Little Forest Burial Ground model intercomparison – preliminary results

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Study objectives

- Transfer of Am-241, Co-60, Cs-137, Sr-90, Pu-238/239, Th-232, and U-234/238 from soils to wildlife at the Little Forest Burial Ground site near Sydney, Australia.
- Small site with trace levels of surface contamination, but offers a diverse range of ten terrestrial species to assess, including indigenous Australian species.
- Challenging pathways: prediction of dose to an acacia tree which has part of its root system in a waste trench.
- Participants: code developers/custodians for the ERICA Tool, FASTer-lite, K-Biota, and RESRAD-BIOTA, as well as users with various levels of experience.
- Compare internal, external, and total dose rates as well as whole-organism tissue concentrations.
- Use of probabilistic parameterisation of whole-organism concentration ratios (CR) and input data, typically using log-normal distributions.

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Basis of the statistical analysis

- Step 1 – Initial inspection.
  - Check for outliers and qualitative explanation of any obvious discrepancies.
  - Normalise all CR and dose values across the different approaches for a particular radionuclide and species to their average.
  - Calculated the standard deviation divided by the average of all the values for a given radionuclide, including all species and approaches, to find what radionuclides experience more data variability.
- Step 2 – Variation analysis. For each organism / approach pair defined $X(i) = (x_1(i),\ldots, x_p(i))$ where:
  - $p = 9$ is the number of radionuclides.
  - i is the index representing the approach.
  - X represents mean CR, tissue concentration or dose.

Basis of the analysis (cont.)

- Step 2 (cont):
  - Calculate a square (p × p) matrix (would be a 6 x 6 matrix assuming 6 participants) in which each element d_{ij} represents the geometric mean of the relative half-differences between two points X(i) = (x_1(i), …, x_p(i)) and X(j) = (x_1(j),…, x_p(j)) in p-dimensional space, defined as:

$$d_{ij} = \sqrt{\frac{1}{N}\sum_{k=1}^{p}\left(\frac{x_k(i) - x_k(j)}{x_k(i) + x_k(j)}\right)^2}$$

Half distance between two numbers…

i,j: approaches; k: radionuclide

…divided by the mean…

…and summed for all radionuclides

- In other words…
  - d_{ij} is a measure of the distance between two columns of data (two approaches), summed row by row (representing radionuclides).
  - Because of division by N this number is always between 0 and 1.

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A simpler explanation

- Basically, we compare each model against each other by calculating a matrix of elements.
- Each element in the matrix is the “deviation” of model A to B, i.e. the sum of distances between values of both models, radionuclide by radionuclide.
- If two models give identical results their matrix elements are all zero.
- Comparison of model A with model B is the same as B with A, so the numbers above the diagonal are the same as below.
- Colouring is added so green = good agreement (low distance) and orange = bad (distance close to 1).
- This immediately reveals trends – when you have an uninterrupted orange row & column it means that a model is under- / over- predicting.

Example

- In this CR comparison for raven, NRPA consistently gives different answers, CEH somewhat less.
- The arithmetic mean of all the elements above the diagonal is 0.22 which is rather low – in the main, models give consistent results.

Raven	CEH	SCK-CEN	JSI	NRPA	KAERI	ANL
CEH	0.00	0.32	0.42	0.60	0.39	0.39
SCK-CEN	0.32	0.00	0.13	0.67	0.04	0.05
JSI	0.42	0.13	0.00	0.60	0.11	0.13
NRPA	0.60	0.67	0.60	0.00	0.63	0.63
KAERI	0.39	0.04	0.11	0.63	0.00	0.02
ANL	0.39	0.05	0.13	0.63	0.02	0.00

NRPA a bit “off”

Diagonal always 0

Geomean above diagonal: 0.22 ← Overall comparison OK

Note: MDW excluded from tis slide as no CR data submitted for raven

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Basis of the analysis (cont.)

- Step 3: Probabilistic outputs.
  - Some participants give mean, others 5th and / or 95th percentile.
  - Not possible to compare everything easily with a "one size fits all" method . However:

    5th percentile $= \mu + z(0.05)\sigma$. $z(0.05) = -1.65$

    95th percentile $= \mu + z(0.95)\sigma$. $z(0.95) = +1.65$
- Primary quantities μ and σ so we take the following index for analysis: normalised SD value σ / μ
  - This number indicates variability not between tools, but for a prediction within the tool.
- create a new vector: $Z(i) = (z_1(i), z_2(i), \ldots, z_p(i))$ where $z_j(i)$ for radionuclide j and approach i are $\sigma_j(i) / \mu_j(i)$
- Do the same matrix analysis.

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Results – initial inspection

Relative standard deviation (RSD) for different radionuclides, treating data for each radionuclide as a set.

