The concept of protection of the environment and the Committee 5 current approach

Joint IES-ICRP Symposium
Aomori, Japan, October 4, 2016

David Copplestone on behalf of all of C5
Secretary, ICRP Committee 5
ICRP 91 (2003)

Review of ethics and principles, recommending that the System for Environmental Protection should

- focus on biota;
- consider *adequate protection* on the basis of understanding of effects;
- identify reference animals and plants (RAPs); and
- let the RAPs guide the derivation of
  - exposure scenarios (CFs and DCFs)
  - effects data
  - dose rates benchmarks
2. THE AIMS AND SCOPE OF THE RECOMMENDATIONS

2.1. The aims of the Recommendations

(26) The primary aim of the Commission’s Recommendations is to contribute to an appropriate level of protection for people and the environment against the detrimental effects of radiation exposure without unduly limiting the desirable human actions that may be associated with such exposure.

(27) This aim cannot be achieved solely on the basis of scientific knowledge on
ICRP Publication 103 – protection goals

(28) Radiological protection deals with two types of harmful effect. High doses will cause deterministic effects (harmful tissue reactions, see Chapter 3), often of an acute nature, which only when the dose exceeds a threshold value. Both high and low doses may cause stochastic effects (cancer or heritable effects), which may be observed as a statistically detectable increase in the incidences of these effects occurring long after exposure.

(29) The Commission’s system of radiological protection aims primarily to protect human health. Its health objectives are relatively straightforward: to manage and control exposures to ionising radiation so that deterministic effects are prevented, and the risks of stochastic effects are reduced to the extent reasonably achievable.

(30) In contrast, there is no simple or single universal definition of ‘environmental protection’ and the concept differs from country to country and from one circum-
(30) ....aim is...preventing and reducing the frequency of deleterious radiation effects to a level where they would have negligible impact on the maintenance of biological diversity, the conservation of species, or the health and status of natural habitats, communities and ecosystems.

(366) .....Reference Animals and Plants.......
(30) ....aim is...preventing and reducing the frequency of deleterious radiation effects to a level where they would have negligible impact on the maintenance of biological diversity, the conservation of species, or the health and status of natural habitats, communities and ecosystems.

(366) .....Reference Animals and Plants.......
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(366) .....Reference Animals and Plants.......
There is **ONE** system of radiological protection
So ..... 

- Why do I say this?

- Does it work?

- What are the similarities and differences in application for humans and the environment?
  - Absence of humans from some environments
  - Protection goals etc.

- Assessments...

- What remains to be done/challenges?
Evolution of Protection System

- Planned, emergency, and existing exposure situations
- Environmental radionuclide concentrations
  - Reference Male & Female, Representative Person
    - Dose limits, constraints and reference levels
  - Reference Animals and Plants
    - Derived Consideration Reference Levels
- Decisions regarding protection of public health and the environment for the same exposure situation by way of representative individuals and representative organisms

[Publication 108]
<table>
<thead>
<tr>
<th>WILDLIFE GROUP</th>
<th>RAP</th>
</tr>
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<tbody>
<tr>
<td>Large terrestrial mammals</td>
<td>Deer</td>
</tr>
<tr>
<td>Small terrestrial mammals</td>
<td>Rat</td>
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<tr>
<td>Aquatic birds</td>
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<tr>
<td>Amphibians</td>
<td>Frog</td>
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<td>Freshwater pelagic fish</td>
<td>Trout</td>
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<td>Marine fish</td>
<td>Flatfish</td>
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<td>Terrestrial insects</td>
<td>Bee</td>
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<td>Marine crustaceans</td>
<td>Crab</td>
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<td>Terrestrial annelids</td>
<td>Earthworm</td>
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<td>Large terrestrial plants</td>
<td>Pine tree</td>
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<tr>
<td>Small terrestrial plants</td>
<td>Wild grass</td>
</tr>
<tr>
<td>Seaweeds</td>
<td>Brown seaweed</td>
</tr>
</tbody>
</table>
ICRP 108 reviews biological characteristics

