

## Use of the ICRP system for the protection of marine ecosystems

D. Telleria<sup>a</sup>, T. Cabianca<sup>b</sup>, G. Proehl<sup>a</sup>, V. Kliaus<sup>c</sup>, J. Brown<sup>d</sup>,  
C. Bossio<sup>e</sup>, J. Van der Wolf<sup>f</sup>, I. Bonchuk<sup>g</sup>, M. Nilsen<sup>d</sup>

<sup>a</sup>*IAEA Assessment and Management of Environmental Releases Unit, Wagramer Str. 5, PO Box 100, 1400 Vienna, Austria; e-mail: D.Telleria@iaea.org*

<sup>b</sup>*Public Health England, Planned Exposure Group, UK*

<sup>c</sup>*Laboratory of Radiation Safety, Republican Scientific-Practical Centre of Hygiene, Republic of Belarus*

<sup>d</sup>*Norwegian Radiation Protection Authority, Norway*

<sup>e</sup>*Nuclear Regulatory Authority, Radiological Safety Assessments Division, Argentina*

<sup>f</sup>*Delft University of Technology, The Netherlands*

<sup>g</sup>*Ukrainian Radiation Protection Institute, Ukraine*

**Abstract**—The International Commission on Radiological Protection (ICRP) recently reinforced the international system of radiological protection, initially focused on humans, by identifying principles of environmental protection and proposing a framework for assessing impacts of ionising radiation on non-human species, based on a reference flora and fauna approach. For this purpose, ICRP developed dosimetric models for a set of Reference Animals and Plants, which are representative of flora and fauna in different environments (terrestrial, freshwater, marine), and produced criteria based on information on radiation effects, with the aim of evaluating the level of potential or actual radiological impacts, and as an input for decision making. The approach developed by ICRP for flora and fauna is consistent with the approach used to protect humans. The International Atomic Energy Agency (IAEA) includes considerations on the protection of the environment in its safety standards, and is currently developing guidelines to assess radiological impacts based on the aforementioned ICRP approach. This paper presents the method developed by IAEA, in a series of meetings with international experts, to enable assessment of the radiological impact to the marine environment in connection with the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter 1972 (London Convention 1972). This method is based on IAEA's safety standards and ICRP's recommendations, and was presented in 2013 for consideration by representatives of the contracting parties of the London

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This paper does not necessarily reflect the views of the International Commission on Radiological Protection.

Convention 1972; it was approved for inclusion in its procedures, and is in the process of being incorporated into guidelines.

*Keywords:* Radiological protection; Protection of the environment; Reference Animals and Plants; System of radiological protection

## 1. INTRODUCTION

Until publication of the 2007 Recommendations of the International Commission on Radiological Protection (ICRP, 2007), the system for radiological protection applied for the management of environmental releases of radionuclides was based on the evaluation of possible resulting radiation doses to humans (ICRP, 1991). It was considered that the limitation of exposures to humans would also provide an adequate level of protection to the environment (ICRP, 1991).

As a result of the growing societal concerns related to possible effects of ionising radiation on the environment, as well as pronounced awareness of environmental issues, considerations were initiated by the international radioprotection community with regard to possible radiological impacts on the environment. ‘Protection of people and the environment’ is identified as a key principle of safety (IAEA, 2006). ICRP now recommends broadening the radiological protection framework beyond the primary aim of contributing to an appropriate level of protection for human beings in an environmental context, to one that includes protection of the environment itself against the detrimental effects of radiation exposure, without unduly limiting the desirable human actions that may be associated with such exposure (ICRP, 2007).

## 2. OBJECTIVES OF PROTECTION OF THE ENVIRONMENT

IAEA defines the environment as the ‘conditions under which people, animals and plants live or develop and which sustain all life and development; especially such conditions as affected by human activities’ (IAEA, 2014). Usually, the environment includes biotic and abiotic components.

It is recognised that, similarly to humans, flora and fauna could be affected by ionising radiation resulting from planned or accidental releases.

The objectives of radiation protection of humans are intended to avoid deterministic health effects and to limit stochastic health effects (IAEA, 2014).

Otherwise, the objectives for the protection of the environment are more generic, and are not quantifiable in a straightforward manner. The aims of environmental protection are to prevent or reduce the frequency of deleterious radiation effects on biota to a level where they would have a negligible impact on the maintenance of biological diversity, the conservation of species, or the health and status of natural habitats, communities, and ecosystems (ICRP, 2007, 2008, 2014).