Nuclide	CR	Tissue conc	Int dose	Ext dose	Tot dose
Co-60	0.82	0.92	0.98	0.41	0.38
Sr-90	1.12	1.42	1.45	1.59	1.35
Cs-137	0.80	0.75	0.83	0.42	0.59
Th-232	0.92	1.35	1.59	0.56	1.58
U-234	1.24	1.28	1.32	0.62	1.32
U-238	1.14	1.28	1.33	1.53	1.32
Pu-238	0.69	1.11	1.17	1.35	1.17
Pu-239	0.70	1.11	1.16	0.96	1.16
Am-241	0.98	1.32	1.37	0.96	1.30

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Results – initial inspection

- Variability for mean total dose rates and CRs lowest (<0.85) for ^{60}Co and ^{137}Cs.
- High variation for Sr in worm - for some organisms ERICA considers a skin/fur shielding factor.
- Higher variation (>1.25) for uranium. Possible cause: In RESRAD, DCCs assume ^{234}Th in equilibrium with ^{238}U.
- Some variation likely relates to how exposure to the species was conceptualised, particularly acacia where some participants manipulated model capabilities to include the sub-surface dose resulting from direct exposure to tree roots within the waste trench, whilst above surface dose only considered in ERICA.
- For the 3 ERICA runs, results group together but show some variation due to default CRs vs. other sources, e.g. draft IAEA Wildlife Transfer Handbook.

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Results – detailed analysis

- Predictions for earthworm (and less so acacia and insects) have much better agreement than for some of the more unusual species (marsupials, etc).
- For CR's there is no clear pattern though:
  - Where there are NRPA and KAERI, data differences between these and the others are often seen.
  - SCK•CEN shows some differences for grass.
  - MDW shows differences for raven, yam and goanna.
- Internal doses have more variability than external, due to influence of tissue concentrations.
- Vegetation (yam, acacia) and grass have highest variation in total dose (of which internal is main component), due to how uptake was conceptualised.
- Echidna stands-out due to variability in tissue concentrations.

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Results – detailed analysis

- For internal doses no clear result across species, but:
  - Tendency for KAERI to diverge (matrix elements > 0.7).
  - SCK-CEN for echidna, fox and wallaby.
- For external doses some trends:
  - Tendency for ANL and MDW diverge but not excessively so (matrix elements > 0.5).
  - Occasional trends for individual species, such as CEH for acacia and SCK•CEN for raven.
- In terms of the probabilistic outputs, CRs, grass insect and echidna have the biggest data spread.
- For probabilistic doses, the data are more difficult to interpret.
- No consistent pattern was observed, except higher relative variance of NRPA for echidna, compared with other approaches.

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CR comparison matrices

Grass	CEH	SCK-CEN	JSI	NRPA	KAERI	ANL	MDW
CEH	0.00	0.60	0.65		0.64	0.67	0.64
SCK-CEN	0.60	0.00	0.77		0.75	0.77	0.75
JSI	0.65	0.77	0.00		0.12	0.15	0.12
NRPA							
KAERI	0.64	0.75	0.12		0.00	0.14	0.00
ANL	0.67	0.77	0.15		0.14	0.00	0.14
	0.64	0.75	0.12		0.00	0.14	0.00

Average above diagonal: 0.46

Acacia	CEH	SCK-CEN	JSI	NRPA	KAERI	ANL	MDW
CEH	0.00	0.42	0.39		0.47	0.40	0.39
SCK-CEN	0.42	0.00	0.02		0.31	0.08	0.00
JSI	0.39	0.02	0.00		0.27	0.10	0.02
NRPA							
KAERI	0.47	0.31	0.27		0.00	0.28	0.27
ANL	0.40	0.08	0.10		0.28	0.00	0.09
	0.39	0.00	0.02		0.27	0.09	0.00

Average above diagonal: 0.24

Yam	CEH	SCK-CEN	JSI	NRPA	KAERI	ANL	MDW
CEH	0.00	0.67	0.76		0.43	0.62	0.79
SCK-CEN	0.67	0.00	0.60		0.53	0.53	0.60
JSI	0.76	0.60	0.00		0.72	0.73	0.12
NRPA							
KAERI	0.43	0.53	0.72		0.00	0.65	0.74
ANL	0.62	0.53	0.73		0.65	0.00	0.73
	0.79	0.60	0.12		0.74	0.73	0.00

Average above diagonal: 0.62

Earthworm	CEH	SCK-CEN	JSI	NRPA	KAERI	ANL	MDW
CEH	0.00	0.11	0.12		0.10	0.35	0.10
SCK-CEN	0.11	0.00	0.05		0.00	0.38	0.00
JSI	0.12	0.05	0.00		0.06	0.34	0.06
NRPA							
KAERI	0.10	0.00	0.06		0.00	0.33	0.00
ANL	0.35	0.38	0.34		0.33	0.00	0.33
MDW	0.10	0.00	0.06		0.00	0.33	0.00

