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

NORM–6

Reporting requirements

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

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MIAC

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1. General information

1.1. Purpose

To outline the minimum acceptable reporting requirements for statutory radiation reports to the Appropriate Authority.

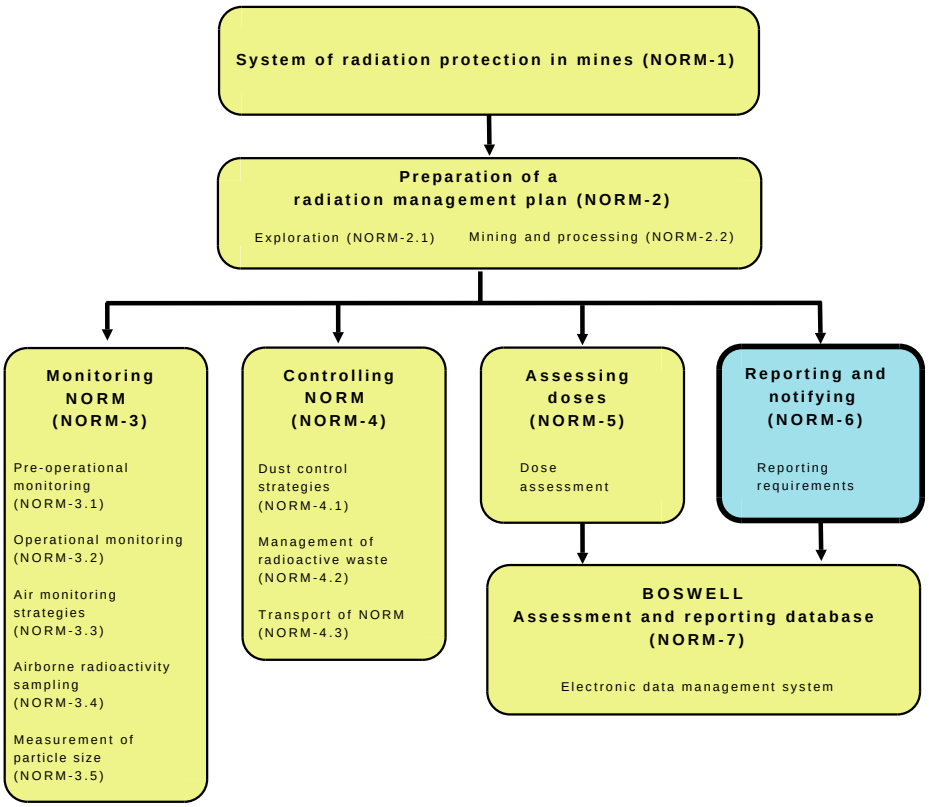
1.2. Scope

This guideline applies to all exploration, mining and mineral processing operations in Western Australia that use or handle 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

The mineral exploration sites, mines and processing plants in Western Australia that use or handle naturally occurring radioactive materials (NORM) come within the scope of Part 16 of the Mine Safety and Inspection Regulations 1995. Some processing plants are not classified as mining sites and are regulated by different legislation (e.g. *Radiation Safety Act 1975* and its Regulations). However, the Mines Safety and Inspection Regulations cover the disposal of waste material from these plants if this disposal occurs at a mining site.

MSIR Regulation 16.26 requires that the manager of a mine must report to the State Mining Engineer at regular intervals the:

- results of the monitoring program; and
- details of the operation of the radioactive waste management system as approved in the radiation management plan.

To address this requirement, two types of radiation monitoring programs are established:

1. occupational; and
2. environmental.

The occupational radiation monitoring program enables a company to determine the radiation doses received by the members of the workforce at a particular site. The data collected in this program typically includes:

- gamma radiation levels in selected site areas;
- personal exposure to external radiation (personal dosimeters/badges and area gamma radiation surveys);
- personal internal radiation exposure:
  - personal air sampling (and, if necessary, positional air sampling in selected areas), with subsequent analysis of collected dust for particle size and radioactivity content;
  - positional radon and/or thoron monitoring (where applicable personal monitoring may also be conducted); and
- drinking water radioactivity content (where applicable).

An annual occupational radiation monitoring report is prepared for each exploration or mining/processing site for the period 1 April to 31 March.

