Dosimetry for animals and plants

Contending biota diversity

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Dosimetry for environmental radiation protection...

What is specific if compared to human radiation protection dosimetry?

The answers are:

- Endpoints
- Immense (bio)diversity

This presentation has neither been approved nor endorsed by the Main Commission of ICRP
ICRP system of radiological protection: the goals

- Radiological protection of human (P103 ICRP, 2007):
  “(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.”

- Radiological protection of animals and plants (P124 ICRP, 2014):
  “(7) The Commission’s environmental protection aims 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. The **biological endpoints** of most relevance are therefore those that could lead to **changes in population size or structure**.”
ICRP system of environmental protection: endpoints

- ICRP Publication 124 (ICRP 2014)

“(8) The biological endpoints of interest to individuals that could have a consequence at a population level are 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
- the induction of chromosomal damage.”
Diversity of non-human biota

Expresses via variability of:

- Environment
- Morphological properties
- Biological properties
- Behavior and life cycle
- Sensitivity to radiation
The current ICRP approach...

... stands on two legs:

- Established points of reference, i.e. a set of the Reference Animals and Plants (RAPs)
- Use of simple albeit plausible and representative models to quantify exposures to environmental radiation sources
Dosimetry for non-human biota – main principles

- Conventional dosimetry (i.e. not micro- or nano-dosimetry)
- Absorbed dose averaged over the whole body
- Simplified representation of exposure geometry, body shape
- Biokinetic is not accounted for (full retention, intake is expressed via lumped equilibrium concentration ratios, CR)
- Idealised sources (homogeneous media, uniform distributions)
- Interpolation and (physically justified) extrapolations, including allometric scaling of biological properties
- Superposition principle: a complex exposure scenario can be split into a series of simpler ones resulting in the same integral effect
The dosimetric approach of ICRP...

... for non-human biota was introduced in the *Publication 108* (ICRP, 2008) and can be characterised as...

- A major step forward
- DCC cover major environmental sources, biota types, radionuclides

- Popular critiques and/or inquires:
  - ‘Gaps’, i.e. situations not addressed by the P108 (e.g. DCC for immersion into contaminated air)
  - Need DCC for a non-reference organism (e.g., cormorant, not duck)
  - Organisms exposed at the interface between media (e.g. ‘flatfish on sediment’)
  - DCC for a radionuclide missing in the printed tables of P108
Current activity of the TG74

Since appearance of the Publication 108, the Task Group 74 continued its work aiming at:

- Improving the existed dosimetric framework
- Extending the dosimetric framework
- Addressing concerns of the community

Now, the new draft report of Task Group 74 is on its way to finalisation
The draft report of TG74 – what’s new?

- Improved DCC for external exposure of terrestrial organisms are:
  - substantially and systematically extended (new sources, heights),
  - harmonised with aquatic (from 1 mg to 1 ton body mass),
  - revised (old sources are completely redone)

- Transition to contemporary radionuclide database (P107) assuming completely revised DCC tables

- A DCC calculator complements the printed tables and provides fully flexible DCC (‘fit-for-purpose’ DCC) for any nuclide from P107

- Three alternative methods to account for effect of radioactive progeny allow for additional flexibility to address various exposure situations (emergency, planned, existing)

- Generalised allometric equations (help to plausibly interpolate biological parameters relevant to a dose assessment)
The new tool to compute DCC

- The DCC calculator stems from its predecessors, the ERICA Tool and *Publication 108*, significantly updating and exceeding those.

- “Now, it is unlike before...” 😊

- The DCC are always ‘fit-for-purpose’, i.e. they can be derived for user-defined and assessment-specific: organism, source(s), time to integrate effect of radioactive progeny.

- Simple, flexible, fast, web-based (planned as an open access software, thus to comply with the ICRP’s main goal: “…works for public good”)

- Accessed via the ICRP web-site or hosted there directly (to be clarified)
The new layout of the revised DCC Tables

- Allows quick and simple interpolations for non-reference organisms or non-standard sources/locations
- Demonstrate that inters-species and inter-sources variability of DCC among RAPs is generally low, so...
- ... the DCC themselves are not among the major sources of uncertainty of an environmental dose assessment
- Priority should be shifted towards reducing uncertainty coming from...
  - Environmental transfer
  - Biology
  - Representativity of an organism
Open issues

- RBE (RWF) for non-human biota: conditional on biological endpoints, organism, exposure type
- Probabilistic assessment (to take care on uncertainty, to quantify uncertainty, ...)
- Risk following highly non-uniform dose distributions (e.g. bone-seeking actinides, lung exposure to alpha-emitters, skin exposure to alpha- and beta-emitters, exposure to hot particles, and etc)
- These may require for selected species and exposure scenarios to do modelling using advanced methods, e.g. CT-based and radiographic images, microdosimetric endpoints and cellular responses to radiation, realistic morphological (voxel phantoms) and biological (biokinetic) models.
Dosimetry for environmental RP: What is different from that for human RP?

<table>
<thead>
<tr>
<th>Human</th>
<th>Non-human</th>
</tr>
</thead>
<tbody>
<tr>
<td>Absorbed dose (Gy)</td>
<td>Absorbed dose (Gy)</td>
</tr>
<tr>
<td>Averaging in organ</td>
<td>Averaging in the whole body</td>
</tr>
<tr>
<td>Endpoints: for individuals, mostly, stochastic (late) effects</td>
<td>Endpoints: for populations, mostly, deterministic (early) effects</td>
</tr>
<tr>
<td>RBE is defined at low doses and dose rates</td>
<td>RBE to be defined at higher doses and dose rates</td>
</tr>
<tr>
<td>RWF, $w_R$, is defined for protection and relevant to cancer, mostly</td>
<td>No recommended value of RWF (though, provisional values: 10-3-1)</td>
</tr>
<tr>
<td>Equivalent dose (Sv)</td>
<td>Weighted dose?</td>
</tr>
<tr>
<td>TWF, $w_T$, are derived from organ-specific cancer risks</td>
<td>?</td>
</tr>
<tr>
<td>Effective dose (Sv)</td>
<td>? DCRL? Weighted?</td>
</tr>
</tbody>
</table>
Thank you for attention!

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