Average above diagonal: 0.15

Insects	CEH	SCK-CEN	JSI	NRPA	KAERI	ANL	MDW
CEH	0.00	0.37	0.22		0.47	0.38	0.23
SCK-CEN	0.37	0.00	0.40		0.34	0.08	0.37
JSI	0.22	0.40	0.00		0.48	0.38	0.07
NRPA							
KAERI	0.47	0.34	0.48		0.00	0.31	0.46
ANL	0.38	0.08	0.38		0.31	0.00	0.36
MDW	0.23	0.37	0.07		0.46	0.36	0.00

Average above diagonal: 0.33

Goanna	CEH	SCK-CEN	JSI	NRPA	KAERI	ANL	MDW
CEH	0.00	0.66	0.63		0.67	0.67	
SCK-CEN	0.66	0.00	0.81		0.70	0.09	
JSI	0.63	0.81	0.00		0.86	0.77	
NRPA							
KAERI	0.67	0.70	0.86		0.00	0.74	
ANL	0.67	0.09	0.77		0.74	0.00	
MDW							

Average above diagonal: 0.66

Raven	CEH	SCK-CEN	JSI	NRPA	KAERI	ANL	MDW
CEH	0.00	0.32	0.42	0.60	0.39	0.39	
SCK-CEN	0.32	0.00	0.13	0.67	0.04	0.05	
JSI	0.42	0.13	0.00	0.60	0.11	0.13	
NRPA	0.60	0.67	0.60	0.00	0.63	0.63	
KAERI	0.39	0.04	0.11	0.63	0.00	0.02	
ANL	0.39	0.05	0.13	0.63	0.02	0.00	
MDW							

Average above diagonal: 0.34

Echidna	CEH	SCK-CEN	JSI	NRPA	KAERI	ANL	MDW
CEH	0.00	0.39	0.50	0.64	0.71	0.54	
SCK-CEN	0.39	0.00	0.07	0.69	0.69	0.29	
JSI	0.50	0.07	0.00	0.69	0.76	0.28	
NRPA	0.64	0.69	0.69	0.00	0.85	0.67	
KAERI	0.71	0.69	0.76	0.85	0.00	0.80	
ANL	0.54	0.29	0.28	0.67	0.80	0.00	
MDW							

Average above diagonal: 0.57

Fox	CEH	SCK-CEN	JSI	NRPA	KAERI	ANL	MDW
CEH	0.00	0.39	0.51	0.75	0.73	0.54	
SCK-CEN	0.39	0.00	0.07	0.70	0.73	0.29	
JSI	0.51	0.07	0.00	0.73	0.80	0.28	
NRPA	0.75	0.70	0.73	0.00	0.65	0.72	
KAERI	0.73	0.73	0.80	0.65	0.00	0.76	
ANL	0.54	0.29	0.28	0.72	0.76	0.00	
MDW							

Average above diagonal: 0.58

Wallaby	CEH	SCK-CEN	JSI	NRPA	KAERI	ANL	MDW
CEH	0.00	0.40	0.51	0.76	0.72	0.52	
SCK-CEN	0.40	0.00	0.06	0.74	0.69	0.29	
JSI	0.51	0.06	0.00	0.77	0.75	0.27	
	0.76	0.74	0.77	0.00	0.64	0.78	
KAERI	0.72	0.69	0.75	0.64	0.00	0.73	
ANL	0.52	0.29	0.27	0.78	0.73	0.00	
MDW							

Average above diagonal: 0.58

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Internal dose matrices

Grass	CEH	SCK-CEN	JSI	NRPA	KAERI	ANL	MDW
CEH	0.00	0.70	0.66		0.83	0.58	0.65
SCK-CEN	0.70	0.00	0.80		0.81	0.81	0.79
JSI	0.66	0.80	0.00		0.62	0.45	0.50
NRPA							
KAERI	0.83	0.81	0.62		0.00	0.75	0.81
ANL	0.58	0.81	0.45		0.75	0.00	0.43
MDW	0.65	0.79	0.50		0.81	0.43	0.00

Geomean above diagonal: 0.68

Acacia	CEH	SCK-CEN	JSI	NRPA	KAERI	ANL	MDW
CEH	0.00	0.68	0.89		0.63	0.82	0.80
SCK-CEN	0.68	0.00	0.67		0.80	0.53	0.46
JSI	0.89	0.67	0.00		0.88	0.51	0.45
NRPA							
KAERI	0.63	0.80	0.88		0.00	0.78	0.80
ANL	0.82	0.53	0.51		0.78	0.00	0.29
MDW	0.80	0.46	0.45		0.80	0.29	0.00