- Occurrence
- Taxonomy
- Life cycle and life span
- Reproductive strategy
- Physiology
- Ecology
- .....other factors.....
RAP selection

- Pragmatic
- Covering different ecosystems
- Example animals/plants
- Considering application as species of conservation interest
- Where possible geographic spread
- Allowing for transboundary (e.g. birds)
- Different lifestages
- Amount of available information
- Potential for future studies
ICRP 108 Derived Consideration Reference Levels, DCRLs

Benchmarks from other studies/systems
1) SOURCE TERM: used maximum release as a mean for calculations

2) EXPOSURE: assumed fish were living at point of discharge

3) ABSORPTION: assumed all fish were 30 cm in diameter which maximized absorbed dose

4) IRRADIATION: behavior of fish ignored, assumed they spent 100% of time bottom sediments where > 90% of radionuclides are located
Human assessment (overview)

RADIONUCLIDE SOURCE → PATHWAY OF EXPOSURE → HABITS DATA

REFERENCE PERSON

TOTAL ABSORBED DOSE

Application of a weighting factors for RBE & different tissues

Compare predicted dose to known biological effects & dose limits

IMPACT
Non-human species assessment (overview)

- **RADIONUCLIDE SOURCE**
- **PATHWAY OF EXPOSURE**
- **REFERENCE ORGANISM**
- **ECOLOGICAL PARAMETERS**

**TOTAL ABSORBED DOSE**

Application of a weighting factor for RBE

Compare predicted dose to known biological or ecological effects & guideline values

**IMPACT**
Site specific models
- Used for human dose assessments
- Take into account local features
- Etc.

But seen wildlife dose assessments that, because a different tool used, and tick box approach.....
Please select the ecosystem, organisms and radionuclides for your assessment. If you do not have media concentrations, you can select a built-in dispersion model to use instead.

<table>
<thead>
<tr>
<th>Isotopes</th>
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<th>Organisms</th>
<th>Selected</th>
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<tbody>
<tr>
<td>Ag-110m</td>
<td></td>
<td>Amphibian</td>
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<tr>
<td>Am-241</td>
<td></td>
<td>Benthic fish</td>
<td></td>
</tr>
<tr>
<td>C-14</td>
<td></td>
<td>Bird</td>
<td></td>
</tr>
<tr>
<td>Cd-109</td>
<td></td>
<td>Bivalve mollusc</td>
<td></td>
</tr>
<tr>
<td>Ce-141</td>
<td></td>
<td>Crustacean</td>
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<tr>
<td>Ce-142</td>
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<td>Gastropod</td>
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<td>Cl-36</td>
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<td></td>
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<td>Vascular plant</td>
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<tr>
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<td></td>
<td>Zooplankton</td>
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<tr>
<td>I-133</td>
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</tr>
</tbody>
</table>

**Ecosystem**
- Freshwater

**Dose rate screening values**
- The ERICA dose rate screening value is 10 μGy h⁻¹.
- 40 μGy h⁻¹ for terrestrial animal and 400 μGy h⁻¹ for terrestrial plants and aquatic biota. It has previously been suggested that below these values (of chronic exposure) no measurable population effects would occur (IAEA 1992; USDOE 2002; UNSCEAR 1996).
- Custom value [μGy h⁻¹]:

**Uncertainty Factor (UF) [unitless]**
- UF = 3: This will test for 5% probability of exceeding the dose screening value, assuming that the RO distribution is exponential.
- UF = 5: This will test for 1% probability of exceeding the dose screening value.
- Custom UF = 1.0

**Media Activity Concentration**
- Use site specific media concentration
- Use IAEA SRS-19 model: Small lake (≤ 400 km²)

**Comment on custom value here!**
Different source terms being used for wildlife and humans.....

- Leads to discrepancies between human and wildlife dose assessments
- Leads to communication issues
- Etc.
Pathways of exposure