While the system of radiological protection of humans applies for individuals, consideration of individual animals or plants is not the aim for protection of the environment, where the target is higher organisational levels such as populations, community levels, and ecosystems.

### **3. ICRP'S APPROACH FOR PROTECTION OF THE ENVIRONMENT**

ICRP has defined an approach to assess and control the effects of radiation on flora and fauna (ICRP, 2007, 2008, 2014) using the concepts of Reference Animals and Plants (RAPs) and Representative Organisms, consistent with the concepts of Reference Person and Representative Person for humans (ICRP, 1991, 2007), and corresponding dose criteria in the form of derived consideration reference levels (DCRLs).

The method to assess the level of protection of the environment where radioactivity releases may occur is to estimate dose rates resulting from radiation exposure of a set of RAPs representative of those more highly exposed, and to compare the resulting doses with a criteria. By this, it is possible to define a level of protection of the environment, or make decisions on managerial options.

The approach to environmental protection has to be commensurate with the overall level of risk, and compatible with other approaches being made to protect the environment (ICRP, 2008).

#### **3.1. Reference Animals and Plants**

In the system of radiological protection for humans, *Publication 103* (ICR, 2007) defined a model called 'Reference Person', and methods to calculate its doses that can be used in assessment of the radiological impact to members of the public. In a similar manner, for flora and fauna, ICRP has defined a small set of RAPs, including models for their dosimetry (ICRP, 2008). An RAP was defined (ICRP, 2008, 2014) as a hypothetical entity with the assumed basic biological characteristics of a particular type of animal or plant, as described to the generality of the taxonomic level of Family, with defined anatomical, physiological, and life-history properties that can be used for the purposes of relating exposures to dose, and dose to effects, for that type of living organism. The selection of the species, which may be used as indicators of the level of environmental protection, is discussed in ICRP (2014). The use of these particular species is somewhat subjective and is related to their connection with particular major ecosystems and, principally, to the existence of databases with information on radiation effects.

#### **3.2. Derived consideration reference levels**

For evaluating the level of radiological impact on flora and fauna, ICRP introduced DCRLs for the set of RAPs. The DCRLs do not represent limits; they should be considered as points of reference to inform on the appropriate level of effort that should be expended on environmental protection, dependent on the overall management objectives, the exposure situation, the actual fauna

and flora present, and the numbers of individuals thus exposed (ICRP, 2007, 2008, 2014).

In a generic assessment, a level of protection established by setting reference criteria below or equal to the lower band of the DCRLs is considered to be an appropriate level of protection for flora and fauna (IAEA, in preparation).

DCRLs are presented in ICRP (2008, 2014).

### **3.3. Representative Organisms**

*Publication 124* (ICRP, 2014) indicates that a 'Representative Organism' is 'a particular species or group of organisms selected during a site-specific assessment, taking account of their assumed location with respect to the source'. The actual choice of Representative Organism will depend upon the purpose of the assessment (ICRP, 2008). In many cases, the actual Representative Organisms chosen for an assessment may be the same as, or very similar to, the RAPs, but in some cases, they may be very different. The selection of Representative Organisms for use in an assessment for protection could be based on assumptions of a generic character or site-specific characteristics (IAEA, in preparation).

## **4. IAEA'S METHOD FOR PROTECTION OF THE ENVIRONMENT**

When considering environmental protection, IAEA (in preparation, 2015) adopted the concepts and use of RAPs, DCRLs, and Representative Organisms defined by ICRP (2007, 2008, 2014), and complemented the approach with the requisite to consider protection of flora and fauna and humans in an integrated manner (IAEA, 2011). This integration of human and flora and fauna protection can be considered, in practical terms, assuming a linkage in the exposure scenarios. Fig. 1 shows a scheme for estimating and evaluating exposures to humans and biota, and indicates the link between the exposure scenarios. All three exposure situations (i.e. planned, existing, and emergency) are considered. The assessment of exposures to humans and flora and fauna is based on measured or estimated radionuclide activity concentrations in the environment.

Using this approach, the managerial decisions related to the environment could be made based on considerations for the protection of humans and flora and fauna in an integral manner.

## **5. RADIOLOGICAL PROTECTION OF THE MARINE ENVIRONMENT IN THE FRAMEWORK OF THE LONDON CONVENTION 1972**

IAEA is the international technical advisor in matters related to radioactive materials for the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter 1972 (IMO, 1972).