Geomean above diagonal: 0.67

Yam	CEH	SCK-CEN	JSI	NRPA	KAERI	ANL	MDW
CEH	0.00	0.71	0.75		0.66	0.72	0.83
SCK-CEN	0.71	0.00	0.61		0.79	0.46	0.64
JSI	0.75	0.61	0.00		0.84	0.55	0.40
NRPA							
KAERI	0.66	0.79	0.84		0.00	0.76	0.85
ANL	0.72	0.46	0.55		0.76	0.00	0.69
MDW	0.83	0.64	0.40		0.85	0.69	0.00

Geomean above diagonal: 0.68

Earthworm	CEH	SCK-CEN	JSI	NRPA	KAERI	ANL	MDW
CEH	0.00	0.09	0.13		0.70	0.49	0.27
SCK-CEN	0.09	0.00	0.08		0.69	0.51	0.30
JSI	0.13	0.08	0.00		0.69	0.51	0.30
NRPA							
KAERI	0.70	0.69	0.69		0.00	0.83	0.80
ANL	0.49	0.51	0.51		0.83	0.00	0.45
MDW	0.27	0.30	0.30		0.80	0.45	0.00

Geomean above diagonal: 0.46

Insect	CEH	SCK-CEN	JSI	NRPA	KAERI	ANL	MDW
CEH	0.00	0.38	0.28		0.81	0.41	0.44
SCK-CEN	0.38	0.00	0.37		0.73	0.37	0.57
JSI	0.28	0.37	0.00		0.83	0.47	0.44
NRPA							
KAERI	0.81	0.73	0.83		0.00	0.80	0.87
ANL	0.41	0.37	0.47		0.80	0.00	0.57
MDW	0.44	0.57	0.44		0.87	0.57	0.00

Geomean above diagonal: 0.56

Goanna	CEH	SCK-CEN	JSI	NRPA	KAERI	ANL	MDW
CEH	0.00	0.68	0.68		0.66	0.58	0.64
SCK-CEN	0.68	0.00	0.10		0.83	0.48	0.71
JSI	0.68	0.10	0.00		0.81	0.45	0.70
NRPA							
KAERI	0.66	0.83	0.81		0.00	0.81	0.69
ANL	0.58	0.48	0.45		0.81	0.00	0.72
MDW	0.64	0.71	0.70		0.69	0.72	0.00

Geomean above diagonal: 0.64

Raven	CEH	SCK-CEN	JSI	NRPA	KAERI	ANL	MDW
CEH	0.00	0.42	0.45	0.60	0.71	0.49	0.73
SCK-CEN	0.42	0.00	0.12	0.70	0.83	0.43	0.76
JSI	0.45	0.12	0.00	0.68	0.84	0.45	0.72
NRPA	0.60	0.70	0.68	0.00	0.76	0.74	0.73
KAERI	0.71	0.83	0.84	0.76	0.00	0.75	0.82
ANL	0.49	0.43	0.45	0.74	0.75	0.00	0.68
MDW	0.73	0.76	0.72	0.73	0.82	0.68	0.00

Geomean above diagonal: 0.64

Echidna	CEH	SCK-CEN	JSI	NRPA	KAERI	ANL	MDW
CEH	0.00	0.70	0.66		0.83	0.58	0.65
SCK-CEN	0.70	0.00	0.80		0.81	0.81	0.79
JSI	0.66	0.80	0.00		0.62	0.45	0.50
NRPA							
KAERI	0.83	0.81	0.62		0.00	0.75	0.81
ANL	0.58	0.81	0.45		0.75	0.00	0.43
MDW	0.65	0.79	0.50		0.81	0.43	0.00

Geomean above diagonal: 0.68

Fox	CEH	SCK-CEN	JSI	NRPA	KAERI	ANL	MDW
CEH	0.00	0.70	0.66		0.83	0.58	0.65
SCK-CEN	0.70	0.00	0.80		0.81	0.81	0.79
JSI	0.66	0.80	0.00		0.62	0.45	0.50
NRPA							
KAERI	0.83	0.81	0.62		0.00	0.75	0.81
ANL	0.58	0.81	0.45		0.75	0.00	0.43
MDW	0.65	0.79	0.50		0.81	0.43	0.00

Geomean above diagonal: 0.68

Wallaby	CEH	SCK-CEN	JSI	NRPA	KAERI	ANL	MDW
CEH	0.00	0.70	0.66		0.83	0.58	0.65
SCK-CEN	0.70	0.00	0.80		0.81	0.81	0.79
JSI	0.66	0.80	0.00		0.62	0.45	0.50
NRPA							
KAERI	0.83	0.81	0.62		0.00	0.75	0.81
ANL	0.58	0.81	0.45		0.75	0.00	0.43
MDW	0.65	0.79	0.50		0.81	0.43	0.00

