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ICRP's approach to protection of the living environment under different exposure situations

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Abstract–The International Commission on Radiological Protection's (ICRP) system to protect the living components of the environment is designed to provide a broad and practical framework across all exposure situations. The objectives of ICRP are therefore also set in fairly broad terms, recognising that national and local environmental protection requirements may need to be set within them. The framework recognises the need to be able to demonstrate an adequate level of protection in relation to planned exposure situations, whilst also providing an ability to manage existing situations and accidents, as well as emergency situations, in a rational way. The objects of protection are always real biota in real exposure situations, and the scientific basis for their protection needs to be based on data originating from studies on the relationships between exposure and dose, dose and effects, and effects and consequences in real animals and plants. The framework that has been developed has therefore had to take such realities into account to make the optimum use of the data currently available, whilst being sufficiently flexible to accommodate new scientific information as it arises without having to alter the framework as a whole.

Keywords: Biota; Environmental protection; Reference Animals and Plants

1. INTRODUCTION

The need to protect the living components of the environment (the biota) by taking either proactive or retrospective action is now widely accepted as part of the regulation and management of any large-scale industrial activity (ICRP, 2003). In the framework of radiological protection developed by the International

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

Commission on Radiological Protection (ICRP), this necessity applies to three exposure situations which, in the context of environmental protection, essentially consist of the following: planned exposure situations, which involve the discharge and disposal of radioactive waste, the decommissioning of installations, and activities related to the eventual remediation and decontamination of sites; existing exposure situations, where the source already exists and a decision on control has to be taken, including prolonged exposure situations after emergencies; and emergency exposure situations that may occur as a result of accidents, malicious acts, or any other unexpected situation in which control of the source has been lost, and urgent actions are required in order to avoid or reduce undesirable consequences.

ICRP's aims for the protection of animals and plants in their natural environmental settings apply to these situations. The aims are those of '... preventing or reducing the frequency of deleterious radiation effects 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).

The questions that naturally arise from these two starting points (different types of exposure situations, and general aims relating to the protection of biota that could be affected by them) therefore include the following:

- Which biological effects of radiation are of relevance?
- To which components of the environment (i.e. which animals and plants) do they apply?
- How would one know what doses these animals and plants have received?
- How can one know what the effects of radiation are on these animals and plants?
- How would one know that the original objectives had been met?

This paper briefly addresses these questions and summarises ICRP's approach to environmental protection from a high-level perspective. Full documentation has been published in *Publications 108*, *114,* and *124* (ICRP, 2008, 2009, 2013); further – and more specific – detail is given in the Proceedings of the First ICRP Symposium on the International System of Radiological Protection (ICRP, 2012).

2. BIOLOGICAL EFFECTS OF RELEVANCE

Given the general aims of ICRP, it is evident that the principal focus is that of the protection of 'populations' or large groups of individuals. This is quite different from the aims in relation to the protection of human beings, which relate to the risks of radiation affecting individuals. However, radiation effects on 'populations' are mediated through effects on individuals. The biological endpoints of interest to individuals that could have a consequence at a population level are therefore those of:

- early mortality (leading to changes in age distribution, death rate, and population density);

- some forms of morbidity (that could reduce 'fitness' of the individuals, making it more difficult for them to survive in a natural environment);
- impairment of reproductive capacity by either reduced fertility or fecundity (affecting birth rate, age distribution, number, and density); and
- induction of chromosomal damage.

ICRP has therefore summarised the information available on the effects of radiation to certain types of animals and plants under these categories, rather than as stochastic or non-stochastic (deterministic) effects as it has for human radiological protection.

3. APPLICATION TO ACTUAL EXPOSURE SITUATIONS

In order to apply ICRP's recommendations in practice, and to meet its overall objective, a framework would ideally include all of the following elements.

- Clearly stated local environmental protection objectives that relate to a specific environmental exposure situation.
- Knowledge of the effects of radiation, at different dose rates, to different tissues, organs, and life stages of the relevant biota relating to such objectives.
- Estimates of the dose likely to be received by the relevant biota under those environmental exposure situations, in terms of the tissues, organs, and life stages most likely to be at risk with regard to the relevant biological endpoints.
- Number of individuals, or fraction of the relevant population, that would be likely to receive such dose rates, and when.
- Actions, or choice of actions, that could be taken to optimise the level of protection of the relevant biota relating to radiation exposure, bearing in mind other possible threats to the same population.

