Managing naturally occurring radioactive material (NORM) in mining and mineral processing — guideline

NORM–2.1

Preparation of a Radiation Management Plan — exploration

Government of **Western Australia**
Department of **Mines and Petroleum**
Resources Safety

The Chamber of Minerals & Energy Western Australia

MIAC

Reference

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1. General information

1.1. Purpose

To provide guidance on the development of a suitably detailed radiation management plan (RMP) for the control and monitoring of radiation exposure and the management of radioactive wastes when exploring for radioactive minerals.

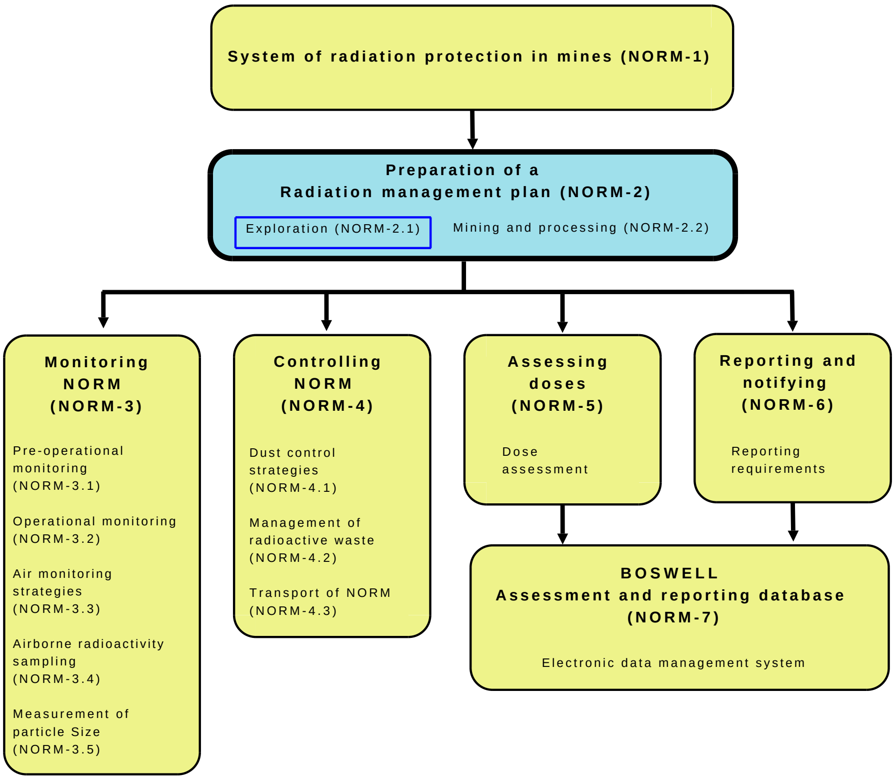
1.2. Scope

This guideline applies to all exploration operations in Western Australia exploring for naturally occurring radioactive material (NORM) and come within the scope of Part 16 of the Mines Safety and Inspection Regulations 1995 ([1]).

1.3. Relationship to other NORM guidelines

The flowchart in Figure 1.1 shows the arrangement of the Radiation Safety Guidelines.

Figure 1.1.: Relationship to other NORM guidelines



2. Guidance

2.1. Summary

Where exploration companies in Western Australia are exploring for naturally occurring radioactive materials (NORM), this activity may come within the scope of Part 16 of the Mines Safety and Inspection Regulations 1995[1]. The drilling and handling of samples that contain uranium or thorium mineralization has the potential to expose workers to a radiation hazard. Therefore, each responsible person at an exploration site (i.e. principal employer, any other employer and the exploration manager) must ensure that adequate measures are taken to control the exposure of employees/contractors and members of the public to radiation from the exploration activities involving NORM. Each responsible person must, therefore, consider the protection of the health and safety of workers and the protection of the environment at all stages of exploration activity. Before commencing exploration, a plan for the safe management of radiation should be submitted to the appropriate authority for approval.

The regulations [1] also require the control of spilt material and releases that could cause contamination in the environment and the decontamination of equipment removed from exploration sites.

It is important to understand that the level of detail to be included in a RMP largely depends on the degree of potential radiation exposure which has been estimated or identified, and the expected difficulty of controlling it. A RMP for an initial greenfield exploration project would not be expected to contain as much detail as one for an advanced project where advanced exploration activities are occurring such as infill drilling campaigns, core storage, JORC Code compliance, trial mining, heap leach trials or costeans.

To ensure ongoing relevance, the Radiation Management Plan should be reviewed as the exploration activities change.

2.2. Government regulation and codes of practice

There are several Acts, Regulations and Codes which may be applicable when radioactive minerals from exploration are handled and transported:-

1. Mines Safety & Inspection Regulations [1] (DMP).
2. *Radiation Safety Act* [3] (Radiological Council of WA).
3. Radiation Safety (Qualifications) Regulations [5] (Radiological Council of WA).
4. Radiation Safety (Transport Radioactive Substances) Regulations [6] (Radiological Council of WA) which adopt the:
   a) Code of Practice Safe Transport of Radioactive Material [9] (Australian National Code) which in turn adopts the;
   b) IAEA Safety Standards Series Regulations for the Safe Transport of Radioactive Material [10] (International Code).

5. Code of Practice And Safety Guide — Radiation Protection and Radioactive Waste Management in Mining and Mineral Processing (Australian National Code) [11].
6. *Mining Act* [12] and Regulations [13](DMP)

Under the Mines Safety & Inspection Regulations, all exploratory excavations including drilling activities fall under the definition of *"Mining"*.

2.3. Exploration for radioactive minerals

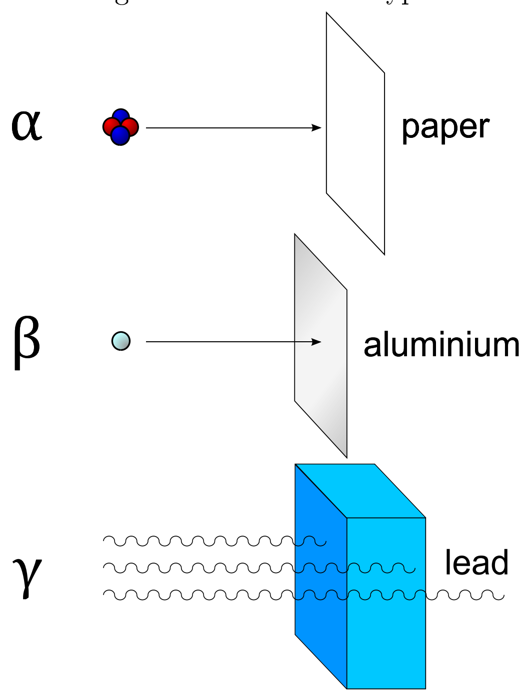
Radiation monitoring is required during drilling and sample preparation as this is where the workers could have the greatest radiation exposure. The results of the monitoring must be reported to the workers.

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

1. Direct gamma irradiation from radiation-emitting materials (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)
4. Ingestion of radionuclides in the dust on hands. This can be transferred to mouth while eating or smoking.

Thorium–232 and uranium–238 are the 'parents' of a series of radioactive elements called 'daughters' which emit alpha (α), beta (β), and gamma (γ) radiation.

Figure 2.1.: Radiation types



The decay series are shown in Appendix B on page 39.

To actively control exposure to these radioactive elements requires:

- dust minimisation, dust suppression through the application of water and, if necessary, use of respiratory protection;
- good housekeeping and personal hygiene practices; and
- ensuring that there are no major quantities of gamma-emitting materials stored in work areas.

Figure 2.2 and Figure 2.3 on the next page demostrate the difference between drilling dry with no dust suppression and drilling with water injection dust suppression. Both of these photos were taken in 2009. Relying purely on masks for dust protection and having no dust suppression as shown in Figure 2.2 is in breach of the Regulations and a Prohibition Notice would be issued.

Figure 2.2.: RC drilling without dust controls

RC drilling with no dust controls in place

Dust is typically the greatest source of exposure, so dust control is the main area that must be addressed. 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, drilling equipment, clothing and collar cutting. Water should be applied accordingly to prevent any form of contamination which may result from the dust being produced.