The environmental radiation monitoring program enables a company to estimate the impact of mining, processing and radioactive waste disposal activities at a particular site on the local environment, and to determine potential radiation exposures of members of the general public in the vicinity of a site. The data collected in this program typically includes:

- pre- and post-mining gamma radiation levels;
- gamma radiation levels at site boundaries and in selected site areas;

- assessment of airborne radioactivity (high volume dust sampling and levels of radon/thoron);
- assessment of waterborne radioactivity (sampling of ground and surface waters);
- assessment of radioactivity content in products and waste streams, their volume/amount and destination and disposal sites (for waste streams — MSIReg.16.32);
- assessment of radioactivity content in emissions from stacks (where applicable); and
- surface contamination assessments (where applicable).

An annual environmental radiation monitoring report is prepared for the period 1 October to 30 September.

Annual reports should be submitted within eight weeks after the end of each reporting period. In exceptional circumstances, the appropriate authority may grant an extension.

2.2. Report details

Reports should be prepared by a suitably qualified professional, typically an approved radiation safety officer (RSO), signed by the RSO and counter-signed by the Registered Manager. The reports should be in a manner that enables the assessment of all possible impacts arising from the use/handling of a particular NORM on employees, members of the public and the environment. The document should be clear to anyone with some background knowledge in radiation protection, as it could be distributed to other government agencies or may be made available for a member of the general public.

The statutory report should contain, for each radiation parameter listed in the radiation monitoring program, the following information:

Individual sample:

- equipment used, calibration records, the type, number, date and time of the measurement;
- name or another suitable identifier for a personal air sample; and
- sampling location for an area gamma radiation measurement and for a positional air sample.

A group of data:

- the range and the mean with estimates of accuracy and precision (such as, for example, a standard deviation);
- a suitably scaled map or plan with direction indicator;
- indications of trends in data, preferably in a graphical form;
- comparison of the obtained results with authorised limits and/or baseline values collected prior to the commencement of operations; and
- reference to the techniques or equipment used.

Each measurement must be undertaken using an agreed technique and appropriate monitoring equipment. Once approved these techniques do not need to be detailed in the reports. However, any changes in the techniques must be approved before being used as the basis of the reports.

2.3. Typical report formats

2.3.1. Occupational radiation monitoring report – suggested minimum contents

1. Table of contents
2. Executive summary
3. Introduction
4. Radioactive materials production figures
5. Workforce
6. Instrument and measurement techniques
7. Occupational monitoring results:
    a) external radiation exposure monitoring data
    b) internal radiation exposure monitoring data, including radon/thoron, water and surface contamination where applicable
    c) work categories
    d) annual dose assessments
    e) designated employees
    f) drinking water monitoring — where applicable
8. Area monitoring results
9. Radiation protection activities:
    a) dust control engineering
    b) respiratory protection
    c) radiation safety education
    d) supervised and controlled areas
    e) particle size analysis
    f) job rotations
    g) other changes
10. Conclusion
11. Monitoring program and list of designated employees for a subsequent year
12. 'Boswell' reports with tables and charts

Typically, the majority of data required for an annual occupational radiation monitoring report may be submitted electronically with the attached up-to-date 'Boswell' database data file (boswellData.mdb). For more information please refer to the Guideline NORM–7 Boswell – assessment and reporting database.

2.3.2. Environmental radiation monitoring report – suggested minimum contents

1. Table of contents
2. Executive summary
3. Introduction
4. Amounts/types of minerals mined, processed and transported
5. Radioactive waste generation statistics
6. Instrument and measurement techniques
7. Gamma radiation measurements:
    a) pre- and post-mining
    b) boundaries
    c) other areas
        i. Airborne radioactivity sampling (radon/thoron and high volume dust monitoring)
        ii. Waterborne radioactivity sampling
            A. ground and surface water
            B. process water discharges — where applicable
8. Stack monitoring
9. Waste management system – detailed data and maps/plans
10. Statistical data for radioactive material sold within Western Australia
11. Conclusion
12. Monitoring program for a subsequent year

Annual environmental radiation monitoring report may be submitted electronically with the copies of all certificates of analyses obtained from off-site laboratories.

Specific sections that may be required in the report are:

1. Summary: conclusions and comments on any unusual measurement, providing the reasons and contributing factors for it and any remedial action, if necessary.
2. Compliance with monitoring program: reasons for failing to meet agreed monitoring requirements.

