

*Radiological protection of the environment: providing knowledge and skills to the user community*

# SETTING AND USING BENCHMARKS IN RADIOLOGICAL ASSESSMENTS OF THE ENVIRONMENT

## ***Objective of this briefing note***

This document aims to provide a basic overview of what benchmarks are and how they are derived and applied within radiological assessments of the environment. Benchmarks are used in all the available assessment tools (ERICA, RESRAD-BIOTA, etc.) and so these notes are not specific to a particular assessment tool. More information will be provided in the course and key references are given below for further reading.

## ***Why do we need a benchmark and how are they used in an assessment?***

Benchmarks, or some form of criteria (usually numeric), allow the outputs of environmental assessments to be placed into context and aid decision making on the need for further assessment or regulatory/remedial action.

A benchmark should:

- have a clearly intended meaning and use;
- be coupled to a protection goal (e.g. what is the assessment being used for);
- be robust and fit for purpose (i.e. actually screen out sites where there is genuinely no cause for concern and identify those that may be of concern);
- be derived using a clearly documented and transparent methodology.

Often benchmark values fall into two types:

- Screening values; where exceeding the values means that additional analyses/work are needed to better understand and quantify the risk. These are frequently linked to tiered risk assessment schemes and serve primarily as a trigger for further investigation. That is, exceeding the screening value at an early (simple, conservative) tier leads to additional analyses/work to refine the exposure assessment.
- Legally binding criteria or standards that must be met to answer a given regulation (for example as Environmental Quality Standards (EQSs) under the EC Water Framework Directive, or USDOEs dose rate limits for wildlife). In these cases, exceeding the values may result in legal or regulatory action.

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Screening values in radiological assessments are often referred to as the Predicted No Effect Dose Rate (PNEDR). The methods used to derive PNEDRs are outlined below; these approaches are often consistent with those used in the risk assessment of chemicals.

For radiological environmental risk assessments the benchmark may be in the form of a dose rate or be back-calculated using the available tools to environmental concentrations for each radionuclide that would give rise to the predicted no effect dose rate. These environmental concentrations (known as Environmental Media Concentration Limits (EMCLs) in the ERICA Tool, or Biota Concentration Guides (BCGs) in RESRAD-BIOTA) can be compared directly to measured or model predicted environmental media concentration values and subsequently used to determine a ‘risk quotient’ (see below). These calculated environmental concentration benchmarks are often applied at earlier tiers or stages of a risk assessment for identifying (or screening out) sites where there is negligible risk of potential impact.

### ***What is a risk quotient?***

A risk quotient (RQ) provides a simple means of assessing risk by integrating the exposure and effects data to determine the likelihood of an ecological risk occurring. It is calculated from the quotient of the estimated exposure and a numeric benchmark (in the case of radiological assessments of the environment this will be in the form of a dose rate or activity concentration). The benchmark dose rate is a dose rate which is assumed to be environmentally ‘safe’. The RQ is defined as:

$$RQ = \frac{\text{predicted environmental dose rate}}{\text{benchmark dose rate assumed to be environmentally 'safe'}}$$

Where the resulting RQ is less than one, then it would generally be considered that no further effort or action would be required. Where the RQ is greater than one, then the assessment would likely need further work (such as collecting more data, refining the exposure assessment, or taking action to reduce the risk). The key here is that the more robust and transparent the derivation of the benchmark being used, the easier it is to communicate the risk estimates.

### ***How are benchmarks derived?***

There are three methods commonly used to derive numeric criteria in ecotoxicology in general:

- Deterministic – based on the application of assessment (or safety) factors to the most restrictive single sensitivity value observed;
- Probabilistic – based on Species Sensitivity Distribution (SSD) modelling;
- A weight of evidence approach – typically using data from field exposures, such as *in situ* measurements of biodiversity indices co-occurring with stressor levels.

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Over the last few years the first two approaches have been applied to radiological assessment. The third method has not been widely used to derive benchmarks for use in radiological assessments of the environment although there are examples for specific sites (e.g. uranium mining, Thompson et al 2005). Historically the derivation of radiological benchmarks for environmental assessment has relied upon ‘expert judgement’ and how the number has been derived has not been totally transparent although this can be improved by better documentation as was done in by the ICRP evaluation of the effects literature in Publication 108.

The first two approaches are based on the guidance provided by the European Technical Guidance Document (TGD) (EC, 2003) for chemical risk assessment. The benchmark produced by both approaches is designed to ensure protection of ecosystem structure and function.

The deterministic approach, for example, takes the lowest dose rate observed to give a significant biological effect available for any tested species and divides it by a predefined assessment/safety factor ranging from 10 to 1000 (10000 for marine ecosystems) according to the quality and quantity of the data available. The assessment/safety factor is supposed to account for uncertainty.