MSIR Reg 9.17. Suppression of dust — drilling operations

(2) If it is necessary for dry drilling to be carried out in a mine (whether underground or on the surface), each responsible person at the mine must ensure that the drilling machine used is fitted with an effective device that —

(a) collects and contains the dust produced by drilling; or

Figure 2.3.: RC drilling with dust controls

RC drilling with water injection and dust controls in place

(b) discharges that dust through ducting to a position where it will not be breathed by any person or where it will be effectively suppressed or contained.

2.3.1. Radiation safety — basic principles

The basic principles of radiation protection are as follows:

1. ALARA — As Low As Reasonably Achievable. All radiation exposure should be minimised wherever possible.
2. Maintain a safe distance from the source.
3. Limit the time spent within this distance.
4. Provide shielding when neither point (1) nor (2) can be applied.
5. Allow for waste produced from exploration activities (i.e. drilling) to be suitably encapsulated on site or removed to an appropriate repository.

2.3.2. Radiation exposure limits

Table 2.1 on the following page shows the kind of dose rates required to reach the dose limits for the three types of exposure groups.

Table 2.1.: Radiation limits and acceptable dose rates to reach each limit working 2000 hours/year

	Member of the general public	Non-designated worker	Designated worker
Radiation exposure limit	1 mSv per year above background	5 mSv per year above background	20 mSv per year above background†
Gamma dose rate	0.11 μSv/hr above background	2.5 μSv/hr above background	10 μSv/hr above background
DAC for uranium ore‡	N/A	0.60 Bq/m^3	2.38 Bq/m^3
DAC for thorium ore‡	N/A	0.26 Bq/m^3	1.04 Bq/m^3

† 50 mSv in any 1 year and 100 mSv summed over 5 years.

‡ DAC — Derived Air Concentration for 5 and 20 mSv over 2000 hours of exposure. Workers are typically exposed to both external gamma radiation and the dust from the ore. For for the DAC values relevant for ores containing uranium and thorium in different ratios, please refer to the guideline NORM–5 Dose assessment. Note: in this table Bq/m^3means the same as αdps/m^3 and does not imply anything about the actual activity of any one radionuclide.

2.3.3. Radiation exposures in perspective

As a guide, the dose rate above an infinite flat slab of outcrop of 1% Uranium ore is roughly 35 μSv/h. Table 2.2 on the next page shows the potential radiation exposures from various activity uranium ores.

The following points are designed to provide guidance as to the type of radiation monitoring and exposure control methods which an operator would be expected to implement as a minimum:

1. At least one person on site should be a trained radiation safety officer. All employees and contractors should receive general training in radiation safety and be aware of the risks of working with radioactive materials and steps which can be taken to minimise their exposure.
2. 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.
3. 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 NORM–3.4 Airborne radioactivity sampling.
4. Regular area monitoring should be conducted and data recorded in a log.
5. Appropriate personal protective equipment (PPE) should be provided to ensure radioactive dust is not able to be ingested.
6. Other than short greenfields campaigns, employees potentially exposed to radiation should wear a personal radiation monitoring badge or electronic dosemeter. Approved suppliers of monitoring badges are listed in Section 2.3.11 on page 12. For short duration greenfields campaigns the doses are assessed based on survey meter readings.
7. Any material identified as a radiation hazard must be clearly labelled and stored separately in a secure area.

Table 2.2.: A guide to potential external and internal exposures from uranium exploration sites

					Potential external gamma dose (mSv) based on a 2,000 hour year					Potential internal dose from 5μm dust (mSv) based on a 2,000 hour year				
Uranium deposit	Avg. Grade U_3O_8	ppm	Bq ^{238}U/g	μSv/h @ 1 m	@ 0.5 m	@ 1.0 m	@ 1.5 m	@ 2.0 m		@ 1 mg/m^3	@ 5 mg/m^3	@ 10 mg/m^3	@ 15 mg/m^3	@ 20 mg/m^3
Cigar Lake, Canada†	20.00%	200,000	2439.0	12.0	97.60	24.40	10.84	6.10	+	40.4	202.0	403.9	605.9	807.8
–	10.00%	100,000	1219.5	6.0	48.80	12.20	5.42	3.05	+	20.2	101.0	202.0	302.9	403.9
–	5.00%	50,000	609.8	3.0	24.40	6.10	2.71	1.53	+	10.1	50.5	101.0	151.5	202.0
–	1.00%	10,000	122.0	0.6	4.88	1.22	0.54	0.31	+	2.0	10.1	20.2	30.3	40.4
Jabiluka, NT†	0.52%	5,200	63.4	0.3	2.54	0.63	0.28	0.16	+	1.1	5.3	10.5	15.8	21.0
Kintyre, WA†	0.40%	4,000	48.8	0.3	1.95	0.49	0.22	0.12	+	0.8	4.0	8.1	12.1	16.2
–	0.20%	2,000	24.4	0.1	0.98	0.24	0.11	0.06	+	0.4	2.0	4.0	6.1	8.1
Yeelirrie, WA†	0.15%	1,500	18.3	0.1	0.73	0.18	0.08	0.05	+	0.3	1.5	3.0	4.5	6.1
Mulga Rock, WA†	0.14%	1,400	17.1	0.1	0.68	0.17	0.08	0.04	+	0.3	1.4	2.8	4.2	5.7
Lake Way, WA†	0.10%	1,000	12.2	0.1	0.49	0.12	0.05	0.03	+	0.2	1.0	2.0	3.0	4.0
Manyingee, WA†	0.09%	900	11.0	0.1	0.44	0.11	0.05	0.03	+	0.2	0.9	1.8	2.7	3.6
–	0.08%	820	10.0	0.1	0.40	0.10	0.04	0.03	+	0.2	0.8	1.7	2.5	3.3
Centipede, WA†	0.06%	630	7.7	0.1	0.31	0.08	0.03	0.02	+	0.1	0.6	1.3	1.9	2.5
Lake Maitland, WA†	0.05%	520	6.3	0.1	0.25	0.06	0.03	0.02	+	0.1	0.5	1.1	1.6	2.1
Thatcher's Soak, WA†	0.03%	300	3.7	0.1	0.15	0.04	0.02	0.01	+	0.1	0.3	0.6	0.9	1.2
Considered radioactive[15]	0.01%	82	1.0	0.1	0.04	0.01	0.00	0.00	+	0.0	0.1	0.2	0.2	0.3

†U_3O_8 average grade information obtained from the now defunct Uranium Information Centre web site.
Note that this is only a guide of potential dose and 'real' measurements must be undertaken.

8. Equipment should be cleaned and assessed for surface contamination prior to leaving site to ensure radioactive material is not being transported off site as shown in Figure 2.4. The resultant washings should report to a sump and be buried by at least 1 metre of clean fill at end of campaign.
9. Dose calculation should be undertaken at the completion of the program with the results supplied to affected personnel and the State Mining Engineer.

Figure 2.4.: Cleaning equipment

High pressure cleaning of equipment after use. Note large sump to right of picture.

Possible radiation exposures in mineral exploration are not expected to be significant. For example, in 2005 at a major WA exploration site where hundreds of thousands of tonnes of uranium ore were moved involving 44 workers, the doses ranged from 0 to 0.33 mSv. The highest dose of 0.33 mSv was received over 786 hours, which is a very low level when compared with both the public exposure limit (1 mSv/y) and the occupational exposure limit (20 mSv/y). With a well designed RMP and acceptable work practices doses on exploration sites should be well below the public limits.

2.3.4. Risk assessment

MSIR 7.27. Risk assessment

Each responsible person at a mine must ensure that —

(a) a suitable assessment is made of the consequences to the health of any person if exposed to hazardous substances at the mine; and

(b) if the assessment indicates a significant risk of exposure to a hazardous substance, a written report is prepared outlining means by which that risk may be reduced.

Resources Safety promotes the application of vigorous risk management and encourages all mining companies to perform regular risk assessment of all mining hazards, including exposure to airborne contaminants (MSIR 7.27 Risk assessment). More information on managing occupational health and safety using a risk management approach can be found in Australian Standards AS/NZS 4360:2004 and AS/NZS 4804:2001. Regular risk assessments of exposure to airborne contaminants are recommended during each phase of all mining operations, including exploration, construction, mining (surface and underground), processing, shutdowns, care and maintenance and rehabilitation activities. This is a requirement of Part 9 of the Mines Safety and Inspection Regulations 1995, and is not specific to the CONTAM system. However, Resources Safety inspectors may request representative sampling results that will be entered into the CONTAM database.

