

# Radiological Protection of the Environment and its Implementation into IAEA Safety Standards

D. Telleria\* and G. Proehl

Division of Radiation, Transport and Waste Safety, International Atomic Energy Agency  
Vienna International Centre, PO. Box 100, A-1400 Vienna, Austria

## ARTICLE INFO

### Article history:

Received 8 November 2013

Received in revised form 23 December 2013

Accepted 30 December 2013

### Keywords:

Radiological protection

Environment

Reference animals and plants

Flora and fauna protection

Ecosystems protection

## ABSTRACT

Radiological protection of the environment has been intensively discussed in recent years. Much progress has been made recently with regard to the development of models: (i) to estimate the uptake of radionuclides by flora and fauna in different habitats and ecosystems; (ii) to calculate internal and external exposures for a wide range of terrestrial and aquatic organisms; and (iii) in investigating and analyzing the effects of radiation exposures to biota.

This paper gives an overview of the current status of this work. Furthermore, the current status of the integration of environmental protection into the radiation protection system is also summarized.

© 2013 Atom Indonesia. All rights reserved

## INTRODUCTION

The present article summarize the evolution of the considerations on the radiological protection of the environment and how the Division of Radiation, Transport and Waste Safety of the International Atomic Energy Agency (IAEA) is incorporating in the international safety standards and guidance for radiological protection of people and the environment, the approach developed by the International Commission on Radiation Protection (ICRP) for assessing and control the level of protection of the environment.

The Consideration of protection of the environment from ionizing radiation began in the 1960s and 1970s [1-3], in order to investigate the possible harm to marine flora and fauna arising from the practice of disposing radioactive waste into the oceans. The Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter (London Convention 1972) [3] was an important milestone which stimulated research in this field as well as the development of approaches to take into account impacts of radionuclide substances on non-human species.

For many years the management of environmental releases of radionuclides was based on the evaluation of possible resulting radiation doses to humans. It was considered that the limitation of exposures to humans would also provide an adequate level of protection to flora

and fauna living in the same environments [4]. As a result of the pronounced awareness of environmental issues, considerations were initiated with regard to possible radiological impacts to flora and fauna arising from radionuclides released into the environment, irrespectively of their connection with human activities. "Protection of people and the environment - now and in the future" is defined as a key principle of safety in [5] and the ICRP [6] recommended to demonstrate demonstrate that the environment is appropriately protected against ionizing radiation.

## Objectives of radiation protection of the environmental

Whereas the objectives of radiation protection of humans are intended to avoid deterministic effects and to limit stochastic effects to individuals [7], the objectives for the protection of the environment are more complex. The consideration of individual animals or plants is not the aim, but approaches in environmental protection target higher organizational levels such as populations, community levels and ecosystems. The goals are related to the conservation of species, the maintenance of biodiversity and the protection of habitats, communities and ecosystems [6-10]. These goals are rather generic and they are not quantifiable in a straightforward manner. Furthermore, one has to be aware that-in any environment-ionizing radiation may represent only one of many stressors and is very likely not to be the most important one.

\* Corresponding author.

E-mail address: D.Telleria@iaea.org

In addition, beyond the sole consideration of radiological impact to humans as well as to flora and fauna, radiological protection of the environment has to ensure the sustainability of natural resources, i.e. agriculture, forestry, fisheries and tourism, and of the use of natural resources. Usually, such considerations are taken into account through the optimization of protection [5,7].

### Framework for radiological protection of the environment

With regard to radiological protection of the environment, frameworks have been developed in the context of the EU-funded projects FASSET and ERICA [11,12] and, in parallel, by the ICRP. The approach takes the system for the radiation protection of humans as an example (Fig. 1), it is described in [10,13]. All three exposure situations (i.e. planned, existing and emergency), are considered, as for humans, the assessment of exposures to both humans as well as to flora and fauna are based on measured or estimated radionuclide concentrations in the environment.

