Australian Government

Australian Radiation Protection and Nuclear Safety Agency

arpansa

Monitoring and Assessment of Radiation in the Australian Environment

A Framework for the development and implementation of environmental monitoring and assessment programs to demonstrate protection of people and the environment

Acknowledgement of Country

The Australian Radiation Protection and Nuclear Safety Agency (ARPANSA) respectfully acknowledges Aboriginal and Torres Strait Islander peoples, communities and their rich cultures. We pay respects to all Elders past and present. We acknowledge Aboriginal and Torres Strait Islander peoples as Australia's First Peoples and the Traditional Owners and Custodians of the lands and waters where we live and work.

We also recognise and value the ongoing contribution of Aboriginal and Torres Strait Islander peoples and communities to Australian life and how this enriches us. We embrace the spirit of reconciliation, working towards the equality of outcomes and ensuring an equal voice.

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Foreword

Dr Rick Tinker

Branch Head and Chief Radiation Health Scientist, ARPANSA

ARPANSA has a **long history of providing environmental radiation protection services to the Australian community**. Over time, the focus of these services has continuously evolved to suit the changing needs of the community, including supporting the rehabilitation of nuclear weapons test sites, monitoring of imported foods following the Chernobyl and Fukushima nuclear power plant accidents, establishing and maintaining a national ultraviolet radiation (UVR) network and evaluation of potential health impacts from new technologies such as wi-fi and mobile phones.

The primary goal of ARPANSA's environmental monitoring and assessment activities is to ensure and demonstrate protection of people and the environment from the harmful effects of radiation.

ARPANSA's activities also support Australians to safely benefit from the positive medical, industrial and commercial uses of radiation, and contribute to meeting Australia's commitment to the United Nation's 2030 Agenda for Sustainable Development and the achievement of the Sustainable Development Goals (SDGs).

As a Commonwealth regulator and the Australian Government's primary authority on radiation protection and nuclear safety, ARPANSA has a unique opportunity to provide high-quality, independent information and advice to all Australians. As Australia faces a rapidly changing nuclear landscape it is timely to again ask ourselves the question, what benefit do our environmental monitoring and assessment services bring to the Australian community?

When reflecting on this question, we saw an opportunity to clarify and reaffirm ARPANSA's role, motivations and vision for environmental protection. The outcome of this reflection is the *Framework for Environmental Monitoring and Assessment*, presented in this report. This Framework brings together decades of practical experience in radiation protection and draws on national and international best practice in environmental protection to provide contemporary, overarching guidance for the monitoring and assessment of radiation in the Australian environment. The Framework provides guidance on establishing environmental programs with clear objectives driven by Community Values and expert judgement, and which consider a full lifecycle during the planning process. The Community Values for Environmental Monitoring and Assessment presented in this report were developed in line with environmental values identified by local and government organisations throughout Australia and were refined following public consultation. The Community Values are intended to help ensure that ARPANSA's monitoring and assessment activities are providing information and advice that is relevant and benefits the Australian community.

As our nuclear landscape continues to evolve, it is imperative that we continue to promote the importance of radiation protection for the environment and for all Australians. It is the responsibility of the radiation protection community to continue to build and maintain resilient, agile systems and processes for protection of people and the environment, to ensure ongoing demonstration of radiation protection for all future uses of radiation in Australia. This includes establishing enduring sovereign capabilities that guarantee effective stewardship and provide open and transparent information to the community. In a federated regulatory system, all jurisdictions play a vital role in achieving this goal.

ARPANSA is proud to take a leading role in promoting the uniformity of radiation protection and nuclear safety across all jurisdictions. This framework provides a significant reference to support consistent radiation protection through meaningful collaboration, generation and publication of high-quality information and a systematic approach to decision making that can be applied by all stakeholders and supports the development of enduring sovereign capabilities that underpin effective stewardship.

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About the authors

Julia Carpenter has more than 15 years' experience in environmental modelling, radiation risk assessment and risk characterisation. Her professional interests lie at the intersections of public and environmental health, and in identifying critical information to inform evidence-based decision-making to protect people and the environment. Her work focuses on evaluating the health impacts of radiation exposures to the public and the environment in planned, existing, and emergency exposure situations.

As the principal advisor for environmental protection at ARPANSA, Julia provides expert advice and guidance on all aspects of environmental radiation protection and offers strategic direction to ARPANSA's environmental monitoring, measurement and assessment programs. With qualifications in environment, physics and earth sciences, she plays a leading role in advancing radiation protection in Australia. Throughout her time at ARPANSA, Julia has also contributed to environmental assessments, code development, regulatory guidance, and health advisory activities. She has represented Australia at the International Atomic Energy Agency Waste Safety Standards Committee and the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management, and is a member of a range of national and international committees including International Commission of Radiological Protection task groups and the Alligator Rivers Region Technical Committee.

Dr Adrian Hawley is a scientist and project management professional with over a decade of experience in government research. Adrian completed his PhD in Chemistry at the University of Bath, UK, where he developed materials for use in solar cell technology before returning to Australia to conduct research and deliver major projects at the Australian Nuclear Science and Technology Organisation's Australian Synchrotron. He combines technical expertise with strategic planning and stakeholder communication skills.

In 2020, he was recognised as part of the team awarded the ANSTO Eureka Prize for Innovative Use of Technology for his work with Monash University pharmaceutical scientists investigating effective drug formulation for malaria treatment.

Since joining ARPANSA, Adrian has applied his expertise in making complex concepts accessible to both academic and public audiences, through contributions to advisory committee engagement and environmental protection research. In addition to his professional experience, Adrian enjoys cooperative strategy board games and volunteering in his community.

Introduction

Australians are exposed to radiation from a variety of natural and artificial sources every day. Natural radioactivity is present in the air we breathe, food we eat, water we drink and even in our bodies. We are also exposed to natural radiation that comes from outer space and passes through the atmosphere of the planet.

Artificial, or man-made, radiation is also found in the environment, typically from controlled discharges by medical and industrial facilities, which are regulated by the relevant jurisdiction, as well as fallout from historical nuclear weapons testing, legacy sites from past practices, and discharges from accidents around the world.

Ongoing protection of natural ecosystems and the services they provide is essential for sustainable development, community wellbeing and economic prosperity. Radiation exposure can impact across jurisdictions, which is why we need a cohesive and collaborative approach from all stakeholders to manage risk and to ensure uniformity in radiation protection outcomes across Australia. The Framework presented here is intended to support the implementation of best-practice environmental monitoring and assessment programs across the country, that encourage greater knowledge sharing, collaborative use of resources, and reduce the likelihood of exposure events while protecting ecosystems and human health.

As the Australian Government's primary authority on radiation protection, the Australian Radiation Protection and Nuclear Safety Agency (ARPANSA) is responsible for protecting people and the environment from the harmful effects of radiation. High-quality environmental monitoring and assessment programs are key to understanding and communicating how radiation is distributed in the environment, the impacts of human activities on environmental radioactivity, and to demonstrate protection of people and the environment.

Section 1 of this report presents a comprehensive framework for the development, implementation and communication of environmental radiation monitoring and assessment activities. The Framework provides guidance on establishing environmental programs with clear objectives driven by Community Values and expert judgement, and which consider the full lifecycle of a program during the planning process.

Section 2 discusses how ARPANSA implements this Framework for environmental monitoring and assessment activities. Several case studies are included to give a better understanding of how ARPANSA applies the Framework in practice, and to demonstrate the links between community values, objectives, indicators, activities and reporting.

Section 1

Framework for Environmental Monitoring and Assessment

Australia's system for managing radiation risks from ionising and non-ionising radiation is closely aligned with international best practice as laid out in the recommendations of the International Commission on Radiological Protection (ICRP), the International Atomic Energy Agency's (IAEA) Safety and Security Series and Codes of Conduct, the International Commission on Non-Ionizing Radiation Protection (ICNIRP) standards, the World Health Organization (WHO) standards and guidance, and in relevant conventions to which Australia is a party.

This section presents a framework for the development, implementation and communication of environmental monitoring and assessment activities that is aligned with international best practice and promotes:

- the use of Community Values to drive and design environmental monitoring and assessment activities
- structured decision making
- clear justification for all proposed work programs
- effective engagement and collaboration with stakeholders
- appropriate documentation and quality management
- considered use of resources
- scientific integrity.