2.3.5. Reducing the risks

> *7.28. Means of reducing risk of exposure to hazardous substances*
>
> *(1) Each responsible person at a mine must, as far as practicable, reduce the risk of a person being exposed to a hazardous*
>
> *substance at the mine by means of preventing exposure to the substance.*
>
> *(2) To the extent that it is not practicable to employ the means referred to in subregulation (1), a responsible person must reduce, so far as is practicable, the risk to a person of exposure to hazards by any, or a combination of, the following —*
>
> *(a) limiting the opportunity for potential exposure of the person to a hazardous substance;*
>
> *(b) using appropriate engineering and ventilation controls;*

2.3.6. Dust Sampling

> *MSIR 7.29. Workplace atmospheric contaminant monitoring to be provided*
>
> *If a report under regulation 7.27 indicates the need for atmospheric contaminant monitoring at a workplace at a mine,*
>
> *each responsible person at the mine must ensure that —*
>
> *(a) samples of atmospheric contaminants at the workplace are taken in accordance with Part 9; and*
>
> *(b) the results of the samples are recorded and reported in accordance with Part 9.*

2.3.7. CONTAM

The CONTAM[17] system uses a database to retrieve and record representative, personal exposure monitoring results randomly collected from mining and exploration activities in Western Australia. It is used to assess the efficiency of management programs aimed to control dust and other airborne contaminants, with the main objectives to:

- collect comparative exposure data for different occupation groups, locations, and industry sectors for analysis of emerging trends within the industry;
- identify exposure groups that contribute to long-term health effects in mining employees; and
- monitor statutory compliance in the maintenance of acceptable working environments.

Sampling quotas are not issued for exploration companies as it is recognised that the nature of their activities make this impracticable. Problems include:

- exploration companies tend to operate with small workgroups;
- work is done at remote and isolated locations without any established occupational health and safety infrastructure or technical support;
- work is seasonal;
- target areas may be campaigned for only short periods; and
- changes to work programs are frequent.

Instead, exploration companies are requested to take a reasonable number of representative personal monitoring samples of exposures to airborne contaminants of all exploration personnel. Important considerations when determining who and how often to sample should include:

- size and nature of the workforce;
- amount of work performed; and
- level of risk associated with the hazardous substances that are encountered during exploration activities.

As a minimum, it is recommended that every employee is sampled at least annually. Where a significant risk is attributed to atmospheric contaminants, additional sampling will be necessary. For example, the sampling frequency must be increased when asbestos is present or suspected. It is expected that representative personal exposure monitoring will be undertaken when exploring on or near existing mining operations, and the results sent to the CONTAM Manager.

2.3.8. Registered sampler

Only CONTAM[17] registered samplers may submit results to the CONTAM system.

The minimum qualification to become a CONTAM registered sampler is the Certificate III (Technician) or IV (Officer) in Surface Ventilation, or completion of a similar course that has been approved by the State Mining Engineer. Subject to proof of qualifications and experience, qualified occupational hygienists, or people with similar qualifications and experience, may be exempted from this certification. Written applications for exemption from the certification requirement must be forwarded to the CONTAM Manager, with the registered sampler form, a curriculum vitae and an example of an occupational hygiene report.

Sampler registration lasts for five years. Samplers whose registration has expired must complete a one-day CONTAM refresher course and send in a new registered sampler form with proof of competency. The CONTAM refresher course updates skills and knowledge about common problems in contaminant monitoring, and introduces new policies and technologies that affect how the CONTAM system functions. Note that similar courses undertaken for professional development to maintain competency and currency of air monitoring skills may satisfy the re-registration requirements — submit a course outline and certificate of competency with the registered sampler form.

2.3.9. MINEHEALTH

> *MSIR 7.30. Health surveillance*
>
> *If a report under regulation MSIR 7.27 indicates the need for surveillance of the health of employees at a mine, each responsible person at the mine must ensure that health surveillance (including biological monitoring) is provided in accordance with Division 4 of Part 3.*

The health surveillance system for mining employees in Western Australia[18] is administered by Resources Safety. Confidential information is recorded on an approved health assessment form and transferred to Resources Safety's MINEHEALTH database.

The objectives of the health surveillance system for mining employees are to:

- assess the health status of all mining industry employees on a regular basis;
- analyse collected data to detect adverse health effects at the earliest opportunity;
- enable appropriate and timely corrective action to be taken in order to safeguard the health and well-being of mining industry employees; and
- provide data for future epidemiological studies.

2.3.10. Radiation exposure control

Gamma radiation does not generally require any active control measures as it can be monitored with a survey meter and individual radiation exposures are measured using personal dosimeters/badges. Important points to remember:

1. An appropriately calibrated portable gamma survey meter should be used to identify any active samples.
2. A personal dosemeter (e.g. 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. Figure 2.5 on the following page shows TLD badges being stored between use. A hook is allocated to each employee and each control badge. Alternatively, an electronic personal dosemeter may be used instead of issuing TLD badges for a short term.
3. Figure 2.6 on page 13 shows a range of equipment to undertake monitoring.

Radon decay products (daughters) in air does not require active control other than in enclosed spaces where active ventilation maybe required. Radon gas will emanate from the uranium in core samples and drill cuttings. Radon gas and radon progeny are not considered to be a significant source of worker radiation exposure because it is assumed that the drill core/cuttings is being handled in a well-ventilated area. Wooden or steel core stores containing significant amounts of mineralised core should be ventilated when workers are inside. Tents are likely to be sufficiently leaky so as not to require ventilation. If large quantities of radioactive material are being stored in an enclosed area, periodic measurements of the radon progeny levels would be required. If in doubt, check.

Airborne alpha emitters in dust (internal dose) can be controlled with:

1. Dust minimisation equipment such as dust extraction systems and using wet rather than dry methods for cleaning work areas and whilst drilling. Figures **??** on page ?? and 2.2 on page 4 show the difference between good dust control and no dust control.
2. Respiratory protection when determined by dust monitoring results, or when evident from the observation of exploration activities.

Figure 2.5.: A typical TLD badge storage board

3. Monitoring results also give the information necessary to decide on the application of the appropriate control measures.
4. 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.
5. Contamination monitoring must be carried out to check work surfaces, desks, tables, and skin contamination levels. Figure 2.7 on page 14 shows the 'Inspector' which has an open window used to detect αradiation on contaminated surfaces. While G-M instruments such as the 'Inspector' are not as capable as specific alpha surface contamination area probes, they are acceptable for use in small greenfields operations when specifically calibrated to measure surface contamination.
6. Radiation monitoring must be carried out to provide data for radiation control and for personal dose estimation which is reported to workers, management, and the regulatory agencies.

2.3.11. Dose assessment

Personal monitoring badges may be sourced from four organisations in Australia:

1. ARPANSA — www.arpansa.gov.au
2. Landauer Australasia — www.landauerastralasia.com
3. Australian Radiation Services — www.australian-radiation-services.com.au
4. Global Medical Solutions — www.gms-aus.com

Figure 2.6.: A typical radiation monitoring kit

Information on how to undertake dose assessments can be found in Guideline NORM–5 Dose assessment.

There are a number of consulting occupational health companies in WA who could undertake dust monitoring, radiation surveys and radon monitoring, if required, on your behalf. The Regulations [1] require the submission of an annual occupational radiation report to the State Mining Engineer.

2.3.12. Long term core storage

1. Core should ideally be placed on a concrete floor which has been sealed and where practicable painted in a different colour to the core.
2. The core should be covered with a roof leaving the sides open.
3. The area should be secured.
4. There should be a supply of water to hose down the floor and keep dust to a minimum.
5. Run off water should pour into a sump, which can be caught, and the sediment stored for future disposal.
6. Signs should be placed around the area advising no entry without authorisation. For the appropriate use of the 'radiation trefoil', refer to guideline NORM–6 Reporting requirements.
7. The area should be located away from other work places.
8. 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.
9. Contributions from dust and radon progeny can be assumed to be negligible if the storage area is well ventilated.

Figure 2.7.: Radiation Alert Inspector $\alpha\beta\gamma$ monitor

Multipurpose instruments with $\alpha\beta\gamma$ detectors, such as the Radiation Alert 'Inspector' are suitable for measuring dose rates and contamination on small greenfields exploration sites . However, they may not be robust enough for large, busy sites. Note the large detector window for detection of α particles.