Due to the immense variety of biota and their presumed response to radiation, any credible system also needs to have some key points of reference that provide some form of auditable trail which links the basic elements of the framework together, or at least could do so if further data were forthcoming, and it is feasible to obtain such data. The advantage of such a systematic approach is that, as the needs for change to any component of the system arise (as in the acquisition of new scientific data, changes in societal attitudes, or simply from experience gained in its practical application), it is possible to consider what the consequences of such a change may be elsewhere within the system, and upon the system as a whole.

Regarding the biota that represent the actual targets of protection in any specific exposure situation, these may already be identified because of existing environmental legislation. Such legislation may relate to the type of habitat or to certain components of, or indeed all of, the local fauna or flora. This protective need may have arisen because of nature conservation or commercial (e.g. fisheries) concerns. Thus, in planned exposure situations, some selection and dialogue with other relevant

regulatory or 'stakeholder' groups may be necessary. In existing exposure situations, however, the objects of concern are those components of the biota that are within the contaminated area, or otherwise associated with it. However, even for the purposes of nature conservation, it is usually impossible to know about all of the species within any ecosystem, and the 'health' of such areas is thus often assessed by studying a subset of its components. Therefore, for the purposes of assessing the actual or potential effects of radiation on an environmental area, it is recommended that Representative Organisms (ROs) should be identified to serve as representatives of a particular species, or a group of organisms, in relation to a site-specific assessment, taking account of their assumed location with respect to the source.

4. ESTIMATING DOSE RATES AND ASSESSING THE POTENTIAL FOR RADIATION EFFECTS

In existing exposure situations, dose rates will usually be made based on direct observations (e.g. external dose rates), or calculated from measured concentrations of radionuclides within, and external to, the relevant biota. In some cases, however, dose rates may need to be estimated from the use of models, either to extrapolate backwards or forwards in time, or to areas that are not readily accessible. For planned (and emergency) exposure situations, however, dose rates are most likely to be obtained from modelling. Obviously the best-available models and databases should be used. Once estimates of dose rates have been obtained, the potential effects of such dose rates need to be assessed.

There is clearly a limit to the amount of information available on the effects of radiation on different types of biota, and a limit to the extent that such information could ever be obtained as a result of laboratory experimentation. Even for those biota that have been the subject of study, the dose rates used are high, and there is no equivalent of the linear, no-threshold model to allow extrapolation from effects at high doses and dose rates to lower doses and dose rates. In general, there is little difference in response across a range of dose rates for mammals, and this may also apply to birds (because they are also homothermic vertebrates with high metabolic rates), but there are insufficient data at present to draw firm conclusions. For other vertebrates, generalisations are again difficult to make because their lower metabolic rates (that are also temperature dependent) are seldom taken into account.

ICRP has therefore used a set of Reference Animals and Plants (RAPs) to serve as points of reference to relate exposure to dose, and dose to effect, for different types of biota. The RAPs were selected on the basis of a number of criteria, including the fact that a reasonable amount of radiobiological information was already available on them, including data on probable radiation effects and/or that they were amenable to future research in order to obtain the necessary missing or imprecise data, particularly with regard to radiation effects. A set of RAPs was therefore identified by ICRP (ICRP, 2008), but there is nothing sacrosanct about the set; other biotic types could have been chosen. They were all considered to be organisms that are 'typical' of different environments, in the sense that one might expect to find them there. The set

is also essentially one of 'wild' animals and plants rather than domesticated organisms. Quite clearly, in order to serve as points of reference, the RAPs needed to be defined fairly precisely and are thus described to the generality of the taxonomic level of Family, with defined anatomical, physiological, and life-history properties.

In order to use existing databases on the effects of radiation, the only pragmatic approach therefore seemed to be to organise the existing databases for each type of RAP into bands of dose within which certain effects have been noted, or might be expected, and then to select a single band for each RAP to serve as a derived consideration reference level (DCRL; i.e. a 'reference level' for effects, transparently derived, that can be considered as the starting point for decision making, depending on the purpose for making decisions under a defined exposure situation). Tables were therefore constructed to cover dose rate ranges, in bands, from <0.1 mGy day^{-1} to >100 mGy day^{-1} (ICRP, 2008). Dose rates >1 Gy day^{-1} are essentially of no environmental relevance. The resultant set of DCRLs can therefore be used 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. The DCRLs have been defined in terms of bands of dose rates spanning one order of magnitude, and are relevant to a large and a small terrestrial mammal, a bird, an amphibian, a marine fish and a freshwater fish, a crustacean, an annelid, a tree, a small plant, and a seaweed.

