ERICA ASSESSMENT TOOL

Environmental Risk from Ionising Contaminants: Assessment and Management – ERICA

- The ERICA Integrated Approach and the ERICA Tool were outputs from an FP6 EURATOM funded project (2004-2007)
  - Project partners:

    SSI, SKB, SUC, Facilia, GSF, CIEMAT, IRSN, EDF, EA, WSC, UniLiv, CEH, UMB, STUK & NRPA (now DSA)

ERICA

- Approach for performing environmental assessments for radioactivity that includes impact assessment, risk characterisation and environmental management considerations*

- The ERICA Tool guides the user through the assessment process, recording information and decisions and allowing the necessary calculations to be performed to estimate risks to selected animals and plants

**Larsson, C. M. (2008). An overview of the ERICA Integrated Approach to the assessment and management of environmental risks from ionising contaminants. Journal of Environmental Radioactivity, 99, 1364–1370.*

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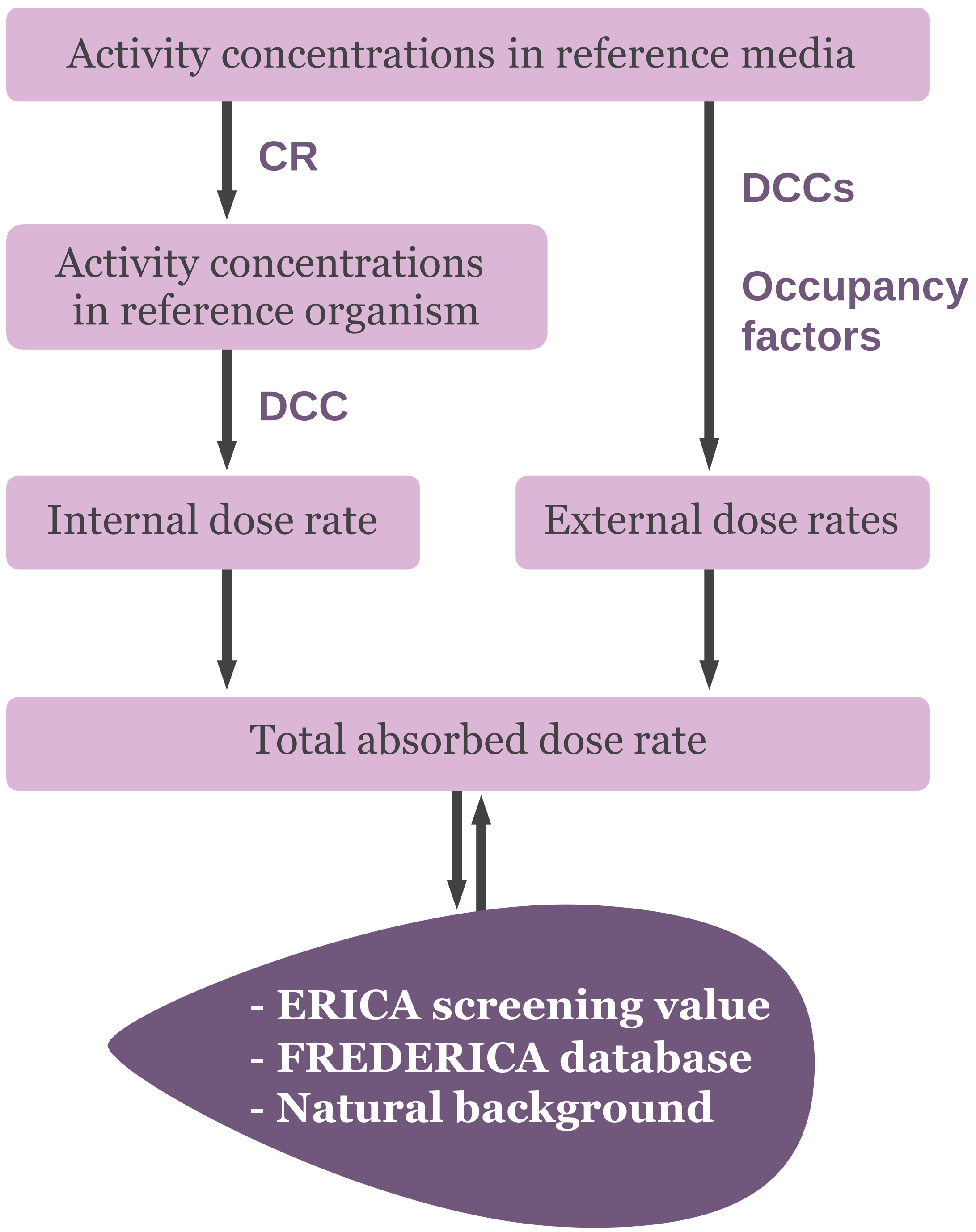
Assessment components

- Modelling transfer through the environment
- Estimating doses to biota from internal and external distributions of radionuclides
- Establishing the significance of the dose-rates received by organisms



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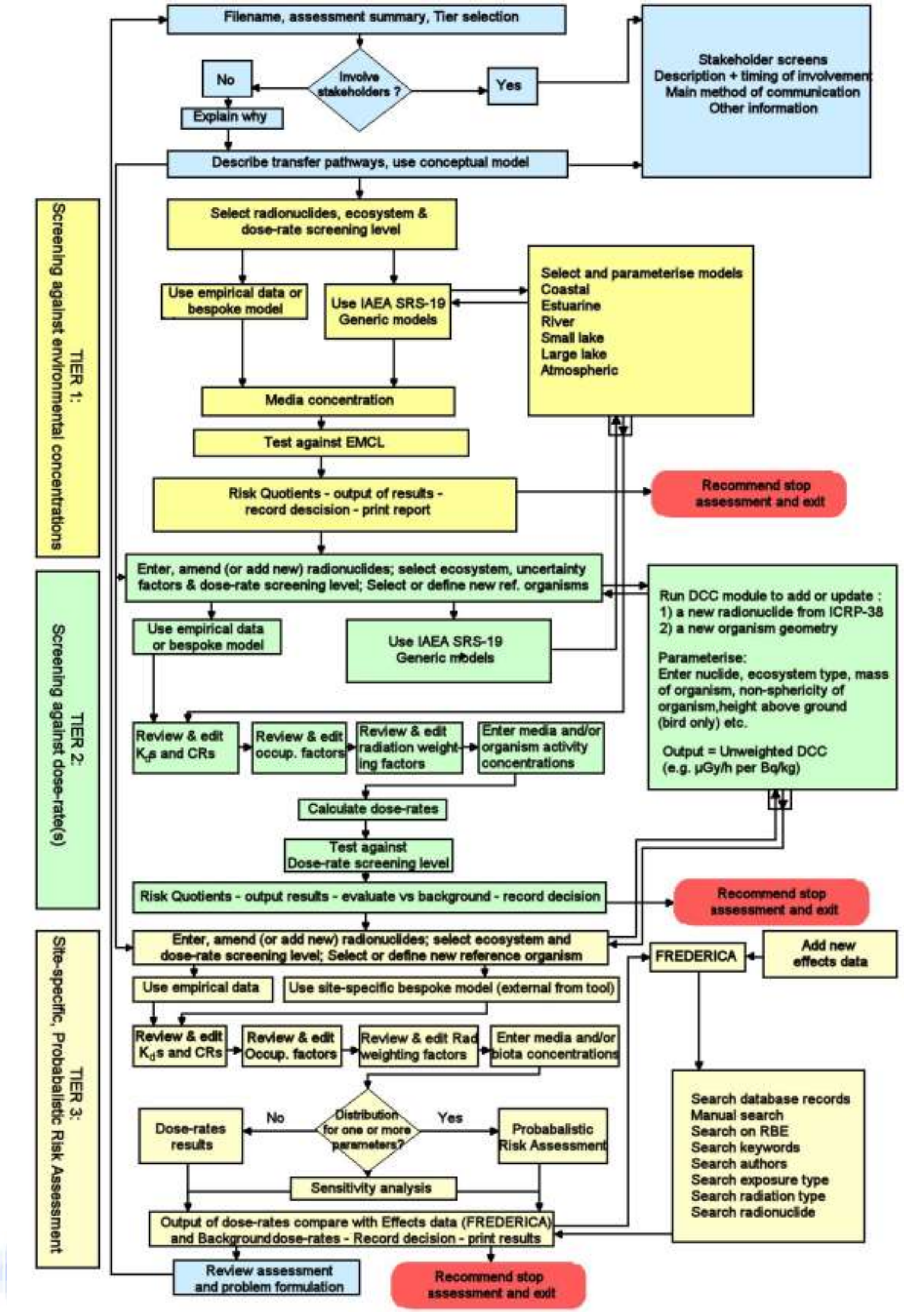