- Soluble and Insoluble Aerosols
- Global Fallout
- Radioactive Gases and Particulates
- Low Level Emission
- Sea-to-Land Transfer
- Marine Discharges
- Waste Disposal to Repositories
- Ground Water Transport
- Soil Contamination
- Plant Uptake
- Infiltration
- Field Loss
- Uptake by Crops
- Resuspension
- Wet and Dry Deposition
Concentration Ratios for 39 elements and 12 RAPs

- with associated statistics;
- based on existing field and laboratory data;
- using new methodology to derive data (‘surrogate data’) where such are missing;
- taking in to account life cycle stages and habitats, when possible; and
- discussing the robustness of the data
Not integrated
- Underpinning databases are different
- Noting that in many cases (as ICRP) it is generally about protection of biodiversity although IAEA consider the importance of environmental resources

Things to consider
- Livestock are not generally considered within environmental protection assessments (are they protected by the human assessments?)

Potential issues
- Non equilibrium situations
Dosimetry

DCCs for simple geometries

Trunk and branch
<table>
<thead>
<tr>
<th>Reference Animals and Plants</th>
<th>Aquatic environment</th>
<th>Terrestrial environment</th>
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<tr>
<td></td>
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<td>On soil</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Planar source</td>
</tr>
<tr>
<td>Deer adult</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Rat adult</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Duck egg</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Duck</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Frog egg</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Frog egg mass</td>
<td>X</td>
<td></td>
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<tr>
<td>Frog tadpole</td>
<td>X</td>
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<td>Frog adult</td>
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<tr>
<td>Crab egg mass</td>
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<tr>
<td>Crab larvae</td>
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<td>X</td>
<td></td>
</tr>
<tr>
<td>Bee</td>
<td>X</td>
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<tr>
<td>Bee colony</td>
<td>X</td>
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<td>Earthworm egg</td>
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<td>Grass</td>
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<td>X</td>
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<tr>
<td>Brown seaweed</td>
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<td></td>
</tr>
</tbody>
</table>
Fig. 4.4. Geometrical model of deer body with liver (large inner ellipsoid) and testes (small inner ellipsoid).
Voxel phantoms

Issues

- Level of complexity?
- Pragmatic and ease to use?
- Needed for whole body dosimetry as required for wildlife from regulatory perspective?
- Good for testing whether the simple ellipsoid is sufficient for our modelling for wildlife?
- And may help with interpreting field effects data
Effects/benchmarks for wildlife
Evaluation of Radiation Effects on Wildlife

- Based on expert judgement
  - All documented in Publication 108

- UNSCEAR reports and FREDERICA as sources of information
The FRED database was originally created as part of the EC fifth framework project FASSET (Framework for the Assessment of Environmental Impact, Contract No.: FIGE-CT-2000-00102) and its main use was to gather literature data to help summarise dose-effect relationships between radiation exposures and their effects on organisms.

The database has been extended, improved and made more user-friendly as part of the EC’s sixth framework project ERICA (Environmental Risk from Ionising Contaminants: Assessment and Management, Contract No.: F6R-CT-2004-508647). The database is now called FREDERICA and is available for use on its own or in conjunction with the ERICA assessment tool for undertaking risk assessments for the impact of ionising radiation on non-human species.

Please note that the site should be accessed using Internet Explorer only (changes to allow other browsers to be used will be made in the future).

The ERICA project website can be accessed from here.
The ERICA deliverable (D1) for this project can be downloaded here as a pdf
Download a manual describing the use of FREDERICA here

If you are not registered, Register Now
If you have forgotten your login details please email us and we will send you a reminder [Password Reminder]

User Name
Password

Login
Evaluation of Radiation Effects on Wildlife

- Based on expert judgement
  - All documented in Publication 108

- UNSCEAR reports and FREDERICA as sources of information

- Again focused on RAPs at Family level where possible

- Endpoints: mortality, morbidity, reduced reproductive success, chromosomal aberrations and mutations
ICRP 124

Application in planned exposure situations

DCRL for relevant RAP

Reference point for the sum of all sources

Increasing dose rate

ARTIST’S VIEW OF A DISPOSAL VAULT IN RELATION TO THE ROCK STRUCTURE
Application TG

Planned situations

Max. concentrations of radionuclides in air, water and ‘soil’

- Authorised Release Rates
  - Representative Persons
  - Dose constraints
  - Representative organisms
  - DCRLs
This approach has been used...