5. MEETING ENVIRONMENTAL OBJECTIVES

As the databases, particularly on radiation effects, are so limited, it would obviously be an advantage – given a choice – to select ROs that are as similar to RAPs as possible. Where this is not possible, differences between ROs and the RAPs should nevertheless be quantifiable, in relation to their basic biology, dosimetry, or radiation effects, and such differences need to be noted and taken into account. The extent to which such factors need to be applied, and their relevant impact on the final management decision, will depend on the nature of the implementation and application of the planning process relevant to protection of the environment. As other regulatory bodies are likely to be involved, such as those responsible for wildlife management, it is essential to have a clearly set out logical link between any radioactive releases and any potential risk of biological effects (for which the RAP framework should be a starting point), and a clearly laid out strategy by which the relevant stakeholders can be engaged in the decision-making process.

From a practical point of view, and to help create a set of reference points, *Publication 108* (ICRP, 2008) also included reference data sets (dose conversion factors) by which concentrations of radionuclides inside or outside the RAPs could be converted into dose rates at an approximate whole-body level, and a further publication (ICRP, 2009) provided reference data sets (concentration ratios) by which concentrations in the ambient media, under equilibrium conditions, could be related to whole-body concentrations for the relevant RAPs.

It is therefore considered that ICRP's original objectives in relation to protection of the environment would be met by reference to the bands of DCRLs. Thus, in planned exposure situations, the lower boundary of the relevant DCRL band should be used as the appropriate reference point for protection of different types of biota within a given area during the planning of controls to be applied to a source. As the DCRL bands apply to animals and plants within a given location, the extent of such an area needs to be determined in advance relative to the overall conservation objectives. The area is unlikely to be sufficiently large to involve an entire 'population' of the relevant biota. In the case of multiple sources of exposure (e.g. from historical discharges or multiple sites), these other sources should be taken into account in comparison with the DCRLs when assessing protection options. If the assessed dose rates are below the appropriate reference point, the level of control is determined by selection of the most reasonable protective action.

Planned exposure situations relating to the management of long-lived wastes are especially difficult with regard to protection of the environment, because the biosphere is likely to change, and may even change substantially, over the long time frames that are considered in such waste disposal. Such changes may entail alterations that are natural or are enhanced, or perturbed, through human action. The default case for protection, and protective actions, should therefore be the set of RAPs, bearing in mind that this set was chosen deliberately because its components are considered to be 'typical' biotic types of the major environmental domains of land, sea, and fresh water.

Planned exposure situations may also involve consideration of the possibilities and magnitude of the consequences of potential events or accidents (potential exposures). Thus, during planning phases, there may be a need to consider different siting options for a specific source (such as placing an outlet into a river, an estuary, or the sea), with regard to the potential environmental impact of accidental releases of radionuclides into these different media. It may also include a need to consider the potential impact of accidental releases (such as an accidental release into the aquatic medium or the atmosphere) from a defined source on the different surrounding media (terrestrial, freshwater, or marine environments) and the mitigating measures that may be available. The DCRL bands again may serve as a point of reference in such assessments, and be used as a mechanism to compare impacts in the overall siting and emergency planning activities.

6. CONCLUSIONS

As the nuclear industries move into an era of 'new build', decommissioning, waste disposal, and coping with the aftermath of (hopefully rare, but always possible) accident and emergency situations, it is essential for them to be regulated within a framework that takes account of the potential impact upon the environment, irrespective of any potential impact upon humans. Confidence in the nuclear industries by the public, and their political representatives, will ensure that this is the case. In the past, such confidence has been lacking because neither a conceptual nor practical

framework existed within which the subject of protection of the environment, with respect to ionising radiation, could be handled in a logical and transparent way. ICRP has, over the last decade, developed such a framework and it remains for it to be applied in a variety of ways in order to mature into a robust basis for future decision making.

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