for effectiveness and regularly subjected to quality assurance, review and assessment to ensure that it’s intent and content are not just being reported and recorded, but implemented to practically utilise the best practices, which protect human health from the possible harmful effects of radiation in a mining operation.

5. PRINCIPAL MINING HAZARD MANAGEMENT PLAN FOR MINING ACTIVITIES AND MINERAL PROCESSING

Each responsible person at a mining and / or processing operation (person controlling a business or undertaking) must ensure that adequate measures are taken to control the exposure of workers and members of the public to radiation at or from the mining / processing operation that handles and / or uses NORMs. Each responsible person must, therefore, consider the protection of the health and safety of workers and the protection of the environment at all stages in the design, planning, construction and operation of the facility. Before commencing operations a plan for the safe management of radiation must be submitted to the appropriate authority for approval and should follow the form of the report detailed below.

It is important that best practicable technology is incorporated into the design of facilities at a mining / processing site. For example, the location of radioactive mineral stockpiles, tailing's storage facilities and exhaust stacks in relation to regularly occupied workplaces and critical groups of the members of the public have a significant effect on the radiation exposure of the different groups of people and on the most effective manner in which operational procedures are carried out.

The level of detail included in the principal mining hazard management plan for mining and mineral processing depends on the degree of potential radiation exposure, which has been estimated or identified, and the expected difficulty of controlling it. The principal mining hazard management plans for uranium milling and monazite treatment would be more comprehensive than those prepared for a mineral sands processing, which in turn would be more comprehensive than those prepared for other mineral processing operations, such as zircon milling or titanium dioxide production, or management of radon in non-uranium underground mines.

There are four main radiation exposure pathways that require some form of control:

- direct gamma irradiation from radiation-emitting materials (for example, from radionuclides in the walls of underground tunnels). This is significant where long periods of time are spent close to large deposits of high grade ore
- inhalation of airborne radionuclides (airborne dust containing uranium and / or thorium)
- radon decay products (inhalation of radon / thoron decay progeny or daughters), and
- ingestion of radionuclides in the dust on hands. This can be transferred to mouth while eating or smoking.

To actively control exposure to radioactivity requires:

- thorough preparation and planning
- dust minimisation and dust suppression through the use of effective ventilation systems, the application of water and, if necessary, use of respiratory protection
- good housekeeping and personal hygiene practices, and
- effective monitoring and recording systems.

5.1 Contents of a principal mining hazard management plan

There are 15 key elements of a principal mining hazard management plan for mining activities and mineral processing. These include:

- o Document format and cover sheet
- o Scope
- o Introduction
- o Workforce information
- o Critical group information
- o Sources and pathways of radiation exposure

- o Equipment and facilities for controlling radiation sources
- o Institutional controls
- o Worker training
- o Radiation monitoring program
- o Records management and reporting
- o Dose assessment
- o Transport of radioactive materials
- o Waste management system
- o Radiation safety resources

These elements are explained in more detail below.

Document format and cover sheet
The principal mining hazard management plan for mining and mineral processing should be a controlled document, with each page dated and clearly identified. The cover sheet should include:

- the title of the document
- document identifier (unique reference number relevant to the operation)
  date of submission to the appropriate authority
  the name of the company and a particular operation, and
  signed endorsement by Registered Manager.

Scope
The principal mining hazard management plan for mining activities and mineral processing should detail the specific operations / facilities described in the document, including the name and location of the mine / plant, the identification number / code of the lease, tenement or other interest and the name and address of the person in control of the business or undertaking at the mine.

The specific operations may include surface mining, underground mining, mineral processing, smelting, refining or waste disposal. Usually a separate principal mining hazard management plan for mining and mineral processing (and, where applicable, a waste management plan) are required for each separate site.

Introduction
The introduction should detail the history of the site and ownership (where necessary) and the reason a principal mining hazard management plan for mining activities and mineral processing is required. Whilst this reason is clear in cases of uranium and mineral sands operations, for other facilities such as tin and tantalum processing, or for some underground mines the source of the radioactivity needs to be described.

The mining and / or mineral processing activities to be undertaken on the site, including a description of the type of mine, the treatment of minerals that is to take place at the site, the expected duration of mining and / or processing operations and the critical project dates for construction and commissioning of facilities, must be summarised. The site operations summary shall be enhanced by the inclusion of a block diagram of broad functional activities, showing inter-relationships.