Agreement on a Methodology for Deriving Environmental Assessment Criteria and their application

(OSPAR Agreement: 2016-07) ¹

Introduction

1. This agreement sets out the methodology for deriving criteria for the radiological environmental assessment of concentrations of radioactive substances in the marine environment of the OSPAR maritime area by OSPAR Contracting Parties. The agreement also describes how the criteria should be applied.

2. The practical aspects of the methodology should be reviewed and updated where necessary by 2020.

Methodology

3. The methodology developed by the International Atomic Energy Agency (IAEA) for deriving the environmental assessment criteria (EAC) is set out in Reference 1 ("the IAEA Methodology") and attached at Annex 1. The principles of the IAEA Methodology were agreed by the OSPAR Radioactive Substances Committee in 2013 subject to further testing and demonstration (see 'Application' below).

4. The scheme used in the IAEA Methodology to assess the radiological impact on humans and non-humans in an integrated manner is summarised in Figure 1.
ICRP 124
Application in emergency exposure situations

Order of magnitude bands of dose rate

Severe Effects Level

Dose rate to relevant biota

Time after event
ICRP 124

Application in existing exposure situations

Potential for dose rate reduction

Minimum level of ambition

DCRL for relevant RAP
New Task Group planned (under consideration within ICRP)

Specific task to look at radiological v non-radiological impacts of remediation option using examples

E.g. Little Forest Burial Ground, Australia

- All human exposure scenarios below 1 mSv
- Reference values not required to be set
- Wildlife considered with most being below relevant DCRL
- But… frog larvae and tree assessments highlighted potential to exceed the relevant DCRL
- Spatial and temporal extent may need to be considered
- Long term management needs to consider wildlife….
What do you consider?

- The nature of the exposure situation – normal, existing, or emergency;
- the area or zone (km$^2$) within which such dose rates were assessed to occur;
- the time period predicted for such dose rates;
- the principal reason for the assessment being made, such as the need to comply with some form of existing legislation;
- the type of managerial interest, such as fisheries management, agriculture, nature conservation, habitat protection, etc.;
What do you consider?

- The presence, or expected presence, of additional sources of chemicals, or other forms of environmental stress, in the same area;
- whether or not the assessment related to actual species, or simply to generalised animal or plant types; and
- the degree of precaution considered necessary for various purposes.
What remains?

- Ecological offsetting (a common mitigation measure)

- Post accident – communication issues and the emphasis will always remain on human radiological protection

- Existing exposure - the aim is to try to ensure that any remediation/optimisation has a positive effect on both wildlife and humans e.g.

Identifying optimal agricultural countermeasure strategies for a hypothetical contamination scenario using the strategy model

G. Cox a, N.A. Beresford b, B. Alvarez-Farizo c, D. Oughton d, Z. Kis c, K. Eged c, H. Thørring f, J. Hunt g, S. Wright b, C.L. Barnett b, J.M. Gil c, B.J. Howard b, N.M.J. Crout a,*
Application TG?

**Representative Organism:**
A typical organism representative of its environment (kangaroo).

**Reference Animal:**
A numerical approximation of organisms within a certain group of wildlife (large herbivorous mammal).

[ARPANSA Safety Guide SG-1(draft 2015)]
Challenges
Chernobyl species decline linked to DNA

By Victoria Gill
Science reporter, BBC News

The scientists have studied the exclusion zone for more than a decade.

Scientists working in Chernobyl have found a way to predict which species there are likely to be most severely damaged by radioactive contamination.

The secret to a species’ vulnerability, they say, lies in its DNA.

This discovery could reveal which species are most likely to decline or even become extinct in response to other types of environmental stress.

The researchers published their findings in the Journal of Evolutionary Biology.