Tiered approach

- **Tier 1** using pre-calculated Environmental Media Concentration Limits (EMCLs) to estimate risk quotients
- **Tier 2** calculates dose rates but allows the user to examine and edit most of the parameters used in the calculation, including additional radionuclides and user-defined representative species
- **Tier 3** allows the option to run the assessment probabilistically if the underlying parameter probability distribution functions are defined

ERICA Consortium & working partnerships

- Since initial development, DSA* has led a group of partners to support maintenance and development of the tool
  - ARPANSA, CIEMAT, Environment Agency, IRSN, SSM
  - UK CEH,University of Stirling & … incl. personal contributions
- New contribution agreements and memoranda of understanding being established to ensure continuing support
- Software development by Facilia**/AFRY
  - Updates in: 2011, 2012, 2014 (Version 1.2), 2016 and 2019 (version 1.3)

**Justin Brown (DSA) & **Boris Alfonso (Facilia)*

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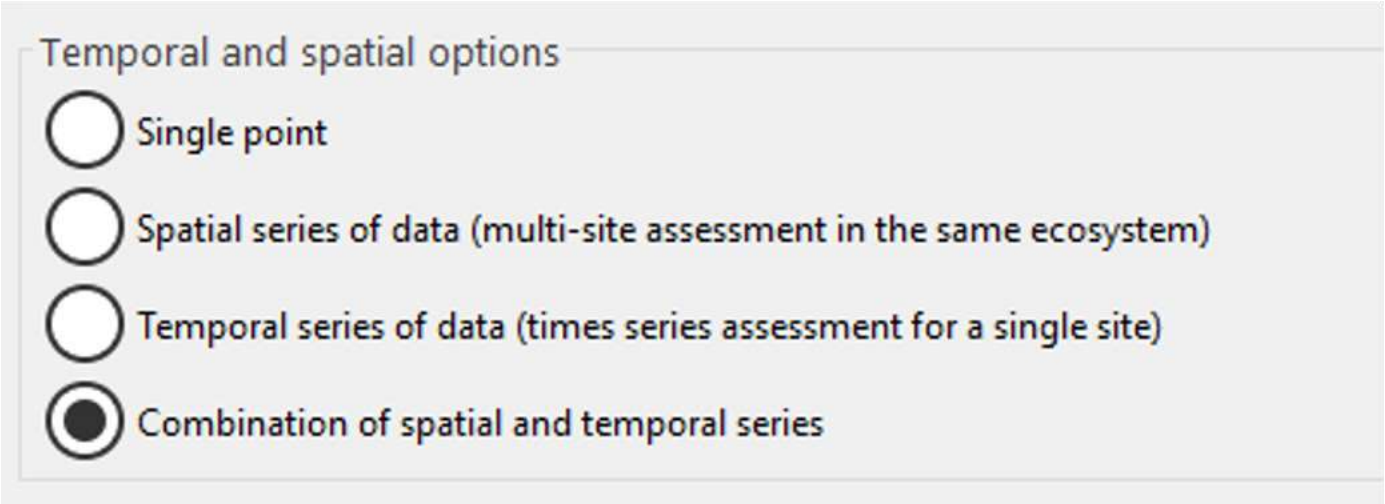
ERICA Tool: previous versions

- Key developments (Version 1.2)
  - New default radionuclides added (consistency with ICRP RAP approach)
  - Updates to assessment parameters (CRs) and EMCLs
  - Rationalisation of reference organisms (consistency with ICRP RAPs and addressing organism gaps)

- Key developments (Version 1.3)
  - Multiple series data functionality, including MS Excel import function



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*Software system with tiered structure of the **ERICA Integrated Approach** for assessing the radiological risk to terrestrial, freshwater and marine biota*

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What has changed?

- New dosimetry
- Updated CRs
- Updated K_ds
- Recalculated EMCLs
- Inclusion of noble gases, incl. Radon
- Add multiple-organisms function

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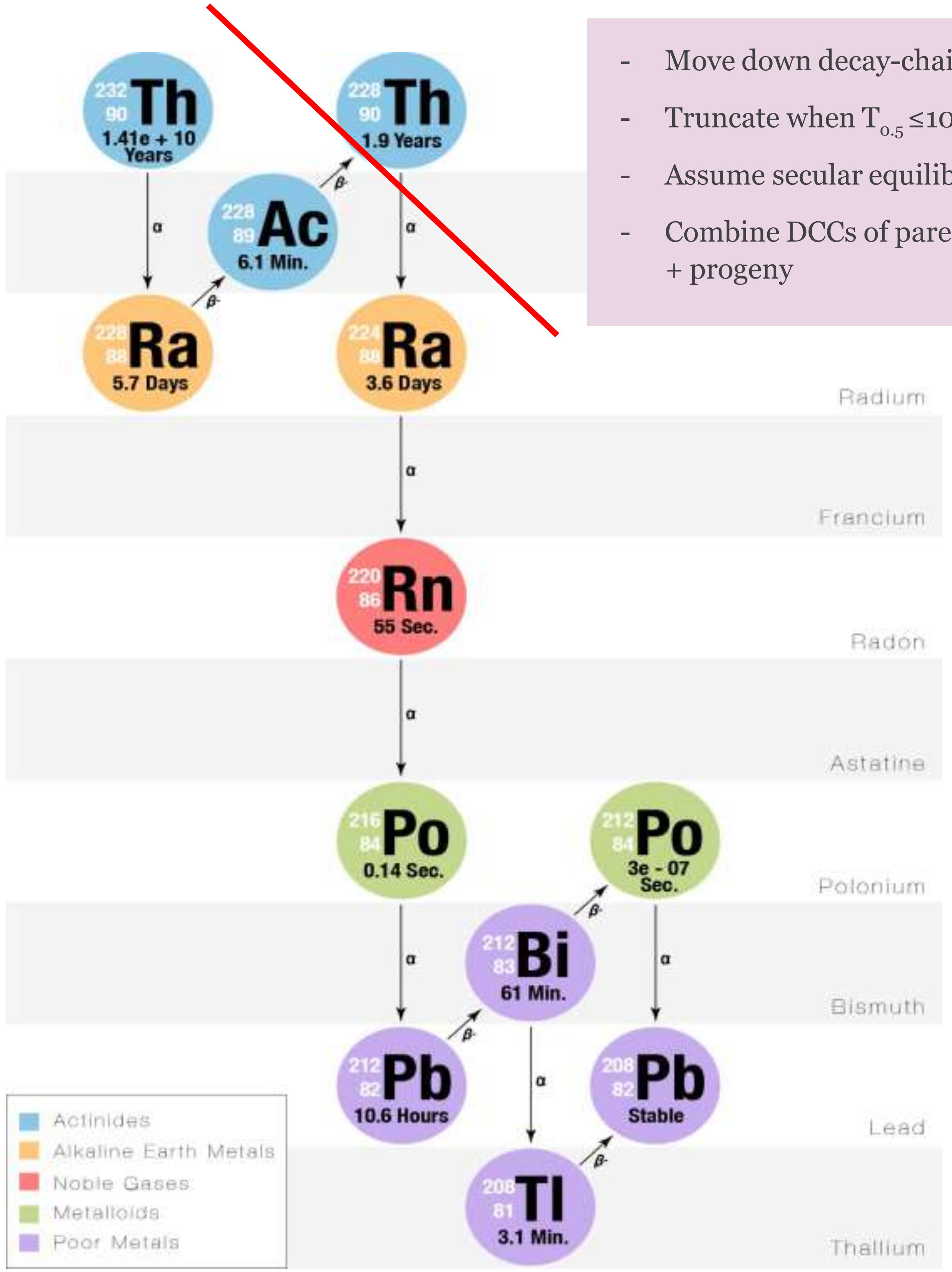
New dosimetry – decay chains

- Original DCC calculations in ERICA were well elaborated and adopted by the ICRP (Publication 108) and tested in numerous IAEA intercomparison programmes (EMRAS etc.)

