Radionuclide biological half-life values for terrestrial and aquatic wildlife: An output of IAEA MODARIA WG8

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Biological half-life $T_{1/2b}$

Describes rate of loss of RNs from organisms – often used to describe rate of uptake

$$T_{1/2b} = \frac{\ln 2}{k}$$
Why bother?

• CR model used in wildlife assessment assumes instantaneous organism to media equilibrium
• Considered fit for purpose if considering authorised releases over prolonged periods
• Not applicable
  – Accidental releases (though used post Fukushima)
  – Assessment of planned pulsed releases
Results - Short term assessment

Daily time steps
(a) Macrophyte

Tc in macrophytes - $T_{1/2} = 1.5 \text{ & 128 days}$
Results - Short term assessment

Daily time steps

(b) Wrinkle

Weighted dose rate (μGy·h⁻¹)

Date


Tc in winkles - \( T_{\text{B1/2}} = 142 \) days
From Vives I Batlle et al. in prep. (IAEA MODARIA WG’s 8+10)
Why - Application in models

- RESRAD-Biota
  - Simple foodchain models using allometrically derived $T_{1/2b}$ at higher tiers (approach adopted other models, e.g. FASTer)
  - Limited to 16 elements (derivation of allometric equations requires $T_{1/2b}$ data)
Why?

- CRs assumed to be isotope independent
  - For short lived isotopes can correct (IAEA 2010):
    \[ CR_{wo-corrected} = CR_{wo-media} \times K \]
    \[ K = \frac{T_{1/2b}}{T_{1/2b} + T_{1/2p}} \]

- Needs information on biological half-life
Why?

• CR is assumed to be conservative (?)
  – Under continuous release conditions – is it?

• IAEA (SRS-19 update Volume 3) working on a methodology which takes this pathway into account (more tomorrow)
  – Needs assumptions about biological half-life
Why?

Number of reasons why we need a comprehensive database of $T_{1/2b}$ values
<table>
<thead>
<tr>
<th>Parameter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Entry ID</td>
</tr>
<tr>
<td>Common name (English)</td>
</tr>
<tr>
<td>Latin name</td>
</tr>
<tr>
<td>Wildlife group</td>
</tr>
<tr>
<td>Organism dimensions (length, width, depth) (m)</td>
</tr>
<tr>
<td>Live weight (kg)</td>
</tr>
<tr>
<td>Developmental stage (e.g. adult, tadpole etc.)</td>
</tr>
<tr>
<td>Metabolic rate (J s(^{-1}))</td>
</tr>
<tr>
<td>Radionuclide</td>
</tr>
<tr>
<td>Compartment (whole organism or specific tissue)</td>
</tr>
<tr>
<td>Experiment type</td>
</tr>
<tr>
<td>Length of study (d)</td>
</tr>
<tr>
<td>Temperature ((^{\circ})C)</td>
</tr>
<tr>
<td>Biological half-life (d) (four columns were included to enable recordings of multiple loss components)</td>
</tr>
<tr>
<td>Fraction released (four column, one for each component of loss)</td>
</tr>
<tr>
<td>Change over time (d) (repeated for multiple loss components)</td>
</tr>
<tr>
<td>Percentage left at time (t)</td>
</tr>
<tr>
<td>Time (t) (d)</td>
</tr>
<tr>
<td>Number of measurements (made in study) to determine (T_{1/2b})</td>
</tr>
<tr>
<td>Measurement interval (d)</td>
</tr>
<tr>
<td>Ecosystem (Marine, Freshwater, Terrestrial or Riparian)</td>
</tr>
<tr>
<td>Sex</td>
</tr>
<tr>
<td>Elimination rate (i.e. k; d(^{-1}))</td>
</tr>
<tr>
<td>Reference</td>
</tr>
<tr>
<td>Notes</td>
</tr>
</tbody>
</table>
Data review principles - freshwater

*Papers published before 2000:* initial review at IRSN in 2007=> summary report (Alonzo, 2009)

*Papers published after 2000:* complementary review (from 2000 to 2014)

- **Databases:** SCOPUS, Science Direct, Pubmed, Inis.

- **Keywords:**
  - biological half-life, biological period, kinetic transfer modelling, accumulation rate, depuration rate
  - radionuclides, elements (list from the ERICA tool)
  - animals, plants
  - aquatic, freshwater

- **No limitation in terms of substances (includes radionuclides as well as stable elements)**

- **No geographical limitation**

+ review of Russian language studies
Database content related to freshwaters (as delivered the 23d of March 2015)

- 81 references, from 1957 to 2012
- 512 values of \( T_b \)

**Data per species (52 taxa)**

- Rainbow trout 15%
- Water flea 7%
- Elodea (canadian waterweed) 2%
- Common carp 6%
- Largemouth bass 6%
- Freshwater shrimp 2%
- Yellow -bellied slider turtle 8%
- Moss 2%
- Midge larvae 3%
- Green algae 4%
- Goldfish 4%
- Clam 2%
- Chara 3%
- Chondrostoma polylepsis 2%
- Zebra mussel 9%
- Asiatic clam 4%
- Brown trout 3%
- Clam 2%

Some overlap between names (green algae / chlorella – mussel / freshwater mussel)
Database content related to freshwaters (as delivered the 23d of March 2015)

- 81 references, from 1957 to 2012
- 512 values of Tb

Data per wildlife group (20 taxa)