A central feature of this approach is the use of Community Values to provide focus and clarity to objectives, and to guide decision making regarding reporting indicators and monitoring and assessment activities. This approach is applicable to both ongoing programs of work that continue for many years, and non-ongoing projects that are discrete work packages designed to answer a specific question, to fill an information gap or to address specific legislative requirements or obligations.

Scope of the Framework

This report establishes a framework for the development, implementation and communication of environmental monitoring and assessment activities, including measurement, analysis, modelling and risk assessment. The Framework applies to ionising and non-ionising radiation exposures to people and the environment from natural and artificial sources.

Recognising that humans live within a broader ecosystem, these monitoring and assessment activities serve to protect both people and the environment by measuring and assessing the ways in which radiation moves through the environment (transport pathways) and identifying exposure pathways for people, plants and animals. Results from measurement, monitoring, and modelling inform radiation risk assessments, which are undertaken in line with the general environmental health risk assessment and risk management methodology. These are described in more detail in Appendix 1, along with the Commonwealth Guidelines for assessing human health risks from environmental hazards (enHealth 2012).

Due to the inherent variability in radiation sources, exposure pathways, management objectives and stakeholder expectations, the Framework is not designed to be overly prescriptive. Rather, it provides a structured approach for decision making and encourages risk-informed prioritisation of resources and effort.

It is also important to recognise and acknowledge that in many cases an activity or practice may present multiple hazards. In such cases an integrated, all-hazards approach to protection may be warranted, with radiation protection considered within a wider management plan.

Community Values for Environmental Monitoring and Assessment

This Framework acknowledges the importance of environmental stewardship; our collective responsibility to care for and protect the environment for future generations. To put this concept into practice, a set of Community Values for Environmental Monitoring and Assessment have been developed in line with environmental values identified by local and government organisations throughout Australia. ARPANSA presented these values for public consultation and refined them to incorporate feedback received. They are now used to guide the design of environmental monitoring and assessment activities, and to ensure these activities are aligned with protecting the ways in which Australians interact with, benefit from, and value the environment. The Community Values should be considered holistically as there are many synergies and overlaps between the Values. There will be times when a monitoring or assessment activity aligns with multiple Values, and times when only one may apply.

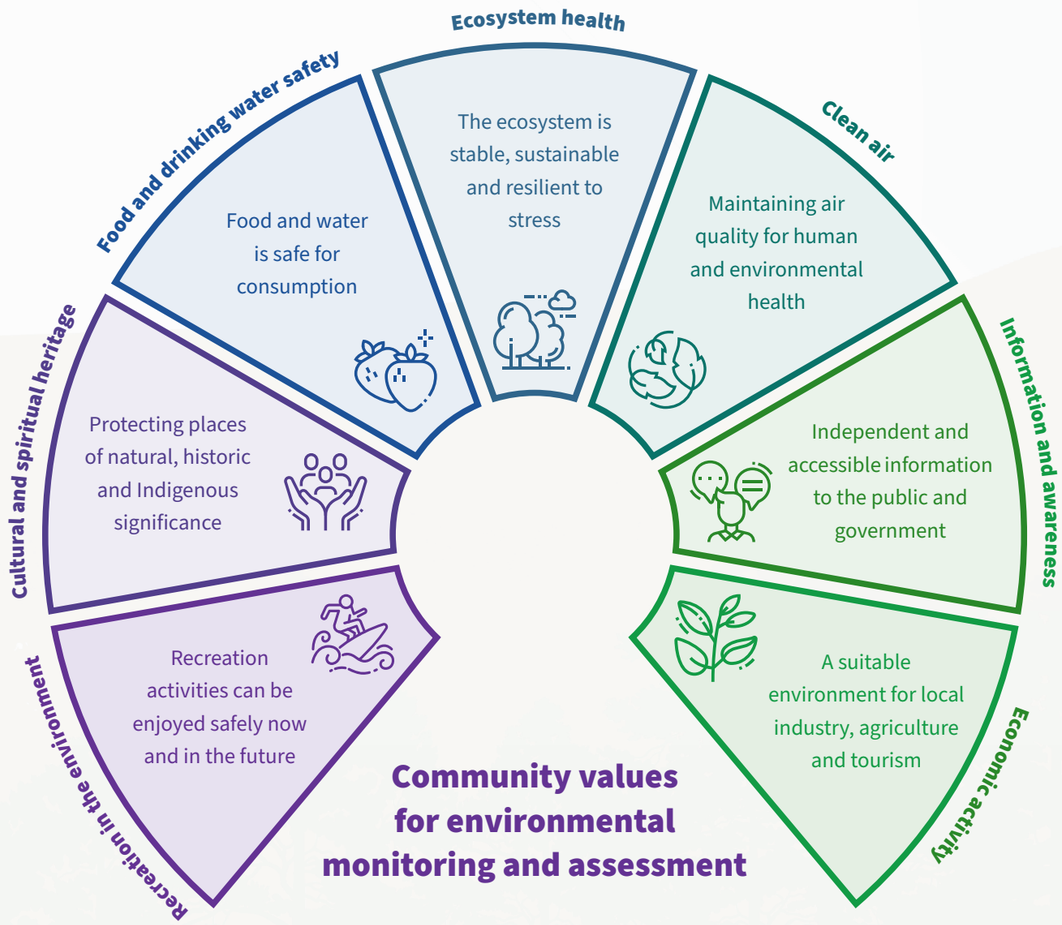

Figure 1: Community Values for Environmental Monitoring and Assessment recognised in the Framework

Ecosystem health

A healthy ecosystem is one that is stable and sustainable over time and resilient to stress.

All living species are exposed to natural radiation in the environment. While there is global variation in the level of background radiation exposure, all ecosystems have always been, and always will be, exposed to radiation. Understanding the levels and variability of natural radioactivity in soil, water and biota, as well as the ways in which these radionuclides move through and interact with the environment, is necessary to establish a baseline against which the impacts of additional radiation exposure due to human activities can be measured and evaluated. Comparing radiation exposure to flora and fauna with internationally recognised reference levels is a key indicator for assessing the potential impact of radiation exposure on populations of plants and animals in their natural habitats.

Food and drinking water safety

Safe food and drinking water supplies are essential for health and sustainable development.[1]

Food and drinking water may contain radionuclides from both natural and man-made sources. For foods, this may be due to uptake of radionuclides from soil and water, and direct deposition from the atmosphere. For drinking water, radionuclides can be absorbed as the water passes over or through rocks and soil. In most situations anthropogenic radiation is only present in small amounts (IAEA n.d.).

Levels of radioactivity in food and drinking water are rarely a health concern in Australia, and food and drinking water can be monitored to confirm safety. Australian and international organisations have established evidence-based guidelines to protect people from contaminated foods and drinking water and to ensure that consumers can be confident that food and drinking water supplies are safe. Targeted monitoring and assessment programs help mitigate potential risks to Australian food and drinking water supplies and provide ongoing assurance of safety.

Clean air

Good air quality is essential for human health and wellbeing.

The links between population exposure to poor air quality and adverse health effects are well established (CES 2023). Inhalation and inadvertent ingestion of dust and other particles can potentially lead to an increase in internal exposure to ionising radiation, as can inhalation of radon, a naturally occurring radioactive gas that can accumulate indoors and in confined underground spaces, such as caves or mines. Air quality can also be impacted in the short term during or following an emergency situation or other contamination event, when atmospheric transport of radioactive particles and gases can be a primary pathway for spreading radioactive material leading to potential internal and external exposures.

Cultural and spiritual heritage

'Heritage includes places, values, traditions, events and experiences that capture where we've come from, where we are now and gives context to where we are headed as a community.'[2]

In the context of environmental radiation protection, stewardship of heritage means protecting natural, historic, and Indigenous places of significance so that they can be experienced and enjoyed by current and future generations. The importance of heritage should be considered holistically in environmental protection. This could mean identifying and prioritising sites of significance for environmental monitoring, ensuring appropriate land use scenarios are included in risk assessments and considering impacts and responsibilities that may be placed on future generations.

[1] World Health Organization 2024

[2] DCCEEW 2023

Information and awareness

Providing independent, meaningful and accessible information and advice to the public and Government.