- Recognised that dealing with decay chains could be improved
  - Identified mismatch of DCCs with other models (Vives i Batlle et al. 2007)
  - Not representative of some cases, e.g. transient equilibrium



- Move down decay-chain
- Truncate when $T_{0.5} \leq 10$ days
- Assume secular equilibrium
- Combine DCCs of parents + progeny

Vives i Batlle, J. et al. (2007). Inter-comparison of absorbed dose rates for non-human biota. Radiat Environ Biophys **46**, *349–373.*

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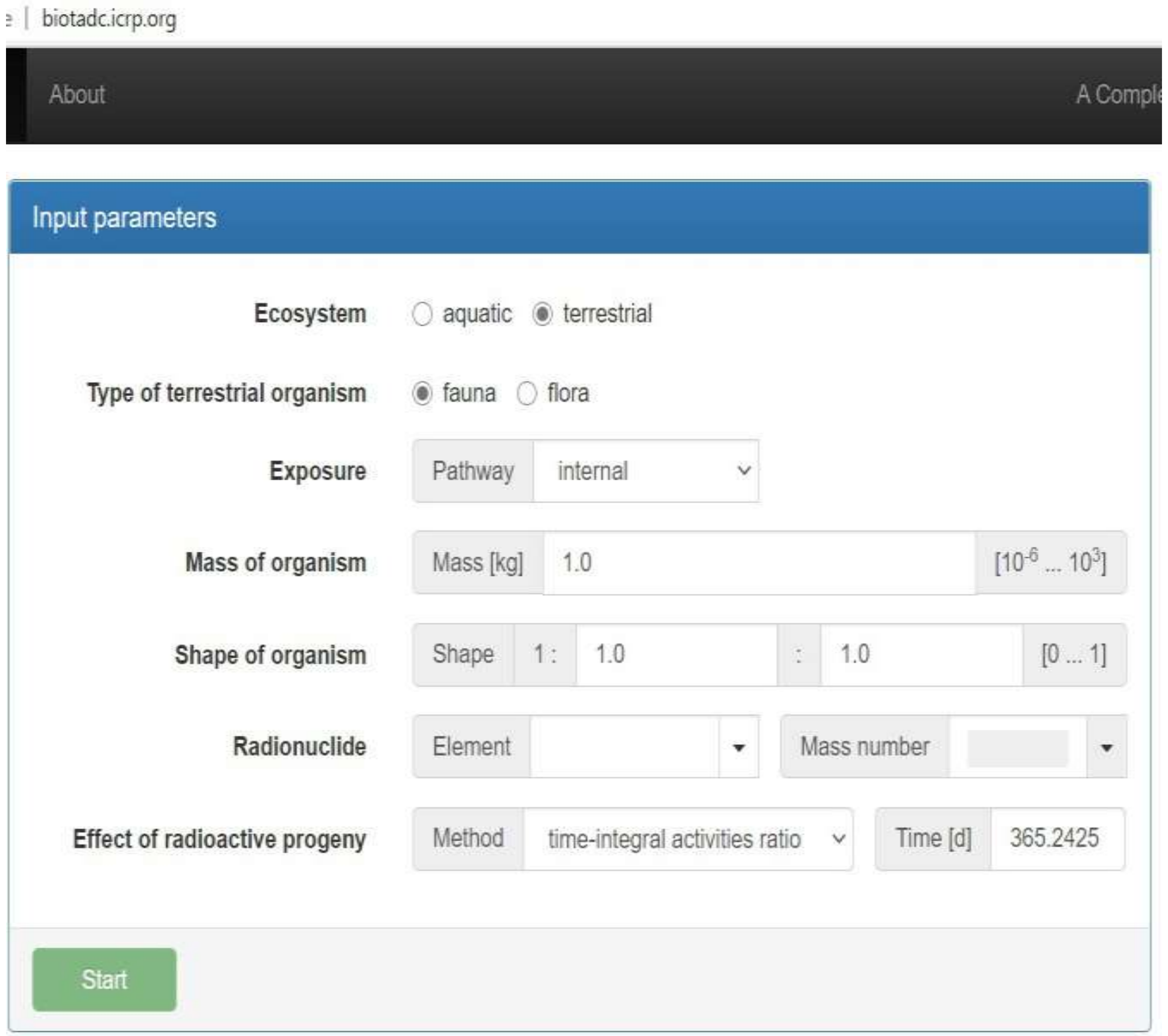
New dosimetry II

- ICRP-136 methodology adopted
  - Collaboration between Facilia/AFRY and ICRP Biota-DC developer (Alexander Ulanovsky)

- Integration time over which decay and in-growth accounted for
  - ICRP – the integration time can be selected to be pertinent to the specific assessment task
  - ERICA – simplification where integration period taken to be 1 year in all cases



ICRP, 2017. Dose coefficients for nonhuman biota environmentally exposed to radiation. ICRP Publication 136. Ann. ICRP 46(2).

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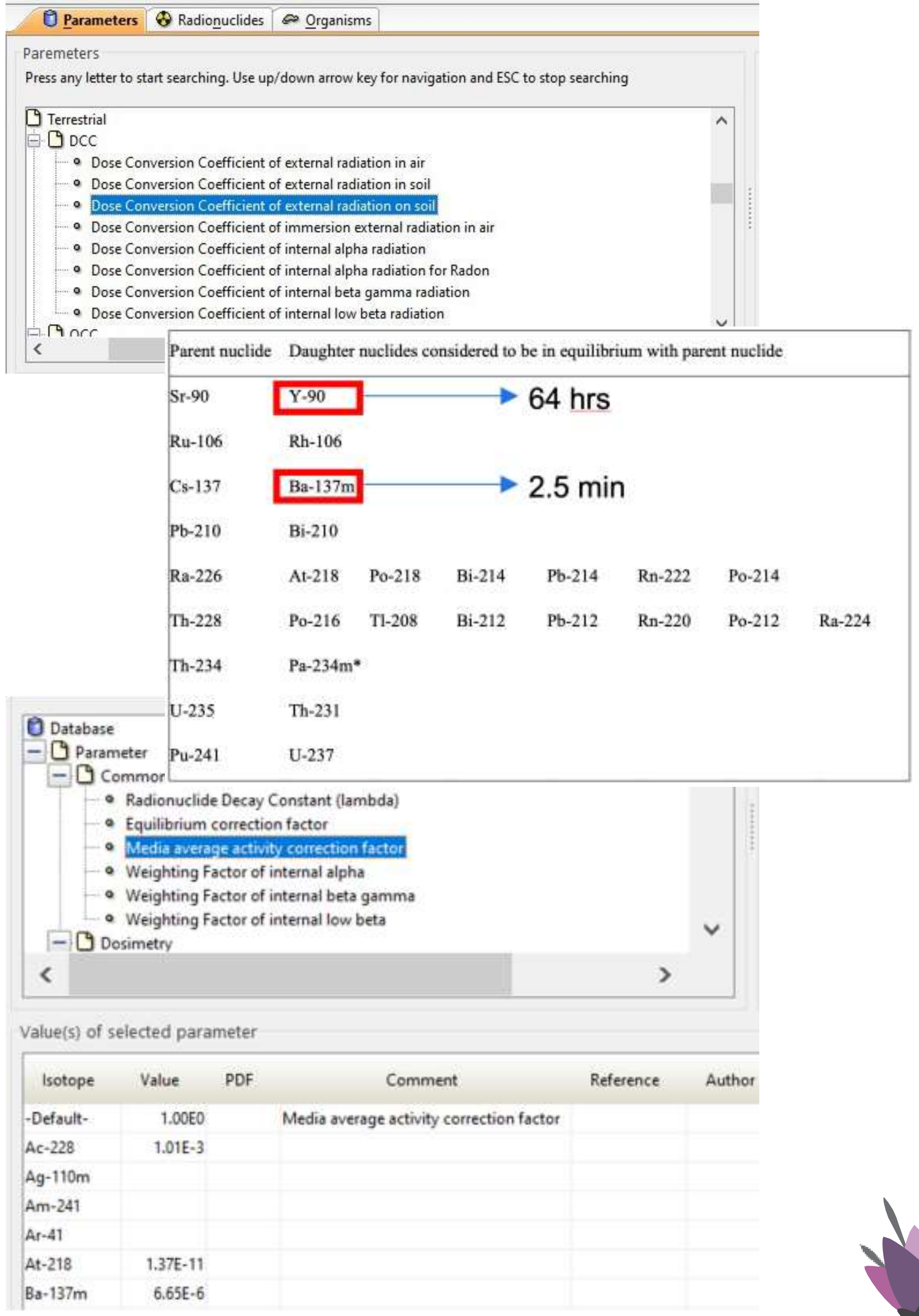
New dosimetry III