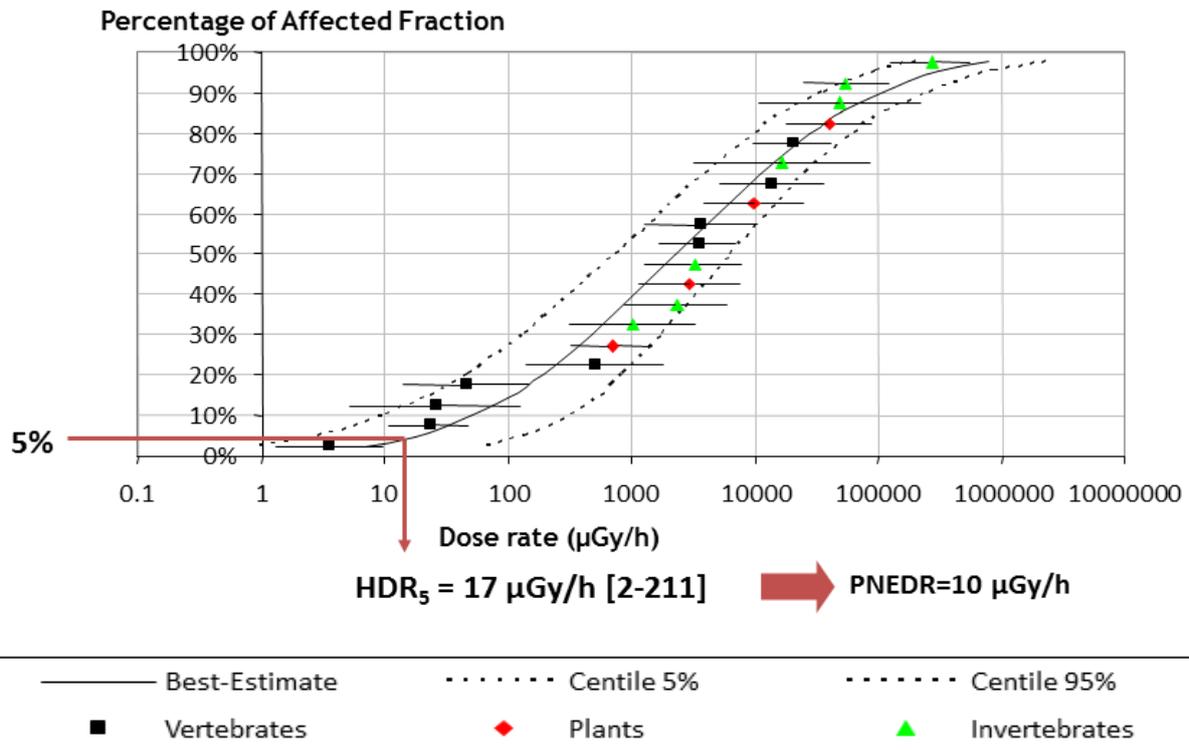
In contrast, the probabilistic approach uses the available (quality-assured) ecotoxicology data to determine the level of radioactivity in a given medium giving a 10% effect resulting distribution for chronic exposure in the ecotoxicological data (the so called effective dose rate for a 10% effect (EDR<sub>10</sub>)). These EDR<sub>10</sub> values are then plotted together for all species for which information exists and are used, as shown in the figure below, to identify (usually) the 5<sup>th</sup> percentile from the species sensitivity distribution (SSD). To account for any residual uncertainty an assessment factor of between 1 and 5 is applied to the 5<sup>th</sup> percentile value based on the available quality and quantity of the data in the SSD to produce the predicted no effect dose rate. This approach is described in full in Garnier-Laplace et al 2006, 2008 and 2010.

A freely available tool from [https://www.rivm.nl/rvs/Risicobeoordeling/Modellen\\_voor\\_risicobeoordeling/ETX](https://www.rivm.nl/rvs/Risicobeoordeling/Modellen_voor_risicobeoordeling/ETX) allows you to produce SSDs for yourself once you have identified the required biological effects data. A report (in English) which describes the tool is also available <http://www.rivm.nl/bibliotheek/rapporten/601501028.html>.

In all cases, the available ecotoxicity data for exposure to ionising radiation is the source of the information. During the EC funded FASSET, ERICA and EPIC projects, data on the biological effects of ionising radiation on wildlife from the literature were compiled into a single database called the FREDERICA radiation effects database which is available on line ([www.frederica-online.org](http://www.frederica-online.org)) and described in Copplestone et al 2008.