Workforce information
The number of persons who will be employed at the facility should be detailed. This requires workforce stratification as a function of the work category, gender and type of employer (company or contractor). The proposed shift roster system to be used, the likely average annual working hours and those workers or categories of workers who will be designated should also be described.

Critical group information

A ‘critical group’ is a group of members of the public comprising individuals, who are relatively homogeneous with regard to age, diet and those behavioural characteristics that may affect the doses received and who are likely to receive the highest radiation doses from a particular operation. The likely critical groups of the public should be identified and the location of these groups shown on a suitable location plan. The size and demographics of the critical groups should also be briefly described. In some cases, identification of the critical group may not be possible due to the distance from the proposed site being too far for a group to receive any measurable radiation dose. However, even in such situations, there still exits a need for the operator to demonstrate that the impact of the operation on the local environment is minimal or negligible; and, in these cases a reference plant/animal may be selected for the study, after the consultation with an appropriate authority. The flora / fauna selected should, in these cases, described in the principal mining hazard management plan for mining activities and mineral processing.

Sources and pathways of radiation exposure

The principal mining hazard management plan for mining activities and mineral processing should contain sufficient information to allow all significant exposure sources and pathways to be identified. This should include plans of the mine and / or processing plant, descriptions of the equipment to be used and processes involved, and estimates of the radionuclides' concentrations in process and tailing streams.

A radionuclide mass balance is typically required, with all inputs, outputs and wastes clearly identified and characterised from a radiological perspective. Consideration should be given to the potential for the accumulation of radioactive scales and / or sludges inside the processing vessels and in associated pipe work. All process inputs, outputs and wastes that require specific consideration from a radiological perspective should be clearly identified.

Estimates of the radiation levels to which various categories of workers and critical group(s) could be exposed should be provided, using appropriate exposure pathway models and / or contemporary experience. Suitable and sufficient scientific justification, including references, where appropriate, should be provided for any models, assumptions or data used in the estimation process.

Equipment and facilities for controlling radiation sources

The principal mining hazard management plan for mining activities and mineral processing should identify the measures that will be implemented to control radiation exposures. This should include provision of such engineering controls as ventilation, dust and fume control measures and shielding.

The specific mining and / or mineral processing equipment to which engineering control methods will apply should be listed and the measures that will assure adequate control of radiation exposure should be outlined.

Elements of plant and equipment design which assist in minimising radiation exposure must also be detailed, such as layout of plant and equipment, housekeeping measures, and contamination and spillage control. Diagrams that show the location of regularly occupied workplaces, such as offices, control and crib rooms, in relation to radioactive process streams, stockpiles and tailings piles should also be included.

Measures limiting access to controlled and restricted areas should also be described, including physical barriers and administrative controls. Summary details of engineering control technology, such as the specifications of the equipment, should be provided together with location details of process exhaust stacks, where applicable.

The features that should be considered during design of a plant processing radioactive minerals include:

- Efficient movement of radioactive materials and process streams and the safe movement of workers.
- Location of dust-generating activities, such as crushing in relation to other activities.
- Physical separation of processes containing elevated concentrations of NORMs from frequently occupied areas.

Ventilation of and provision of services such as washing facilities to, control and crib rooms.

- method of movement of dry materials by conveyors or through pipes and chutes
- efficiency of various ventilation control techniques (the fact that high ventilation rates used to reduce radon accumulation may result in excessive dust re-suspension from surfaces should be taken into account, where applicable)
- accessibility of equipment for the purposes of maintenance, removal and replacement
- materials used in the construction of plant and equipment (for example, the use of hard materials would prevent particles of mineral embedding firmly onto surfaces and will therefore, reduce the potential for non-removable contamination of surfaces)
- need for containment bunds and the manner in which spilt process material will be returned to the process
- the degree of automation for identified critical processes, such as handling and packaging of radioactive material
- use of high reliability equipment with minimal maintenance requirements in circuits where materials with significantly elevated concentrations of radionuclides are treated
  the most important consideration in the design of facilities for the processing of NORMs is the containment of radioactive materials. The materials that cannot be effectively contained within the process should be controlled by means of ventilation and dust suppression to prevent the release of the material into the environment and to minimise the potential occupational exposure
- adequately designed and balanced ventilation and dust control systems are typically the most effective methods of minimising radiation exposure in both underground and surface mines, and in the plants processing dry minerals
- the generation of dust should be minimised by the use of appropriate techniques such as the use of water and other means of suppressing dust and the use of appropriate equipment
- where dust is generated, it should be suppressed at the source. If practicable, the source should be enclosed under negative air pressure
- care should be taken to avoid the re-suspension of dust as a result of equipment vibration and high air velocities
- during maintenance operations, special care should be taken to control the occupational exposures that may arise from the build up of dust on internal and external surfaces of the equipment, accumulation of radioactive material in pipes and vessels due to the formation of sediments and the build up of scale, and build-up of radon / thoron in enclosed areas such as mineral storage tanks
- only when engineering methods of dust control do not achieve acceptable air quality in working areas, personal respiratory protection should be provided to workers
- it is also important to ensure that dust control is an integral part of an overall system of occupational hygiene. For example, some elements of dust extraction / collection system may be a significant source of exposure of workers to unacceptable levels of noise.