- Some slight reconfiguration of DCCs required
  - e.g. ‘on soil’ as opposed to external low-β and β-γ on soil

- In practice all radionuclide DCCs, including for short-lived progeny, need to be included explicitly
  - requires inclusion of other parameters (CRs and K_ds for these short-lived radionuclides)

- Media average activity correction factor
  - to account for decay for the ‘unsupported’ component over the integration period for short-lived radionuclides



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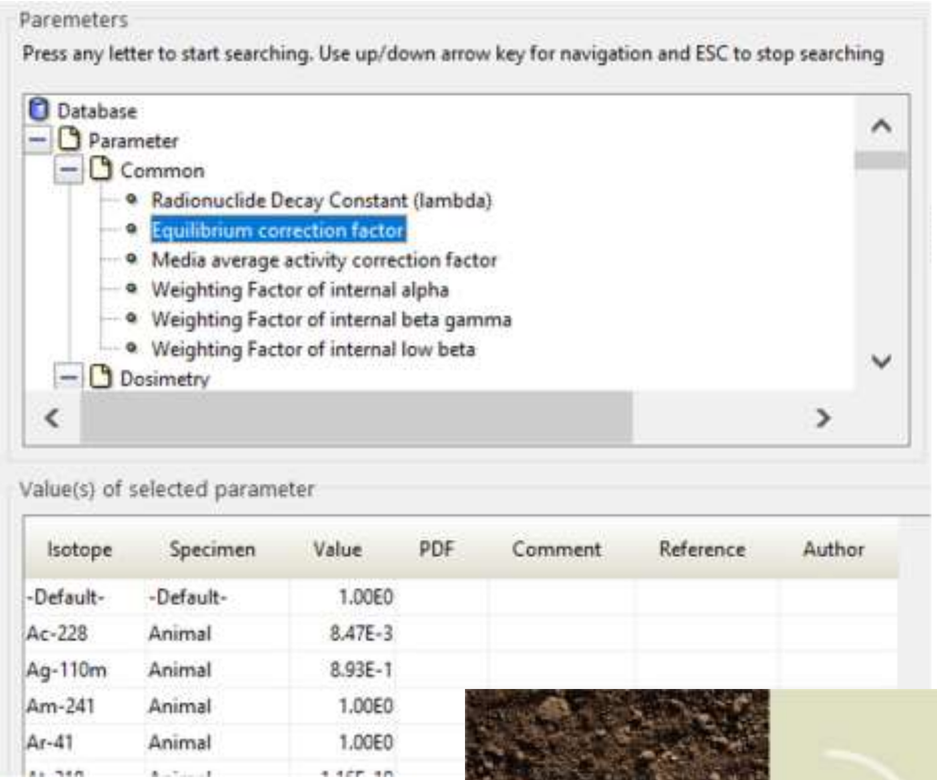
Biological transfer – use of CRs

- A problem previously identified in applying CRs, based on stable elements and long- lived radionuclides, to radionuclides with short physical half-lives

- Adjustment is required to account for lower steady state activity concentrations in organisms occuring due to radioactive decay

- Addressed through application of an equilibrium correction factor
  - Based on solution for freshwater organisms in IAEA TRS-472, expanded to all ecosystems



IAEA, 2010. Handbook of Parameter Values for the Prediction of RadionuclideTransfer in Terrestrial and Freshwater Environments. IAEA Technical Report Series No. 472. International Atomic Energy Agency, Vienna.

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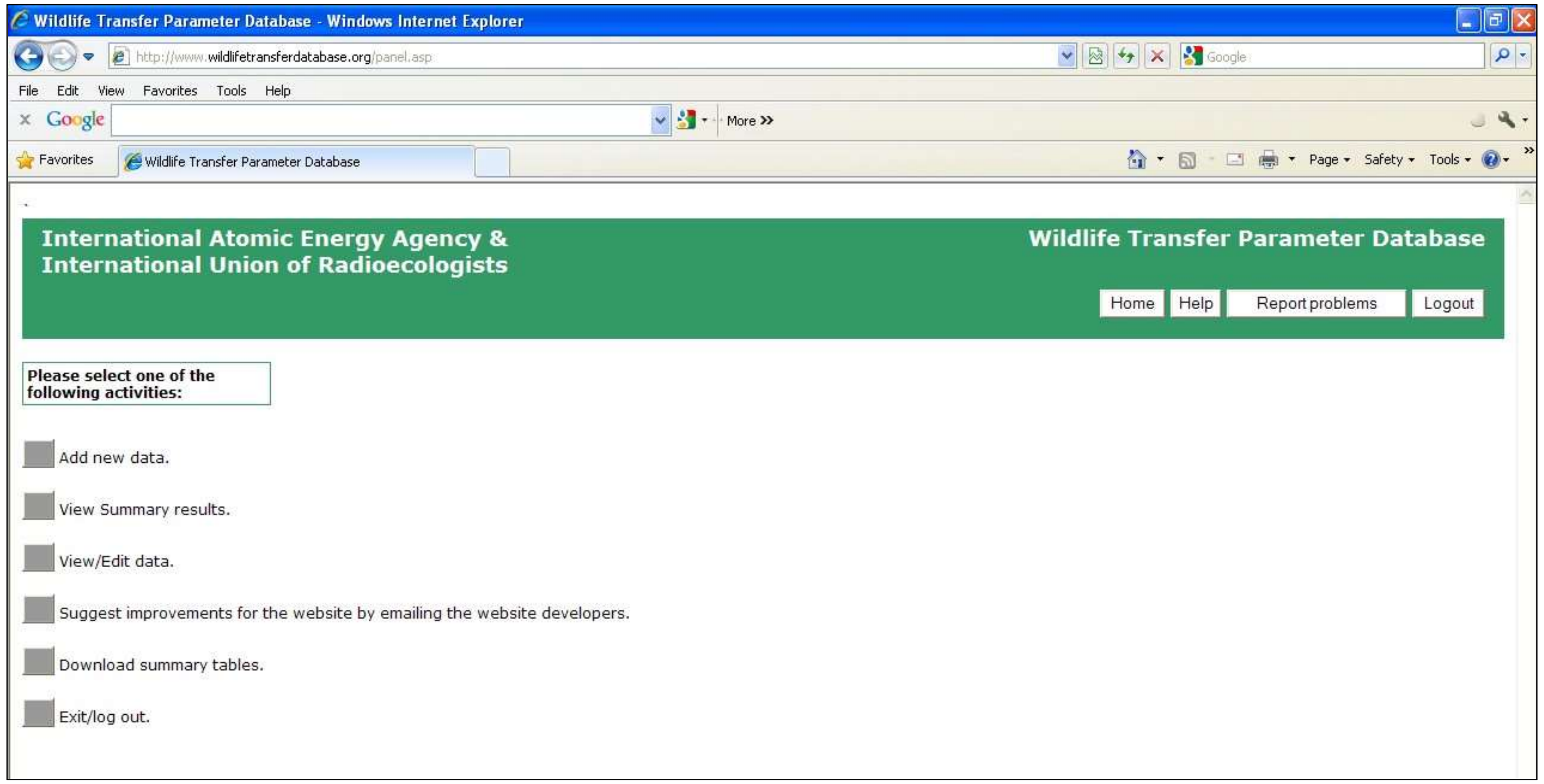
CRs update

- Collaboration with UK CEH to extract data from the Wildlife transfer database

- Discussed in the next presentation (Nick Beresford)



Statistical data for organism of interest		Surrogate dataset	Approach
Mean	***SD***		
*A**	*A*	*A*	*Semi – conjugate (non-informative)*
A	*A*	*NA***	*Using data as it is (assume lognormal PDF)*
A	*NA*	*A*	*Using ratio of SD to mean for the surrogate to derive the missing SD from the data mean*
A	*NA*	*NA*	*Using mean and assume exponential PDF*

*A – available; **NA - not available.

