Radiological Protection of Flora and Fauna throughout Australia – Developing a National Approach

Marcus Paul Grzechnik

Australian Radiation Protection and Nuclear Safety Agency

Abstract

Australia's longstanding approach to radiation protection of non-human biota (flora and fauna) has been to assume that if humans are adequately protected then other species are also protected. This approach has now changed. The 2007 Recommendations of the ICRP defined environmental protection objectives distinct from those for humans, and subsequently established a framework within which radiation exposures to flora and fauna from radionuclides released to the environment can be assessed. The framework uses reference organisms in order to estimate dose rates to living organisms which are representative of those within a contaminated environment.

In order to provide definitive guidance across all Australian jurisdictions that is consistent with Best International Practice, a Safety Guide is being produced in collaboration with expert representatives from Government and Industry. Emerging radiation practices in Australia to which specific advice on radiation protection on non-human biota may apply are likely to include potential radioactive waste management facilities and expansion of rapidly growing mining and ore processing industries.

Australia is host to a variety flora and fauna with unique characteristics. It is important that strategies for the assessment of these unique species are captured in any National approach. These may involve the definition of specific reference organisms based on the ICRP's reference animals and plants. Relevant parallel projects collating concentration ratio data and determining data gaps in Australian environments provide a valuable resource for inclusion in the Safety Guide.

This paper will discuss the current status of the Safety Guide, future plans and timescales, as well as the specific challenges and risks involved in this project.

Key Words: biota, flora, fauna, Australia

1. Introduction

International developments in radiation protection indicate the need in some circumstances to be able to demonstrate directly that non-human species in natural habitats are protected against deleterious radiation effects from practices releasing radionuclides to the environment (ICRP, 2009).

The 2007 Recommendations of the International Commission on Radiological Protection (ICRP, 2007) defines environmental protection objectives distinct from human protection objectives and establishes a framework within which radiation exposures to non-human species from radionuclides released to the environment can be assessed and interpreted. The framework uses reference organisms as conceptual and numerical proxies for the estimation of radiation dose rate to living organisms which are representative of a contaminated environment; reference levels are then used to evaluate radiation risks to non-human species and to guide decision making on radiological environmental protection.

In Australia, the longstanding approach to radiation protection of non-human species has been to assume that if humans are adequately protected then other species are also protected (ARPANSA, 1995). This approach is based on past recommendations of the International Commission on Radiological Protection (ICRP, 1991) and is no longer consistent with best international practice.

Some Australian industries and operators are exploring the use of the reference organism approach to assess radiation exposures to flora and fauna from radionuclides released to the environment by their practices. One Australian State (or jurisdiction) has released guidelines on managing naturally occurring radioactive material (NORM) in mining and mineral processing which supports the use of the reference organism approach for assessing radiation impacts on the non-human environment, where other jurisdictions are silent on the matter. Without uniform national guidance, the potential exists for inconsistency between jurisdictions in how radiation protection of non-human biota is implemented, assessed and interpreted by both operators and regulators.

Text on protection of the environment has been prepared for inclusion in the replacement for Radiation Protection Series No. 1 (ARPANSA, 1995). The text outlines radiological environmental protection objectives and recommends the use of the reference organism approach for assessing radiation exposures to non-human species from radionuclides released to the environment. A safety guide on radiation protection of non-human species from radionuclides released to the environment would provide additional detail on the conceptual and practical elements of the approach.

The types of radiation practices (planned, existing and emergency releases) to which specific advice on radiation protection of non-human species may apply in Australia is likely to include:

- Radioactive waste management facilities,
- Mining and processing of radioactive ores,
- Other NORM-producing industries (e.g. offshore oil and gas),
- Research reactor operations, and
- Hospital discharges of nuclear medicine wastes.

The objective of this project is to produce uniform national guidance on protection of the environment (viz. non-human species) from radionuclide releases. The outcome of this project will be a common understanding among operators and regulators across all jurisdictions of the reference organism approach for assessing radiation exposures to non-human species from radionuclides released to the environment and the circumstances where such assessments may be necessary. This will help to ensure the protection of the environment from the harmful effects of radiation and to minimise unnecessary burden to industry.