There is a strong desire from the public for independent, transparent and accurate information about current situations and trends over time. The provision of accessible, evidence-based environmental data has many benefits, including:

- supporting individuals to understand radiation risks and make informed decisions about their actions. For example, providing real-time, location-specific information about the UV index supports individuals to take preventative actions, such as wearing sunscreen and a hat when the risk is higher
- enhancing awareness of normal background exposures to ionising and non-ionising radiation, which provides context to measurement, monitoring, and assessment results and supports genuine and effective stakeholder engagement
- providing opportunities for education and risk communication, which builds the capability and capacity of stakeholders to respond to environmental challenges.

Recreation in the environment

'Being active outdoors offers immense physical and mental benefits from early childhood development through to adolescence and into our adult lives'[3]

Being able to safely access and enjoy the natural environment supports and promotes health and wellbeing. The environment also provides the essential components required for many popular recreational activities, such as camping, fishing, swimming and hiking. Considering recreational land use scenarios during radiation risk assessments and assessing against radiological guideline values appropriate for these scenarios supports the ongoing availability of the environment for recreation and enjoyment.

Economic activity

Many industries, such as agriculture, aquiculture, and tourism benefit from a clean and safe environment in which to operate.

Economies are intrinsically linked to the natural environment. This interaction is complex, with different sectors of an economy delivering and receiving different environmental costs and benefits. In the context of this Framework, this community value represents the importance of ensuring that exposure to radiation does not negatively impact the many industries, businesses and organisations that support sustainable communities. Consideration of commercial activities during radiation risk assessment may indicate the need for targeted monitoring activities such as measurement of radon levels in tourist caves and testing of food and water. Programs such as these help to address public concerns and provide confidence to local industries and activities, particularly where there may be real or perceived risks to the health and wellbeing of workers or consumers.

[3] Department of Local Government, Sport and Cultural Industries 2021

Stakeholder engagement

Stakeholders for environmental monitoring and assessment are groups and individuals that directly or indirectly use, derive benefit from, or have an impact on the environment of interest. This includes those who have concerns about or interests in an activity that is proposed or already taking place in that environment. Possible stakeholders include Commonwealth, state and local governments, regulators, operators, First Nations groups, industry representatives, community groups, and members of the public.

Stakeholders are an asset who will contribute knowledge to the planning and decision-making processes. Where appropriate, stakeholders should be mapped, and engagement planned, as part of the planning process. Stakeholders and their level of involvement will vary at different stages of program development and implementation, and will also vary between different programs and projects.

It is important to consider not only the outcomes of stakeholder engagement but also the processes and procedural values adopted during the engagement. An effective engagement process that prioritises accountability, transparency and inclusiveness should provide stakeholders with clear, relevant and timely information that allows them to effectively participate in the decision-making process.

Justification and prioritisation

Making informed decisions about which proposed monitoring and assessment activities to pursue is critical to ensure effective and efficient use of limited resources. Prioritisation of proposed activities is required and should consider:

- the issue that needs to be addressed, objectives of the program, and whether the proposed activities can provide the information needed to meet the objectives
- how the proposed program aligns with the Community Values for monitoring and assessment
- the potential risks to people and the environment and how the proposed program contributes to managing and/or mitigating these risks
- the current level of understanding, including whether existing data is adequate and the level of uncertainty in existing knowledge
- stakeholder interest and sensitivities, including concerns raised, or expected to be raised, by government and the public regarding exposure to radiation, and consideration of domestic and international experience of public interest or concerns in similar situations
- any current protection measures, including standards, recommendations or guides, and exposure mitigation practices
- any legislative requirements for the program or associated with the program.

With competing demands and finite resources, it is rarely possible to resource and support all proposed monitoring and assessment programs. To optimise the benefits from environmental monitoring and assessment, prioritisation of proposed programs should include consideration of the likelihood of the programs delivering their stated objectives. Even if considered a high priority, an activity should not commence if the information it will provide is insufficient to meaningfully address the objective, or if the activity cannot be sufficiently resourced to deliver its objectives. In these cases, alternative solutions should be considered to ensure that protection of people and the environment can be maintained.

Solutions may include:

- selecting alternate monitoring and assessment activities
- undertaking desktop assessment
- redistributing resources
- establishing partnerships with external organisations
- considering alternate funding opportunities.

Radiation risk assessment

Radiation risk assessment is a process of evaluating the potential impact of a radiation hazard on people and the environment.

A radiation risk assessment may be needed for situations where there is a plausible possibility of harm to people or the environment from a radiation source or nuclear activity. The assessment should follow a graded approach; it should be as simple as possible but as complex as necessary. This supports the efficient and effective use of resources and is consistent with best practice when considering the design of an environmental monitoring program for radiation protection.

In some cases, it is appropriate for a desktop assessment to be undertaken using existing data and modelling software of varying complexity. In other cases, new monitoring or analysis may be required to inform the assessment. In all cases, assumptions will need to be made. It is very important to clearly document and explain these assumptions so that decision makers and stakeholders, including the public, can interpret the results accurately and have a record for future reference.

The key steps in a radiation risk assessment are shown in Figure 2. An important outcome of this process is a clear understanding of the possible radiation source/s, the way in which these sources move through the environment, and the pathways by which people and the environment could be exposed to the hazard. This understanding is critical to inform decisions about the justification for, and design of, potential monitoring programs. This process also highlights where there are gaps in data or understanding that may indicate a need for additional measurement or assessment activities.

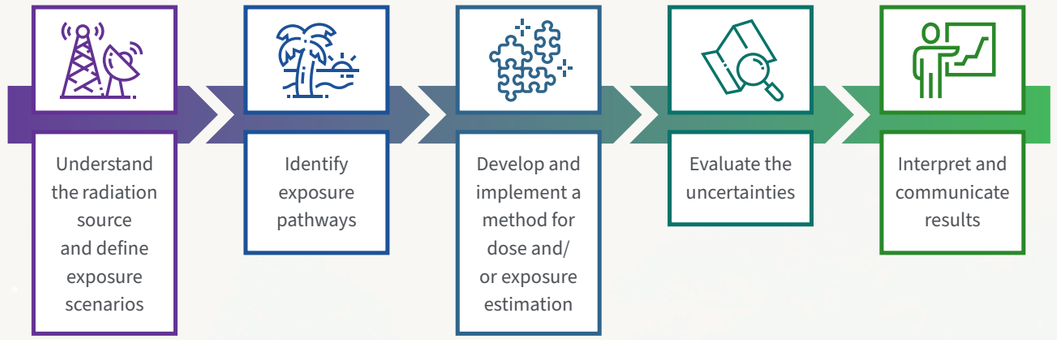

Figure 2: Steps to undertake a radiation risk assessment

Developing a monitoring program or project

Measuring radiation levels in the environment provides valuable information and evidence that supports:

- understanding the level of natural background radiation exposure in Australia and establishing a baseline against which changes can be assessed
- identification of any changes in environmental radiation levels and exposure
- decision making regarding management options
- validation and refinement of environmental modelling
- provision of information, advice and assurance to stakeholders, including the community and government.

A key measure of the success of radiation measurement and monitoring programs is the ability to provide information and evidence that supports these activities.

The recommended process for designing and implementing environmental radiation monitoring programs is shown in Figure 3. This is not intended to be a prescriptive process as monitoring programs are typically developed, implemented and reviewed in an iterative process that enables ongoing improvement and refinement. This means that the time spent at each step will vary depending on the scope of the program or project and the resources that are available, and that the process will not always be implemented in a linear manner. Additional information on each step is provided on the following pages.

Figure 3: Iterative process for the design, implementation and review of environmental monitoring programs, which may include measurement, analysis and risk assessment activities

Step 1: Define the issue

The first step in establishing a monitoring or assessment program is to identify the purpose of the program. A clear statement defining the problem, question or issue to be addressed provides clarity and focus for development, implementation and reporting throughout the program.

Step 2: Examine current knowledge and understanding

This step involves gathering and examining existing knowledge and understanding of the site or issue to inform planning, prioritisation and decision making in future stages. An assessment of the adequacy, appropriateness, and completeness of current data and information is necessary to identify knowledge gaps that may impact the scope and design of the proposed monitoring or assessment program.

Assessment of the current knowledge and understanding could consider information such as:

- key drivers for the program, such as legislation, regulatory requirements, government requests, stakeholder concerns, known or potential contamination, planned activities
- any previous radiation risk assessments that may have been completed (see Appendix 1 for more detail)
- source terms for any existing or planned activities, including co-located sources and activities
- sources of non-ionising radiation exposure
- environmental transport and exposure pathways
- biogeochemical interactions of radionuclides in the environment
- key environmental sites or ecosystem receptors of particular sensitivity or interest
- radiological baseline and background variability
- local habits and land use
- local climate, weather, including natural disasters, seasonal conditions and variability over time.