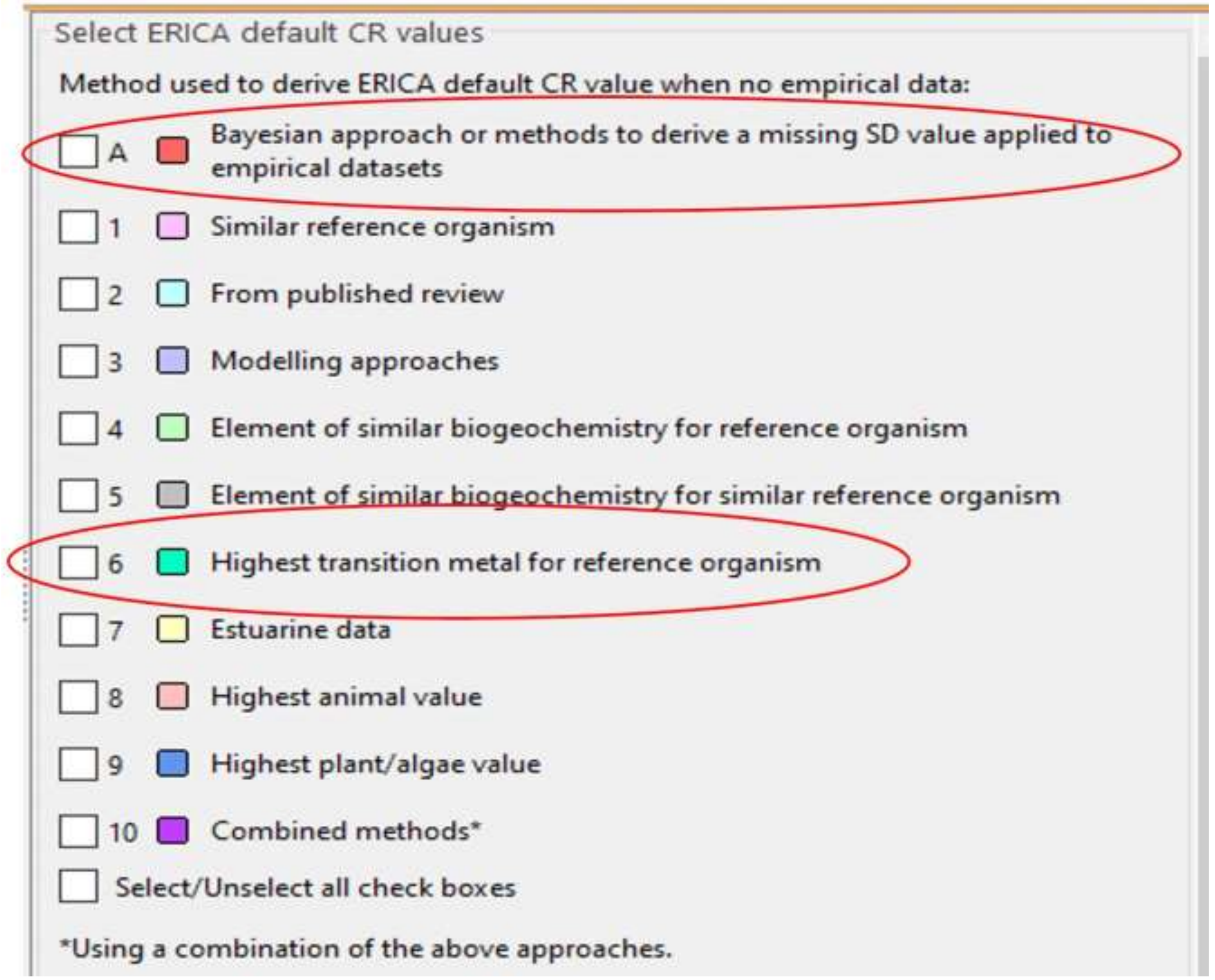
Step 1 – Consider small datasets

Step 2 – Apply Bayesian rules

Step 3 – Apply extrapolation approaches

CR – data gap filling methodology

- Revised the data-gap filling methods to distinguish between
  - approaches that partly used empirical data for the given organism in combination with a surrogate (A) and
  - those that used a surrogate only
- The highest transition metal CR was often an appropriate method for addressing data gaps



K_d updating

- New freshwater data collated by IAEA MODARIA working group
- Data presented as GMs and GSDs so statistical changes required to derived AMs and AMSDs
  - Order of preference established for selection of data for application in ERICA, e.g.:
    - *Field and Deposited sediment (DS)*
    - *Adsorption and DS (the rationale being that adsorption best represents a prospective planned release)*
    - *Desorption and DS…*
- Some flexibility / judgement necessary to account for data coverage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Extended K_d distributions for freshwater environment

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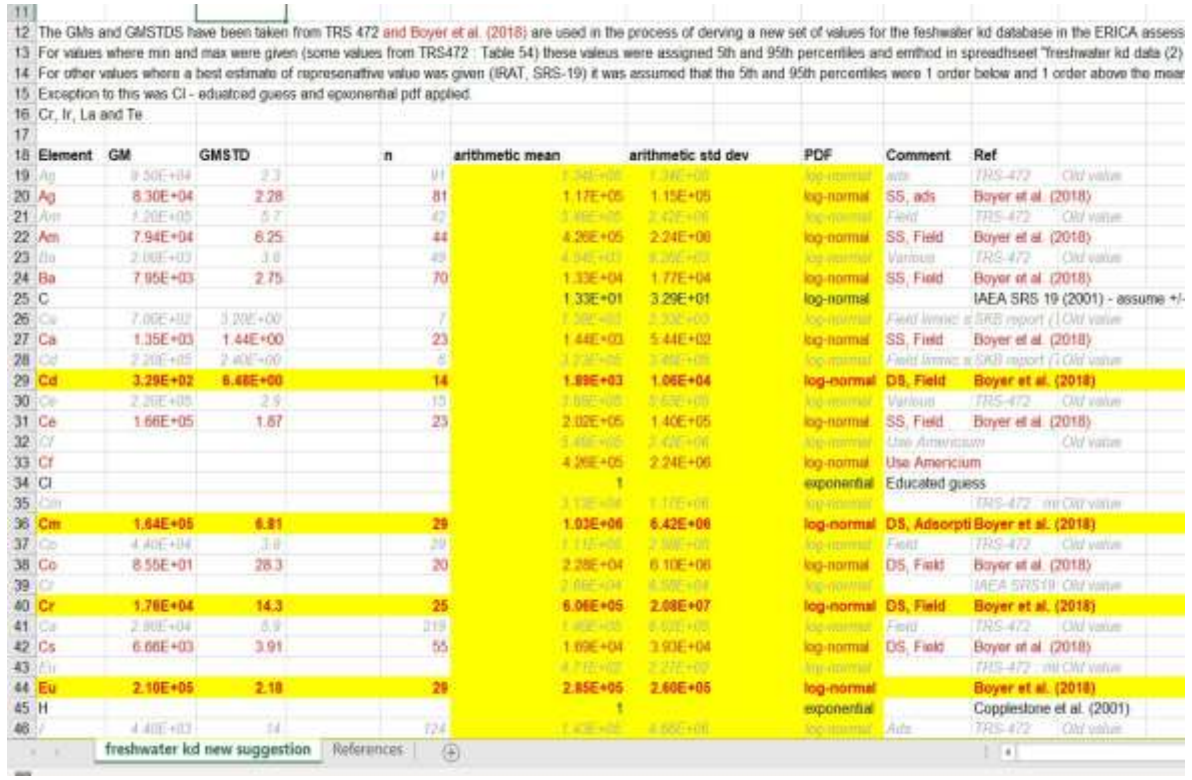
12 The GMs and GMSTDS have been taken from TRS 472 and Boyer et al. (2018) are used in the process of derving a new set of values for the feshwater kd database in the ERICA assess
13 For values where min and max were given (some values from TRS472 : Table 54) these valeus were assigned 5th and 95th percentiles and emthod in spreadhseet "freshwater kd data (2)
14 For other values where a best estimate of represenative value was given (IRAT, SRS-19) it was assumed that the 5th and 95th percentiles were 1 order below and 1 order above the mear
15 Exception to this was Cl - eduatced guess and epxonential pdf applied
16 Cr, Ir, La and Te