2. Current Status of Projects in Australia

An evaluation of the suitability of ICRP recommendations (ICRP, 2009) and the use of the ERICA Integrated Approach (Larsson, 2008; Howard and Larsson, 2008) in an Australian context has been undertaken and reported by Doering (2010). The conclusions of this report are that;

- *At the international level, the International Commission on Radiological Protection has established a framework for radiological assessment and protection on non-human species based on a reference animal and plant approach;*
- *In an Australian context, there is a need for specific national guidance on protection of non-human species, identified through the National Directory for Radiation Protection, and realised by the need of the uranium mining industry to integrate world best practice standards for assessing environmental impacts;*
- *The ERICA Integrated Approach and ERICA Tool provide a practical framework for assessing absorbed dose rates to non-human species and can potentially be adapted to Australian situations;*
- *Research is required to collect and assemble data on fauna and flora common to major Australian environments in order to establish a set of Australian reference organisms and to facilitate the implementation of the ERICA framework in an Australian context.*

As a direct result of this evaluation report, two major projects with regard to radiation protection of the environment in Australia have recently been launched, viz.;

- Concentration ratios for non-human biota inhabiting Australian uranium mining environments, and
- Development of a Safety Guide for guidance on radiation protection of the environment.

2.1 Concentration ratios for non-human biota inhabiting Australian uranium mining environments

The reference animal and plant approach (ICRP, 2009) uses concentration ratios to estimate the transfer of radionuclides from the environment to non-human biota. The magnitude of the concentration ratio can vary between different environmental conditions and biota types. This means that concentration ratios appropriate to assess biota in one environment type (such as temperate European) may not be appropriate to assess biota in other, dissimilar environment types (such as arid, semi-arid or wet-dry tropical Australian).

Concentration ratio is an empirical quantity, derived from measurements of radionuclide activity concentration in both biota and environmental media (ICRU, 2001). The Concentration Ratio (CR) varies depending on the type of surrounding media, and is generally defined as the ratio of activity concentration in biota whole-body to the activity concentration in the surrounding media.

Some initial work to consolidate CR values (largely based on tissue-media ratios) for Australian terrestrial wildlife and livestock in semi-arid conditions has been undertaken by Johansen and Twining (2010). However, there is currently no consolidation of existing Australian data on whole body concentration ratios to support non-human biota radiological assessments in the Australian uranium mining context. This impedes the ability of the industry to undertake assessments.

The objective of the one-year concentration ratio project is to collate existing Australian data holdings on concentration ratios for flora and fauna in uranium mining environments (locations considered include current and prospective mine sites). The concentration ratio data collated will be checked for quality and evaluated to identify short-comings, including biota types and environmental conditions, for which data is most lacking. Further work (as a follow-up to this project) may be identified to fill these data gaps where considered necessary.

These concentration ratio data holdings can be applied for radiation protection of the environment in various climate zones of Australia. Their inclusion within the environmental dose assessment tools

(such as ERICA) combined with the guidance provided by the Safety Guide described in this paper will enable the most up-to-date organism- and site-specific radiological assessments to be undertaken.

2.2 Development of a Safety Guide for guidance on radiation protection of the environment

The background to this project has been discussed in the Introduction of this paper. The development of Regulatory Documents (such as Safety Guides) within Australia is overseen by the Radiation Health Committee (RHC). Their role is to advise on matters relating to radiation protection, including formulating draft national policies, codes and standards for consideration by the Commonwealth, States and Territories. The RHC includes representatives from all States and Territories of Australia.

With the approval of the RHC, a working group was formed for the production of a *Safety Guide on radiation protection of the environment from radionuclide releases* (known as "the Safety Guide" in this paper). This group includes expert representatives from Government and Industry. This group has met and finalised a work plan, including the review of international documents and initial drafting currently under way. A first draft of the Safety Guide is expected to be ready for submission to the RHC in December 2012.

During 2013 it is planned for the draft to be reviewed by a consultative group. This group will involve a variety of stakeholders, including;

- Government agencies (mining, environment, radiation regulation),
- Industry,
- International community,
- Conservation bodies.