- Algae: 4%
- Bryophytes: 2%
- Crustacean - Benthic: 4%
- Fish: 3%
- Fish - Benthic: 5%
- Fish - Benthic - Carnivorous: 0%
- Fish - Benthic - Foraging: 8%
- Fish - Benthic - Omnivorous: 0%
- Fish - Piscivorous: 6%
- Fish - Pelagic: 2%
- Fish - Pelagic - Carnivorous: 19%
- Fish - Pelagic - Omnivorous: 0%
- Insect larvae: 4%
- Mollusc - Benthic: 13%
- Mollusc - Benthic - Gastropod: 1%
- Mollusc - Benthic - Gastropod: 1%
- Mollusc - Benthic: 13%
- Mollusc: 2%
- Phytoplankton: 4%
- Reptile: 8%
- Vascular Plant: 5%

Some overlap between categories (fish / fish-benthic / fish-benthic-carnivorous)
Database content related to freshwaters (as delivered the 23d of March 2015)

- 81 references, from 1957 to 2012
- 512 values of Tb

Data per isotope (36 isotopes of 27 elements)

Some overlap between categories (Zn / Zn-65)
Database content related to freshwaters (as delivered the 23d of March 2015)

- 81 references, from 1957 to 2012
- 512 values of Tb

Summary

Couple (fish-caesium) => 133 of the 512 values ca 26% of the dataset
Data used marine

- Detailed Westlakes review of marine biokinetic data quoting more than 130 papers (2004 – 2007)
  - Review focussed on I, Cs, Tc, Pu and Am

- New references identified after the above 1066 pages of data!
  - New papers compiling metal bioaccumulation ($^{51}$Cr, $^{59}$Fe, $^{60}$Co, $^{65}$Zn, $^{75}$Se, $^{85}$Sr, $^{95}$Nb, $^{109}$Cd, $^{131}$I, $^{141}$Mn) in fish, invertebrates
  - General reports and large monographs from the grey literature (Livermore, SANDIA, US EPA...)
  - Review of Russian studies (Fesenko et al.): 38 new entries for $^{54}$Mn, $^{89,90}$Sr, $^{106}$Ru, $^{144}$Ce, $^{137}$Cs, $^{210}$Po, $^{239}$Pu and U isotopes

- **Total 235 entries**

- **No limitation in terms of substances (includes radionuclides as well as stable elements) or geographical location**
Marine database content (by wildlife group)

- Fish: 23.9%
- Macroalgae: 18.8%
- Mollusc - Bivalve: 25.2%
- Mollusc - Gastropod: 10.3%
- Crustacean - Large: 6.8%
- Crustacean - Small: 0.4%
- Echinoderm: 0.9%
- Crustacean: 7.7%
- Annelid: 3.4%
- Sea anemones/True Coral: 0.4%
- Zooplankton: 0.4%
- Phytoplankton: 1.7%
Marine database content (by element)
Terrestrial

• Key reviews: Kitchings et al. (1976), Whicker & Schultz (1982), Stara et al. (1971) & DiGregorio et al. (1978)
  – Used to ID source references (where possible)

• For more recent studies on-line:

  *Journal of Environmental Radioactivity, The Science of the Total Environment, Radiation Protection Dosimetry, Health Physics, International Journal of Radiation Biology, Journals of Radiological Protection and Radiation Research*
<table>
<thead>
<tr>
<th>Wildlife group</th>
<th>Number of entries</th>
<th>Number of species*</th>
<th>Radionuclides</th>
</tr>
</thead>
<tbody>
<tr>
<td>Terrestrial</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Annelid</td>
<td>57</td>
<td>≥9</td>
<td>Cd, Co, Cs, Cu, Hf, Hg, I, Mn, Pb, Sc, Sr, Tb, U, Zn</td>
</tr>
<tr>
<td>Arachnid</td>
<td>11</td>
<td>≥6</td>
<td>Ca, Cs, K, Na, P, Zn</td>
</tr>
<tr>
<td>Arthropod</td>
<td>119</td>
<td>&gt;53</td>
<td>As, Ca, Co, Cr, Cs, Cu, Fe, I, Ir, K, Na, P, Pb, Rb, Ru, Sr, W, Y, Zn</td>
</tr>
<tr>
<td>Bird</td>
<td>4</td>
<td>2</td>
<td>Cs, I</td>
</tr>
<tr>
<td>Mammal</td>
<td>522</td>
<td>≥39</td>
<td>Ag, Am, Au, Be, C, Cd, Ce, Cf, Co, Cr, Cs, Eu, Fe, H, Hg, I, In, Ir, K, Mn, Na, Nb, Np, P, Pa, Pb, Po, Pu, Ra, Rb, Ru, Sb, Sc, Se, Sn, Sr, Tb, Te, Th, U, W, Y, Zn, Zr</td>
</tr>
<tr>
<td>Mollusc</td>
<td>2</td>
<td>1</td>
<td>Cs, Na</td>
</tr>
<tr>
<td>Reptile</td>
<td>29</td>
<td>6</td>
<td>Co, Cr, Cs, Fe, I, Mn, Na, Rb, Zn</td>
</tr>
</tbody>
</table>
Summary – provisional #’s

• 1580 entries
  – 233 Marine
  – 513 Freshwater
  – 744 Terrestrial
  – 88 Riparian

• 52 elements

• 29 wildlife groups
Forthcoming Outputs


A new simplified allometric approach for predicting the biological half-life of radionuclides in reptiles

N.A. Beresford a,b, *, M.D. Wood b

Making the most of what we have: application of extrapolation approaches in radioecological wildlife transfer models

Nicholas A. Beresford a,b, *, Michael D. Wood b, Jordi Vives i Batlle c, Tamara L. Yankovich d, Clare Bradshaw e, Neil Willey f