The London Convention 1972 prohibits the disposal of radioactive wastes and other radioactive matter at sea. However, natural radionuclides are present in all

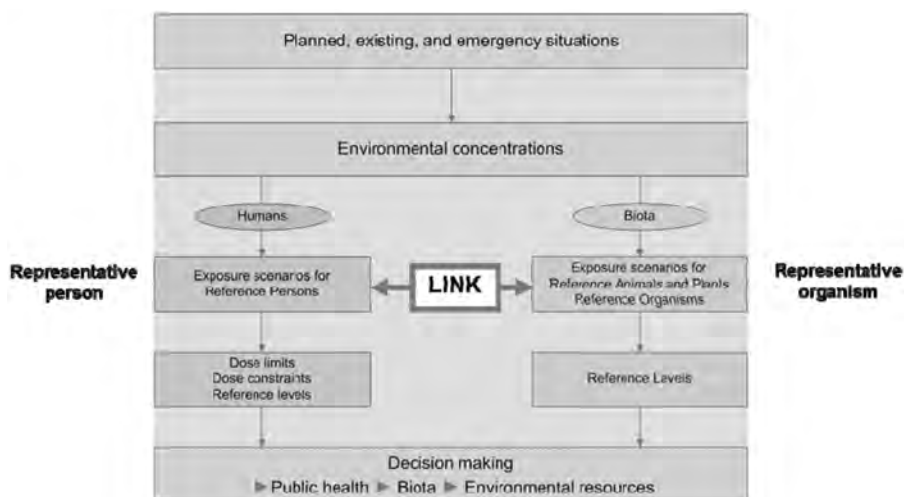


Fig. 1. Scheme illustrating the integrated approach proposed by the International Atomic Energy Agency to assess and manage the radiological protection of humans and the protection of the environment.

materials, including natural and inert materials, which can also contain artificial radionuclides from anthropogenic sources such as fallout due to past atmospheric nuclear testing. Therefore, there was a need to develop definitions and guidelines so that candidate materials containing less than de minimis levels of specific radioactivity (IAEA, 1999) can be regarded as ‘non-radioactive’, and may be disposed of at sea, subject to the other provisions of the Convention.

In 2003, IAEA was requested by the contracting parties of the London Convention 1972 to expand the method to determine if materials that are candidates for dumping have trivial radiological impact and, consequently, can be dumped in the framework of the Convention. Originally, this method considered human protection aspects (IAEA, 2003), but, in order to fill a conceptual gap and in accordance with the international trends on this topic, contracting parties requested that protection of the marine flora and fauna should be considered more explicitly.

For the purpose of the London Convention 1972, and thanks to the recent progress in this area by ICRP, IAEA could develop, with the cooperation of international experts, a method for assessing the impact on humans and the marine environment related to the dumping of materials containing radioactive residues.

This method is of a generic and conservative character, and is based on ICRP’s approach for protection of flora and fauna combined with the approach to consider humans and the environment in an integrated manner as proposed by IAEA. The method was approved by the Contracting Parties to the London Convention in October 2013 (IAEA, 2015).

### **5.1. Calculation of radionuclide concentrations in water, sediment, and marine biota**

A box model is used to simulate the dispersion and dilution of the radionuclides in the water column of the region surrounding a dumping site. Details are presented in IAEA (2003) and IAEA (2015). The radionuclide concentrations in seawater and sediments predicted by the model are average values over the entire volume of the box in the year of release. The model assumes instantaneous equilibrium between radionuclides in the soluble phase, and those adsorbed on particles suspended in the water column and on particles in the top sediment boundary layer.

### **5.2. Selection of Reference Animals and Plants**

For the marine environment and under the exposure situations related to the framework of the London Convention 1972, IAEA indicates that the relevant ICRP RAPs are a marine fish, a marine crustacean, and a type of seaweed (IAEA, 2015). IAEA notes that this is a generic approach, and, although applicable to other similar exposure situations and regulatory frameworks in principle, it is important that careful consideration of the particularities of the exposure scenarios are taken into account before using the same methodology (IAEA, 2015).

### **5.3. Representative Persons and Representative Organisms**

Representative Persons in the case of members of the public are those living near to the shoreline in the area of influence of the planned dumping activity, eating seafood coming from the same sea region where materials are dumped, and occupying the beach during some time in the year.

In the case of flora and fauna, the Representative Organisms are the RAPs located in the sea region of the dumping activity.