10. Core cutting should be undertaken using wet methods.

A useful reference on the storage of radioactive cores is available from the South Australian Department of Primary Industries and Resources [14].

It should be noted that a Core Store containing a significant amount of radioactive material must be registered with the Radiological Council under the *Radiation Safety Act*.

2.3.13. 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:

Natural disequilibrium: 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.

Induced disequilibrium: This may occur during percussion drilling and is caused by the 'degassing' of radon.

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).
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).

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.

2.3.14. Radioactive mineral samples and rock chips

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

Some guidelines for radioactive mineral samples:

1. Wash hands with soap and water after handling samples.
2. Never store specimens, even the smallest of size, in an inhabited room.
3. Where samples are stored in bags, these should be sealed and in good condition.
4. Store specimens in a well ventilated area.
5. Never eat, drink, smoke, or sleep near radioactive material.
6. Clearly label all radioactive samples as such.
7. Don't carry radioactive minerals in your pocket.
8. Try to keep radioactive mineral samples in a container with a lid. This helps to control small pieces that may break off during handling. A boxed radioactive mineral keeps you from directly touching the specimen, which helps to minimise radiation exposure to your skin.
9. Clean up small particles that may break off of radioactive specimens with soap and water.

2.3.15. 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.

1. 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.
2. The levels should be as close to the background as possible.
3. It is necessary to ensure that material is dry before surface contamination readings are taken.

2.3.16. Radioactive waste management

A separate radioactive waste management plan (RWMP), as required by ARPANSA [11] 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.

Among other requirements, good radiation protection practices for the disposal of the solid waste are:

1. Drill cuttings and other collected materials that are classified as 'radioactive' should be disposed down drill holes. The holes should then be capped in accordance with the DMP standard – either temporarily or permanently.
2. 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.
3. 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.
4. 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.
5. In situations where thorough radiation monitoring shows that empty sample bags, PPE and other materials have negligible contaminated – they can be disposed of in landfill, after the 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 and in these cases the preparation and approval of a specific Radioactive Waste Management Plan (RWMP) may be necessary.
6. 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 being undertaken. Ideally, drill sites must be returned to the original pre-exploration radiation levels.

2.3.17. Definition of a radioactive material

The classification of what is a 'radioactive material' varies depending on the the legislation used. The IAEA Standards [15], the Transport Regulations [10], the Contaminated Sites legislation [8], and the *Radiation Safety Act 1975* [3], all have different definitions. The Mining Code [11]accepts the same 1Bq/g as the IAEA for head-of-chain uranium or thorium ores or mineral concentrates.

For example, in the IAEA Basic Safety Standards 115 it is a material containing greater than 1 Bq/g ^{238}U and ^{232}Th while under the *Radiation Safety Act 1975* [3] it is material containing greater than 30 Bq/g whole ^{238}U and ^{232}Th Decay Series. Under the contaminated sites legislation, it is considered any material above the natural background for the site. Please seek professional advice from the the relevant regulator when determining which definition applies.

3. Elements to be included in a Radiation Management Plan

3.1. Document format and cover sheet

The RMP should be a 'controlled' document, with each page dated and clearly identified. The cover sheet should include:

1. The title of the document.
2. Document identifier (unique reference number relevant to the operation).
3. Date of submission to the appropriate authority.
4. The name of the company and a particular operation.
5. Signed endorsement by the site Registered Manager.

3.2. Scope of the Radiation Management Plan

The RMP should detail the specific operations/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.

3.3. Introduction

The introduction should detail the history of the site and ownership (where necessary) and the reason a RMP 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.

3.4. 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 employees.

3.5. 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 RMP.

3.6. Sources and pathways of radiation exposure

The RMP 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 employees 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.

3.7. Equipment and facilities for controlling radiation sources

The RMP should identify the measures that will be implemented to control radiation exposures including:

1. 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.
2. Where dust is generated, it should be suppressed at the source.
3. Care should be taken to avoid the re-suspension of dust as a result of equipment vibration and high air velocities.
4. During maintenance operations, special care should be taken to control the occupational exposures that may arise from the buildup of dust on internal and external surfaces of the equipment.
5. Only when engineering methods of dust control do not achieve acceptable air quality in working areas, personal respiratory protection should be provided to employees.

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 employees to unacceptable levels of noise.

3.8. Institutional controls

The RMP 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 an RMP is usually delegated to the appropriately trained and 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 exploration RSO is expected to have attended a radiation protection course relevant to the mineral industry, and to have had some experience in sampling of air contaminants and gamma-radiation measurements in the mining environment.

Please note that in order to take dust samples on an exploration site, the person is expected to have the minimum qualification of a surface ventilation technician/officer and be a 'CONTAM registered sampler'.

Information on the CONTAM system is available on the DMP web site in the Resources Safety area — http://www.dmp.wa.gov.au/6749.aspx.

The main duties of the RSO are advising the management on the implementation of the RMP and on all matters in relation to radiation protection of employees, public and the environment; and the RMP should clearly describe these duties.

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

1. Designation and control of supervised or controlled areas (e.g. physical barriers, signs, special work permits).
2. Designation of employees according to the levels of radiation exposure.
3. General housekeeping measures.
4. Correct operation of control equipment, including preventative maintenance measures and schedules.
5. Standard operating procedures for critical operations from a radiation protection perspective.
6. Use of personal protective equipment.
7. Inspection and auditing programs to ensure that correct work practices and procedures are being followed.

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 an exploration site to which members of the public may have access, but signs at the entrance to the site may cause unwarranted concern.

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 a 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.

For additional guidance please refer to Appendix B of the guideline NORM–4.1 Dust control strategies.

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.

3.9. Employee training

All employees who may be exposed to radiation and all persons responsible for the implementation of the RMP should receive appropriate training.

Senior management and employees in other departments (such as public relations, human resources, administration, etc.) should also be provided with information on radiation-related risks and detailed description of sources and pathways of radiation exposure at relevant exploration sites.

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

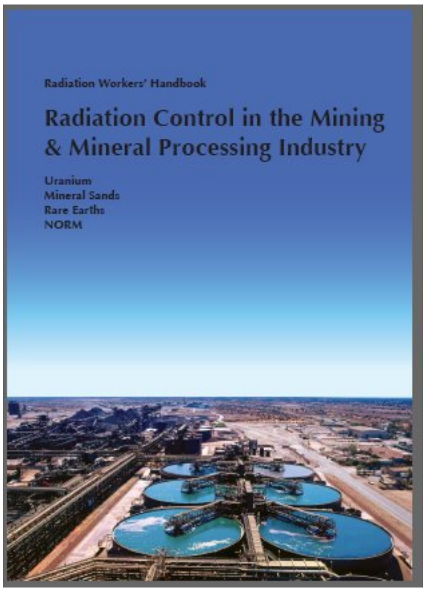
Training programs should include relevant information and the following information should be provided in the RMP:

1. Details of the induction program (i.e. training for new employees), including summary of topics covered, duration and context in relation to overall induction.
2. Details of periodic re-training, including format, duration and frequency.
3. Details of any additional training given to the management personnel.

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 employee training is expected to vary with job requirements and responsibilities.

Figure 3.1.: Radiation worker's handbook



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 web site.

www.aua.org.au

3.10. 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 employees 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 (e.g. 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 RMP. 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 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 general monitoring guidance is suggested in Table 3.1.

Table 3.1.: General monitoring guidance

Radiation radionuclide level	Monitoring
Average levels $<$ 25% of occupational limits.	Initial assessment and periodic confirmatory surveys; repeat as conditions change.
Significant number of individual measurements $>$ 25% of derived occupational exposure limits.‡	Commence routine monitoring of the workplace.
Dose, average concentration, $\geq$ 25% of occupational limits.	Individual exposure assessment: External — personal dosimeters/badges. Internal — personal samplers (dust), area sampling and exposure time (radon).
Individual measurements approach or exceed derived occupational exposure limits.‡	Repeat the measurement.
Confirmed level approaches or exceeds occupational exposure limits.	Intensive monitoring in conjunction with re-evaluation of dose-reduction planning (with an advice from the appropriate authority).

‡Derived limit = radiation level that would result in the annual exposure equal to the statutory limit.