Comment from the consultative group will be considered by the working group and required changes incorporated and agreed by the RHC (planned by the end of 2013). The updated draft of the Safety Guide will then be made available for public consultation (early 2014). Comments will be collated and responded to, and the document finalised and endorsed for final publication near the end of 2014.

3. Setting Reference Levels in Australia

Australia's climate varies widely, and can largely be classified into six major classes based predominantly on native vegetation type using a modification of the Köppen (1931) classification system (Stern et al., 2000). These classification groups (shown in Figure 1) are;

- Equatorial,
- Tropical,
- Subtropical,
- Desert,
- Grassland,
- Temperate.

Current approaches to setting reference organisms and levels of exposure adopted worldwide will influence the approach to be adopted in Australia. Various examples of internationally adopted reference levels that have been assessed for relevance to Australian recommendations are described in the sections that follow.

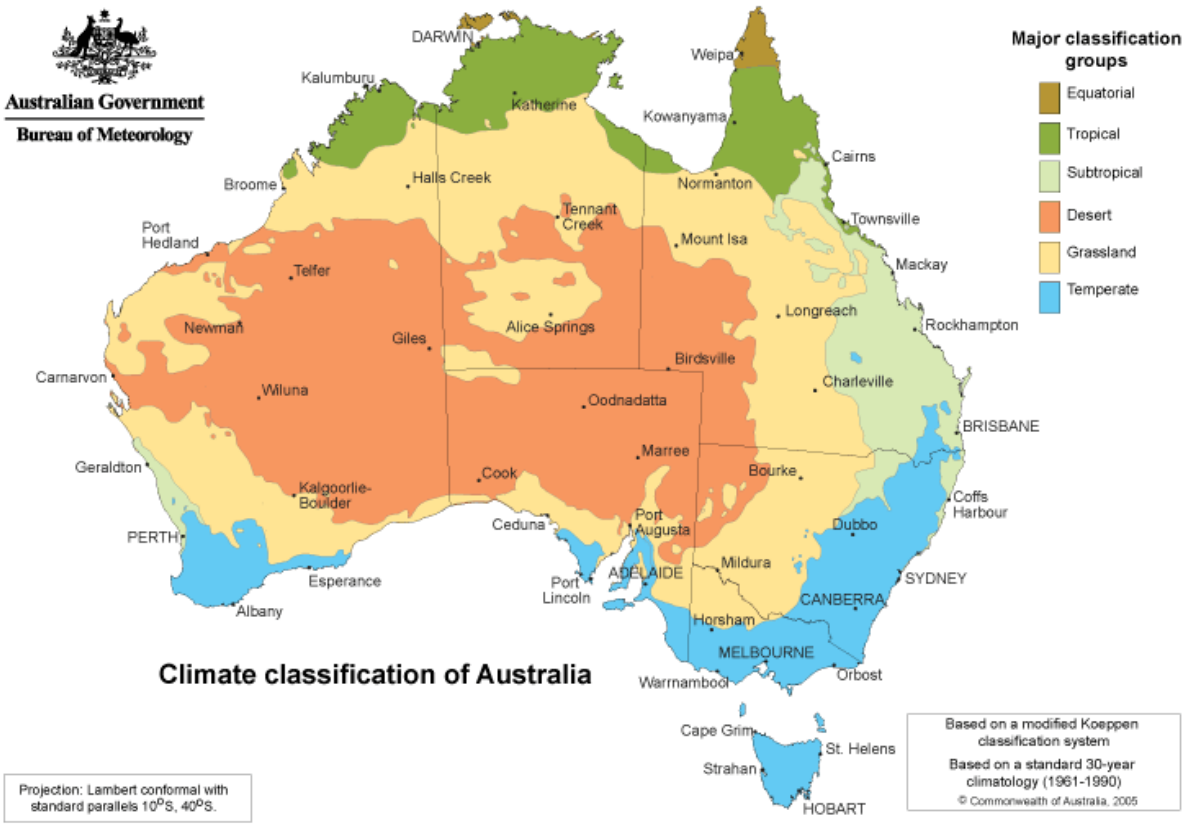

Figure 1. Climate zones of Australia using a modified Köppen classification system (courtesy of Australian Bureau of Meteorology, updated from Stern et al., 2000).