In analogy to the reference person [4,6], ICRP defined a number of Reference Animals and Plants (RAPs) [10]. RAPs represent different ecosystems (e.g. terrestrial, freshwater, marine) and different organisms (i.e. animals and plants). The RAPs are described at the taxonomic level of family, if applicable. RAPs have been selected to represent significant wild life groups that are found in most of the environments around the world. Databases have been elaborated in order to enable the estimation of exposures in different natural environments, and the understanding of the significance of the exposure in terms of biological effects [10].

Exposures are calculated for RAPs respectively. Decisions needing to be made in relation to human exposure are guided by comparison with dose limits and constraints for planned exposures and with reference levels for existing and emergency exposure situations. Exposures to biota may be evaluated by comparison with reference criteria like the Derived Consideration Reference Levels (DCRLs), as defined by ICRP [10], taking into account the specific conditions of the exposure situations [13].

### SCIENTIFIC BACKGROUND

Much work was done during the last decade to elaborate the basis for the assessment and evaluation of radiological impacts to flora

and fauna. In 2005, the ICRP established a Committee dedicated to Protection of the Environment with the aim of setting up a framework for assessment and evaluation of exposures to biota. The work of the Committee was closely linked to the activities of the EU-funded projects FASSET and ERICA [11,12].

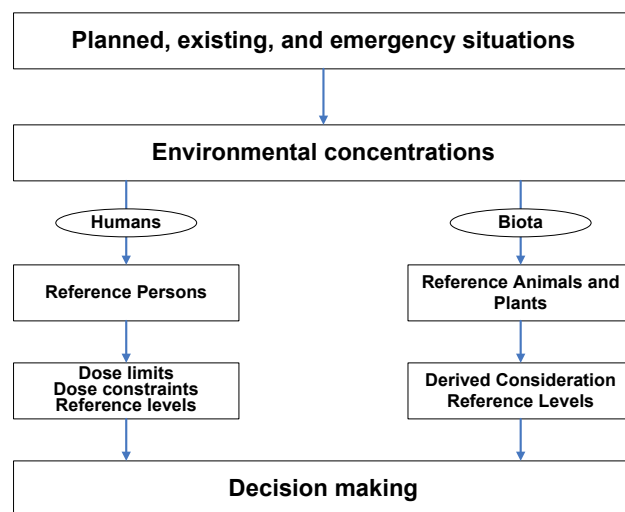


Fig. 1. Scheme for estimating and evaluating exposures to humans and biota.

Table 1. Reference Animals and Plants as derived in [10].

Ecosystem	Wildlife group	Reference
Terrestrial	Large terrestrial mammal	Reference deer
	Small terrestrial mammal	Reference rat
	Large terrestrial plant	Reference pine
	Small terrestrial plant	Reference grass
	Insect	Reference bee
	Annelid	Reference earthworm
Terrestrial/aquatic	Amphibians	Reference frog
	Aquatic bird	Reference duck
Freshwater	Freshwater pelagic fish	Reference trout
Marine	Seaweed	Reference brown seaweed
	Marine crustaceans	Reference crab
	Marine fish	Reference flatfish (benthic)

The approach to assess exposures is summarized in Fig. 2. Following the releases of radionuclides to the aquatic or terrestrial environments, flora and fauna may receive radiation

doses through internal and external exposure. The assessment of exposures starts from measured or estimated activity concentrations in water, sediments or soil. For their estimation, the same dispersion models typically used for the estimation of doses to members of the public arising from discharges to the environment can be applied.

Specific data needed for the exposures of reference animals and plants are: (1) Transfer parameters are compiled to allow the estimation of the uptake by reference animals and plants from water, sediments or soil in order to calculate activity concentrations in reference animals and plants [14]. A compilation of transfer parameters for a wider range of taxa is published in [15]. The values provide the ratio of the average activity concentration in the considered reference organism and the surrounding environmental medium; and (2) Dose conversion coefficients (DCC) for assessing internal and external radiation exposures to terrestrial and aquatic biota were developed. The DCCs for internal exposure are calculated for a homogeneous distribution of the radionuclides in both terrestrial and aquatic organisms. For the calculation of DCCs for external exposure, it is assumed that aquatic organisms are immersed by water; for terrestrial RAPs, habitats in-soil, on-soil and above-soil are assumed.