The exposure scenario to humans and flora and fauna is linked by these assumptions.

### **5.4. Exposure pathways to humans and marine flora and fauna**

The following exposure pathways are considered for members of the public:

- external exposure to radionuclides deposited on the shore;
- ingestion of seafood caught in the area around the dumping site;
- inadvertent ingestion of beach sediments;
- inhalation of particles resuspended from beach sediments; and
- inhalation of sea spray.

In the case of marine flora and fauna, the following external and internal exposures are considered:

- external irradiation due to radioactive material diluted in the water and in the marine sediments; and
- internal exposure from incorporated radioactive material.

The simplifications in assessing internal and external exposures to flora and fauna are discussed in ICRP (2008).

### **5.5. Estimation of doses to members of the public and flora and fauna**

Individual doses to members of the public are calculated starting from estimations of the annual average activity concentrations in water and sediments, resulting from the dumping of materials with radioactive residues.

For estimating the activity concentration, a generic box in the sea of  $10 \text{ km} \times 10 \text{ km} \times 20 \text{ m}$  located at the point of release is defined.

It is assumed that members of the public eat seafood from that box and, using consumption rates and the corresponding dosimetric factors, internal doses are estimated. For the internal and external doses related to the occupation of the beach by the public, the activity concentrations in beach sediments and sea spray is estimated using transfer factors.

Collective doses to the public are assessed using external and internal pathways, and generic factors determining the number of individuals affected (e.g. length of the coastline affected by the dumping activity, and annual amount of seafood caught in the area affected by a single dumping).

Doses to the defined marine RAPs are estimated for external and internal exposures using the activity concentration in water and marine sediments in the same generic box as for public and transfer parameters, and dosimetric factors provided in ICRP (2009) and ICRP (2008), respectively.

Based on this approach, a practical set of screening coefficients to estimate individual and collective doses to members of the public, and dose rates to marine RAPs (fish, crustacean, and seaweed), were calculated. For these screening coefficients, models and parameters which tend to overestimate the dose assessment were used in order to obtain conservative results.

IAEA (2015) provides these screening coefficients for the purpose of the London Convention 1972 and the details of the assessment described in this section, including models, assumptions, parameters, and sources of information.

### **5.6. Criteria for humans and marine flora and fauna**

IAEA (2015) indicates that, under the framework of the London Convention 1972, candidate material may be considered for disposal, verifying other non-radiological requirements in the London Convention Guidelines (IMO, 2006), if:

- the estimated annual individual dose to members of public is equal to, or less than,  $10 \mu\text{Sv}$ ;
- the estimated annual total collective dose is less than, or equal to,  $1 \text{ man-Sv}$ ; and
- the estimated dose rate for each marine RAP is below, or equal to, the corresponding DRCL.

If the material satisfies all these criteria for members of the public and flora and fauna, it can be considered for dumping.

## 6. CONCLUSIONS

The 2007 Recommendations (ICRP, 2007) enhanced the system of radiological protection by providing an approach to assess and manage the protection of the environment, based on consideration of the radiological impact on flora and fauna. This approach includes the concepts of RAPs, DCRLs, and Representative Organisms (ICRP, 2008, 2014), consistent with the concepts of Reference Person, dose limits, constraints, reference levels, and Representative Person used to assess and manage the protection of the public against the effects of ionising radiation (ICRP, 2007).

IAEA considered protection of people and the environment in its Safety Standards (IAEA, 2006), and added the requisite of an approach that must consider humans and flora and fauna in an integrated manner (IAEA, 2014).

The London Convention 1972 asked IAEA to provide a method to assess the radiological impact to marine flora and fauna more explicitly, in order to authorise disposal of materials to the oceans from the radiation protection point of view.

IAEA has expanded previous work undertaken for the London Convention 1972 (IAEA, 2003), which considered human protection aspects alone, by incorporating explicit considerations for marine flora and fauna into the assessment (IAEA, 2015).

The work undertaken by IAEA, with the assistance of international experts, resulted in a practical methodology applicable for the London Convention 1972 (IAEA, 2015); this methodology was approved by the contracting parties in October 2013, and is in the process of being incorporated into guidelines (IMO, 2006).

The proposed assessment procedure is based on the state of the art in radiological protection of the environment, in line with ICRP recommendations and IAEA safety standards.

The application of these practical procedures would be appropriate to protection of the marine environment and use of the marine resources in a sustainable manner, without imposing unnecessary burden on the potential users.

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