3.1 United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR)

The UNSCEAR 1996 Report to the General Assembly (UNSCEAR, 1996) included a scientific annex on 'Effects of radiation on the environment' which reviewed and summarised the scientific literature on effects of ionising radiation on animals and plants in the environment. The UNSCEAR suggested dose rates to animals and plants below which detrimental effects at the population level are not expected to occur are those given in Table 1.

The UNSCEAR 2008 Report to the General Assembly includes a scientific annex on 'Effects of ionizing radiation on non-human biota' (UNSCEAR, 2011). Information on estimating doses to non-human biota, selection of reference organisms, radioecological modelling, radionuclide transfer and radiation dose effects is discussed.

Table 1. UNSCEAR suggested dose rates to animals and plants in the environment below which population level effects are not expected to occur.

Biota	**Dose rate (μGy h^{-1})**
Terrestrial animals	40
Aquatic animals	400
Terrestrial plants	400

3.2 International Commission on Radiological Protection (ICRP)

The 2007 Recommendations of the ICRP (ICRP, 2007) define environmental protection objectives distinct from human protection objectives and establishes a framework within which ionising radiation exposures to non-human species from radionuclides in the environment can be assessed and interpreted. Reference Animals and Plants (RAPs) – hypothetical entities that can be used for the purposes of relating exposure to dose and dose to effect – form the basis of the framework. The ICRP has defined a set of 12 RAPs (ICRP, 2009). Dose-effect relationships for RAPs can be put into a radiological risk context using derived consideration reference levels (DCRLs) as described in ICRP (2009);

> *A band of dose rate within which there is likely to be some chance of deleterious effects of ionising radiation occurring to individuals of that type of reference animal or plant (derived from a knowledge of defined expected biological effects for that type of organism) that, when considered together with other relevant information, can be used as a point of reference to optimise the level of effort expended on environmental protection, dependent upon the overall management objectives and the relevant exposure situation*.

Preliminary DCRLs for RAPs were published in ICRP Publication 108 (ICRP, 2009) and are provided in Table 2. The values were derived from a review of the scientific literature on effects of ionising radiation on animals and plants.

Table 2. Preliminary derived consideration reference levels for the ICRP Reference Animals and Plants.

RAP	**DCRL (μGy h^{-1})**
Deer, Rat, Duck, Pine tree	4–40
Frog, Trout, Flatfish, Wild grass	40–400
Bee, Crab, Earthworm, Brown seaweed	400–4000

3.3 International Atomic Energy Agency (IAEA) & US National Commission for Radiological Protection (NCRP)

Reference radiation dose rates were given by IAEA (1992) for Terrestrial Plants (10 mGy d^{-1}) and Terrestrial Animals (1 mGy d^{-1}). Aquatic organisms were considered by NCRP (1991), with suggested reference radiation dose rates of 10 mGy d^{-1}.

3.4 Environmental Risk from Ionising Contaminants: Assessment and Management (ERICA)

One aspect of the ERICA project (Howard and Larsson, 2008; Brown et al., 2008) was to derive a screening level dose rate for risk characterisation in environmental radiological assessment. Species sensitivity distribution analysis – an objective scientific method – was used to derive the screening level from radiation effects data in the Framework for Assessment of Environmental Impact (FASSET) (Larsson, 2004) radiation effects database. The ERICA tool uses a derived screening level (**10 μGy h^{-1}**) applicable to incremental (i.e. above background) exposures (as calculated by Garnier-Laplace and Gilbin, 2006). The tool also allows other screening dose rates to be used (e.g. those of the IAEA and UNSCEAR).