Based on an analysis of the existing data on radiation effects in cells, tissues, organisms and - in a few cases - on population and ecosystems, the ICRP has derived the set of Derived Consideration Reference Levels (DCRL) for the 12 RAPs. These DCRLs, which are bands of doses which cover one order of magnitude (Table 2), represent bands of doses that are associated with no, or very little, adverse effects. A wide range of effects has been considered and are classified into rbidity, mortality, reduced success in reproduction and mutations.

DCRLs do not represent dose limits, they should be considered as zones of doses at which a more detailed analysis should be carried out. For this evaluation of the exposure conditions, factors should be taken into account such as, e.g. the type of exposure situation (i.e. planned, existing, emergency), the size of area that is affected, the time period for such exposures, the fraction of a population of a species that is exposed to such dose levels, the appropriateness of the database used for the dose estimation, and the degree of precaution that is needed for the assessment.

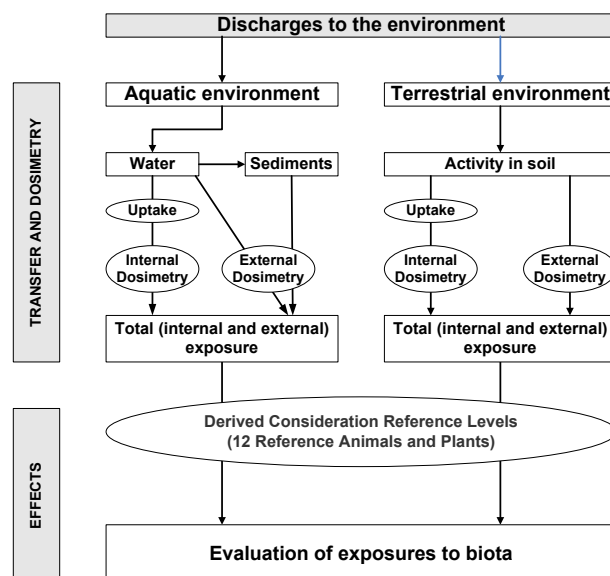


Fig. 2. Scheme to estimate and evaluate exposures to biota in the aquatic and terrestrial environments.

Table 2. Derived Consideration Reference Levels for Reference Animals and Plants [10].

Reference Animal and Plants	Derived Consideration Reference Level (mGy/d)
Reference deer, rat, duck, pine	0.1-1
Reference frog, trout, flatfish, brown seaweed, grass	1-10
Reference bee, earthworm, crab	10-100

## RESULTS AND DISCUSSION

### Implementation of radiological protection of the environment in the IAEA basic safety standards and related safety guides

In the IAEA's International Basic Safety Standards [7], objectives for radiological protection of flora and fauna are defined in accordance with [6] (section 2). However, it is also stressed that radiological protection of the environment should not be considered in isolation since man is an integral part of the environment. Besides the pure radiological protection of man and flora and fauna, the sustainable use of natural resources for e.g. agriculture, forestry fishery and tourism – now and in the future – should be ensured, which is in general warranted by the appropriate application of the optimization principle [5]. The BSS [7] explicitly requires the consideration of protection of the environment for registration and licensing of activities during setting discharge limits for facilities, it is not specified to what level of detail this should be considered. Specific numerical dose

levels to be applied for control of exposures of flora and fauna are not included in the BSS.

Protection of the environment is one factor for consideration during optimization in existing and emergency exposure situations.

Four IAEA Safety Guides are currently being revised or newly developed in order to address requirements of the BSS with regard to exposures of the public and the consideration of radiological impacts to the environment from radionuclides released to, or existing in, the environment. Planned, existing and emergency exposure situations are addressed; the recommendations are summarized in the following key points: (1) For planned exposure situations, e.g. when setting conditions for radionuclide discharges to the terrestrial or aquatic environments, the lower boundary of the relevant DCRL band (Table 2) should be applied as a reference for protection of different types of biota within a given area. The impact of multiple sources should be taken into account. Should resulting exposures to the different types of biota exceed the lower end of the DCRL, further actions to improve the level of protection could be considered, bearing in mind that DCRLs are not limits and taking into account the specific circumstances of exposures. If doses to the considered biota are above the upper end, the planned activity would very likely create a significant environmental contamination, indicates a stronger need for further protection efforts. The potential environmental consequences of emergency actions should be considered as part of the planning phase, which will in turn involve consideration and optimization of protection strategies; and (2) For existing and emergency exposure situations, radiological impacts to wildlife cannot, or only marginally, be controlled. However, the environmental consequences of the mitigating and remediation actions for optimizing human protection should be taken into account, as appropriate. The set of the DCRL's might be used for providing information of the radiological impacts and possible effects to wildlife and how long such effects are going to exist.