Information sources may include, but are not limited to, previous and current measurement or assessment activities in the region, published literature, local knowledge (including state and local governments, community groups, indigenous communities, members of the public), content of licence applications and management plans and operator experiences.

Step 3: Review Community Values and define objectives

This step is about understanding and clearly articulating the objectives of the environmental monitoring and/or assessment program.

Designing a monitoring program that aligns with the Community Values explicitly recognises and acknowledges the benefits humans derive from healthy ecosystems and ensures a direct link between monitoring activities and the ecosystem services that we endeavour to monitor and protect.

Additionally, a clear statement of the objective of both the overall program and each component or individual monitoring activity is essential to provide clarity and focus to the program. The objective should be specific, measurable and should reflect the desired outcome of the monitoring or assessment program. In many cases the objective will be directly linked to a public health outcome or an environmental management goal. Monitoring activities should provide data to verify and assess progress towards the objective.

The objectives of an environmental program or project are informed by:

- the information gathered in Steps 1 and 2
- Community Values for Environmental Monitoring and Assessment
- understanding the interests and/or concerns of stakeholders
- management goals: what is the desired level of protection?

Understanding the interests and concerns of stakeholders is critical to defining both the relevant Community Values and objectives that meet the needs of all stakeholders. In some cases, the primary objective of the program will be to provide information for stakeholders, whether that is to provide independent data for public assurance, to provide information to enable informed decision making or to support evidence-based advice.

Step 4: Establish reporting indicators

Collecting data through measurement, monitoring, and assessment activities generates a significant volume of information that can be complex to understand and communicate. Indicators summarise and give context to this information and aid communication of key health messages by providing clear, comparable and actionable information to support decision making. Consistency in indicators over time and location also contributes to the goal of providing an equivalent level of health protection for people and the environment across all Australian jurisdictions.

In the context of this Framework, indicators may be linked to health outcomes for people and the environment or to the performance of networks, such as down time, reporting timeframes, or data availability. Where possible, indicators should be linked to evidence-based standards and guidance appropriate for Australian conditions, such as the ARPANSA Radiation Protection Series (RPS) series (ARPANSA n.d.), Australian Drinking Water Guidelines (NHMRC 2011), public exposure limits and other applicable or relevant legislation or standards. However, there will be situations where expert judgment is required to develop an appropriate indicator.

While it is important for the overarching indicators to be consistent, the data and evidence that is used to make an assessment against these indicators can and should vary across locations to reflect site-specific conditions and concerns. Where available, multiple lines of evidence can be used to inform assessment against indicators. Each of these lines of evidence provides information that is often more granular than, and gives context to, the higher-level indicator. This evidence can also be used to help understand any trends or variations in the indicators over time.

Step 5: Determine appropriate measurement, monitoring, and assessment activities

A key measure of the success of the program is its ability to generate evidence that can be used to inform advice and support decision making. Measurement, monitoring, and assessment activities should be designed to produce data that progress the objectives and management goals identified in Step 3, and report against the indicators established in Step 4.

A clear plan should be produced identifying each measurement or assessment type in the program and the critical information associated with the measurement. Information should include (where appropriate):

- measurement or assessment type
- method and techniques, such as Standard Operating Procedures (SOPs) or International Organization for Standardization (ISO) standards, if available
- details on sampling design if applicable, for example, locations, number of samples, frequency, factors considered in design.

It is also important to consider other related monitoring or assessment programs and to look for opportunities for harmonisation of approaches. Technical factors that may be considered in the design of monitoring programs are provided in Appendix 2, with a focus on considerations for sampling and analysis.

It is likely that trade-offs will need to be made during program development. A record of key decisions and the factors that were considered should be kept to support ongoing review and optimisation of measurement, monitoring, and assessment activities. This also supports efficient development of similar programs in the future.

Step 6: Establish guidelines for reporting

Measurement and reporting guidelines should be established for each indicator. Efforts should be made to promote consistency in reporting, however it is recognised that the data and information used to provide evidence against each indicator will vary between programs. While existing limits and levels should be considered, it is not always feasible or useful to produce generic minimum detection limits and notification levels for use across all measurement and monitoring programs.

Each program should clearly establish key measurement and reporting criteria. These may include:

- minimum detectable levels/activities
- minimum reportable levels/activities
- how a ‘not detected’ value will be treated in data analysis and reporting
- ‘screening levels’, defined as the criteria that will be used to trigger consideration of an investigation into unusual or high detections
- ‘action criteria’ and an explanation of what actions will be taken if these criteria are met.

Planning how to communicate results should begin before a monitoring program is implemented, including planning for resource requirements for reporting from the program. This may be in the form of a reporting strategy that addresses:

- the appropriate method of reporting, such as online, journal, annual report, and report card
- timing and frequency of reporting
- expectations for required format, length and level of detail
- data management, security and record keeping
- data presentation, with a focus on clarity and providing useful and meaningful information to stakeholders
- a communication strategy.

It is important to consider the objectives of the program and the needs of stakeholders when developing the reporting strategy. Results should be reported as soon as practicable unless the agreed reporting timeframes indicate otherwise.

Different approaches to presentation of results should be considered to ensure that the needs of the target audiences are met. In general, it should not be assumed readers have a strong background in radiation concepts and information should be presented in a manner that is accessible and readily understood. However, information and data should also be made available at a more detailed level for peer-review and for those who wish to engage with the information in greater depth. This may be achieved by facilitating and promoting access to more detailed information and results.

Once measurement guidelines and reporting plans have been established, it should be confirmed that these plans will meet the objectives of the environmental program or project previously defined at Step 3. Any gaps, misalignment, or opportunities for improvement can be used to refine the environmental program or project as part of the ongoing iterative review.

Step 7: Implement program

Implementation will vary considerably between each project and program. However, the following factors should be considered where relevant:

Project management and documentation

- An individual project plan or equivalent document should be developed prior to commencement of the program, which includes clear information on the justification for the program and indicators.
- Ongoing internal review within the program to ensure quality requirements are met and to support ongoing improvement of the program, especially during the initial implementation of an ongoing program where new information may support refinement of the program.
- Ongoing project management proportional to the scale of the project, which includes progress tracking, risk management and issue resolution.

Sampling, measurement and data collection

- Sampling, measurement and data collection should not begin until methods have been agreed and clearly documented.
- Sampling and measurement should be undertaken in compliance with standards and procedures relevant to the sampling being undertaken. A review of the applicable standards should form part of the development of an environmental monitoring program or project.
- All staff undertaking sample collection and analysis should be appropriately trained in the relevant methods.
- The safety of workers undertaking sampling, measurements, and assessments should be considered in all phases of the project. Work health and safety (WHS) planning should follow established safety frameworks, plans and procedures, including undertaking safety assessments during the design and implementation stages of environmental activities and looking for opportunities for continuous improvement.

Interpret data and report results

- Results should be reviewed by appropriately trained staff and should meet all quality requirements before being reported.
- Results should be reported as soon as practicable unless the agreed reporting timeframes indicate otherwise. Consideration should be given to any explanatory information to be provided alongside results to aid interpretation and understanding.
- Appropriate consideration should be given to where results are to be reported, for example, online real time, peer reviewed scientific journals and technical reports.
- Public reporting and public release of data are particularly important to consider where program objectives include public interest, transparency and accountability.

Step 8: Review, evaluate and refine

A review of program and project performance is essential to achieve continual improvement and to adapt to changes in priorities, methods, technology and stakeholder needs. It is important to ensure that strengths and weaknesses are formally evaluated, either at the end of the program or at a pre-defined time period, and that findings are shared and considered in other projects and programs.

Ongoing review and evaluation may consider:

- Does the program deliver information that meets the program objectives?
- What do key stakeholders think of the program? Does it meet their needs?
- Does the data obtained support reporting against indicators?
- Is the program efficient and effective?
- Does the program remain a priority?
- Is there a need to continue the current program or does it need to be modified or closed?
- What has been done well?
- What lessons have been learned and what are the opportunities for improvement?

For fixed-term projects, the review provides an objective assessment of the performance of the project itself and provides valuable information to improve the development of future programs and projects.