The RMP 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:

1. Quality and specifications of equipment and instruments.
2. Training and experience of personnel using equipment and instruments.
3. Verification of measurement procedures by the analysis of control samples and the use of standard methods for analysis (where applicable).
4. Frequency of calibration and maintenance of equipment and instruments.
5. Details and frequency of independent audits (where applicable).
6. The need for traceability of the results of monitoring programs to a National Standard.
7. 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.

3.11. Records management and reporting

The RMP 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 RMP should require the records that are kept include the following:

1. 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).
2. 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).

It is recommended that RMP contains a requirement that the individual annual occupational exposure record includes the following:

1. Unique identification of the individual (e.g. MineHealth surveillance number).
2. The exposure for the current year and, where available, for the relevant five-year period.
3. Results of the measurements for the estimation of the external dose, and methods of assessment.
4. Results of the measurements for the estimation of internal dose (result of personal dust and radon/thoron monitoring), and methods of assessment.
5. The allocated dose for lost or damaged monitors or samples.
6. Any special radiation exposure assigned to the employee.
7. Record of the formal declaration of pregnancy, any revocations of such declaration, and measures taken to ensure that dose to this employee is kept under 1 mSv over the remainder of the pregnancy.

The RMP 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 employees, at least on an annual basis. Operational requirements may require more frequent reporting and analysis to management and to an appropriate authority.

For additional guidance in regards to the format of statutory reports and for the levels that, when detected, would typically require investigation please refer to NORM–6 Reporting requirements.

3.12. Dose assessment

The RMP should specify how the results of the monitoring program, detailed in Section 3.10 on page 22, would be used in the assessment of doses of employees.

It should include an estimate of the likely doses to be received by the various categories of employees, together with documentation of all assumptions used.

For any single component of occupational exposure (external and internal) these assessments could be considered if monitoring indicates that annual exposure may exceed 1 mSv, and must be conducted if the estimated dose is likely to exceed 5 mSv per year.

For additional guidance please refer to the NORM–5 Dose assessment.

3.13. Waste management system

It is unlikely that a separate Radioactive Waste Management Plan (RWMP) will be required for an exploration site. The prevention of contamination to the environment and the management of waste from the drilling and moving of radioactive material is an integral part of the RMP. It is the responsibility of the exploration company to be able to demonstrate that environmental radionuclide levels have not been altered due to exploration activities.

The RMP should include a detailed description of procedures for environment contamination controls, including:

1. Pre and post exploration monitoring programs.
2. Water monitoring, where necessary.
3. Record keeping.
4. Reporting.
5. Disposal techniques.
6. Rehabilitation techniques.

For additional guidance please refer to the NORM–3.1 Pre-operational monitoring.

3.14. Transport of radioactive material

The RMP should include a detailed description of procedures for transport of radioactive materials that includes:

1. Types of packaging (where applicable) and signposting.
2. Details of mode of transport and containers.

3. Number of employees involved in transport and their estimated exposure times and doses.
4. Amounts and radioactivity content of transported materials, frequency of transport movements.
5. 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).
6. Summary of operational procedures, particularly illustrating measures taken to ensure strict compliance with transport safety regulations.

3.14.1. Transport arrangements for Excepted Packages[16]

Package (container) The package must be such that it will retain its contents under routine transport conditions.

The design should provide for strength of lifting attachments, ease of handling and securing, and ease of decontamination.

The package should not have external surface alpha contamination above 0.4 Bq/cm^2. In practice this condition is met if there is no visible contamination or dust on the surface.

Documentation The shipment must be accompanied by documentation, which includes (in the following order):

1. 'Radioactive Material, Excepted Package – Limited Quantity of Material'.
2. 'UN Class Number 7, UN2910'.
3. 'Uranium ore samples – solid'.
4. The maximum activity of the shipment. For material of 1000ppm U, this is 12 KBq/kg. As the activity (grade) will generally not be known, make a generous estimate based on this figure.
5. A declaration in the form — 'I hereby declare that the contents of this consignment are fully and accurately described above by the proper shipping name and are classified, packed, marked and labelled, and are in all respects in proper condition for transport by road according to the applicable international and national governmental regulations.' — signed and dated.
6. Sender and receiver details.

Labels

1. Each Excepted Package should be labelled 'Radioactive' on an internal surface such that upon opening, the warning is clearly visible.
2. The package is marked 'UN2910' on the outside surface.
3. Sender and receiver details should be marked on the outside surface.
4. Packages exceeding 50kg the mass to be marked on the outside.

3.14.2. Transport arrangements for LSA material[16]

LSA – 1 package Higher activity samples where the dose-rate $> 5\ \mu$Sv/h, must be transported as Low Specific Activity Material (LSA). The transport arrangements are described below assuming samples are packaged within a single vehicle.

Package (container) Package requirements for transporting solid LSA material are similar to those for Excepted Packages, with the additional requirement that the smallest external dimension of the package must not be less than 10 cm. Contact the Radiological Council for advice if there is a need to transport liquid LSA–1 material.

Transport Index – package

1. A Transport Index (TI) must be determined for the package. The TI reflects the external radiation hazard associated with the handling of the package.
2. The TI is determined by first measuring the dose rate (in mSv/hr) at 1 metre from the package surface. For core samples, the dose rate is typically less than 1 mSv/hr.
3. The TI is the measured dose rate multiplied by 100 (if dose rate has been measured in μSv/hr, divide by 10 to determine the TI).
4. The determined TI is to be rounded up to the first decimal place. However, a TI of 0.05 or less can be rounded to zero (0).

Transport Index – vehicle

1. A TI needs to be determined if shipping multiple packages together in a container or on a single vehicle. In this case the TI is either the sum of the TIs of all the contained packages or it can be determined by direct measurement of radiation level for the vehicle of container (as above).
2. For tanks, freight containers and unpackaged LSA–1 material the TI is modified by a multiplication factor based on the size of the load as shown in 3.2.

Table 3.2.: Multiplication factors for tanks, freight containers, and unpackaged LSA–1 and SCO–1

Size of load[a]	Multiplication factor
size of load $\leq$1 m^2	1
1 m^2 $<$ size of load $\leq$5 m^2	2
5 $m^2$$<$ size of load $\leq$ 20 m^2	3
20 m^2 $<$ size of load	10

[a]Largest cross-sectional area of the load being measured.

Documentation and labels

1. If the TI is less than 1 and the surface dose rate is less than 0.5 mSv/h the package is a II–Yellow category. The label shown in Figure 3.2 on the facing page must be attached to the package on two opposite sides.
2. The contents of “LSA–1” and the maximum activity of the package contents must be marked on the label. The TI of the package is to be included on the label.

Figure 3.2.: Category II - Yellow package label

3. Sender and receiver details should be marked on the outside surface.
4. The package is marked “UN2912” and “Radioactive material, low specific activity (LSA–1)” on the outside surface.
5. Packages exceeding 50kg the mass to be marked on the outside.
6. If the surface dose rate of any package exceeds 0.5 mSv/hr contact the Radiological Council for further advice.

Placards The vehicle transporting the LSA packages must have placards attached as shown in the Figures 3.2 and 3.3 on the following page.

For additional guidance please refer to the NORM–4.3 Transport of NORM.

Figure 3.3.: Vehicle placard for radioactive material

3.15. Radiation safety resources

The RMP 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. Where applicable, qualifications and experience of personnel undertaking the monitoring will also be necessary. The RMP 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 RMP should also list the monitoring equipment and support facilities, including:

1. The make and model of the equipment.
2. The purpose of the particular instrument and its suitability for the particular purpose.
3. Calibration methods and frequency, and traceability to a National Standard.
4. Maintenance and replacement schedule.

3.16. List of commitments

The final section of the RMP should summarise all the commitments made throughout the document, with references to their location within the RMP.

3.17. Examples of figures and tables to be included in the Radiation Management Plan

The following examples are provided to illustrate the type of figures and tables that could be included in the RMP to enhance the presentation of specific information.

3.17.1. Figures

1. General location diagram of operations/facilities.
2. Map/plan of the site, showing layout of infrastructure in relation to the tenement boundaries and the national grid.
3. Location of critical groups of the public.
4. Diagrams of waste disposal facilities, showing relevant engineering details.