18	Element	GM	GMSTD	n	arithmetic mean	arithmetic std dev	PDF	Comment	Ref	
19	Ag	9.50E+04	2.3	91	[illegible]	[illegible]	log-normal	ads	TRS-472	Old value
20	Ag	8.30E+04	2.28	81	1.17E+05	1.15E+05	log-normal	SS, ads	Boyer et al. (2018)	
21	Am	1.20E+05	5.7	42	[illegible]	2.42E+06	log-normal	Field	TRS-472	Old value
22	Am	7.94E+04	6.25	44	4.26E+05	2.24E+06	log-normal	SS, Field	Boyer et al. (2018)	
23	Ba	2.00E+03	3.6	49	[illegible]	[illegible]	log-normal	Various	TRS-472	Old value
24	Ba	7.95E+03	2.75	70	1.33E+04	1.77E+04	log-normal	SS, Field	Boyer et al. (2018)	
25	C				1.33E+01	3.29E+01	log-normal		IAEA SRS 19 (2001) - assume +/-	
26	Ca	7.00E+02	3.20E+00	7	[illegible]	[illegible]	log-normal	Field limnic a SKB report (1		Old value
27	Ca	1.35E+03	1.44E+00	23	1.44E+03	5.44E+02	log-normal	SS, Field	Boyer et al. (2018)	
28	Cd	2.20E+05	2.40E+00	6	[illegible]	[illegible]	log-normal	Field limnic a SKB report (1		Old value
29	Cd	3.29E+02	6.48E+00	14	1.89E+03	1.06E+04	log-normal	DS, Field	Boyer et al. (2018)	
30	Ce	2.20E+05	2.9	15	[illegible]	[illegible]	log-normal	Various	TRS-472	Old value
31	Ce	1.66E+05	1.87	23	2.02E+05	1.40E+05	log-normal	SS, Field	Boyer et al. (2018)	
32	Cf				[illegible]	2.42E+06	log-normal	Use Americium		Old value
33	Cf				4.26E+05	2.24E+06	log-normal	Use Americium		
34	Cl				1		exponential	Educated guess		
35	Cm				[illegible]	[illegible]	log-normal		TRS-472 : mi	Old value
36	Cm	1.64E+05	6.81	29	1.03E+06	6.42E+06	log-normal	DS, Adsorpti	Boyer et al. (2018)	
37	Co	4.40E+04	3.6	29	[illegible]	[illegible]	log-normal	Field	TRS-472	Old value
38	Co	8.55E+01	28.3	20	2.28E+04	6.10E+06	log-normal	DS, Field	Boyer et al. (2018)	
39	Cr				[illegible]	[illegible]	log-normal		IAEA SRS19	Old value
40	Cr	1.76E+04	14.3	25	6.06E+05	2.08E+07	log-normal	DS, Field	Boyer et al. (2018)	
41	Cs	2.90E+04	5.9	219	[illegible]	[illegible]	log-normal	Field	TRS-472	Old value
42	Cs	6.66E+03	3.91	55	1.69E+04	3.93E+04	log-normal	DS, Field	Boyer et al. (2018)	
43	Eu				[illegible]	[illegible]	log-normal		TRS-472 : mi	Old value
44	Eu	2.10E+05	2.18	29	2.85E+05	2.60E+05	log-normal		Boyer et al. (2018)	
45	H				1		exponential		Copplestone et al. (2001)	
46	I	4.40E+03	14	124	[illegible]	[illegible]	log-normal	Ads	TRS-472	Old value

freshwater kd new suggestion | References

Derivation of EMCL

- Essentially this is the activity concentration of a given radionuclide in media (soil, sediment water) that will result in a dose-rate to **the most exposed reference organism** equal to the screening dose-rate.

- Updated to reflect changes to dosimetry and parameter values

$$EMCL = \frac{D_{lim}}{F_{exp}}$$

Where:

F is the dose rate that an organism will receive for the case of a unit concentration in environmental media (in µGy/h per Bq/L or kg of medium). 'exp' = most exposed

D_{lim} is the screening dose-rate or PNEDR (default = 10 µGy/h (ERICA D5); tool allows 40; 400 µGy/h (IAEA conclusions) or custom to be selected)

'F' depends upon reference organism type (affects the DCC values, CRs and position within habitat) and radionuclide (affects the DCC values, CRs and K_ds).