Institutional controls

The principal mining hazard management plan for mining activities and mineral processing should clearly show the assignment of responsibilities in regards to radiation protection and accountability for radioactive sources, and the commitment of the organisation to maintain high levels of occupational health and safety. Where necessary, a specific radiation protection policy should also be developed.

The primary responsibility for the implementation of the principal mining hazard management plan for mining activities and mineral processing is usually delegated to the appropriately qualified radiation safety officer (RSO). The requirements may change depending on the scale of operations and the levels of potential radiation exposure but, typically, an RSO is expected to have a degree in physical science or equivalent and several years of experience in radiation protection, preferably in the mining and mineral processing industry. Where RSO is also undertaking air monitoring it is important to note that the person is expected to have appropriate qualifications for such.

The main duties of the RSO are advising the management on the implementation of the principal mining hazard management plan for mining and mineral processing and on all matters in relation to radiation protection of workers, public and the environment; and the principal mining hazard management plan for mining activities and mineral processing should clearly describe these duties.

A description of the operational procedures and practices should be provided in the principal mining hazard management plan for mining activities and mineral processing including among other issues:

- designation of supervised, controlled and restricted areas and procedures for access control (for example, physical barriers, signs, special work permits)
- designation of workers according to the levels of radiation exposure
- general housekeeping measures
- correct operation of control equipment, including preventative maintenance measures and schedules
- standard operating procedures for critical operations from a radiation protection perspective, including special procedures to be followed during certain identified maintenance tasks (it is sometimes practical to compile these procedures in a separate document that may be submitted to the appropriate authority as a supplement to principal mining hazard management plan for mining and mineral processing)
- emergency planning and response for accidents involving radiation
- use of personal protective equipment
- inspection and auditing program to ensure that correct work practices and procedures are being followed, and
- controlled area work rules.

The location of controlled and supervised areas should be marked on an appropriate plan together with the location of caution signs. Details of the wording of signs, notices and special work permits used for access control should also be provided.

Although it may be appropriate in many cases for the boundaries of supervised areas to be marked with signs, this may not always be necessary or productive. It may be necessary to designate a supervised area within a mining and / or processing site to which members of the public may have access, but signs at the entrance to the site may cause unwarranted concern.

The areas in which gamma dose rates or airborne concentration limits may be approached or exceeded should be designated as requiring special precautions for entry and classified as restricted areas. The additional requirements for personnel performing operations, maintenance and repair work in such areas should be specified, together with any specific instructions and training to be provided to workers.

Procedures for visitors should also be provided.

The primary reliance for radiation safety and control must be placed on properly designed facilities and engineered controls rather than on personal protective equipment. Dust (and radon / thoron) should usually be controlled in such a way that protective equipment is not necessary for routine tasks. However, there may be situations where engineered controls cannot reasonably be provided and the use of such equipment is necessary. Respiratory protection equipment may also be needed in emergencies, for repair and maintenance, and in special short term circumstances.

The situations when personal protective equipment is required should be summarised, with details being provided of the location, task, reason for the need of protective equipment, its type, and expected frequency and duration of task. The procedures for proper fitting, training, cleaning, maintenance and inspection of personal protective equipment should also be summarised.

Personal hygiene rules should also be established and compliance with them should be continuously monitored. In the first aid procedures, special precautions in cleaning of wounds potentially contaminated with radioactive material must be clearly described.

Job rotation, however, should not be used as a substitute for the development of an appropriate radiation protection system.

Worker training

All workers who may be exposed to radiation and all persons responsible for the implementation of the principal mining hazard management plan for mining activities and mineral processing should receive appropriate training.

Senior management and workers in other departments (for example, public relations, human resources, administration and marketing) should also be provided with information on risks associated with radiation exposure and detailed description of sources and pathways of radiation exposure at relevant mining and processing sites.