Geomean above diagonal: 0.68

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External dose matrices

Grass	CEH	SCK-CEN	JSI	NRPA	KAERI	ANL	MDW
CEH	0.00	0.02	0.05		0.02	0.68	0.67
SCK-CEN	0.02	0.00	0.05		0.02	0.68	0.67
JSI	0.05	0.05	0.00		0.05	0.69	0.68
NRPA							
KAERI	0.02	0.02	0.05		0.00	0.67	0.66
ANL	0.68	0.68	0.69		0.67	0.00	0.06
MDW	0.67	0.67	0.68		0.66	0.06	0.00

Geomean above diagonal: 0.38

Acacia	CEH	SCK-CEN	JSI	NRPA	KAERI	ANL	MDW
CEH	0.00	0.59	0.62		0.56	0.59	0.51
SCK-CEN	0.59	0.00	0.06		0.08	0.55	0.66
JSI	0.62	0.06	0.00		0.11	0.57	0.68
NRPA							
KAERI	0.56	0.08	0.11		0.00	0.53	0.64
ANL	0.59	0.55	0.57		0.53	0.00	0.29
MDW	0.51	0.66	0.68		0.64	0.29	0.00

Geomean above diagonal: 0.47

Yam	CEH	SCK-CEN	JSI	NRPA	KAERI	ANL	MDW
CEH	0.00	0.12	0.09		0.36	0.57	0.62
SCK-CEN	0.12	0.00	0.16		0.38	0.54	0.59
JSI	0.09	0.16	0.00		0.32	0.59	0.65
NRPA							
KAERI	0.36	0.38	0.32		0.00	0.66	0.72
ANL	0.57	0.54	0.59		0.66	0.00	0.17
MDW	0.62	0.59	0.65		0.72	0.17	0.00

Geomean above diagonal: 0.43

Earthworm	CEH	SCK-CEN	JSI	NRPA	KAERI	ANL	MDW
CEH	0.00	0.02	0.05		0.03	0.53	0.59
SCK-CEN	0.02	0.00	0.05		0.02	0.53	0.59
JSI	0.05	0.05	0.00		0.05	0.53	0.60
NRPA							
KAERI	0.03	0.02	0.05		0.00	0.53	0.59
ANL	0.53	0.53	0.53		0.53	0.00	0.21
MDW	0.59	0.59	0.60		0.59	0.21	0.00

Geomean above diagonal: 0.33

Insect	CEH	SCK-CEN	JSI	NRPA	KAERI	ANL	MDW
CEH	0.00	0.02	0.05		0.02	0.67	0.65
SCK-CEN	0.02	0.00	0.05		0.02	0.67	0.64
JSI	0.05	0.05	0.00		0.05	0.68	0.65
NRPA							
KAERI	0.02	0.02	0.05		0.00	0.67	0.64
ANL	0.67	0.67	0.68		0.67	0.00	0.18
MDW	0.65	0.64	0.65		0.64	0.18	0.00

Geomean above diagonal: 0.38

Goanna	CEH	SCK-CEN	JSI	NRPA	KAERI	ANL	MDW
CEH	0.00	0.45	0.46		0.44	0.62	0.53
SCK-CEN	0.45	0.00	0.05		0.02	0.52	0.53
JSI	0.46	0.05	0.00		0.05	0.51	0.54
NRPA							
KAERI	0.44	0.02	0.05		0.00	0.52	0.53
ANL	0.62	0.52	0.51		0.52	0.00	0.29
MDW	0.53	0.53	0.54		0.53	0.29	0.00

Geomean above diagonal: 0.40

Raven	CEH	SCK-CEN	JSI	NRPA	KAERI	ANL	MDW
CEH	0.00	0.03	0.40	0.57	0.48	0.59	0.64
SCK-CEN	0.03	0.00	0.39	0.56	0.47	0.59	0.64
JSI	0.40	0.39	0.00	0.29	0.33	0.50	0.53
NRPA	0.57	0.56	0.29	0.00	0.44	0.52	0.50
KAERI	0.48	0.47	0.33	0.44	0.00	0.60	0.62
ANL	0.59	0.59	0.50	0.52	0.60	0.00	0.16
MDW	0.64	0.64	0.53	0.50	0.62	0.16	0.00

Geomean above diagonal: 0.47

Echidna	CEH	SCK-CEN	JSI	NRPA	KAERI	ANL	MDW
CEH	0.00	0.02	0.05		0.02	0.68	0.67
SCK-CEN	0.02	0.00	0.05		0.02	0.68	0.67
JSI	0.05	0.05	0.00		0.05	0.69	0.68
NRPA							
KAERI	0.02	0.02	0.05		0.00	0.67	0.66
ANL	0.68	0.68	0.69		0.67	0.00	0.06
MDW	0.67	0.67	0.68		0.66	0.06	0.00