For ongoing environmental programs, periodic review and assessment is important to support the development of effective future programs and projects and the ongoing refinement of the program. This assists with keeping monitoring programs aligned with their objectives, so that the work continues to support the protection of the Australian people and environment from the harmful effects of radiation.

Quality management

Quality management principles should be implemented throughout the development and implementation of any environmental monitoring or assessment program. This provides confidence in the validity of the measurement and analysis results and supports consistency between different monitoring and assessment activities.

Quality management in environmental measurement and monitoring includes:

- competency of the person collecting samples or making the measurement
- selection of appropriate equipment and techniques for the measurement
- appropriate calibration of equipment
- clear and consistent labelling of samples collected and adherence to chain of custody protocols to prevent loss, contamination or tampering
- secure recording of results and data storage
- recording of the methods and assumptions used in the sampling and measurements, and any deviations from the specified procedures
- backing up of documentation and results.

Quality management should be consistent with ISO 9001 standards (ISO 2015). Quality planning should include work being performed by an ISO 17025 (ISO/IEC 2017) accredited laboratory or a comparable system of assurance. Sampling and measurement should be undertaken in compliance with standards and procedures relevant to the sampling being undertaken and a review of which standards or procedures apply should form part of the design process for environmental programs and projects.

The person conducting the sampling, measurement, or assessment should have appropriate training in quality management and is responsible for complying with relevant standards.

Section 2

Applying the Framework at ARPANSA

ARPANSA is the Australian Government's primary authority on radiation protection and nuclear safety. The objective of the *Australian Radiation Protection and Nuclear Safety Act* (ARPANS Act) is to 'protect the health and safety of people, and to protect the environment, from the harmful effects of radiation'.

ARPANSA's environmental radiation monitoring and assessment programs directly support this objective by producing data and information that can be used to demonstrate protection of people and the environment. These programs are developed and implemented following the approach described in this report. This ensures the programs are best placed to provide high-quality information and are consistent with ARPANSA policies and expectations. Where monitoring programs already exist, this Framework is used to guide ongoing review and optimisation of these activities.

Reporting on these monitoring and assessment programs is an essential activity to support ARPANSA's Chief Executive Officer to deliver on the key functions of the ARPANS Act.

In addition to the Community Values for Environmental Monitoring and Assessment, the following guiding principles underpin ARPANSA's environmental monitoring and assessment activities, and are embedded within ARPANSA's application of the Framework:

Graded approach

Effort and resource allocation is optimised with consideration to the risks to environmental health and public health and wellbeing. Activities should be undertaken in a way that is as simple as possible, but as complex as necessary to meet the desired objectives.

Evidence-based

ARPANSA strives to deliver high-quality measurement and assessment services that provide meaningful, reliable and accessible data and information.

Transparent and independent

Clear, accessible information and transparent decision making are key drivers of public trust. ARPANSA's commitment to independence and transparency includes the timely and accessible publication of environmental data.

Figure 4: ARPANSA's Guiding Principles for Environmental Monitoring and Assessment Services

Current ARPANSA activities

ARPANSA undertakes a wide range of environmental radiation monitoring and assessment activities contributing to the protection of the Australian environment and the public.

ARPANSA's environmental work supports radiation protection by:

- monitoring radiation in the environment to provide independent information and advice to the Australian public to enable informed decision making and to address public concerns
- conducting and reviewing research into the effects of radiation on people and the environment
- understanding the level of natural background radiation exposure in Australia and to establish a baseline against which changes can be assessed
- determining long-term trends, so that changes in the environment are identified and decisions can be made related to the need for mitigation or corrective actions
- evaluating radiation risk to people and the environment
- verification of the environmental compliance data collected by ARPANSA licence holders and to provide regulatory assurance
- carrying out Australia's radionuclide monitoring obligations for the Comprehensive Nuclear-Test-Ban Treaty (CTBT)
- maintaining knowledge and expertise to support responding to radiation incidents.

ARPANSA's commitment to aligning our environmental monitoring and assessment activities to the Community Values outlined in this Framework helps ensure that these environmental programs are targeted towards activities that consider and address the expectations and concerns of the community. When planning a monitoring or assessment activity at ARPANSA, a key step is identifying the relevant Community Values and setting clear objectives. Appropriate indicators are then selected, along with the measurement, monitoring and assessment activities that allow for effective tracking and reporting against these indicators. Consideration of how results will be reported also takes place in the initial planning process as shown in Figure 5.

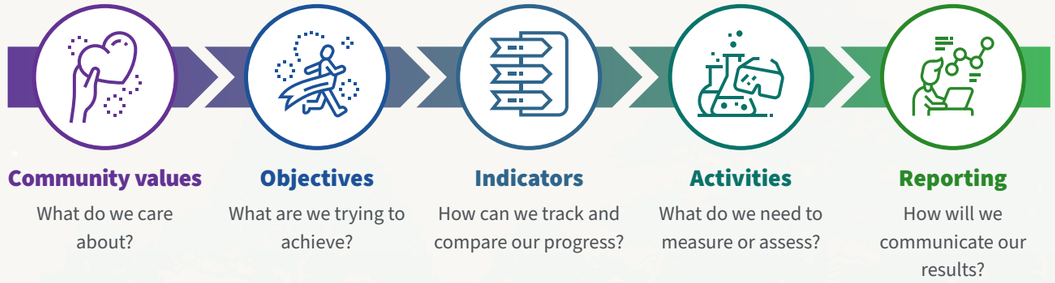

Figure 5: Questions which may be considered to guide development of an activity, beginning with identifying which Community Values are most relevant to the program through to the selection of appropriate measurement and reporting activities

The following 4 case studies of ARPANSA's monitoring activities are presented here to demonstrate the links between community values, objectives, indicators, activities and reporting.

Case study

Ambient gamma monitoring

Ambient gamma detectors take continuous measurements of gamma radiation. This allows ARPANSA to monitor and increase understanding of the variability of background radiation over time and to identify trends or significant changes to the radiological state of the environment.

Community values

- Ecosystem health
- Information and awareness

Objectives

- To increase understanding of background variability of gamma dose rate in Australia
- To identify and inform stakeholders of any trends or significant changes to the radiological state of the environment

Indicators

- **Initially:** report background conditions to establish a radiological baseline
- **Future:** report any significant increase in ambient does rate
- Report on trends and changes over longer timescales

Activities

- Continuous measurement of gamma dose rate
- Locations informed by stakeholder engagement and risk assessment
- Track data availability

Reporting

- **Initially:** regular newsletters and/or website updates
- **Future:** establish near-real-time data reporting of gamma dose rates and provide data availability statistics
- Provide explanatory information to assist with understanding and interpreting results

Case study

Ultraviolet radiation monitoring network

Ultraviolet (UV) radiation exposure is the leading cause of skin cancer in Australia, and Australia has one of the highest UV exposure levels in the world. ARPANSA maintains a network of solar UV radiation detectors in major Australian cities and in the Australian Antarctic Territories. The UV radiation data is collected by detectors that respond to UV radiation in a manner similar to human skin. The data collected is then updated in the form of UV index every minute.

Community values

- Information and awareness
- Recreation in the environment

Objective

- To provide data to the public in real-time to allow people to make risk-informed choices and to take preventative actions to minimise UV radiation exposure and associated health risks

Indicator

- At least 95% data availability across the network over each reporting period

Activities

- Continuous measurement of UVR at selected locations
- Modelled UV radiation using a computer program that considers multiple parameters including time of year and averaged ozone values
- Tracking of data availability

Reporting

- Results made available on the SunSmart App and the ARPANSA website

Case study

Drinking water monitoring

Australia's drinking water is among the safest in the world with a consistent and reliable supply of safe, high-quality drinking water. Radionuclides may be present in water due to natural processes, such as the decay of elements like uranium or radon or due to human activities such as mining or industrial processes.

The Australian Drinking Water Guidelines (ADWG) provide a framework for managing water quality to ensure that drinking water is safe for consumption. It specifies guideline values for various substances, including radionuclides, and outlines the need for regular monitoring and study to protect human health.