## CONCLUSION

Radiological protection of the environment is a topic that has been intensively discussed in the recent years. The main achievements are summarized below.

Frameworks have been developed to estimate the exposures of reference animals and plants, flora and fauna and to evaluate exposures with regard to adverse effects induced by ionizing radiation. These methods allow the assessment of external and

internal exposures to RAPs in terrestrial and aquatic environments.

For the evaluation of exposures, the ICRP has derived DCRLs, a set of bands of dose rates for the RAPs within which there is likely to be some chance of deleterious effects of ionizing radiation occurring to individuals of that type of reference animal or plant.

The consideration of the protection of the environment has been included in the International Basic Safety Standards and guidance is currently being developed for the implementation of these requirements.

It should be noted that routine discharges of radionuclides to the environment that comply with radiation protection criteria for humans may hardly affect wildlife, whereas exposures to wildlife in the band of the Derived Consideration Reference Levels would very likely imply restrictions with regard to human activities in those areas.

As environmental protection issues attract public attention, further scientific studies would improve the understanding of the interaction of ionizing radiation on communities, habitats and ecosystems and facilitate the communication with the public. This is in particular important for the analysis and evaluation of effects that might be reported for areas affected by nuclear accidents.

Exposures to humans and to wildlife should not be considered in isolation, but assessed and evaluated in an integrated approach in order to achieve consistent conclusions and well-balanced decisions.

## REFERENCES

1. Anonymous, Radioactive Waste Disposal into the Sea, IAEA Safety Series No. 5, IAEA (1961).
2. Anonymous, A Methodology for Assessing Impacts of Radioactivity on Aquatic Ecosystems, TRS-190, IAEA (1979).
3. Anonymous, *Final act of the conference with attachment including the Convention for the Prevention of Marine Pollution by Dumping of Wastes and Other Matter*, Intern. Conf. on the Convention on Dumping of Wastes at Sea (1972).
4. Anonymous, The 1990 Recommendations of the International Commission on Radiological Protection, ICRP Publication 60, Elsevier (1991).
5. Anonymous, Fundamental Safety Principles, IAEA Safety Standards Series SF-1, IAEA (2006).

6. Anonymous, The 2007 Recommendations of the International Commission on Radiological Protection, ICRP Publication 103, Annals of the ICRP (2007).
7. Anonymous, Radiation Protection and Safety of Radiation Sources: International Basic Safety Standards, General Safety Requirements No. GSR Part 3, IAEA (2011).
8. Anonymous, Ethical considerations in protecting of the environment from the effects of ionizing radiation – A report for discussion: IAEA-TECDOC-1270, IAEA (2002).
9. Anonymous, A Framework for Assessing the Impact of Ionising Radiation on Non-human Species, ICRP Publication 91, Elsevier (2003).
10. Anonymous, Environmental Protection: The Concept and Use of Reference Animals and Plants, ICRP Publication 108, Annals of the ICRP, (2008).
11. C.M. Larsson, J. Rad. Prot. **24** (2004) A1–A12.
12. C.M. Larsson, J. Environ. Radioact. **99** (2008) 1364.
13. Anonymous, Protection of the Environment under Different Exposure Situations, Approved for publication, ICRP.
14. Anonymous, Environmental Protection: Transfer Parameters for Reference Animals and Plants, Ann. ICRP (2009) 39 (6).
15. Anonymous, Handbook of Parameter Values for the Prediction of Radionuclide Transfer to Wildlife, Technical Reports Series, Publication Approved (2013).