3.5 Current Australian position on reference levels for the protection of non-human species

Whilst there is much international data available that will help to shape the methodology and reference levels adopted for Australia, Doering (2010) suggested that;

> *...the RAPs may not be appropriate to serve as the representative organism in all circumstances: differences in biology, radionuclide transfer, dosimetry or radiation effects, or other discriminating factors, may preclude their choice. It may therefore be necessary to establish a set of secondary reference organisms for a specific purpose or location using more specific data on local animals and plants which may already be available with respect to specific sites. These may be regarded as 'representative organisms' in analogy with the 'representative person' approach in human radiation protection. The idea of establishing secondary reference organisms may apply to Australian situations where some of the RAPs are perhaps not appropriate to serve as the representative organism (e.g. using Reference Deer as the representative organism for kangaroo living in a semi-arid region of Australia is imaginably inappropriate because of obvious differences in biology and ambient environmental conditions which may affect radionuclide transfer), though this necessitates that Australian data for endemic animals and plants is available.*

As such, it is prudent that in situations where the radiation exposures to non-human biota from radionuclides in the environment justify assessment, a structured numerical approach based on the concept of reference organism should be adopted. When considered in the context of environmental reference levels, these assessments would provide a basis upon which some management decisions in relation to radiological protection of the environment could be made.

ARPANSA has previously issued the following specific advice on reference levels for protection of non-human species in its 2006 regulatory guidance for radioactive waste management facilities (ARPANSA, 2006);

> *Specifically with regard to protection of the environment from the effects of radiation, the applicant should undertake a screening assessment of doses to non-human biota in the vicinity of the repository using one of the internationally currently accepted screening tools. The assessment should demonstrate that the dose rate is below 1 mGy/d for animals and 10mGy/d for plants, these being the dose rates suggested by UNSCEAR where detrimental effects on the most sensitive populations would not be expected to occur. Should the screening tool indicate that these dose rates might be approached, then a more sensitive analysis would need to be carried out.*

An update to this document has been drafted, where the protection of non-human biota is addressed using a graded approach. In this document it is advised that if a simple (or screening) assessment of the situation identifies incremental dose rates to animals and plants above 10 μGy/h, then a more complex assessment could be made. This assessment could use, for example, less conservative assumptions or site-specific data obtained from an environmental monitoring program. If this complex assessment of the situation still identifies incremental dose rates to animals and plants above 10 μGy/h, then an assessment could be made of the probability, magnitude and distribution (spatially and temporally) of radiation exposures and possible adverse effects.

At this point in time, this approach is expected to be reflected within the Safety Guide, combined with more detailed information on how to perform an environmental dose assessment.

4. Development of a Safety Guide

Numerous inclusions in the contents of the Safety Guide have been discussed and agreed by the working group. While it is expected that some details may change during the drafting and consultation processes, the overall structure described here should remain.

The Safety Guide will provide the objectives of radiation protection of the environment. It will describe the framework for radiation protection of the environment, including the concepts of reference organisms and environmental reference levels. It will break down guidance based on

practice (planned, existing and emergency) and will provide specific guidance on assessment considerations that will consider a complex-as-necessary but as-simple-as-possible approach.

Some of the risks involved with the development of this Safety Guide and steps taken to resolve them include;

- Working Group Time Shortages – Project planning and possible use of external consultant,
- Industry acceptance – Explanation of the benefits to industry, as well as involvement with the project on the Working and Consultative Groups.
- Defining a standard set of Australian Flora/Fauna – A wide range of experts have been involved with the Working Group.
- Data gaps within Australia – Collaboration with other parallel ARPANSA projects to improve data quality, availability and storage.

It should be noted that the Safety Guide is not intended to be prescriptive. It will offer advice on how to perform an environmental assessment (including general advice on relevant tools), but will not recommend a preferred assessment tool or specific tier within an assessment tool.

5. Summary and Conclusions

A three year project is under way to produce an Australian *Safety Guide for Radiation Protection of the Environment*, overseen by the Radiation Health Committee. This involves the formation of an expert Working Group, which will draft the text, distribution to stakeholders (in the Consultative Group), and comment from the public.

Previous advice has been given that environmental assessments using the *Reference Organism* approach coupled with *Environmental Reference Levels* is appropriate for use in Australian radiation exposure situations. The Safety Guide is expected to expand on this advice and offer general guidance to operators and regulators on how to effectively perform environmental assessments.

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