Community value

- Food and drinking water safety

Objective

- Drinking water meets Australian Drinking Water Guidelines (ADWG) for radiological contaminants

Indicators

- Compare results to ADWG Radiological Value (1 mSv/yr reference level)
- Report activity concentration in water for specific radionuclides of interest (if applicable)

Activities

Depending on location and risk factors, a selection of:

- gross alpha/ beta screening
- activity concentration measurement of targeted radionuclides
- dose assessment to support reporting against reference level

Reporting

- Summary of results published on ARPANSA website
- Provide explanatory information to assist in understanding and interpreting results

Case study

Atmospheric radionuclide sampling

ARPANSA has responsibility for carrying out Australia's radionuclide monitoring obligations for the Comprehensive Nuclear-Test-Ban Treaty (CTBT), which aims to eliminate nuclear weapons by restricting the development and qualitative improvement of new types of nuclear weapons.

ARPANSA has established and maintains radionuclide monitoring stations that can detect radioactive debris from atmospheric explosions or vented by underground or underwater nuclear explosions. The presence of specific radionuclides provides unambiguous evidence of a nuclear explosion. ARPANSA also operates 2 stations capable of measuring for the presence of noble gases.

The data relating to the sampling conditions and radionuclides measured is provided to the International Data Centre in Vienna where it is compiled and released to countries participating in the Treaty.

Community values

- Ecosystem health
- Information and awareness

Objective

- To meet Australia's monitoring obligations for the CTBT, including establishment, operation and maintenance of International Monitoring System (IMS) stations and meeting data provision and quality targets

Indicators

- At least 95% data availability across the network over each reporting period
- Obligations specified in contract with the Comprehensive Nuclear-Test-Ban Treaty Organization (CTBTO) are met

Activities

- Daily operation of radionuclide monitoring stations and tracking of data availability
- Ongoing maintenance and support to stations
- Analysis of CTBTO products including in-depth investigation in the case of anomalous results

Reporting

- Data forwarded to CTBTO daily for compilation and release to participating countries
- Provide results of any analysis undertaken to national and international stakeholders

Alignment with United Nations Sustainable Development Goals

There are many intersections between the Community Values used in this Framework and the sustainable development goals (SDGs) identified in the United Nation's 2030 Agenda for Sustainable Development (United Nations 2015). The SDGs recognise that protection of the environment, economic development, eliminating poverty, reducing inequality, and improving health and wellbeing are all intrinsically interrelated and must be addressed holistically.

ARPANSA's environmental protection programs directly align with the 5 SDGs shown in Figure 6:

Prevention of non-communicable diseases such as skin cancer

Risk assessment to support development of radiological drinking water guidelines, and drinking water sampling

Recognition and protection of sites of national and cultural heritage

Risk assessment, monitoring and protection of marine ecosystems

Risk assessment, monitoring and protection of terrestrial and freshwater ecosystems to protect flora and fauna biodiversity

Figure 6: UN Sustainable Development Goals related to ARPANSA's environmental programs, and an example of how these programs support the goals

Integration with other ARPANSA activities and responsibilities

All of ARPANSA's environmental monitoring and assessment services are designed and implemented with consideration of broader national and organisational objectives. Wherever possible, environmental programs developed under this Framework strive for uniform standards, approaches, equipment, processes, data handling, and IT platforms, and seek to capitalise on synergies with other ARPANSA activities. This allows for increased collaboration and knowledge sharing, while also enabling staff to utilise skills and equipment to maintain competency and to support the efficient use of finite resources.

Information and results should be presented consistently across ARPANSA's environmental programs to allow for comparison of results over time and across various locations. During the planning and implementation of environmental activities the handling and presentation of data is considered in the context of other ARPANSA activities to support and enable consistency.

Agency policies and procedures

ARPANSA activities undertaken under this Framework must comply with all Australian government requirements and agency-wide frameworks, policies and procedures. It is the responsibility of all staff to be aware of these requirements and to maintain appropriate training as necessary.

These include, but are not limited to, requirements and responsibilities related to:

- workplace health and safety (WHS)
- risk management, including ensuring relevant risks are identified, managed and captured in project, branch and agency risk registers
- quality management
- security management, including physical and digital security and alignment with the Protective Security Policy Framework
- project management
- record keeping
- data management
- financial management and procurement policies.

Regulation

ARPANSA's Radiation Health Services Branch provide a range of environmental monitoring and assessment services to support ARPANSA's regulatory function. These services include sampling, measurement, analysis and monitoring programs for regulatory assurance, review and assessment of selected aspects of licence applications, and any other support requested by ARPANSA's Regulatory Services Branch. The Framework described in this report is used to guide the delivery of these services and supports the ongoing delivery of high-quality measurement and assessment services to enable effective regulation for radiation protection and nuclear safety.

Emergency management

Environmental monitoring and assessment are critical activities for effective Emergency Preparedness and Response (EPR) throughout each phase of an emergency situation. Additionally, any data obtained from ARPANSA's environmental programs provide useful information that can be used to assess the impact of an incident on the environment and for justification and optimisation of remediation if required.

During the active response to an emergency, measurement, monitoring, modelling and risk assessment provide important information to support first responders and to guide decision making. Ongoing monitoring and assessment post-incident inform the justification, planning and optimisation of remediation efforts and provides evidence to support advice to the public and government.

Where capabilities are identified as being necessary to maintain for EPR, there may be opportunity to exercise these capabilities within business-as-usual environmental programs and projects. The planning and development of an environmental monitoring or assessment program considers opportunities to align with maintaining EPR capability by using similar approaches and methods for sampling, measurement, and assessment. This includes consideration of staffing, equipment, systems, processes and data handling.

Commitment to high-quality environmental services

As the Australian Government's primary authority on radiation protection and nuclear safety, ARPANSA strives to deliver high-quality, sustainable monitoring and assessment programs that balance efficiency and complexity. The primary goal of ARPANSA's environmental monitoring and assessment activities is to ensure and demonstrate protection of people and the environment from the harmful effects of radiation. ARPANSA activities also support Australians to safely benefit from the positive medical, industrial and commercial uses of radiation.

The Framework presented in this report provides a risk-informed approach to establishing environmental programs driven by community values, with clear objectives, indicators and reporting guidelines. Applying this Framework across all environmental monitoring and assessment services ensures that these services will continue to provide high-quality data to support the ongoing provision of evidence-based advice to the public and to government.

Appendices

Appendix A1 – Radiation risk management: protecting health and the environment from radiation risks

This appendix briefly outlines ARPANSA's approach to radiation risk management, which is closely aligned with national and international best practice. Radiation Risk Assessment, which is addressed in the *Framework for Environmental Monitoring and Assessment*, is one component of risk management, as shown in Figure 7. Risk assessments for radiation are undertaken in line with Commonwealth guidelines for assessing human health risks from the environment (see Figure 10 at the end of this appendix for a summary of this approach) (enHealth 2012).

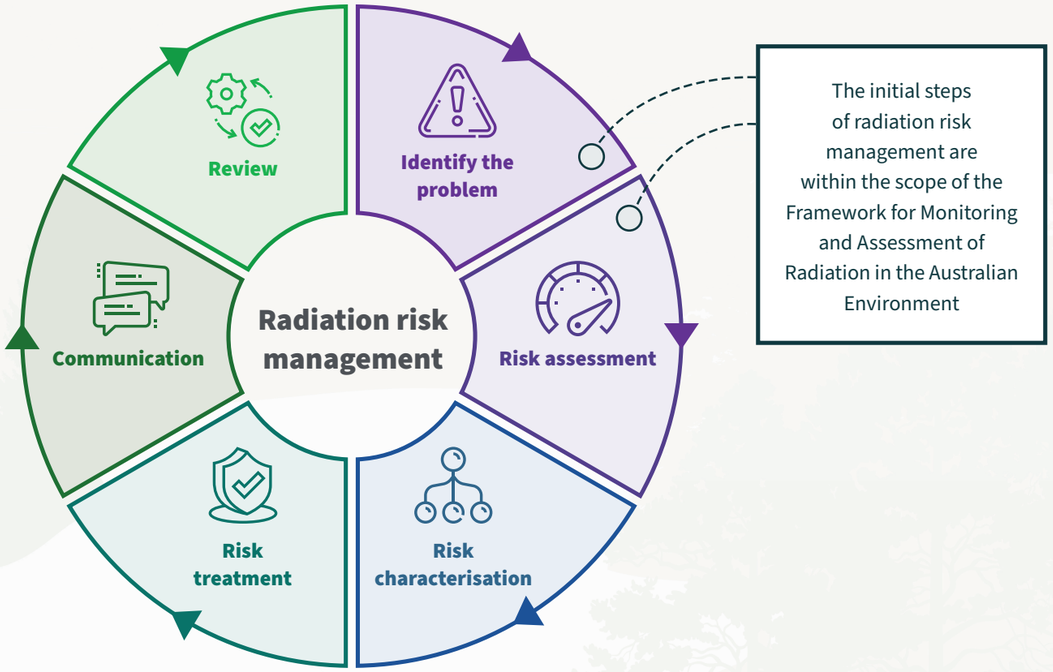

Figure 7: The cycle of radiation risk management

Radiation risk assessment

In the context of this Framework, radiation risk assessment is a process of systematically evaluating the potential impact of a hazard on defined individuals or populations. A radiation risk assessment may be needed for situations where there is a plausible chance that there could be an increased risk of harm to people or the environment from a product, process, situation or activity. ARPANSA undertakes risk assessments to evaluate the risks of radiation exposure to people and the environment.