3.17.2. Tables

1. Summary of site history.
2. Workforce stratification information, including shift patterns.
3. Summary of sources/pathways of radiation exposure.
4. Radiation monitoring program.
5. List of radiation monitoring equipment.
6. Summary of dose estimation calculations, by work category and exposure pathway.
7. Outline of employee induction programs.

It is recommended that typical results obtained during routine monitoring be included in the form of tables and charts. Where special forms associated with the RMP have been developed (such as, for example, a 'clearance form' for the removal of potentially contaminated equipment from the site), it is recommended to provide an example of a completed document instead of the blank form.

A. Appendix showing a Radiation Management Plan checklist

	Standard	Intent	MSIR Regulation [1]	Mining Code [11]	✓
1	Front cover				
	Controlled document	To verify that proper control of documentation is in place.	Reg. 16.7(3)	Sec. 3.8.3	
	Each page dated and identified	To verify changes to the RMP are controlled.	Reg. 16.7(6)	Sec. 2.9.6	
	Title of document	To verify the purpose of the document.	Reg. 16.7(1)	Sec. 2.7.1.	
	Reference number of document	To verify the RMP is stored in a records management system.	Reg. 16.25	Sec. 2.7.2(e)	
	Date of issue	To verify the RMP is current and reviewed every 2 years.	Reg 16.7(4)	Sec. 2.9.6	
	Date of submission	To verify the RMP has been provided to the State Mining Engineer.	Reg. 16.7(3)	Sec. 2.9.6	
	Name of Company	To verify owner of the RMP.	Reg. 16.7	Sec. 2.10.1	
	Name of Operation	To verify site where RMP applies.	Reg. 16.7	Sec. 2.10.1	
	Endorsed by Exploration Manager	To verify that the responsible person has complied.	Reg. 16.7	Sec. 2.10.1	
2	Scope				
	Details of operations and facilities	To verify the the size and scope of the operations.	Reg. 16.8(2)	Sec. 2.7.2	
	Details of location	To verify the exact location of the site.	Reg. 16.7	Sec. 2.7.2	
	Details of Lease or Tenement	To verify the site location under the Mining Act.	Reg. 16.7	Sec. 2.7.2	
3	Introduction				
	History of site or ownership	To verify current RMP includes previous records or plans.	Reg. 16.25	Sec. 3.8.1(f)	
	Reason for Radiation Management Plan	To verify a RMP is required.	Reg. 16.2	Sec. 2.7.1	
	Exploration activities on site	To verify use of appropriate equipment, facilities and operational procedures.	Reg. 16.7(2)(a)(i)	Sec. 2.3.2	

	Standard	Intent	MSIR Regulation [1]	Mining Code [11]	✓
	Expected duration of exploration	To verify use of appropriate equipment, facilities and operational procedures.	Reg. 16.7(2)(a)(i)	Sec. 2.7.1	
	Critical project dates	To verify use of appropriate equipment, facilities and operational procedures.	Reg. 16.7(2)(a)(i)	Sec. 2.7.1	
4	Workforce				
	Number of persons employed	To verify use of appropriate equipment, facilities and operational procedures.	Reg. 16.7(2)(a)(i)	Sec. 2.7.2(b)	
	Stratification – company/contractor	To verify use of appropriate equipment, facilities and operational procedures.	Reg. 16.7(2)(a)(i)	Sec. 2.10.1(m)(p)	
	Work categories	To verify use of appropriate equipment, facilities and operational procedures.	Reg. 16.7(2)(a)(i)	Sec. 3.6.7	
	Roster system	To verify use of appropriate equipment, facilities and operational procedures.	Reg. 16.7(2)(a)(i)	Sec. 2.7.2(b)	
	Average working hours	To verify use of appropriate equipment, facilities and operational procedures.	Reg. 16.7(2)(a)(i)	Sec. 2.7.2(b)	
	Radiation exposures	To verify use of appropriate equipment, facilities and operational procedures.	Reg. 16.7(2)(a)(i)	Sec. 2.7.2(b)	
5	Critical groups				
	Identification	To verify that members of the public are not exposed to radiation from the operation.	Reg. 16.9	Sec. 2.8.2(c)	
	Location	To verify that members of the public are not exposed to radiation from the operation.	Reg. 16.9	Sec. 2.8.2(e)	
	Size	To verify that members of the public are not exposed to radiation from the operation.	Reg. 16.9	Sec. 2.8.2(e)	
	Demographics	To verify that members of the public are not exposed to radiation from the operation.	Reg. 16.9	Sec. 2.8.2(e)	
	Land-use maps	To verify that members of the public are not exposed to radiation from the operation.	Reg. 16.9	Sec. 2.8.2(e)	
	Location plan or map	To verify that members of the public are not exposed to radiation from the operation.	Reg. 16.9	Sec. 2.8.2(e)	
	Radiation exposures	To verify that members of the public are not exposed to radiation from the operation.	Reg. 16.9	Sec. 2.8.2(e)	

	Standard	Intent	MSIR Regulation [1]	Mining Code [11]	✓
6	Sources & pathways of radiation exposure				
	Identified Sources & Pathways	To verify that adequate monitoring programs are in place.	Reg. 16.7(2)(a)(ii)	Sec. 2.8.1(a)	
	Plans of exploration activities	To verify that adequate monitoring programs are in place.	Reg. 16.7(2)(a)(ii)	Sec. 2.8.1(a)	
	Descriptions of equipment	To verify that adequate monitoring programs are in place.	Reg. 16.7(2)(a)(ii)	Sec. 2.8.2	
	Processes involved	To verify that adequate monitoring programs are in place.	Reg. 16.7(2)(a)(ii)	Sec. 2.8.2(a)	
	Risk assessments	To verify that adequate monitoring programs are in place.	Reg. 16.7(2)(a)(ii)	Sec. 2.8.2(d)	
7	Control of radiation exposure				
	Measures implemented	To verify measures to keep employee doses as low as practicable.	Reg. 16.15	Sec. 3.8.1(b)	
	Engineering controls, methods and specifications	To verify that the best practicable technology is incorporated on site.	Reg. 16.7(5)	Sec. 3.8.1(b) Sec. 3.9.1	
	Dust controls	To verify dust suppression is being used.	Reg. 9.17(2)	Sec. 2.6.2 Sec. 3.8.1(b)	
	Shielding	To verify use of appropriate equipment, facilities and operational procedures.	Reg. 16.7(2)(a)(i)	Sec. 2.6.2 Sec. 3.8.1(b)	
	Exposure minimisation techniques	To verify use of appropriate equipment, facilities and operational procedures.	Reg. 16.7(2)(a)(i)	Sec. 2.6.2 Sec. 3.8.1(b)	
	Housekeeping measures	To verify use of appropriate equipment, facilities and operational procedures.	Reg. 16.7(2)(a)(i)	Sec. 2.6.2	
	Contamination control	To verify use restricted release zones.	Reg. 16.7(2)(c)(i)	Sec. 2.6.2	
8	Institutional controls				
	Responsibilities of personnel	To verify use of appropriate equipment, facilities and operational procedures.	Reg. 16.7(2)(a)(i)	Sec. 3.10.1	

	Standard	Intent	MSIR Regulation [1]	Mining Code [11]	✓
	Accountability	To verify that the manger is advised on matters to do with implementing RMP.	Reg. 16.9(3)	Sec. 3.10.1	
	Commitment	To verify manager is committed to implementing the RMP.	Reg. 16.8(1)	Sec. 2.8.2(a)	
	Radiation Safety Officer	To verify that a appropriate RSO has been appointed.	Reg. 16.8	Sec. 2.10.1(d)	
	Designation of supervised areas	To verify doses are being controlled.	Reg.16.16	Sec. 2.10.1(m)	
	Housekeeping measures	To verify use of appropriate equipment, facilities and operational procedures.	Reg. 16.7(2)(a)(i)	Sec. 2.6.2	
	Operating procedures	To verify use of appropriate equipment, facilities and operational procedures.	Reg. 16.7(2)(a)(i)	Sec. 2.10.1(a)	
	Personal protective equipment	To verify use of appropriate equipment, facilities and operational procedures.	Reg. 16.7(2)(a)(i)	Sec. 2.6.2(c)	
	Inspection and auditing programs	To verify adequacy of resources.	Reg. 16.8(2)	Sec. 2.8.3(b)	
	Signage	To verify the use of appropriate equipment, facilities and operational procedures.	Reg. 16.7(2)(a)(i)	Sec. 2.10.2	
	Personal hygiene rules	To verify the use of appropriate equipment, facilities and operational procedures.	Reg. 16.7(2)(a)(i)	Sec. 2.10.2	
	Job rotation	To verify doses are kept as low as practicable.	Reg. 16.15	Sec. 3.8.1(b)	
9	Employee training				
	Induction program	To verify the instruction and training program.	Reg. 16.7(2)(a)(v)	Sec. 2.7.2(d) Sec. 3.8.1(e)	
	Periodic re-training	To verify the instruction and training program.	Reg. 16.7(2)(a)(v)	Sec. 2.7.2(d) Sec. 3.8.1(e)	
	Radiation safety training of personnel	To verify the instruction and training program.	Reg. 16.7(2)(a)(v)	Sec. 2.7.2(d) Sec. 3.8.1(e)	
	Details of person giving training	To verify the instruction and training program.	Reg. 16.7(2)(a)(v)	Sec. 2.7.2(a) Sec. 3.8.1(e)	