Geomean above diagonal: 0.38

Fox	CEH	SCK-CEN	JSI	NRPA	KAERI	ANL	MDW
CEH	0.00	0.02	0.05		0.02	0.68	0.67
SCK-CEN	0.02	0.00	0.05		0.02	0.68	0.67
JSI	0.05	0.05	0.00		0.05	0.69	0.68
NRPA							
KAERI	0.02	0.02	0.05		0.00	0.67	0.66
ANL	0.68	0.68	0.69		0.67	0.00	0.06
MDW	0.67	0.67	0.68		0.66	0.06	0.00

Geomean above diagonal: 0.38

Wallaby	CEH	SCK-CEN	JSI	NRPA	KAERI	ANL	MDW
CEH	0.00	0.02	0.05		0.02	0.68	0.67
SCK-CEN	0.02	0.00	0.05		0.02	0.68	0.67
JSI	0.05	0.05	0.00		0.05	0.69	0.68
NRPA							
KAERI	0.02	0.02	0.05		0.00	0.67	0.66
ANL	0.68	0.68	0.69		0.67	0.00	0.06
MDW	0.67	0.67	0.68		0.66	0.06	0.00

Geomean above diagonal: 0.38

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CR probabilistic matrices

Grass	CEH	SCK-CEN	JSI	NRPA	KAERI	ANL	MDW
CEH	0.00	0.32	0.30		0.33	0.59	
SCK-CEN	0.32	0.00	0.37		0.39	0.48	
JSI	0.30	0.37	0.00		0.27	0.54	
NRPA							
KAERI	0.33	0.39	0.27		0.00	0.65	
ANL	0.59	0.48	0.54		0.65	0.00	

Average above diagonal: 0.42

Acacia	CEH	SCK-CEN	JSI	NRPA	KAERI	ANL	MDW
CEH	0.00	0.36	0.33		0.13	0.37	
SCK-CEN	0.36	0.00	0.07		0.37	0.16	
JSI	0.33	0.07	0.00		0.34	0.11	
NRPA							
KAERI	0.13	0.37	0.34		0.00	0.39	
ANL	0.37	0.16	0.11		0.39	0.00	

Average above diagonal: 0.26

Yam	CEH	SCK-CEN	JSI	NRPA	KAERI	ANL	MDW
CEH	0.00	0.15	0.28			0.26	
SCK-CEN	0.15	0.00	0.37			0.35	
JSI	0.28	0.37	0.00			0.18	
NRPA							
KAERI							
ANL	0.26	0.35	0.18			0.00	

Average above diagonal: 0.27

Earthworm	CEH	SCK-CEN	JSI	NRPA	KAERI	ANL	MDW
CEH	0.00	0.10	0.07		0.09	0.09	
SCK-CEN	0.10	0.00	0.09		0.00	0.13	
JSI	0.07	0.09	0.00		0.09	0.11	
NRPA							
KAERI	0.09	0.00	0.09		0.00	0.12	
ANL	0.09	0.13	0.11		0.12	0.00	
MDW							

Average above diagonal: 0.09

Insects	CEH	SCK-CEN	JSI	NRPA	KAERI	ANL	MDW
CEH	0.00	0.11	0.38		0.43	0.48	
SCK-CEN	0.11	0.00	0.26		0.45	0.37	
JSI	0.38	0.26	0.00		0.48	0.32	
NRPA							
KAERI	0.43	0.45	0.48		0.00	0.31	
ANL	0.48	0.37	0.32		0.31	0.00	
MDW							

Average above diagonal: 0.36

Goanna	CEH	SCK-CEN	JSI	NRPA	KAERI	ANL	MDW
CEH	0.00	0.17	0.19			0.19	
SCK-CEN	0.17	0.00	0.13			0.28	
JSI	0.19	0.13	0.00			0.20	
NRPA							
KAERI							
ANL	0.19	0.28	0.20			0.00	
MDW							

Average above diagonal: 0.19

Raven	CEH	SCK-CEN	JSI	NRPA	KAERI	ANL	MDW
CEH	0.00	0.13	0.55	0.58	0.14	0.56	
SCK-CEN	0.13	0.00	0.17	0.07	0.04	0.16	
JSI	0.55	0.17	0.00	0.26	0.16	0.12	
NRPA	0.58	0.07	0.26	0.00	0.10	0.21	
KAERI	0.14	0.04	0.16	0.10	0.00	0.12	
ANL	0.56	0.16	0.12	0.21	0.12	0.00	
MDW							

Average above diagonal: 0.22

Echidna	CEH	SCK-CEN	JSI	NRPA	KAERI	ANL	MDW
CEH	0.00	0.15	0.26	0.62		0.35	
SCK-CEN	0.15	0.00	0.13	0.60		0.26	
JSI	0.26	0.13	0.00	0.57		0.21	
NRPA	0.62	0.60	0.57	0.00		0.52	
KAERI							
ANL	0.35	0.26	0.21	0.52		0.00	
MDW							