2.4. Records management

Complete and accurate records of measurements made within a monitoring program must be kept up-to-date and be readily available (Mines Safety and Inspection Regulations, Regulation 16.25 [1]). In particular, personal radiation exposure data for all monitored employees should be available at any time and regularly updated. This should be facilitated by the use of a computer database (e.g. 'Boswell'). For more information please refer to the Guideline NORM–7 Boswell – assessment and reporting database.

A schedule of the type, location and frequency of radiation monitoring measurements forms an integral part of the approved site monitoring program. An annual report summarises the results obtained from this program, and additional information may be requested at a later date by an Appropriate Authority.

Therefore, accurate records or descriptions of the several parameters listed below must be maintained:

1. The method for the determination of employee exposure to external radiation (including the procedure of the assessment of an external dose for a period when a particular monitoring device was either lost of malfunctioned).
2. The type of gamma radiation surveys conducted, criteria for determining the location of the survey, number of readings to be taken, frequency of surveys and action levels.
3. The number of and category descriptions for employees whose exposure will be routinely monitored ('designated employees' list, where applicable).
4. Monitoring devices used, their range and sensitivity.
5. The type and number of radiation survey instruments, their sensitivity, range, calibration methods and latest calibration certificates.
6. The procedure followed in the determination of the intake of radioactive materials for designated and other employees (including the procedure for assessment of intake from special exposures).
7. The methods used to control the spread of radioactive materials from work areas, controlled and restricted area work rules, engineering controls, contents of training sessions and general radiation protection activities.
8. The details of the environmental radiation monitoring program, particularly the maps with all monitoring locations clearly marked.
9. Programs for the stabilisation of temporary stockpile areas and for the rehabilitation of tailings disposal areas.

It is also important that basic worksheets, together with any collected samples are kept for at least two years. Basic worksheets are the original field measurement sheets, containing the record of the raw data (as measured before any conversions or calculations – including the unit of measurement), date, time, instrument serial number, operator's name and other relevant information.

Record sheets that show the results of any necessary calculations carried out on the raw data are typically stored on a computer in a format compatible for data submission to the appropriate authority. These records, together with copies of all statutory reports, should be maintained on at least one computer storage system for at least the life of the exploration or mining/processing site and its subsequent decommissioning and closure.

2.5. Investigation and reporting levels

Typically, the numerical value of a monitoring result determines whether an investigation into the exposure is necessary. Investigation levels will vary with company and work category and should be based on levels, which are unusual for the category. For example, an unusual result may be one that is three standard deviations greater than the mean of the work category.

The investigation level for some gamma radiation surveys depends on a background radiation level that was established for a particular site during a baseline survey prior to the commencement of operations. In the absence of this value for historical reasons, an average background radiation levels in a particular area can be used as a reference.

Company 'in-house' investigation levels should be much less than derived limits or concentrations that are based on regulatory dose constraints or dose limits. It is suggested that these values are established at the levels that are 50–75% of the values in Table 2.1 on page 8.

Some mandatory investigation and reporting levels are detailed below. These investigation levels have been set to provide a threshold for formal investigative action in order to keep radiation exposures

as low as practicable. They are not limits and exceeding them should not necessarily be interpreted as a failure of protective measures.

However, when a radiometric or gravimetric result is found to exceed the relevant investigation level, action is required to be undertaken to investigate the cause; to take corrective measures if necessary and to record the findings. The circumstances of the excursion and the results of the investigation are to be reported as soon as reasonably practicable after the event is noted. Table 2.1 on the following page shows the investigation and reporting levels.