	Standard	Intent	MSIR Regulation [1]	Mining Code [11]	✓
	Syllabus	To verify the instruction and training program.	Reg. 16.7(2)(a)(v)	Sec. 2.7.2(d)	
10	Radiation monitoring program				
	Compliance with limits	To verify radiation dose is kept as low as practicable.	Reg 16.15	Sec. 3.8.1(c)	
	Exposure to employees and public	To verify radiation dose is kept as low as practicable.	Reg. 16.15	Sec. 3.8.1(c)	
	Impact of operations on environment	To verify environmental radiation monitoring program.	Reg. 16.6	Sec. 2.8.2	
	Effectiveness of controls	To verify radiation dose is kept as low as practicable.	Reg 16.15	Sec. 3.8.1(c)	
	Employees monitored	To verify radiation dose is as kept low as practicable.	Reg. 16.15	Sec.3.8.1(c)	
	Type of monitoring and sampling	To verify adequacy of monitoring program.	Reg 16.7(2)(ii)	Sec. 3.8.1(c)	
	Duration	To verify adequacy of monitoring program.	Reg. 16.7(2)(ii)	Sec. 3.8.1(c)	
	Frequency	To verify adequacy of monitoring program.	Reg. 16.7(2)(ii)	Sec. 3.8.1(c)	
	Sampling equipment	To verify adequacy of equipment.	Reg. 16.8(2)	Sec. 2.7.2(c)	
	Calibration records for all equipment	To verify monitoring equipment is being maintained.	Reg 16.8(3)	Sec. 3.8.3(a)	
	Radiation types monitored	To verify adequacy of monitoring program.	Reg. 16.7(2)(ii)	Sec. 3.8.1(c)	
	Radionuclides	To verify adequacy of monitoring program.	Reg 16.7(2)(ii)	Sec. 3.8.1(c)	
	Surface contamination	To verify adequacy of monitoring program.	Reg. 16.7(2)(ii)	Sec. 3.8.1(c)	
	Radon/Thoron dose estimations/measurements	To verify procedures for the assessment of dose.	Reg. 16.7(2)(iii)	Sec. 3.8.1(c)	
	Equipment specifications	To verify that the best practicable technology is available.	Reg. 16.7(5)	Sec. 2.7.2(c)	
	Training and experience of personnel	To verify adequacy of staff .	Reg 16.8(2)	Sec. 3.10.1(l)	
	Calibration and traceability of results/schedules	To verify monitoring equipment is being maintained.	Reg. 16.8(3)	Sec. 3.8.3(a)	
	Audits	To verify adequacy of monitoring program.	Reg. 16.7(2)(ii)	Sec. 2.7.2(g) Sec. 3.8.3(b)	

	Standard	Intent	MSIR Regulation [1]	Mining Code [11]	✓
	Quality Assurance Program	To verify adequacy of monitoring program.	Reg. 16.7(2)(ii)	Sec. 2.7.2(g) Sec. 3.8.3(b)	
11	Records management & reporting				
	Information on radiological conditions	To verify that appropriate records are being kept under the RMP.	Reg. 16.25(1)(d)	Sec. 2.7.2(e)	
	Assessments of exposures	To verify that records are being kept of dose assessments.	Reg. 16.25(1)(a)	Sec. 2.10.1(n) Sec. 2.10.1(o)	
	Impact on local environment	To verify that appropriate records are being kept under the RMP.	Reg. 16.25(1)(d)	Sec. 2.10.1(n)	
	Relevant documentation	To verify that appropriate records are being kept under the RMP.	Reg. 16.25(1)(d)	Sec. 2.7.2(e)	
	Identification of individuals	To verify that monitoring records are being kept.	Reg. 16.25(1)(b)	Sec. 3.8.1(f)	
	Easy, secure long term access to data	To verify that appropriate records are being kept under the RMP.	Reg. 16.25(5)	Sec. 3.8.1(f)	
	Reporting to the State Mining Engineer	To verify that results from the monitoring program and waste management plan are reported to SME.	Reg. 16.26	Sec. 2.10.1(g)(i)(j)(h)	
12	Dose assessment				
	Methodology for exposure calculations	To verify the use of appropriate procedures for the assessment of dose.	Reg. 16.7(2)(a)(iii)	Sec. 2.7.2(b) Sec. 2.8.1(d)	
13	Waste management controls				
	Pre/post exploration monitoring program	To verify environmental radiation monitoring program.	Reg. 16.6	Sec. 2.8.2(b)	
	Water monitoring	To verify environmental radiation monitoring program.	Reg. 16.6	Sec. 2.8.2(d)	
	Record keeping	To verify records are being kept and maintained.	Reg. 16.25	Sec. 3.9.4	
	Reporting	To verify reporting on waste management system.	Reg 16.26(b)	Sec. 2.8.2(g)	