Average above diagonal: 0.37

Fox	CEH	SCK-CEN	JSI	NRPA	KAERI	ANL	MDW
CEH	0.00	0.15	0.26	0.39		0.35	
SCK-CEN	0.15	0.00	0.15	0.31		0.26	
JSI	0.26	0.15	0.00	0.30		0.21	
NRPA	0.39	0.31	0.30	0.00		0.38	
KAERI							
ANL	0.35	0.26	0.21	0.38		0.00	
MDW							

Average above diagonal: 0.28

Wallaby	CEH	SCK-CEN	JSI	NRPA	KAERI	ANL	MDW
CEH	0.00	0.15	0.24	0.44		0.34	
SCK-CEN	0.15	0.00	0.11	0.38		0.26	
JSI	0.24	0.11	0.00	0.38		0.17	
	0.44	0.38	0.38	0.00		0.40	
KAERI							
ANL	0.34	0.26	0.17	0.40		0.00	
MDW							

Average above diagonal: 0.29

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Dose probabilistic matrices

Grass	CEH	SCK-CEN	JSI	NRPA	KAERI	ANL	MDW
CEH							
SCK-CEN							
JSI			0.00			0.34	1.00
NRPA							
KAERI							
ANL			0.34			0.00	1.00
MDW			1.00			1.00	0.00

Geomean above diagonal: 0.76

Acacia	CEH	SCK-CEN	JSI	NRPA	KAERI	ANL	MDW
CEH							
SCK-CEN							
JSI			0.00			0.19	1.00
NRPA							
KAERI							
ANL			0.19			0.00	1.00
MDW			1.00			1.00	0.00

Geomean above diagonal: 0.73

Yam	CEH	SCK-CEN	JSI	NRPA	KAERI	ANL	MDW
CEH							
SCK-CEN							
JSI			0.00			0.26	1.00
NRPA							
KAERI							
ANL			0.26			0.00	1.00
MDW			1.00			1.00	0.00

Geomean above diagonal: 0.75

Earthworm	CEH	SCK-CEN	JSI	NRPA	KAERI	ANL	MDW
CEH							
SCK-CEN							
JSI			0.00			0.15	1.00
NRPA							
KAERI							
ANL			0.15			0.00	1.00
MDW			1.00			1.00	0.00

Geomean above diagonal: 0.72

Insect	CEH	SCK-CEN	JSI	NRPA	KAERI	ANL	MDW
CEH							
SCK-CEN							
JSI			0.00			0.18	1.00
NRPA							
KAERI							
ANL			0.18			0.00	1.00
MDW			1.00			1.00	0.00

Geomean above diagonal: 0.73

Goanna	CEH	SCK-CEN	JSI	NRPA	KAERI	ANL	MDW
CEH							
SCK-CEN							
JSI			0.00			0.10	1.00
NRPA							
KAERI							
ANL			0.10			0.00	1.00
MDW			1.00			1.00	0.00

Geomean above diagonal: 0.70

Raven	CEH	SCK-CEN	JSI	NRPA	KAERI	ANL	MDW
CEH							
SCK-CEN							
JSI			0.00	0.99		0.15	1.00
NRPA			0.99	0.00		0.99	1.00
KAERI							
ANL			0.15	0.99		0.00	1.00
MDW			1.00	1.00		1.00	0.00

Geomean above diagonal: 0.86

Echidna	CEH	SCK-CEN	JSI	NRPA	KAERI	ANL	MDW
CEH							
SCK-CEN							
JSI			0.00			0.34	1.00
NRPA							
KAERI							
ANL			0.34			0.00	1.00
MDW			1.00			1.00	0.00

Geomean above diagonal: 0.78

Fox	CEH	SCK-CEN	JSI	NRPA	KAERI	ANL	MDW
CEH							
SCK-CEN							
JSI			0.00			0.34	1.00
NRPA							
KAERI							
ANL			0.34			0.00	1.00
MDW			1.00			1.00	0.00

Geomean above diagonal: 0.78

Wallaby	CEH	SCK-CEN	JSI	NRPA	KAERI	ANL	MDW
CEH							
SCK-CEN							
JSI			0.00			0.34	1.00
NRPA							
KAERI							
ANL			0.34			0.00	1.00
MDW			1.00			1.00	0.00