Table 2.1.: Investigation and reporting levels

Radiation parameter	Investigation level	Comment
1. Area gamma dose rate		
1.1 Site boundary	More than 0.11 μGy/hr above background	$>$ 1 mSv/year for a member of the public (8760 hours/year)
1.2 Supervised area	More than 0.50 μGy/hr above background	$>$ 1 mSv/year for an employee (2000 hours/year)
1.2 Controlled Area	More than 2.50 μGy/hr above background	$>$ 5 mSv/year for an employee (2000 hours/year)
1.3 Restricted	More than 7.50 μGy/hr above background	$>$ 15 mSv/year for an employee (2000 hours/year)
2. Personal external dose		
2.1 Designated worker	$>$ 2.5 mSv in a quarter	$>$ 10 mSv/year
2.2 Non-designated worker	$>$ 0.5 mSv in a quarter	$>$ 2 mSv/year
3. Personal internal dose		
3.1 Designated worker	$>$5 mSv in a quarter	Assessed from air sampling
4. Airborne radioactivity[a]		
4.1 Total alpha activity on the personal air sample – U dust	$>$ 9.9 Bq/m^3 for 12-hour shift sample	$\sim$ 0.5 mSv/shift
4.2 Total alpha activity on the personal air sample – Th dust	$>$ 4.3 Bq/m^3 for shift sample	$\sim$ 0.5 mSv/shift
4.3 Total alpha activity on the personal air sample – U dust	4 consecutive samples $>$ 2.4 Bq/m^3	Indicates potential for significant exposure
4.4 Total alpha activity on the personal air sample – Th dust	4 consecutive samples $>$1.0 Bq/m^3	Indicates potential for significant exposure
4.5 Total alpha activity	$>$ Mean + 3 std deviations	Indicates potentially unusual working conditions
4.6 Total alpha activity on environmental air sample - U dust	$>$ 2 mBq/m^3 on high volume air sampler	$>$ 100 μSv/year for a member of public continuously exposed. ($>$10% of exposure limit)

Radiation parameter	Investigation level	Comment
4.7 Total alpha activity on environmental air sample – Th dust	$>$ 1 mBq/m^3 on high volume air sampler	$>$ 100 μSv/year for a member of public continuously exposed. ($>$10% of exposure limit)
5. Airborne dust[b]		
5.1 Inhalable dust on personal air sample	$>$ 10 mg/m^3	Statutory limit for respirable dust concentration
5.2 Respirable dust on personal air sample	$>$ 3 mg/m^3	Statutory limit for respirable dust concentration
6. Radon/Thoron in air[c]		
6.1 Radon (^{222}Rn) in air – workplaces	$>$ 3.5 mJh/m^3	$>$ 5 mSv/year for an employee (2000 hours/year)
6.2 Thoron (^{220}Rn) in air – workplaces	$>$ 10.7 mJh/m^3	$>$ 5 mSv/year for an employee (2000 hours/year)
7. Radionuclides in water[d]		
7.1 ^{226}Ra in ground water or surface water	$>$ 0.5 Bq/L ^{226}Ra or 2 $\times$ average pre-operational levels for waters containing naturally high levels of radium	100 µSv/year for ingestion of 2 L/day for year.
7.1 ^{228}Ra in ground water or surface water	$>$ 0.2 Bq/L ^{228}Ra or 2 $\times$ average pre-operational levels for waters containing naturally high levels of radium	100 µSv/year for ingestion of 2 L/day for year.
8. Stack emissions		
8.1 Amount of thorium and/or emitted per day	$>$ 150 g/day	An operational control limit
9. Surface contamination[e]		
9.1 Low toxicity alpha emitters (^{238}U, ^{232}Th, ^{228}Th, ^{230}Th) on a surface	$>$0.4 Bq/cm^2	Averaged over 300 cm^2. Non-fixed — can be removed from surface during handling
9.2 Other alpha emitters (^{226}Ra, ^{224}Ra, ^{210}Po) on a surface [a]	$>$0.04 Bq/cm^2	Averaged over 300 cm^2. Non-fixed — can be removed from surface during handling

[a]The values detailed above are for uranium and thorium dust only; for levels associated with the dust where both thorium and uranium are present, please refer to the Guideline NORM-5 Dose assessment.

[b]Adjustments for 10-hour or 12-hour shifts are applicable to these values. Most dust in workplaces where radioactive

material is handled has the potential to contain other contaminants. The analysis technique for alpha activity in air requires that there be none or minimal self absorption of alpha particles in the sample. Depending on the volume of the sample, dust concentrations in excess of 5–10 mg/m^3 are likely to result in self-absorption problems.

[c]The ICRP recommend that exposure to radon should be excluded from their system of protection and treated separately, *"unless the relevant regulatory agency has ruled otherwise, either in a defined geographical area or for defined practices"*. Where employees work directly with radioactive materials, radon must be included in the system of radiation protection and as such, measurement of radon concentrations should be considered as a part of the approved monitoring program for the particular site.