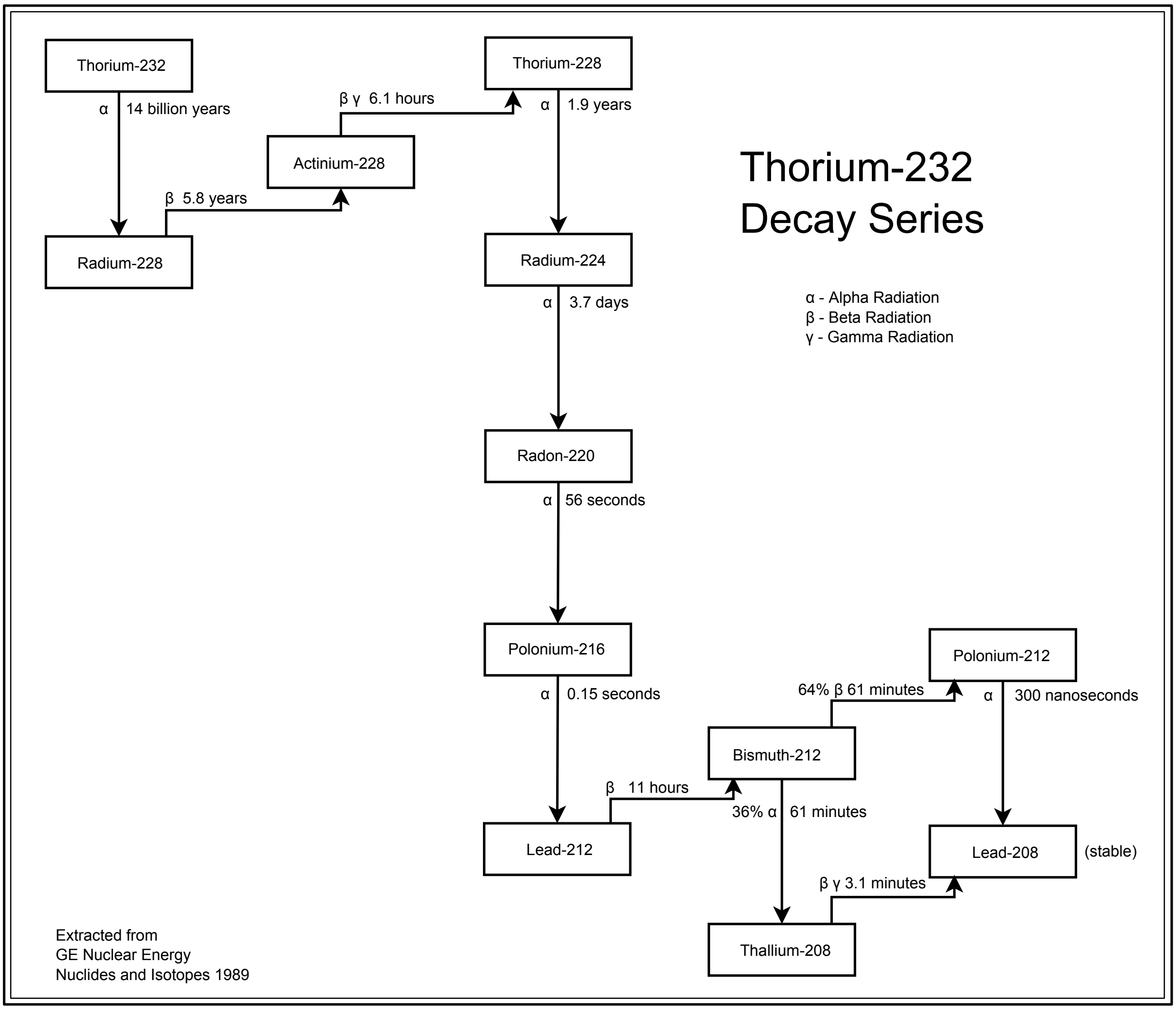
	Standard	Intent	MSIR Regulation [1]	Mining Code [11]	✓
	Disposal techniques	To verify waste management system.	Reg. 16.7(2)(c)	Sec. 2.8.2(c) Sec. 2.10.2(b)	
	Rehabilitation	To verify rehabilitation of site.	Reg. 16.7(2)(c)(iii)	Sec. 2.8.2(h)	
14	Transport				
	Types of packaging	To verify the use of appropriate equipment, facilities and operational procedures.	Reg. 16.7(2)(a)(i)	Sec. 3.8.1(b)	
	Signposting	To verify the use of appropriate equipment, facilities and operational procedures.	Reg. 16.7(2)(a)(i)	Sec. 3.8.1(b)	
	Details of transport mode and containers	To verify the use of appropriate equipment, facilities and operational procedures.	Reg. 16.7(2)(a)(i)	Sec. 3.8.1(b)	
	Numbers of employees involved	To verify the use of appropriate equipment, facilities and operational procedures.	Reg. 16.7(2)(a)(i)	Sec. 3.8.2(a)	
	Estimates of exposures and doses	To verify adequacy of monitoring program.	Reg. 16.7(2)(ii)	Sec. 3.8.1(b)	
	Amounts of radioactivity (per package & annual)	To verify the use of appropriate equipment, facilities and operational procedures.	Reg. 16.7(2)(a)(i)	Sec. 3.8.1(b)	
	Frequency and transport movements	To verify the use of appropriate equipment, facilities and operational procedures.	Reg. 16.7(2)(a)(i)	Sec. 3.8.1(b)	
	Transport routes	To verify the use of appropriate equipment, facilities and operational procedures.	Reg. 16.7(2)(a)(i)	Sec. 3.8.1(b)	
	Operational procedures	To verify the use of appropriate equipment, facilities and operational procedures.	Reg. 16.7(2)(a)(i)	Sec. 3.8.1(b)	
	Emergency procedures	To verify the use of appropriate equipment, facilities and operational procedures.	Reg. 16.7(2)(a)(i)	Sec. 2.7.2 (f)	
15	Radiation safety resources				

	Standard	Intent	MSIR Regulation [1]	Mining Code [11]	✓
	Lists of equipment and facilities	To verify use of appropriate equipment, facilities and operational procedures.	Reg. 16.7(2)(a)(i)	Sec. 2.7.2(c)	
	The name and qualifications of the RSO and list of people involved in monitoring	To verify use of appropriate equipment, facilities and operational procedures.	Reg. 16.7(2)(a)(i)	Sec. 2.7.2(a)	
16	List of commitments				
	Commitments clearly laid out	To verify that the responsible person will ensure the RMP is complied with.	Reg. 16.8(1)	Sec. 2.7.1	
17	Glossary				
	Lists of word meanings	To verify the meanings of the terms used in RMP	Reg. 16.7(2)(a)(i)	Sec. 2.3.4	

B. Appendix showing the Radionuclide decay series

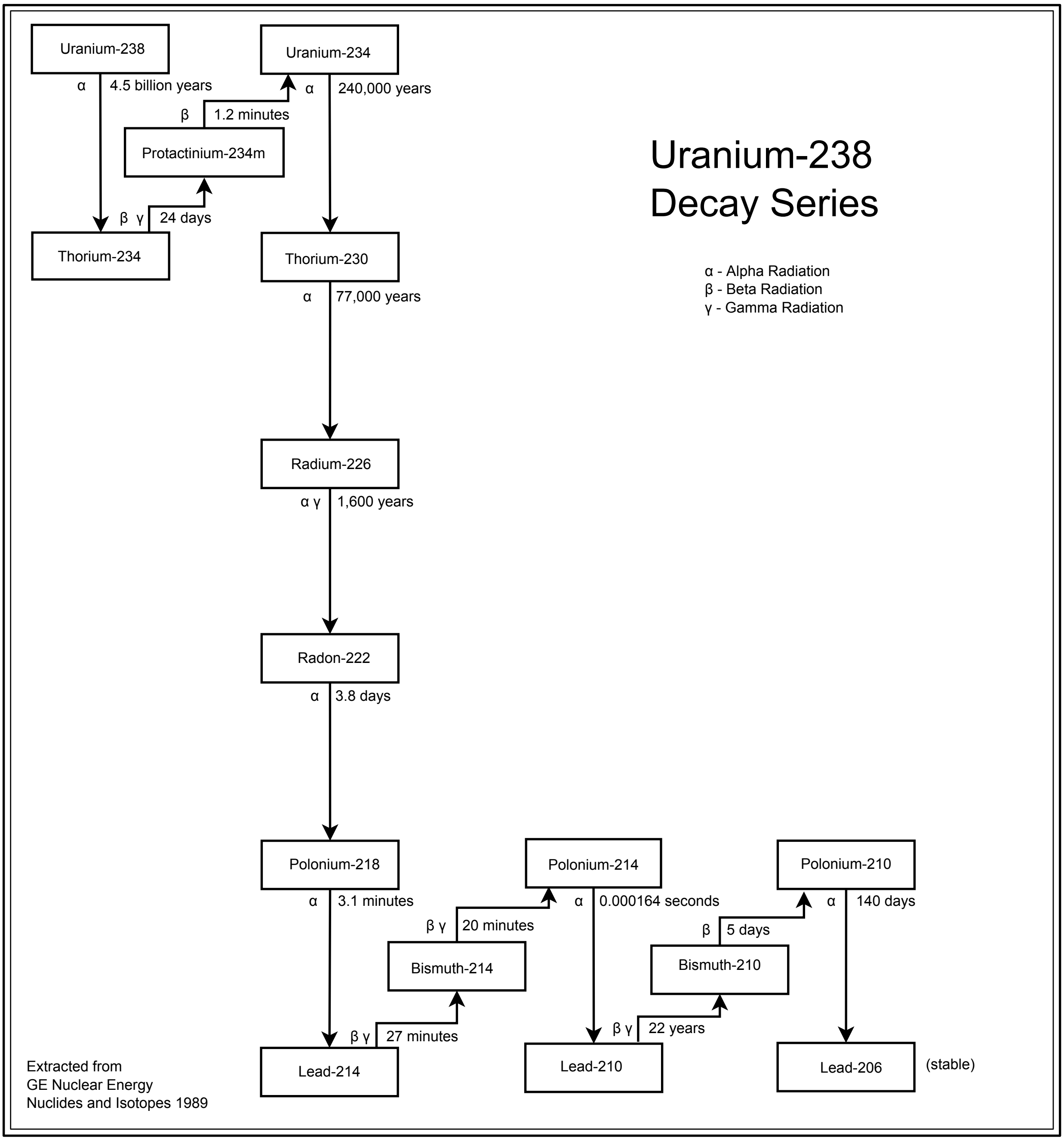
B.1. Thorium–232

Figure B.1: Thorium–232 decay series



B.2. Uranium–238

Figure B.2: Uranium–238 decay series



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