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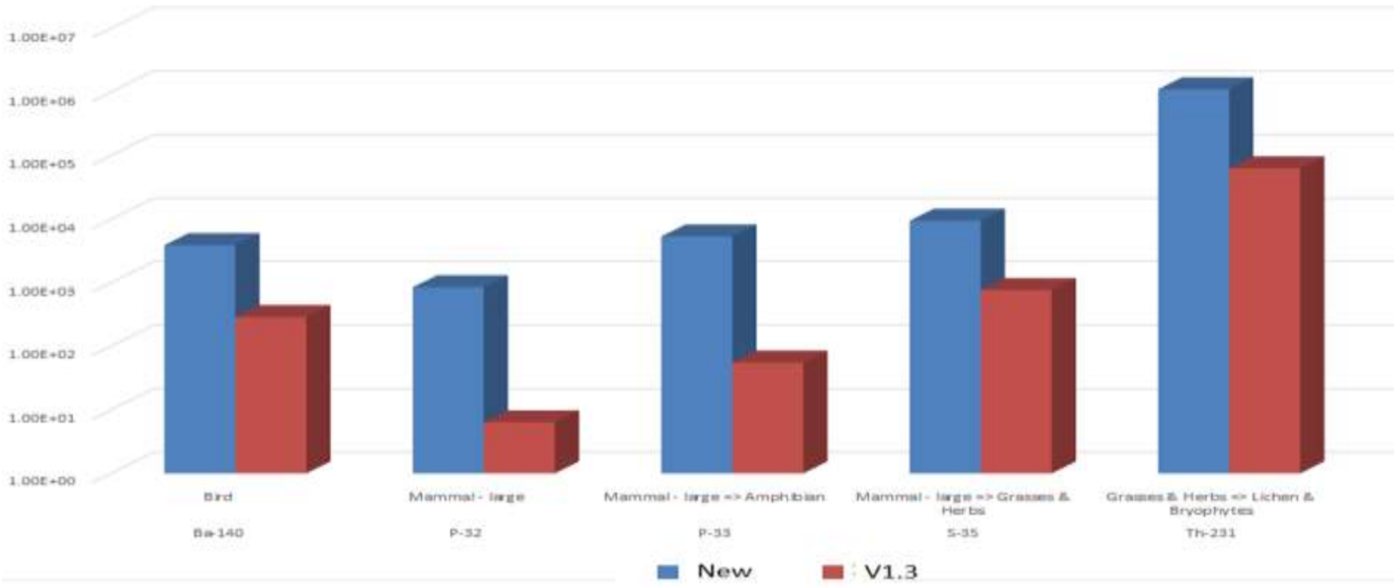
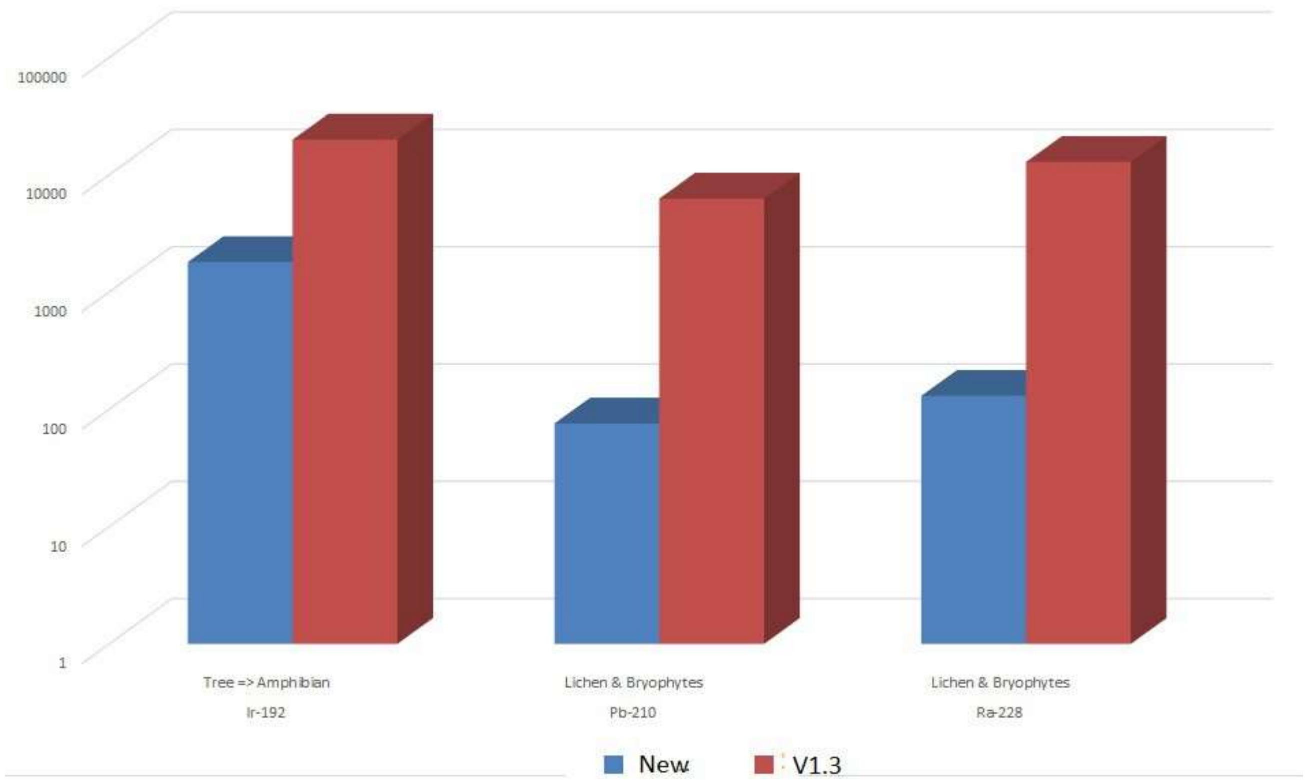
Quality Assurance of EMCLs



Terrestrial Cases where New EMCLs > 10 x ***higher*** *than V1.3 (Old) EMCLs.*

- For Ba-140, this is accounted for by order of magnitude decrease in CR for bird
- For P-32, P-33, S-35 the EMCLs now relate to soil not air
- Th-231 $t_{0.5} \approx 1$ day
  Change in Th-231 value due to application of equilibrium correction factor.



Terrestrial Cases where New EMCLs > 10 x ***lower*** *than V1.3 (Old) EMCLs.*

- Many of the new Iridium CRs show > a factor of 100 increase.
- EMCL decrease for Pb-210 accounted for by the new dosimetry which includes substantial internal alpha component associated with Po-210 ingrowth over the integration period (the old version set the internal alpha component to 0). Similar situation for Ra-228.

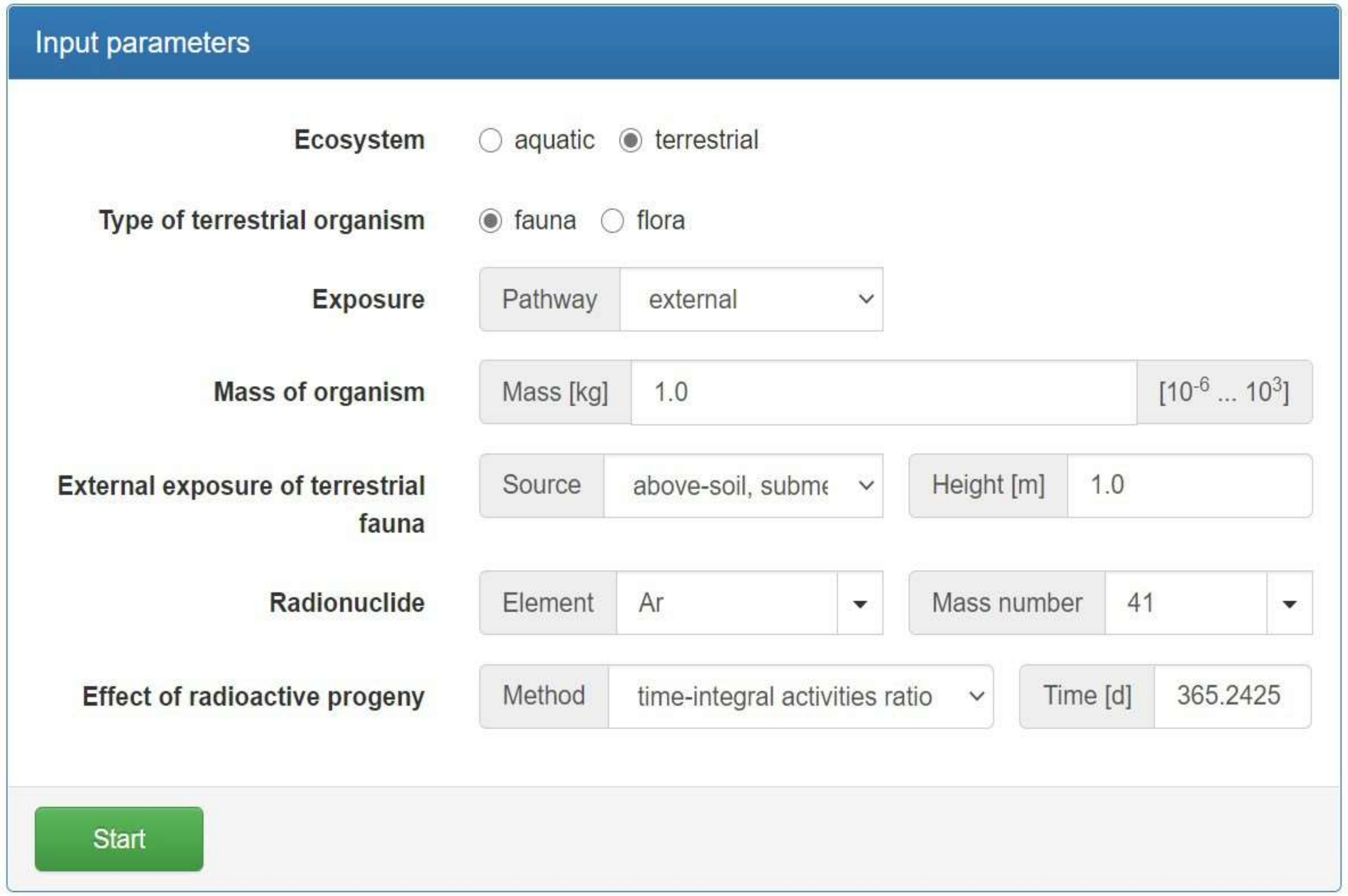
Noble gases

- A suite of noble gases is now included as default (Tier 2 only):
  - Ar-41,
  - Kr-85, Kr-85m, Kr-87, Kr-88
  - Xe-131m, Xe-133m, Xe-133, Xe-135, Xe-138
  - Rn-220, Rn-222

- Concentration ratios (for all ecosystems) and distribution coefficients (freshwater and marine only) are set to 0 by default in the underlying system of equations.
  - Assuming that noble gases neither interact with ambient media, such as sediment, nor with biological material. Transfer to organisms can reasonably be assumed to be negligible.