Workers whose work may impact on the levels of radiation exposure (designers, planners) should also be provided with basic information.

Training programs should include relevant information and the following information should be provided in the principal mining hazard management plan for mining activities and mineral processing:

- details of the induction program (*i.e.* training for new workers), including summary of topics covered, duration and context in relation to overall induction
- details of periodic re-training, including format, duration and frequency
- details of any additional training given to the management personnel, and
- details of any emergency response and preparedness training.

The qualification and experience of the person conducting the training (if not done by the RSO) should also be provided.

The nature and extent of worker training is expected to vary with job requirements and responsibilities. For a person whose duties do not include work in a controlled area, a simple description of the working environment, protective measures and average levels of exposure may be sufficient. However, for a person who is typically required to perform tasks in controlled areas on a regular basis, much more detailed and extensive training program is necessary, particularly in relation to the compliance with safe work procedures and the use and maintenance of protection equipment.

Radiation monitoring program

The main aims of monitoring radiation levels in the workplace and in the environment are to:

- determine compliance with regulatory limits
- determine radiation exposure of workers and members of general public
- assess the impact of operations on the local environment
- provide information on the effectiveness of control measures, and
- assess whether doses are as low as practicable (for example, checking the effectiveness of control measures, studying specific tasks, identifying poor work practices, investigating incidents).

A detailed description of the radiation monitoring program should be provided in the principal mining hazard management plan for mining activities and mineral processing. The program should list for each radiation-related parameter (external radiation, airborne radioactivity, waterborne radioactivity, radon / thoron, and surface contamination) the following:

- location, task or category or workers monitored
- environmental media (air, water) monitored
- type of sampling (personal, positional, ground water, surface water,)
- duration of sampling
- frequency of measurement
- sampling equipment and calibration records
- analysis method, the type of radiation or radionuclides measured, and
- any other information, as applicable.

In the case of a new operation, an initial monitoring program should be exhaustive in order to thoroughly characterise the radiological environment and to identify any locations and / or work practices requiring special attention. When the radiation levels stabilise and it is established that a facility operates under normal conditions, monitoring frequencies and locations should be adjusted to reflect the level and variability of different radiation parameters. In general, more frequent monitoring is required where levels are higher and variable; less frequent monitoring is required where levels are low and relatively constant.

Surface contamination measurements are the main method of assessing housekeeping standards, and are useful in the inspection of equipment prior to maintenance. Surface contamination monitoring is very important in the control over release of potentially contaminated equipment from site and, therefore, will usually be an integral component of the monitoring program.

The need for monitoring of radon / thoron concentrations is dependent on a particular site conditions. In mineral sands operations, it is not usually necessary to assess radon / thoron concentrations in open pits; however, in situations where large amounts of mineral are present in enclosed buildings, this monitoring is part of a program. These measurements are also usually necessary in underground mines, and in situations where materials contain elevated concentrations of uranium.

The principal mining hazard management plan for mining activities and mineral processing should include details of the quality assurance program for the radiation monitoring program, including the various actions, which are taken to assess the adequacy of equipment, instruments and procedures against established requirements such as the:

- quality and specifications of equipment and instruments
  training and experience of personnel using equipment and instruments
- verification of measurement procedures by the analysis of control samples and the use of standard methods for analysis (where applicable)
- frequency of calibration and maintenance of equipment and instruments
- details and frequency of independent audits (where applicable)
- need for traceability of the results of monitoring programs to the National Standard, and

degree of documentation needed to demonstrate that the required quality has been achieved and is maintained.

The samples such as filters from dust monitoring need to be kept for two years for the purpose of comparative analyses, if necessary.

Records management and reporting

The principal mining hazard management plan for mining activities and mineral processing should list the type of records to be kept, their format and method of storage. Records of monitoring results, dose assessments (including calculation methods), and related information should be retained in an easily retrievable form and kept for a period of at least 30 years. The amount of records to be kept and their type will depend on the magnitude of potential radiation exposure on a particular site.

Typically the principal mining hazard management plan for mining activities and mineral processing should require the records that are kept include the following:

- Information on radiological conditions at the particular site (external gamma-radiation surveys; airborne and waterborne radioactivity surveys, particle size characterisation assessments, surface contamination surveys, inventory of radioactive materials, methods and locations for the disposal of radioactive wastes).
  Assessments of radiation exposure of workers and members of the public (external and internal radiation doses, and methods for their determination, bio-assay data - where applicable).
- Assessments of impact on the local environment (measurements of all potential pathways of radioactive material discharges, environmental exposures - modelling and assumptions used in assessments).
- All documentation relevant to the implementation of the system of radiation protection on the site (safety assessments of whole operations and designs of relevant processing equipment; descriptions of unusual operational events, standard operating procedures and relevant company policies, descriptions of training programs, quality assurance data and reports of all external audits conducted on the site).