The results of radiation risk assessments can also be used to provide information about the safest option or to compare radiation risks to other risks encountered in everyday life. Assumptions and estimates are always made when undertaking risk assessments. It is very important to clearly document and explain these assumptions so that decision makers, including the public, can interpret the results accurately. Drawing on evidence-based science, ARPANSA takes a conservative approach when making assumptions and managing uncertainties for public and environmental risk assessments, which is intended to reduce the chance of harm occurring.

Understand the radiation source and define exposure scenario

Identify potential sources of radiation and consider the ways a person or the environment could be exposed to these sources. A range of factors need to be considered including the way the radiation source moves through the environment, the characteristics of those exposed (age, habits, etc.), the length of exposure and the characteristics of the radiation source.

Identify exposure pathways

Exposure pathways are the ways in which radiation can impact tissues and organs in the body. External exposures to ionising and non-ionising radiation occur when the radiation source is outside the body. For ionising radiation, internal exposures occur when a radiation source is ingested, inhaled or enters the bloodstream.

Develop and implement a method for dose and/or exposure estimation

There are many different methods that can be used to estimate dose, exposure and risk. The approach chosen depends on the purpose of the assessment, and on the measurements, data and models available. The chosen approach should be as simple as possible, but as complex as necessary.

Evaluate the uncertainties

There are uncertainties and assumptions made in all steps of the assessment process. It is essential to clearly identify, analyse and communicate these uncertainties and assumptions to establish the credibility of the results and allow decision makers, including the public, to make informed decisions based on the results.

Interpret and communicate results

The results of the risk assessment must be interpreted and presented in a way that provides a complete and understandable picture of the assessment. The purpose, method, uncertainties and results of the assessment should be clear to the reader.

Risk characterisation

Risk characterisation brings together all the available information (qualitative and quantitative) to reach a conclusion about the radiation risk that is complete, informative and useful for decision makers. Decision makers include individuals (members of the public, workers, patients), scientific experts, managers or governments. While it is not purely scientific evidence that drives decision making, regardless of the type of information used, it is important to use an evidence-based approach to managing radiation risk. Each case will be different, and the process needs to be flexible to allow decision makers to consider all the evidence and information provided. The end result of risk characterisation is an understanding of the relative urgency of each risk and the underlying factors that drive that urgency.

The issues that ARPANSA may consider for radiation risk characterisation are shown in Figure 8. This list is not exhaustive as the factors vary depending on the situation and the risk being considered. There are many dependencies and interdependencies between these issues, and risk characterisation is most beneficial when these issues are considered together rather than independently.

Figure 8: Issues that may be considered in radiation risk characterisation

Risk characterisation should:

- be transparent, with assumptions clearly identified and documented
- distinguish conclusions drawn from evidence with those based on policy
- include a summary of the key issues and conclusions from the radiation risk assessment
- include a summary of the overall strengths and limitations of the assessment and conclusions
- apply an appropriate degree of conservatism to protect public and environmental health
- include a detailed description of areas of uncertainty.

Risk characterisation is challenging as each case will be unique and the assessor needs to identify and incorporate all issues into the characterisation. Some common challenges encountered during this process include:

- inferring risks where hypotheses regarding causal relationships have not been deemed proven
- extrapolation of risks over lifetime
- inferring risks from low level exposure
- inference of health effects on human from animal studies or cellular studies
- inference of health effects from a single study or from low quality studies, or unreplicated results
- uncertainty analyses attempt to quantify what is unknown, unreliable or indefinite
- incorporation of non-scientific concerns where appropriate
- considering the consequences of false positive and false negative assumptions
- difficulties in proving a ‘non-effect’ or providing an absolute guarantee of safety.

Risk treatment and risk communication

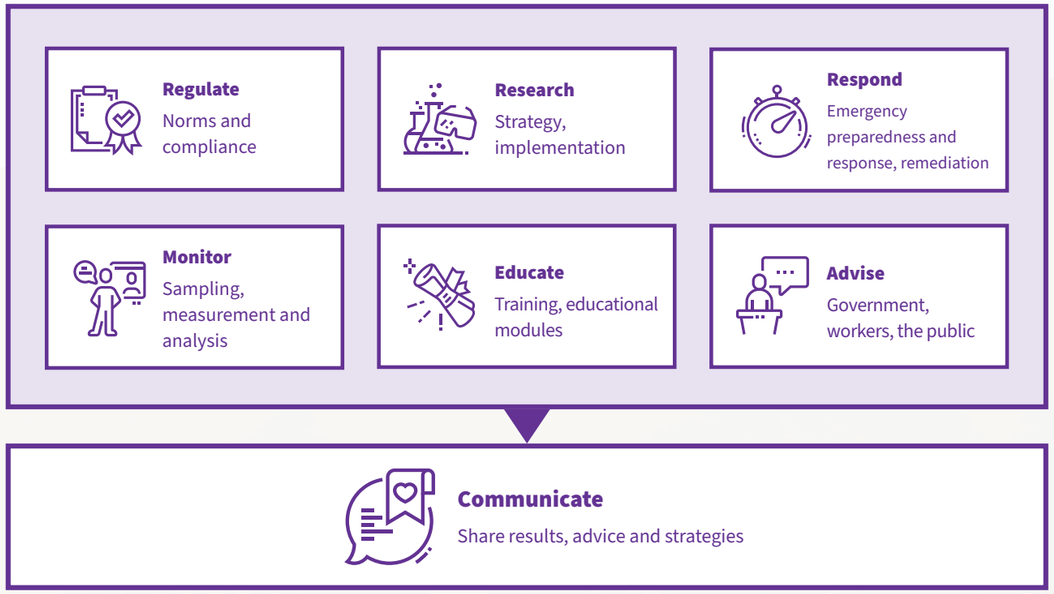

Figure 9: A selection of options to consider in risk treatment

If the outcome of risk characterisation suggests that action may need to be taken to treat or mitigate the risk there are various options to pursue. Some approaches applied by ARPANSA are shown in Figure 9. While the details of these approaches are beyond the scope of this report, environmental monitoring and assessment activities aim to support risk mitigation through provision of data and information used to inform decisions and track progress.

Key considerations for risk treatment include:

- deciding whether something needs to be done to mitigate the risk, based on the risk severity
- developing and assessing a range of options for mitigating the risk
- preparing and implementing action plans and communication plans.

Communication is a vital component of any risk treatment option. ARPANSA aims to share information, data, and advice that informs and empowers individuals to understand the risks from different sources of radiation and to take proportionate actions to reduce risks when required.

Ongoing review

ARPANSA actively monitors developing research in radiation protection and ensures that the advice provided to government and the public is up to date and based on current knowledge. This is achieved through:

- regular literature surveys, published on the ARPANSA website
- establishing measurement and monitoring programs to better understand and track levels of radiation in the environment
- undertaking independent research and development and collaboration with active research groups both nationally and internationally
- advice to the CEO from the Radiation Health and Safety Advisory Council and Nuclear Safety Committee
- ongoing review and update of information fact sheets
- active participation in national and international standards committees, research collaborations and professional societies
- regular communication and feedback from the community on issues of concern through ARPANSA's Talk to a Scientist program, public representation on ARPANSA committees and written correspondence.

Further reading

Additional information and guidance on assessing human health risks from environmental hazards has been developed by the Environmental Health Standing Committee (enHealth). Figure 10 outlines the environmental health risk assessment process described in the enHealth guidance (enHealth 2012).