Noble gases II

- Immersion DCCs from ICRP-136 (Biota-DC) have been used
- It is assumed that the organism is 100 % of the time present in contaminated air (irrespective of whether the organism is above or below ground)
- Occupancy factors can be ignored (simplifying the relevant calculation)



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Radon and thoron

- For Radon and thoron (^{222}Rn and ^{220}Rn), the contribution of these radionuclides (and more importantly their progeny) to dose rates arising from inhalation and deposition in the lung is taken into account - in consultation with Jordi Vives i Batlle

Parameters for calculation and values of aggregated unweighted DCs for internal exposure of animals due to progeny of radon isotopes $^{220,222}Rn$.

Parameter or quantity	Amphibian (ICRP frog)[a]	Reptile (ERICA snake)[a]	Mammal small (ICRP rat)	Mammal big (ICRP deer)	Bird (ICRP duck)[a]
M (kg)	0.0314	0.744	0.314	245	1.26
a (m)	0.08	1.2	0.2	1.3	0.3
b (m)	0.03	0.035	0.06	0.6	0.1
c (m)	0.025	0.035	0.05	0.6	0.08
B ($m^3 h^{-1}$)	2.1×10^{-3}	0.023	0.012	2.5	0.034
DCs per air concentration of ^{222}Rn ($\mu Gy\ h^{-1}\ Bq^{-1}\ m^3$)					
DC_B	1.4	1.8	1.7	4.2	1.9
DC_{TB}	0.15	0.20	0.18	0.46	0.21
DC_L	0.032	0.014	0.017	4.1×10^{-3}	0.012
DC_{WB}	3.8×10^{-4}	1.7×10^{-4}	2.1×10^{-4}	5.8×10^{-5}	1.5×10^{-4}
DCs per air concentration of ^{220}Rn ($\mu Gy\ h^{-1}\ Bq^{-1}\ m^3$)					
DC_B	22	28	26	65	30
DC_{TB}	2.4	3.0	2.8	7.0	3.2
DC_L	0.49	0.21	0.26	0.062	0.18
DC_{WB}	5.9×10^{-3}	2.6×10^{-3}	3.2×10^{-3}	8.9×10^{-4}	2.4×10^{-3}

[a] DC for non-mammals are shown for illustrative purposes only.

- This component of dose is treated as an 'internal' contribution to exposure and uses values based on the methodology of Vives i Batlle et al. (2017).

- For Rn-222 and Rn-220 in decay chains, emanation coefficients are applied to derive soil air concentration from parent radionuclide concentrations in soil (e.g. Ra-226 → Rn-222)

Vives i Batlle, J., Ulanovsky, A., Copplestone, D. (2017). A method for assessing exposure of terrestrial wildlife to environmental radon (^{222}Rn) and thoron (^{220}Rn). Science of The Total Environment, 605–606, pp. 569-577.

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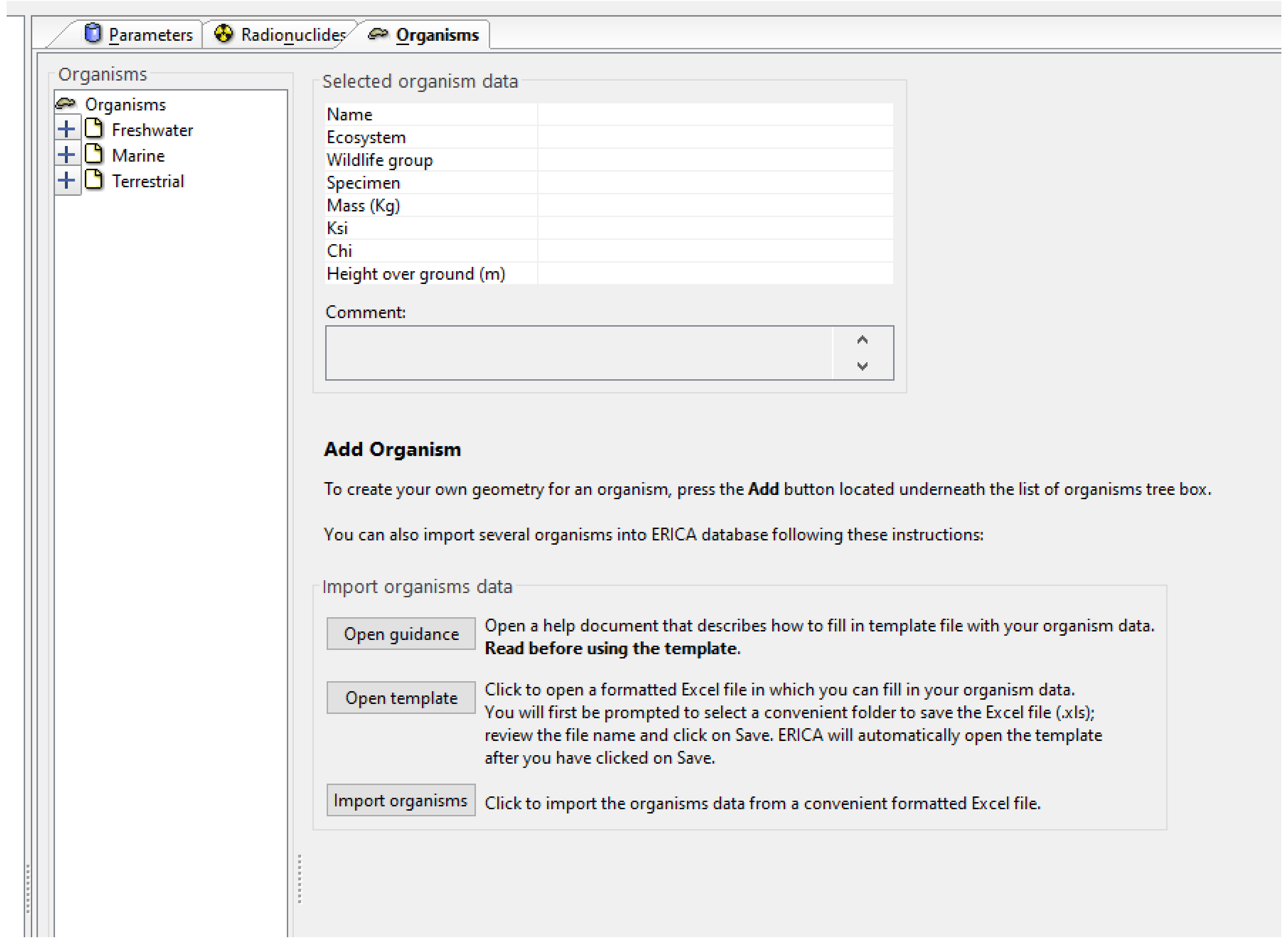
Add organism wizard

- New function to allow multiple new representative organisms to be added at one time
  - Export/import function creates structured MS Excel file for user-defined organisms to be uploaded
  - Assigning new organisms to specific wildlife groups (e.g. Bird, Aquatic Plant) allows CRs for short-lived progeny in decay series to be automatically assigned
  - Wizard Help file to guide users on data entry



- Function also supports sharing of user-defined organisms between assessors

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Next steps

- Ongoing development plans:
  - Further analysis of ERICA End-users questionnaire responses to identify additional end user needs/aspirations
  - Further development of website to provide more user-interface and feedback on needs and aspirations and to inform users of ongoing developments
  - Ideas bank of prioritised areas for development maintained
  - Update of summary effects table & help file for link to FREDERICA database
  - Implementation of dynamic model functionality

- Training courses
  - Full training courses for those new to ERICA
  - Update/refresher courses to introduce the new features of the tool

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Acknowledgements

- ERICA Consortium

- Justin Brown, DSA
- Boris Alfonso, Facilia/AFRY
- Nick Beresford, UK CEH
- Jordi Vives i Batlle, SCK-CEN
- Alexander Ulanovsky, IAEA/ICRP
- David Copplestone, University of Stirling
- Karen Smith, RadEcol

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