[d]Some ground waters may have had elevated radium levels prior to the commencement of exploration, mining or mineral processing activities.

[e]Not all surface contamination is removable, some of the contamination is bonded to or embedded in the surface and may only be removed using chemical or physical means. In cases like this, the determination of the end use of the equipment as to what extent decontamination is required is carried out. If the equipment is leaving site (particularly if it is intended for the use in other industries or is being sold as scrap metal) a thorough decontamination is required to the limits specified in the table. If the equipment is being put in storage for future use on the same site, then only easily removable contamination could be removed, but the fact that the equipment is contaminated should be evident to any person needing to handle it; a tagging and log system should be invoked to warn individuals of contamination.

2.6. Notification requirements

Notifications are required to both employees and the appropriate authority.

Notifications to the appropriate authority can be classified into two broad categories:

1. Significant process engineering, structural or developmental changes to mining and/or processing operations.
2. Variations to agreed operational and/or administrative procedures affecting radiation protection on a site.

Notifications to employees are required when:

- a change in the process may increase employees' radiation exposure (either due to the technological cause, such as temporary reduction in the dust collection system capacity due to maintenance; or due to changes in the material processed at a plant, such as decrease in dust particle size and/or increase in radionuclides' concentrations in the material);
- significant changes are made to the site's radiation management plan, such as re-aligning supervised and controlled areas, or changes in monitoring programs directly affecting employees;
- a result of individual monitoring for a particular employee is in excess of specified limits and an investigation of causes of elevated result will need to be carried out; and
- a change occurs in the designated status of an employee.

Table 2.2 on the next page summarises the examples of information that would be typically required for specific notifications at sites using and/or handling NORM. A listing of operational changes that would not usually require a formal notification is provided in Section 2.7 on page 12.

Table 2.2.: Information required for specific notifications

Notification	Information required
1. New mine / plant development	Location Size and expected life of the mine Expected radioactive material content Pre-mining gamma radiation survey Baseline data for airborne and waterborne radioactivity
2. Cessation of operations	Location Radioactive waste disposal details Post-mining gamma radiation survey Post-mining data for airborne and waterborne radioactivity Summary of rehabilitation activities
Notes to notifications (1) and (2): • A public environmental report and registration/licensing (with the Radiological Council) matters should also be considered; • The appropriate authority should be notified approximately three months in advance in case a site visit and/or a comparison survey are required.	
3. Significant changes to the operations 3.1 Any major plant or circuit upgrade 3.2 Any major change to process routing involving radioactive streams 3.3 Changes to the ventilation system in underground mines that affects the radon/thoron and/or dust concentrations	A description of plant or circuit including throughput; radioactivity content of the feed material, products and waste generated – including liquid and gaseous effluents Ventilation engineering report (if required)
3.4 Any process equipment modifications involving a change from wet to dry mining and/or processing	A plan or outline of significance of the change (process equipment locations, controlled areas, offices/crib/control rooms)
3.5 Change in boundaries of supervised, controlled and restricted areas	A description of the management controls to be instituted (work rules, occupancy times, personnel protective measures, etc.) Engineering controls to be adopted to minimize radiation exposure (dust suppression, shielding barriers, automation of the process, etc.) Assessment of expected dose rates, airborne radioactivity concentrations and radiation exposure of employees Number of employees affected by the change Modifications to the radiation monitoring program as a result of the change

Notification	Information required
4. Radioactive material storage and/or handling changes	Structural changes Location (if changed) Changes to handling procedures and reasons for change
5. New site buildings in a vicinity of supervised, controlled and restricted areas (offices, workshops)	Location details Survey of current dose rates and airborne radioactivity levels Predicted radiation exposure Modifications to the radiation monitoring program as a result of the change
6. Designated employees	Listing
7. Radioactive material including surface contaminated objects – sales, burial/disposal	Quantity, purchaser, proposed use (only if sold within the State of Western Australia) Disposal location details Proposed remedial action (if necessary)
8. Radioactive materials transport (including surface contaminated objects)	Changes to the mode of transport, locations of temporary material storage areas or significant changes in the amount of the material or its radioactivity content Note: Approval to be sought from the Radiological Council of WA for any changes
9. Radiation protection safety instructions (significant changes only)	Summary of instructions and procedures and the reason for change
10. Release of airborne or waterborne radioactivity	Details of release Measures to prevent recurrence
11. Unusual situations and incidents	Causes Measures to prevent recurrence

2.7. Operational changes not requiring notifications

1. Day-to-day mine/plant operations.
2. Movement of process machinery that does not involve new construction or re-routing of radioactive product/tail streams.
3. Minor changes to ventilation.
4. Changes of mining schedule when notification of that mining has already been given.
5. Changes to radioactivity content of the mined/processed material unless particularly radioactive streams are encountered (short-term fluctuations excepted).

