IAEA EMRAS Biota Working Group

Regular participants:
Belgium - SCK·CEN; Canada – AECL;
Czech Republic - SÚJB; France – IRSN;
Japan – NIRS; Lithuania – IoP; Netherlands – NRG;
Norway – NRPA; Russia – Spa-Typhoon;
UK – CEH, EA, WSC; Ukraine – IRL; USA - ANL
Models and approaches participating

- **RESRAD-BIOTA** (USA)
- *Environment Agency ‘R&D 128’* (England & Wales)
- **ERICA** (& FASSET) (European)
- Atomic Energy Canada Limited approach
- **LIETDOS-BIOTA** (Lithuania)
- **DosDiMEco** (Belgium)
- **D-Max** (UK)
- **EDEN-CENTEaur** (France)
- **LAKE(ECO)** (Netherlands)
- **ECOMOD** (Russia)
- **FASTer** (European)
- **EPIC-DOSES3D** (European)
- **SÚJB approach** (Czech Republic)
Activities

• Two exercises to compare dosimetry and transfer components of models.
• Two case study scenarios (predictions v’s data): Perch Lake (Canada) and terrestrial ecosystems within Chernobyl 30 km exclusion zone.
Exercise 1 - dosimetry comparison

• Assume 1 Bq per unit media or organism
• Estimate unweighted internal and external dose rates for Cs-137, Am-241, Co-60, U-238, C-14, Sr-90, H-3
• Organisms selected from list of proposed ICRP Reference Animals & Plants
• Equates to comparison of dose conversion coefficients (DCCs) used within models where:

\[
DCC = \frac{\text{unweighted absorbed dose rate (µGy / h)}}{\text{Activity concentration (Bq / kg) (whole – body organism or media)}}
\]
Internal dose rates

• Internal dose estimates generally all within 20% of mean (of predictions)
  – exception being for U-238: two approaches including U-234 as daughter (resulting in 2x higher DCC)
External dose rates

• Considerably more variability between models – especially for β- emitters
e.g. Duck on soil surface
predictions for Sr-90

1.0E-11
1.0E-10
1.0E-09
1.0E-08
1.0E-07
1.0E-06
1.0E-05
1.0E-04
1.0E-03

DCC

AECL  EA  EDEN  ERICA  LIETDOS  RESRAD  SCK  SUJB
External dose rates

• More variable between models – especially for β-emitters
  – Especially H-3 & C-14 (e.g. external DCC for duck on soil for H-3 ranged 0 to 5E-11)

• Media assumptions (density and distribution of contamination) can be seen to result in some variation

• Differences in approaches that do not matter:
  – use of specific geometries v’s nearest default
  – number of emissions assumed
Exercise 2 – transfer comparison

- Assume 1 Bq per unit media to estimate wholebody freshweight activity concentration of range of radionuclides ($^{241}$Am, $^{14}$C, $^{60}$Co, $^{137}$Cs, $^{131}$I, $^{210}$Po, $^{239}$Pu, $^{226}$Ra, $^{90}$Sr, $^{99}$Tc, $^{232}$Th & $^{238}$U) in 19 terrestrial & freshwater organisms

<table>
<thead>
<tr>
<th>Terrestrial organisms</th>
<th>Freshwater organisms</th>
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<tbody>
<tr>
<td>Grass/Herb</td>
<td>Phytoplankton</td>
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<tr>
<td>Shrub</td>
<td>Zooplankton</td>
</tr>
<tr>
<td>Earthworm</td>
<td>Macrophyte</td>
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<tr>
<td>Herbivorous mammal</td>
<td>Benthic mollusc</td>
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<tr>
<td>Carnivorous mammal</td>
<td>Benthic crustacean</td>
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<tr>
<td>Bird egg</td>
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</tbody>
</table>
Approaches

- Many use concentration ratios (CR):
  \[
  CR = \frac{\text{Activity concentration in biota whole body (Bq kg}^{-1} \text{ fresh weight)}}{\text{Activity concentration in soil (Bq kg}^{-1} \text{ dry weight)}}
  \]
- But others using foodchain models, often incorporating allometric relationships for dietary intake and radionuclide biological half-lives
  - \[Y = a \cdot (\text{liveweight})^b\]
- Some have ‘guidance’ derived values in the absence of defaults
Predicted activity concentrations

- Considerable variation between predictions (3-orders of magnitude being common)