It is recommended that principal mining hazard management plan for mining activities and mineral processing contains a requirement that the individual annual occupational exposure record includes the following:

- unique identification of the individual
- the exposure for the current & previous years
- results of the measurements for the estimation of the external dose, and methods of assessment
- results of the measurements for the estimation of internal dose (result of personal dust and radon / thoron monitoring), and methods of assessment
- the allocated dose for lost or damaged monitors or samples
- any special radiation exposure assigned to the workers, and
- record of the formal declaration of pregnancy, any revocations of such declaration, and measures taken to ensure that dose to this worker is kept to an acceptable level over the remainder of the pregnancy.

The principal mining hazard management plan for mining activities and mineral processing needs to include a commitment for reporting the results of monitoring programs (both occupational and environmental), and all related information. Reports will be required to the regulatory authority, management, and for the workers, at least on an annual basis.

Operational requirements may require more frequent reporting and analysis to management and to the appropriate authority.

Dose assessment
The principal mining hazard management plan for mining activities and mineral processing should specify how the results of the monitoring program would be used in the assessment of doses of workers.

For new operations, the principal mining hazard management plan for mining activities and mineral processing should include an estimate of the likely doses to be received by the various categories of workers, together with documentation of all assumptions used. An individual dose assessment should be required for any worker, who is normally employed in a controlled area. For any single component of occupational exposure (external and internal) these assessments could be considered if monitoring indicates that annual exposure may exceed acceptable levels and must be conducted if the estimated dose is likely to exceed an action level.

Transport of radioactive materials
The principal mining hazard management plan for mining activities and mineral processing should include a detailed description of procedures for transport of radioactive materials, including the:

- types of packaging (where applicable) and signposting
- details of mode of transport and containers
- number of workers involved in transport and their estimated exposure times and doses
- amounts and radioactivity content of transported materials, frequency of transport movements
- transport routes, estimates of potential exposure of members of the general public and the environment in the course of normal operations and in case of transport accidents (specific emergency response procedures should also be developed), and
- summary of operational procedures, particularly illustrating measures taken to ensure strict compliance with transport safety regulations.

Waste management system
The radioactive waste management is an integral part of the principal mining hazard management plan for mining activities and mineral processing and, in some circumstances, a separate waste management plan should be developed for the operation.

The nature and extent of information provided in the principal mining hazard management plan for mining activities and mineral processing or waste management plan in relation to waste management will depend upon the nature, volume and radioactivity of the wastes and other site-specific factors. For example, if the highest concentration of radionuclides in the waste material at a particular site is in order of several Bq/g and no chemical treatment of mineral takes place, the waste management strategy will be very simple. However, if numerous waste streams are generated at a site using chemical and / or thermal treatment of minerals and concentrations of radionuclides are in order of several tens of Bq/g or above, the separate waste management plan will need to be prepared.

The principal mining hazard management plan for mining activities and mineral processing or waste management plan should include a summary of the chemical, physical and radiological characteristics and quantity of each of the solid materials and liquid and airborne effluents that may be classified as radioactive waste and will, therefore, require management from a `radiation perspective'. Examples of such materials include uranium processing tailings, some tailings from processing of different NORMs, certain slimes from settling ponds, material collected by the dust extraction systems, scrubber effuents, stack emissions, liquids in discharge pipes and storm sewers, contaminated parts of plant and equipment, scales and sludges from process vessels and pipes, *etc.*

Most waste generated during mining and processing of NORMs contains non-radiological hazardous components similar to those present in waste from other mining and processing activities. In certain cases, chemical toxicity of some of the contaminants in the waste may cause significant environmental and occupational health impacts when the concentrations of radionuclides are considerably below those that require a special program for the management of this waste from the radiological perspective. It is, therefore, important to ensure that radioactive waste management is an integral part of an overall environmental management program for the particular site.