6. Changes to existing wet separation plants including changes in location (Radiation gauges excluded).

A. Appendix

A.1. Basic Principles for the reporting of data

There are three important points in reporting measurement data. The reported value of a measurement result must always:

- be unequivocal and properly dimensioned (i.e. the units must be clearly understood and suitable for the value);
- be expressed in an appropriate number of significant figures; and
- include an uncertainty statement (whose meaning is unambiguous).

A.1.1. Units

SI units must be used, with the most appropriate multiple or sub multiple (micro, kilo, mega, etc.) and results should be expressed using exponential notation where necessary. Recommended convention for radiation monitoring parameters is provided in Appendix A.3 on the next page.

A.1.2. Significant figures

Results should not be reported with excessive significant figures, such that they appear more precise than they actually are. The appropriate number of significant figures is determined by the magnitude of the total uncertainty associated with the value. The reported estimate of uncertainty should contain no more than two significant figures. The reported result itself should contain the same number of decimal places as the reported uncertainty.

For example if the result of water sampling is reported as 123.45 mBq/L for an activity concentration with an estimated total uncertainty of ±12% (i.e. ± 14.8 mBq/L), the result should be reported as: 123±15 mBq/L or $(1.23 \pm 0.15) \times 10^{-5}$ Bq/L.

A.1.3. Uncertainty estimates

Results that are not reported as below the lower limit of detection should include uncertainty or error estimates.

(a) Random errors are those that change each time a measurement is made. A typical random error is counting uncertainty. The overall standard deviation due to random error SR is obtained by adding in quadrature several separate standard deviations:

$$S_R = [S_a^2 + S_t^2 + S_s^2 + S_h^2 + S_p^2 + S_m^2]^{\frac{1}{2}}$$

where the suffixes denote:

R – total, a – space, t – time, s – sampling, h – sample handling, p - sample processing, m - measurement.

In practice several of these separate standard deviations will not be known and will have to be estimated.

(b) Systematic errors stay the same from measurement to measurement, an efficiency calibration error can serve as an example. Since systematic errors are usually an estimate of the upper error bound, they are taken to be 99% confidence, or three standard deviations. This must be allowed for when combining with random error standard deviations at 68% confidence.

(c) Total uncertainty (UT) is obtained by combining the random and systematic errors in quadrature:

$$U_T\,(1\sigma) = \left[S_{R^2} + \frac{1}{3}S_S^2\right]^{\frac{1}{2}}$$

where:

$S_s$is the total systematic error obtained by combining the individual systematic errors in quadrature.

Some uncertainty calculations (e.g. for an upper confidence level) are also built into the 'Boswell' database and there is usually no need to assess it manually.

A.2. Lower limit of detection

For the purposes of this guideline, the lower limit of detection (LLD) is defined as the smallest amount of the quantity being measured that has a 95% probability of being detected. For a measurement system where a background is subtracted from the measured value this is given by:

$$LLD = 4.65\sigma \left(= 2\sqrt{2} \times 1.64\right) \sigma$$

where:

σ is the standard deviation of the background of the detection system. Where possible the value of σ should be based on actual observed variance of the measurement technique rather than a theoretically predicted variance.

If an obtained result is less than the lower limit of the detection, the LLD value should be used in all calculations. Any reported results where the LLD is used should be marked "<LLD".

A.3. Recommended conventions for radiation monitoring parameters

Units for:

Activity concentration in solid samples – Bq/g.

Activity concentration in airborne particulate or gas samples – Bq/m^3 (or mBq/m^3).

Radon/thoron daughter concentrations in air – mJ/m^3 (the 'working level' unit WL equals 2.1x10^{-5} mJ/m^3).