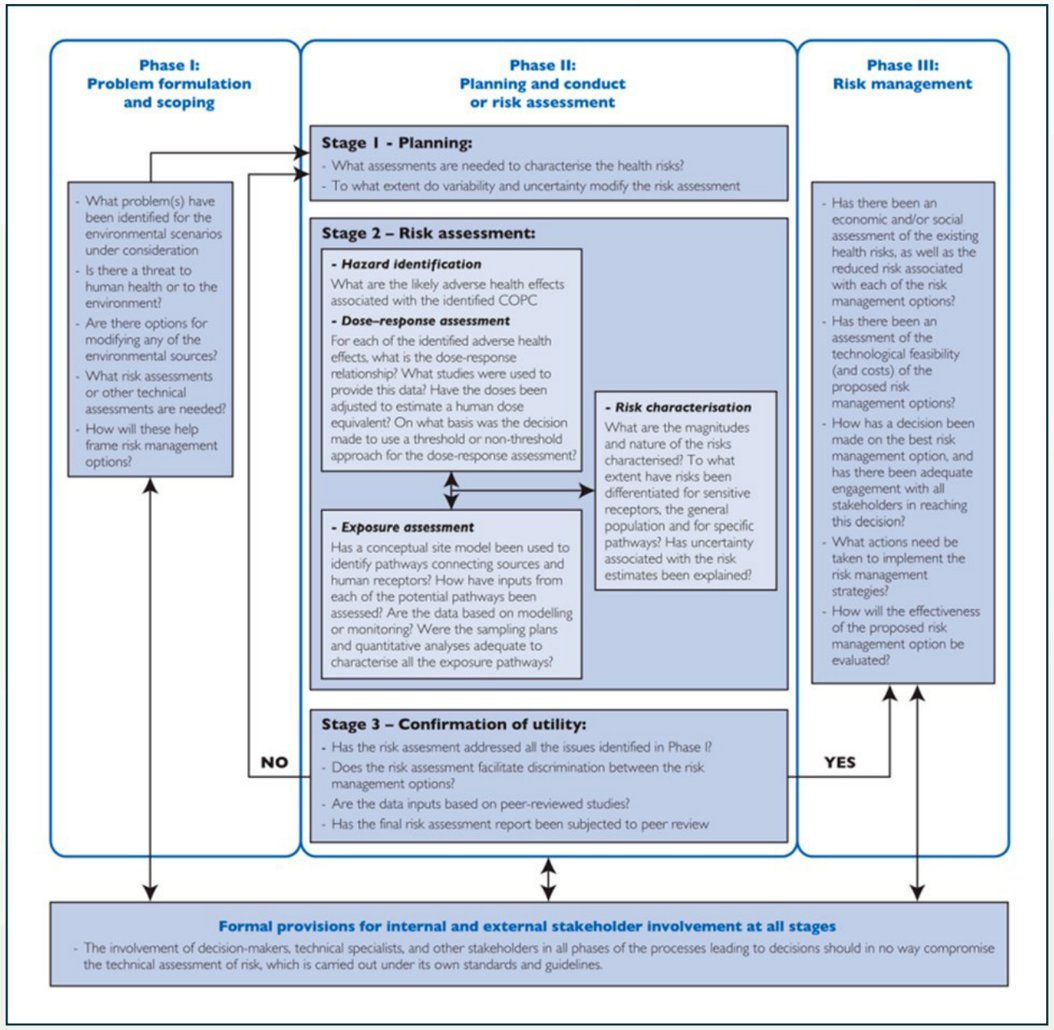

Figure 10: Extract from the Guidelines for assessing human health risks from environmental hazards (enHealth 2012) outlining the recommended process for environmental health risk assessment

Appendix A2 – Technical considerations for design of a monitoring program: sampling and analysis

It is important that the data and information obtained from environmental monitoring activities is suitable to meet the objectives of relevant programs. One way to support collection of high-quality, reliable data is to follow a systematic process to consider sampling, analysis and data requirements for the relevant monitoring activity.

Determining the type, quantity, and quality of data required to meet the program's objectives is essential. This includes identifying and defining the following:

- The sources of exposure (ionising and/or non-ionising), what needs to be measured and the media that will be sampled.
- The types of data to be collected. Will data be qualitative (numerical measurements that provide precise information), qualitative (descriptive information that provides contextual information) or a combination?
- The spatial and temporal boundaries of the program and the associated samples. Samples should be collected from a range of locations to capture spatial variability. For example, this may include upwind and downwind locations for air quality, upstream and downstream sites for water quality, and different land uses for soil quality. For capturing seasonal variations, samples may need to be taken annually at periodic intervals.
- The quantity of data, including sampling frequency (for example continuous monitoring and/or periodic sampling) and sample size. Sample size should be sufficient to achieve the desired confidence level and account for inherent uncertainties and an acceptable margin of error. Statistical methods as well as expert judgement may be used.

Plans and controls should be in place to ensure good governance and quality control. This may include the following:

- Developing a sampling and analysis plan; a detailed plan for sampling and analysis, including selecting sample types (for example, air, water, soil), sampling location and frequency, and analytical methods.
- Implementing robust Quality Assurance and Quality Control (QA/QC) procedures to ensure data reliability and accuracy. This may include instrument calibration, use of control samples, and regular audits.
- Utilising a system data management and validation that includes data entry, validation, storage, retrieval and reporting. Procedures should be implemented to validate data, including checking for outliers, consistency, and completeness.
- Maintaining effective documentation procedures, including keeping and maintaining detailed records of sampling methods, locations, times, and conditions, to ensure traceability and reproducibility.

Feasibility, optimisation and justification of methods for sampling and analysis

Understanding the planning, expertise, equipment, field measurement, sampling, analysis, and reporting required to meet the objectives of an environmental program or project enables an informed estimation of the resources required to adequately implement the program or project. The feasibility of the program also depends on the availability of resources. For some measurement programs it may also be appropriate to consider alternative approaches, such as contracting measurement, analysis, or possible sample collection to a business or a commercial laboratory.

To support optimisation and justification of proposed monitoring programs and to allow for assessment of feasibility the following technical factors should be considered.

- Sample Size Optimisation: statistical methods may be used to determine the optimal number of samples needed to achieve the desired confidence level and decision error rates.
- Sampling Location Justification: justify sampling locations based on expert judgement, statistical sampling theory and site-specific conditions. Visual and statistical tools are available to support this justification.
- Cost-Benefit Analysis: perform a cost-benefit analysis to ensure the sampling design is cost-effective while meeting data quality objectives. This can be achieved by estimating and comparing costs of different sampling designs, including costs of field sampling methods, analytical methods and reporting requirements.
- Performance Assessment: assess the performance of the sampling design with the use of graphical and statistical analysis tools. This includes evaluating the probability of detecting contamination and the precision of the estimates.

Justification should be provided for the chosen sampling design, including assumptions, decision criteria, and statistical methods used. In addition to technical factors, consideration also needs to be given to factors that strongly impact the ongoing feasibility and cost effectiveness of the program, such as:

- costs, both capital and ongoing
- capability, availability, and capacity of staff required for planning, safety, field work, analysis, data interpretation, and reporting
- suitability of existing equipment and established procedures to meet the needs of the program
- travel commitments
- equipment availability, maintenance, reliability and durability
- IT support, including data collection and storage, data processing and integration with existing systems
- data security.

Key concepts and definitions

Detection limits are the minimum concentration of a radionuclide that can be reliably detected by the monitoring equipment. Ensure that the detection limits of the chosen instruments are appropriate for the expected levels of radioactivity in the environment and/or to meet the objectives of the program.

Sensitivity refers to the ability of the monitoring equipment to detect low levels of radioactivity. High sensitivity is crucial for identifying trace amounts of radionuclides in the environment and appropriate instruments should be chosen.

Turnaround Time (TAT) is the time taken from sample collection to the reporting of results. Short TAT is essential for timely decision making, especially in emergency situations. Streamline sample processing and analysis workflows and use automated systems where possible to reduce TAT.

Frequency refers to how often samples are collected and analysed. The frequency should be sufficient to capture temporal variations in radioactivity levels. Establish a sampling schedule based on program requirements and site-specific conditions.

Accuracy is the degree to which the measured values reflect the true levels of radioactivity. High accuracy is essential for reliable data. Ensure proper calibration of instruments, use quality control samples, and follow standardised procedures for sample collection and analysis.

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