A Probabilistic Biosphere Analysis for Derivation of Pathway Dose Conversion Factor

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In this paper, the nonparametric distributions of the biosphere pathway dose conversion factors(PDCFs) used for the groundwater release scenario and intrusion scenario analyses are derived from a probabilistic biosphere analysis. The statistical characteristics of the output distributions are obtained by a MS Excel spreadsheet with the @Risk probabilistic sampling add-on module, allowing probabilistic sampling of parameters.

The biosphere model takes account of three potential receptors points: a contaminated well, a contaminated river, and contamination in seawater. Exposures are considered from multiple pathways, including ingestion, inhalation, and external exposure. The biosphere is assumed to have a much shorter time constant than other portions of the system. As a result, the biosphere can be represented as a set of steady-state, radionuclide-specific PDCFs that are multiplied by the appropriate release rate from the far field for each pathway. The biosphere model consists of a set of algebraic expressions on water concentrations, soil concentrations, water ingestion, crop ingestion, meat and milk consumption, soil consumption, fish consumption, external exposure, and inhalation exposure. The overall pathway dose conversion factor for each radionuclide is the sum over all exposure pathways and environmental media. For individual exposure scenarios, a limited set of the equations may be used. For instance, there is no fish exposure for a well exposure scenario, and for the ocean or lake scenario, only the fish exposure is considered. Input parameters for the biosphere model have been taken from literature values, suitable for application to this generic analysis. Distributions for input parameters needed for the probabilistic analysis of ingestion, inhalation, and external dose the biosphere analysis have been adopted from Yu et al.[1] and NCRP[2]. A number of key elemental parameters are assigned lognormal distributions. For the generic biosphere implemented here, the dose factor are chosen from ICRP 72[3] for each radionuclide. Ingestion rates and geosphere dilution factors used in the analysis are shown in Table 1 and 2, respectively.

The statistical outputs for each PDCF for the given set of nuclides are shown in Table 3, calculated using the @RISK spreadsheet model. The statistical results of the analysis are presented in Table 2. These distributions can be implemented in the probabilistic assessment parameter sampling process as truncated distributions, typically as triangular or loguniform distributions.

Table 1. Ingestion rates used in the analysis

Ingestion rate	Distribution	Values
milk (L/d)	triangular	Minimum: 60 Maximum: 200 Most likely: 102
meat (kg/y)	lognormal	mean: 100, geometric standard deviation 1.15
vegetable and grain(kg/y)	triangular	Minimum: 135 Maximum: 318 Most likely: 178
Soil(g/y)	triangular	Minimum: 0 Maximum: 36.5 Most likely: 18.3
water (L/y)	lognormal	mean: 6.015, geometric standard deviation: 0.489
water by cattle (m^3/y)	constant	30
soil by cattle (kg/y)	constant	220
fodder by cattle (kg/y)	constant	3650

Table 2. Generic dilution factors applied in the biosphere analysis

Exposure Pathway	Generic Dilution Factor (m^3/y)
Well	250
River	1000
Lake/Ocean	10000

Table 3-1. Well PDCF statistical output.

Outputs	C-14	Co-60	H-3	Tc-99	I-129
Minimum	3.80E-13	2.13E-11	1.86E-15	2.66E-13	2.08E-11
Maximum	6.27E-08	8.78E-05	1.00E-13	1.29E-09	1.12E-09
Mean	8.27E-11	1.88E-07	1.17E-14	6.58E-12	7.14E-11
Standard Deviation	1.99E-09	2.83E-06	6.73E-15	5.48E-11	6.01E-11
Variance	3.98E-18	7.98E-12	4.53E-29	3.00E-21	3.61E-21
Skewness	3.11E+01	3.00E+01	3.84E+00	1.80E+01	9.64E+00
Kurtosis	9.82E+02	9.33E+02	3.79E+01	3.72E+02	1.36E+02

Table 3-2. River PDCF statistical output.

Outputs	C-14	Co-60	H-3	Tc-99	I-129
Minimum	1.11E-13	4.90E-12	1.86E-15	6.67E-14	2.08E-11
Maximum	1.80E-09	4.43E-06	1.00E-13	4.58E-10	1.12E-09
Mean	9.76E-12	2.92E-08	1.17E-14	1.47E-12	7.14E-11
Standard Deviation	9.88E-11	1.91E-07	6.73E-15	1.52E-11	6.01E-11
Variance	9.77E-21	3.64E-14	4.53E-29	2.32E-22	3.61E-21
Skewness	1.58E+01	1.64E+01	3.84E+00	2.74E+01	9.64E+00
Kurtosis	2.64E+02	3.31E+02	3.79E+01	8.13E+02	1.36E+02

Table 3-3. Sea PDCF statistical output.

Outputs	C-14	Co-60	H-3	Tc-99	I-129
Minimum	5.08E-13	1.66E-14	7.15E-18	1.82E-16	3.52E-14
Maximum	5.89E-10	1.91E-11	1.41E-17	2.64E-13	1.43E-10
Mean	2.85E-11	1.02E-12	9.95E-18	1.29E-14	4.52E-12
Standard Deviation	4.17E-11	1.49E-12	9.98E-19	1.88E-14	7.39E-12
Variance	1.74E-21	2.22E-24	9.97E-37	3.53E-28	5.46E-23
Skewness	5.28E+00	5.11E+00	3.13E-01	5.24E+00	8.61E+00
Kurtosis	4.94E+01	4.43E+01	3.20E+00	4.85E+01	1.34E+02

References

1. Yu, C., D. LePoire, E. Gnanapragasam, J. Arnish, S. Kamboj, B.M. Biwer, J.J. Chang, and S.Y. Chen, "Development of Probabilistic RESRAD 6.0 and RESRAD-Build 3.0 Computer Codes," NUREG/CR -6697, 2000.
2. NCRP, "Recommended Screening Limits for Contaminated Surface Soil and Review of Factors Relevant to Site-Specific Studies," NCRP Report 129, 1999.
3. ICRP 72, "Age Dependent Doses to Members of the Public from Intake of Radionuclides: Part 5 Compilation of Ingestion and Inhalation Dose Coefficients," ICRP Publication 72, 1996.