Activity concentration in liquid samples – Bq/L. (or mBq/L).

Absorbed gamma dose rate in air – Gy/h (usually μGy/h).

Effective dose equivalent – Sv (usually mSv).

Time – second (s), minute (min), hour (hr), day, year.

A.4. Particle size characterisation report

If the particle size characterization monitoring is a part of the radiation monitoring program at a site a separate report may need to be submitted to the appropriate authority.

The default size of ore dust particles is 5 μm. If it is likely that the actual particle size at a particular size significantly differs from that value, a separate report detailing the assessments of the means of Activity Median Aerodynamic Diameter (AMAD) and Mass Median Aerodynamic Diameter (MMAD) during the reporting period is prepared. The purpose of this report is to establish the dose conversion factor, which is dependent upon the particle size prior to individual dose assessments in the annual occupational radiation monitoring report.

Suggested data presentation:

1. Introduction
2. Results, including table detailing calculated AMAD and MMAD values for each sample
3. Summary tables and charts comparing current and historical values
4. The copies of 'raw data' data entry and calculation sheets for each sample

A.5. Annual occupational radiation monitoring report: 'Boswell' requirements

'Boswell' is a Microsoft Access database administered by the DMP that stores radiation monitoring information from the mining and mineral processing industry, analyses it and creates reports.

Detailed information on data entry processing, reports and charts that can be generated is available in electronic documentation accompanying the database files. For more information please refer to the Guideline NORM–7 Boswell – assessment and reporting database.

The completed database forms a part of the annual occupational radiation monitoring report and the minimum list of tables and charts that should be generated is presented below:

1. Personal Dust
    a) Personal dust – rad / grav - by employee number
    b) Personal dust – rad / grav - by month & work category
    c) Personal dust – rad / grav - 5 years & work category
    d) Personal dust – rad / grav - statistics
2. Work Area
    a) Area dust - radiometric / gravimetric
    b) Area dust - rad / grav - by month & area
    c) Area dust - rad / grav - 5 years & area
    d) Area dust - rad/ grav - statistics
3. Personal dosimeter
    a) Personal dosimeter external exposure – by employee number
    b) Personal dosimeter external exposure – by work category

c) Personal dosimeter external exposure – 5 years & work category

d) Personal dosimeter external exposure – statistics

4. Effective Dose Equivalent (EDE)

a) EDE – by employee number

b) EDE – by work category

c) EDE – statistics by personnel dose

It is important that relevant information is entered into the database on a regular basis (at least monthly), particularly if the 'Boswell' database is used not only for reporting of the monitoring data but also for:

- calculations of dust and radioactivity concentrations;
- personal dose assessments; and
- observing trends or changes that may be promptly remedied.

Personal exposure to external gamma radiation (personal dosemeter) is entered directly from the laboratory certificate (where applicable, minimum detectable level value should be entered instead of zero). The working hours for each monitored employee are also directly entered from available information.

Data entry sequence for personal and positional dust monitoring data:

1. Gravimetric data entry

a) Employee's name and date of birth (or an area/location) entered;

b) Appropriate work category (or area/location) for the sample selected from a 'drop-list';

c) Monitoring equipment and cassette type are picked up from 'drop-lists';

d) Start and finish date/time for the sample entered; and

e) Filter weight prior to sampling and after the sampling entered.

2. Radiometric data entry

a) Details of alpha-counting equipment relevant calibration entered;

b) The particular alpha-counting equipment is picked up from a 'drop-list'; and

c) Date, number of obtained counts and time of counting entered.

3. Other data entry

If it is evident that the result of the monitoring is in excess of reportable values, an appropriate note (for example, the reference to a particular incident investigation number) is entered into the relevant section ('Notes').

If the value of dust specific activity (Bq/mg) is significantly different from the one typically obtained from a selected work category (location) an explanation would also be necessary.')

Trend analysis table and charts for radon and thoron concentrations in mJh//m^3should also be included, where applicable.

A.6. Annual environmental radiation monitoring report – data presentation

The size and character of the annual environmental radiation monitoring program differs from site to site and the following are the general suggestions on data presentation.