Waste management system should utilise the best practicable technology and be designed to minimise the release of radioactivity into the environment. All possible pathways for dispersion of radionuclides in the environment should be considered. Initial assessment should include handling, treatment, storage, and disposal of radioactive waste, and it is recommended that following elements are described in detail:

- outline of the operation and the processes generating waste
- characterisation of wastes including nature of materials (chemical, physical and radiological), contaminants, and quantities and rates of generation
- detailed characterisation of the environment: climate, terrain, soils, vegetation, hydrology
- heritage (social and cultural), and land use (present, potential and future)
- waste management facilities and practices, waste conditioning (where applicable) and containment
- possible discharges: form (gas, liquid or solid), discharge and release criteria
- contingency measures for natural events, incidents, equipment and operational failures, temporary cessation of operations
- monitoring programs, assessments of results and reporting
- the need for restricted release zone, and
- outline of the proposed closure plan for the site, including decommissioning, decontamination and rehabilitation concepts, proposals for long-term surveillance and reporting, records management, institutional controls (where required), and the description of possible future caveats to land use.

When all characteristics of each potentially radioactive waste stream are known, the specific management strategy should be described for each material, including (in addition to the list above):

- the facilities and procedures, including control technologies used in handling and treatment of the waste
  monitoring program, including the specific radiation parameters to be measured and any independent audits undertaken
  in the case of final disposal in a specifically designed facility (for example, for the disposal of tailings from a uranium or rare earth processing plant) include:
  - information on the design, operation and expected performance capability of the disposal facility and its exact location
  - techniques to be used for the disposal, such as method of deposition, tails conditioning, dam lining, depth of cover, cover material
  - the possibility for leaching of radionuclides, potential for their off-site migration and procedures to prevent this process
  - institutional controls to be implemented, such as long-term monitoring and record-keeping, and
  - an exact amount of material disposed in the facility, its radiological characteristics and description of other hazards associated with the particular waste.

The principal mining hazard management plan for mining activities and mineral processing or waste management plan should include suitable diagrams and maps / plans to describe the design and location of storage or disposal facilities and the location of restricted release zones. It is important that the blending of materials is carried out with caution, particularly in cases when the material to be diluted was a subject to a chemical and / or thermal processing and mobility of some radionuclides may have increased in comparison with the material's original state. And systems must be in place to ensure that dilution process is carried out in accordance with any special conditions that may be imposed by the appropriate authority.

The blending of radioactive waste with other mined material is typically practical only in cases where no chemical and / or thermal treatment of mineral has taken place and radionuclides in both uranium and thorium decay chains are in the state of secular equilibrium.

Radiation safety resources

The principal mining hazard management plan for mining activities and mineral processing should describe the management and reporting structure for the particular site, and the duties and qualifications of relevant personal and, in particular, the radiation safety officer. The principal mining hazard management plan for mining and mineral processing should also include a clear commitment to provide adequate staff with appropriate qualifications and experience, to advise the management on all aspects of radiation protection on the site.

The principal mining hazard management plan for mining activities and mineral processing should also list the monitoring equipment and support facilities, including:

- the make and model of the equipment
- the purpose of the particular instrument and its applicability for the particular purpose;
- calibration methods and frequency, and traceability to the national standard, and
- maintenance and replacement schedule.

The principal mining hazard management plan for mining activities and mineral processing must be adequately resourced so as to give effect to its intent & content.

Once developed, the principal mining hazard management plan for mining activities and mineral processing should be fully implemented, monitored for effectiveness and regularly subjected to quality assurance, review and assessment to ensure that it's intent and content are not just being reported and recorded, but implemented to practically utilise the best practices, which protect human health from the possible harmful effects of radiation in a mining operation.

APPENDIX A – OTHER RELEVANT INFORMATION

Codes of Practice

- *Code of Practice: Work Health and Safety Management System, Safe Work Australia*
- *Code of Practice: How to Manage Work Health and Safety Risks, Safe Work Australia*
- *Code of Practice: Work Health and Safety Consultation, Co-operation and Co-ordination, Safe Work Australia*

Other Key Publications

- *Australian Radiation Protection and Nuclear Safety Agency Act 1998* (ARPANSA Act)
- Australian Radiation Protection and Nuclear Safety Agency (ARPANSA) Code of Practice and Safety Guide entitled "*Radiation Protection and Radioactive Waste Management in Mining and Mineral Processing*", Radiation Protection Series Booklet Number 9.
- Resources Safety, Department of Mines and Petroleum, Western Australia series:
    - NORM 1 - Applying the system of radiation protection to mining operations
    - NORM 2.1 - Preparation of a Radiation Management Plan – exploration and,
    - NORM 2.2 - Preparation of a radiation management plan - mining and processing.