Pu-239

![Bar chart showing predicted activity concentrations for different scenarios and species.](chart.png)
Predicted activity concentrations

• Some variation can be understood, e.g.:
  – Missing value guidance approach often give comparatively high estimates (often for little studied organisms)
  – National (and single site) data
  – Some approaches (used to) include reindeer data in derivation of CRs leading to high predictions for mammals (especially Po-210)

• Tc-99 predictions had least variation
  – Very few data and all using similar approach
Perch Lake Case Study

- H-3, Cs-137, Co-60, Sr-90 data for wide range of freshwater biota
Cesium-137 in Aquatic Macrophytes

Modeled-to-Measured $^{137}$Cs Concentration

- Emergent Macrophytes
- Free-floating Macrophytes
- Float-leafed Macrophytes
- Submergent Macrophytes

Minimum Measured (free-floating)
Maximum Measured (free-floating)
Minimum Measured (floating-leafed)
Maximum Measured (free-floating)
Minimum Measured (submergent)
Maximum Measured (submergent)
Strontium-90 in Freshwater Fishes

The graph shows the modeled-to-measured 90Sr concentration in different models and species of freshwater fish. The models include AECL, ERICA (CEH), EA R&D128, ECOMOD, LakeCo, RESRAD-BIOTA (UK), and RESRAD-BIOTA (NRPA). The species include Brown Bullhead, Cyprinids, and Pumpkinseeds. The x-axis represents the models, while the y-axis shows the modeled-to-measured 90Sr concentration on a logarithmic scale. The data points are color-coded to indicate the minimum and maximum measured concentrations for each species.
Cobalt-60 in Freshwater Mammals

Modeled-to-Measured $^{60}$Co Concentration

- **Star-nosed Mole**
- **American Water Shrew**

Models:
- ERICA (CEH)
- EA R&D128
- ERICA (NRPA)
- Dmax
- RESRAD-BIOTA (UK)
- RESRAD-BIOTA (NRPA)
Chernobyl Case Study

- Available data for Cs-137, Sr-90, Am-241, Pu-isotopes data - bias towards mammals (some birds, amphibians, invertebrate, plant, reptile).
- TLD measurements for small mammals.
<table>
<thead>
<tr>
<th>Species</th>
<th>Common name</th>
<th>Number of predictions</th>
<th>$^{90}$Sr</th>
<th>$^{137}$Cs</th>
<th>Pu</th>
<th>$^{241}$Am</th>
<th>Dose rates</th>
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Pu and Am-241 results
Cs-137
Absorbed dose rate - *Microtus arvalis*
Contributions to total dose rate
Great tit (CT36a)

Contributions to total dose rate
Summary

• Dosimetry – largely comparable
  – External dose minor contributor (occupancy factor assumptions have little impact)

• Transfer – highly variable
  – Concentration ratio and foodchain model approaches – broadly comparable
Future

• Collaboration with ICRP C4 (+ PROTECT project)
  – Discussion began yesterday

• Biota ‘TRS364’ Transfer sub-group

• Effects data sub-group – quality & interpretation (population modelling?)

• Scenarios – focused to consider situations regulators/industry having to consider
  – Waste repository/new build NPP’s/TeNORM
PROTECT
Protection of the environment from ionising radiation in a regulatory context
(EC Euratom 6th Framework programme: Contract No. FP6-038425)

WP2: Assessment approaches: practicality, relevance and merits

Contribute your views on models/tools used to estimate the radiation exposure of non-human biota

One of the objectives of PROTECT is to evaluate existing and developing approaches (i.e. the models and tools) used for demonstrating protection of the environment from ionising radiation. To obtain as many opinions as possible we are also asking interested parties to complete a simple (only four questions) feedback form. Please return completed form to cdf@ceh.ac.uk by 18th January 2008.

Please accept our thanks in advance if you can find the time to do this.

Specific Aims
Evaluate existing and developing approaches (i.e. the models and tools) used for demonstrating protection of the environment from ionising radiation. Apply recommended benchmark values and assess the potential consequences of their use.

Approach
This work package will bring together those organisations using or developing approaches to the protection of the environment from ionising radiation in order to:

- Evaluate the practicability of existing and developing approaches
- Consider acceptability and relevance of the approaches with respect to the requirements of regulators and industry (identified by WP1)
- Apply numerical targets recommended by WP3 and others
- Assess the user friendliness of the approaches to potential users

Application of the available approaches to case studies will be used to help achieve these objectives.