A.6.1. Site master plan(s)

These are essential in every report and give a general view of the site (in a form of an aerial photo or a map/plan) containing:

1. Location of mining, processing and waste disposal locations in the reporting period.
2. Location of all air monitoring locations, all ground water bores monitored in the reporting period and surface water monitoring points, and the location of all stacks on site.

A.6.2. Gamma radiation surveys

A.6.2.1. Pre and post-mining surveys:

1. A general plan highlighting all areas surveyed in the reporting period.
2. A separate map for each survey with numbers for each point.
3. The table with all results and a summary.

These surveys are typically carried out on a grid 50×50 or 100×100 metres with monitoring locations determined with the help of portable global positioning system (GPS) receiver.

A.6.2.2. Area surveys (temporary stockpiles, etc.):

These surveys are carried out to monitor possible spread of radioactive material into the environment. One of the ways in which the data can be clearly presented consists of:

1. A map of the area with monitoring points marked in even intervals as matrix.
2. A general table with all results and averages.
3. 3D charts or contour maps representing radiation levels.

A.6.2.3. Site boundary surveys:

1. A map of the site highlighting boundary and monitoring points (for example, 1–2–. . . –50).
2. When number of readings exceeds 100: a table of results for each 'monitoring line' (for example, 'line 14–15' — number of measurements, range, average and standard deviation), compared with results in the last several monitoring periods (a comparative summary table for results in the last 8–10 years may also be useful).
3. When number of readings is less than 100, the data may be placed directly on a map/plan.

A.6.3. Air monitoring

The monitoring is carried out using high volume (70–80 m^3/hr) dust sampler and reported data is typically as follows:

1. A table specifying results for each location in the reporting period and a comparison with the results obtained in previous years, containing: sample location, number, date, duration (hours), dust concentration (mg/m^3), dust activity (Bq/m^3).
2. Trend analysis table and charts for both mg/m^3 and Bq/m^3.
3. Trend analysis table and charts for radon and thoron concentrations in mJh/m^3, where applicable.

A.6.4. Water monitoring

The monitoring of both ground and surface waters in the reporting year could be summarized as follows:

1. A table specifying results for each location in the reporting period and a comparison with the results obtained in previous years, containing: location, sample date, radionuclide concentrations (^{226}Ra, ^{228}Ra and, if necessary, ^{228}Th), in Bq/L. The analysis for 'Gross α', 'Gross β' (including sampling for ^{40}K) is also sometimes carried out, but results obtained for individual radionuclides are considered to be more reliable.
2. Copies of all laboratory certificates for samples taken during the reporting period. The analyses should be carried out by a NATA certified laboratory (National Association of Testing Authorities — www.nata.asn.au).

A.6.5. Stack emissions

Where applicable, stack testing is carried out on a quarterly basis and results may be summarized in the report as follows:

1. A table specifying results for each location in the reporting period and a comparison with the results obtained in previous years, containing: sample number, sample date, particulate concentration (mg/m^3), U emission (g/day), Th emission (g/day).
2. Copies of all laboratory certificates for samples taken during the reporting period. The analyses should be carried out by a NATA certified laboratory.

Figure A.1.: Stack testing

A.6.6. Tailings and stockpile management

The record of the tailings disposal should be kept and results typically provided in the report are:

1. Detailed map (a supplement to site master plans) with all stockpiles and tailings locations marked, the depth of deposited tailings should also be provided.
2. Volumes (tonnages) and radionuclides' concentrations for the material deposited in the reporting period.

3. A table for each tails stream and product specifying radionuclides' concentrations on the monthly basis and a comparison with results obtained for the same streams in previous years.

In some cases only physical separation of minerals takes place (such as gravimetric, magnetic separation) and it is typically sufficient to analyse materials only for uranium and thorium concentrations. Much more often thermal and/or chemical treatments are used in the processing of NORM and it is expected that secular equilibrium of uranium and thorium decay chains will be disrupted. In these cases the analysis of the material for additional radionuclides is needed. This is done in addition to the typical analysis for uranium and thorium and concentrations of the following radionuclides need to be determined: ^{228}Ra, ^{228}Th, ^{212}Pb from the thorium decay chain and ^{230}Th, ^{226}Ra, ^{210}Pb from the uranium decay chain.

Bibliography

[1] Part 16 –Radiation Safety, Mines Safety & Inspection Regulations, 1995.

[2] *Mines Safety & Inspection Act, 1994.*

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