Related stories

Mammals decline in Chernobyl zone

Wildlife defies Chernobyl radiation

By Stephen Mulvey
BBC News

It contains some of the most contaminated land in the world, yet it has become a haven for wildlife - a nature reserve in all but name.

The exclusion zone around the Chernobyl nuclear power station is teeming with life.

As humans were evacuated from the area 20 years ago, animals moved in. Existing populations multiplied and species not seen for decades, such as the lynx and eagle owl, began to return.

There are even tantalising footprints of a bear, an animal that has not trodden this part...
Estimated absorbed dose rate (Gy/h) to small mammals in Red Forest  (Gaschak et al. 2011, Health Physics)
Dose meter measurement at ground level
(2-3 measurements per transect?)

Mammals

(p < 0.0001; R^2=0.31)

12 species

Moller & Mousseau 2013
Mammals

Dose meter measurement at ground level
(2-3 measurements per transect?)

Moller & Mousseau 2013

(p < 0.0001; R^2=0.31)
Mammals

Dose meter measurement at ground level
(2-3 measurements per transect?)

(p < 0.0001; $R^2=0.31$)

Moller & Mousseau 2013
Invertebrates

1986:
Pine forest 3 km from NPP
- 30-fold reduction soil dwelling mites (29 Gy)
- Larvae/nymphs of many species absent
Agricultural soils 3-7 km from NPP
- Lower abundance of young earthworms

1988/89:
- Mesofauna population size restored

Mid-1990’s:
- Changes in species composition as consequence of changing ecosystems
- Reduced mesofauna diversity

Geras’kin et al. 2008. Environment International
Invertebrates

Chernobyl

Møller & Mousseau 2009
Biol. Lett.
ERICA ‘no effect level’
ICRP ‘expect effects’

ERICA ‘no effect level’
ERICA ‘no effect level’

ICRP ‘expect effects’

UK natural background

(a) 10^2

no. of humble-bees

10

1

(b) 10^2

no. of butterflies

10

1

(c) 10^2

no. of grasshoppers

10

1

(d) 10^2

no. of dragonflies

10

1

radiation (µGy h⁻¹)

10⁻² 10⁻¹ 1 10 10²
Phenotypic modification in butterflies


Loss of leader shoot in Japanese fir trees

*Sci. Rep. 5, 13232; DOI: 10.1038/srep13232 (2015)*

Population impact on barn swallows

*Scientific American Feb 2015*
Japan butterflies

- Butterfly larvae fed plants harvested from Fukushima evacuated area
- $LD_{50} = 1.9 \text{ Bq}$
Butterfly larvae fed plants harvested from Fukushima evacuated area

$LD_{50} = 1.9 \text{ Bq}$

$LD_{50}$ equates to a maximum of $c. 8\mu\text{Gy/h}$
- Below ‘no-effect’ and in natural background range?

Comment by Copplestone & Beresford, 2014, *The Conversation*
Japan butterflies

- Butterfly larvae fed plants harvested from Fukushima evacuated area
- $\text{LD}_{50} = 1.9 \text{ Bq}$
- $\text{LD}_{50}$ equates to a maximum of c. $8\mu\text{Gy/h}$
  - Below ‘no-effect’ and in natural background range?
- From previous studies $\text{LD}_{50}$ for sub-adults $\geq 1 \text{ Gy}$
## Dose rates, Okuma Town, June 2011

<table>
<thead>
<tr>
<th>RAP</th>
<th>Dose-rate estimate</th>
<th>Lower end DCRL</th>
<th>Ratio of estimate to benchmark</th>
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<tbody>
<tr>
<td></td>
<td>µGy/h</td>
<td></td>
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</tr>
<tr>
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<td>18</td>
<td>400</td>
<td>0.04</td>
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<td>4</td>
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<td>26</td>
<td>40</td>
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Summary

• A robust system has evolved that is for humans and the environment

• There are differences and similarities when actually undertaking assessments

• Considering the environment in its own right is appropriate and facilitates communication

• Further advice and recommendations are still being developed but there is enough information to apply the one system of radiological protection now