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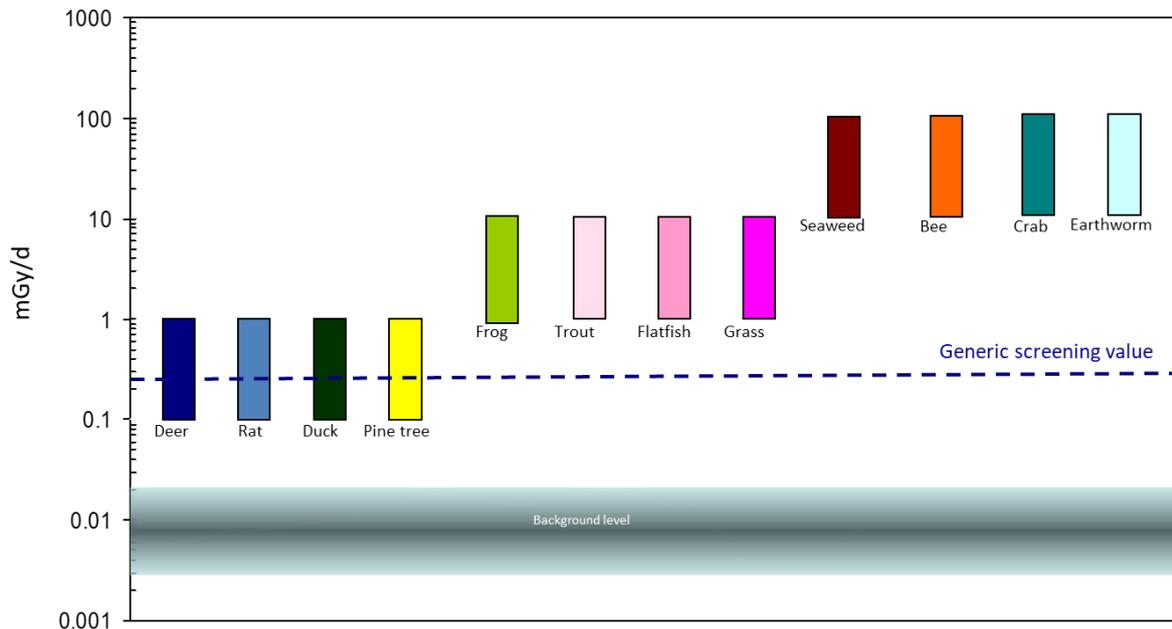
The SSD approach was used to derive the default ERICA screening dose rate (10  $\mu\text{Gy h}^{-1}$ ) and the FREDERICA database provides effects data within the Tool.



***ICRP's Derived Consideration Reference Levels***

The ICRP has outlined its framework for radiological protection of the environment in its Publication 108 (ICRP, 2008) and described its use of Reference Animals and Plants. Within Publication 108, the RAPs and expert judgement have been used to produce Derived Consideration Reference Levels (DCRL) (see following figure) for each RAP. The DCRLs are defined as *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 RAP (derived from a knowledge of 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.* The application of the DCRLs in planned, existing and emergency exposure situations has been described in ICRP Publication 124 (ICRP, 2014)

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***Taxonomic screening levels***

One thing that is clear from the DCRLs for each RAP figure is that the bands in which biological effects may be expected reflect the radiosensitivity of the different RAPs. The EC funded PROTECT project attempted to produce taxonomic screening levels (i.e. screening levels that reflected the radiosensitivity of different species or groups of species) but found it difficult to do this using the SSD approach because of a lack of available biological effects data. The PROTECT project also highlighted the need for the international community to consider what to do if the screening level is exceeded (in terms of provision of advice on how to evaluate the dose rates that are being predicted against the available biological information). This will be discussed further during the lecture.

***References***

Some useful **references** are:

Copplestone D, Hingston JL and Real A (2008) The development and purpose of the FREDERICA radiation effects database. *J. Environ. Radioact.* 99 1456-1463

EU (2003) Technical Guidance Document in support of Commission Directive 93/67/EEC on Risk Assessment for new notified substances, Commission Regulation (EC) No 1488/94 on Risk Assessment for existing substances and Directive 98/8/EC of the European Parliament and of the Council concerning the placing of biocidal products on the market. (Luxembourg: Office for Official Publication of the European Commission). Available from: <http://ecb.jrc.ec.europa.eu/tgd/>

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Garnier-Laplace J, Della-Vedova C, Gilbin R, Coplestone D, Hingston JL and Ciffroy P (2006) First derivation of predicted no effect values for freshwater and terrestrial ecosystems exposed to radioactive substances. *Environ. Sci. Technol.* 40 6498-6505

Garnier-Laplace J., Coplestone, D., Gilbin R., Alonzo F., Ciffroy P., Gilek M., Agüero A., Bjork M., Oughthon D., Jaworski, A., Larsson C.M. and Hingston J. (2008) Issues and practices in the use of effects data from FREDERICA in the ERICA integrated approach. *Journal of Environmental Radioactivity* 99(9), 1474-1483

Garnier-Laplace J., Della-Vedova C., Andersson P., Coplestone D., Cailles C., Beresford N.A., Howard B.J., Howe P. and Whitehouse P. (2010) A multi-criteria weight of evidence approach to derive ecological benchmarks for radioactive substances. *Journal of Radiological Protection.* 30, 215-233

ICRP (International Commission on Radiological Protection) (2008) Environmental protection: the concept and use of reference animals and plants. *Ann. ICRP* 108 (4-6)

ICRP 2014 Protection of the Environment under Different Exposure Situations. ICRP Publication 124 (Ann. ICRP 43(1) 2014).

Thompson PA, Kurias J and Mihok S (2005) Derivation and use of sediment quality guidelines for ecological risk assessment of metals and radionuclides released to the environment from uranium mining and milling activities in Canada. *Environ. Monit. Assess.* 100 71-85