Geomean above diagonal: 0.78

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Mean above diagonal

	Transfer		Doses			SD/mean ratios	
	CRs	Concs	Int dose	Ext dose	Tot dose	CRs	Tot dose
Grass	0.46	0.48	0.68	0.38	0.62	0.42	0.78
Acacia	0.24	0.45	0.67	0.47	0.58	0.26	0.73
Yam	0.62	0.62	0.68	0.43	0.64	0.27	0.75
Earthworm	0.15	0.16	0.46	0.33	0.47	0.09	0.72
Insect	0.33	0.33	0.56	0.38	0.49	0.36	0.73
Goanna	0.66	0.64	0.64	0.40	0.60	0.19	0.70
Raven	0.34	0.57	0.64	0.47	0.61	0.22	0.86
Echidna	0.57	0.48	0.68	0.38	0.62	0.37	0.78
Fox	0.58	0.48	0.68	0.38	0.62	0.28	0.78
Wallaby	0.58	0.48	0.68	0.38	0.62	0.29	0.78
Mean	0.45	0.47	0.64	0.40	0.59	0.27	0.76

- Comparison for external doses more successful than for internal due to variability in tissue concentrations.
- Similar CR but different activity concentrations: possibly how people are accounting for occupancy.

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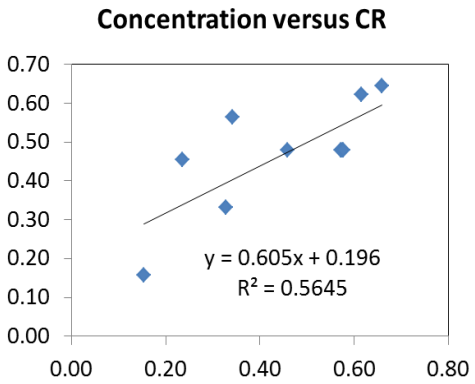
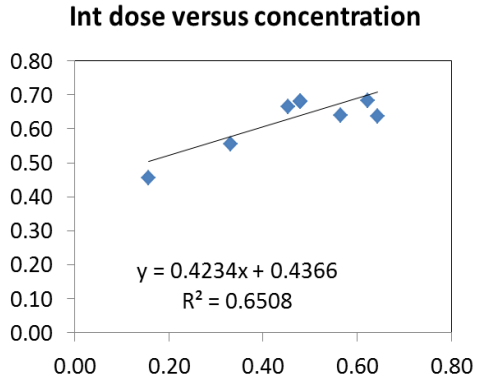
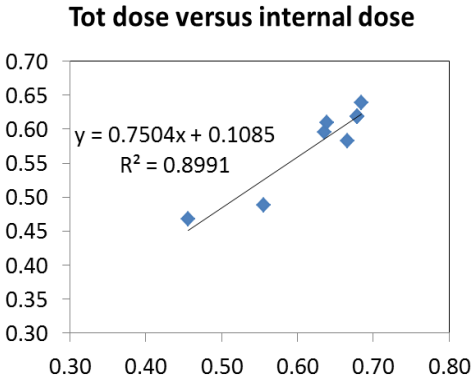
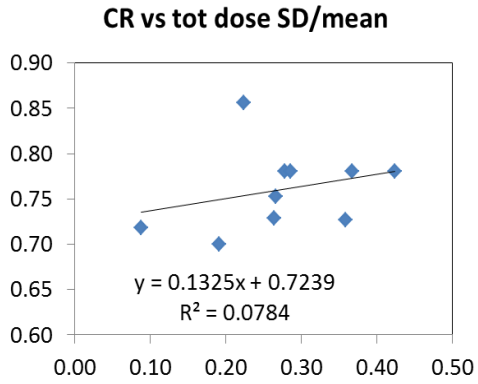
Geomean above diagonal

- Some influence of variability in CR to tissue concentration ($r^2 = 0.56$), tissue over internal dose ($r^2 = 0.65$) and internal dose on total dose ($r^2 = 0.90$).









- No relationship in variability for model-predicted standard deviation per unit mean of the distribution, neither for CRs nor for total dose ($r^2 = 0.08$).

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What to do with these results

- This is more “results” than “discussion”. We need to explain differences and relate them to methodology, with the help of participants.
  - What people did differently and see if makes a difference to overall result? – e.g. occupancy assumptions re occupancy
  - How plants, especially tree, were handled; what about animal in tree?
- Look at any large and/or unexpected differences in transfer.
  - Potential issue: some may have used DW plant CRs rather than FW (there is a suspicious x 4 difference in CEH and SCK yam results for a number of radionuclides).

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Potential additional analysis

- Include the last corrections and freeze the database.
- Sub-groupings: compare among the 3 ERICA runs to see to what extent the 3 different approaches are evident in results.
- Also, we may want to do independent comparisons among codes (ERICA, RESRAD, etc).
- Probabilistic outputs: if possible discuss example where different type of distribution was used but everything else was equal.
- These results are preliminary: we need to check and consolidate the exercise.
- Publication in a peer-reviewed journal – manuscript around March?

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Thank you for your attention!