Environmental Radionuclides Concentrations Below Which Non-Human Biota Experience No Effects

Sohan L. Chouhan, Tamara L. Yankovich and Philip A. Davis

AECL, Chalk River, Ontario, K0J 1J0, Canada, chouhans@aecl.ca

INTRODUCTION

Canadian nuclear facility owners must demonstrate that non-human biota are protected from the effects of radionuclide releases during the normal operation of their sites. In this regard, a conservative summary table was developed listing generic environmental concentrations of relevant CANDU radionuclides below which no effects are expected on non-human biota (Chouhan *et al*., 2006).

WORK DESCRIPTION

We reviewed three available approaches (FASSET, 2004; RESRAD-BIOTA, 2003; IMPACT, 2003) for estimating doses to non-human biota, and adopted the concentration ratio (CR) approach used in FASSET and RESRAD-BIOTA. The CR approach uses a single transfer factor to predict concentrations in plants or animals from concentrations measured in air, soil, water or sediments. Most of the CR values required for the calculations came from FASSET documentation although some values came from RESRAD-BIOTA and IMPACT (Table 1).

For tritium and C-14, we derived CR values based on specific activity (SA) concepts, assuming full SA equilibrium in all environmental compartments. For example, for tritium, it was assumed that the tritium concentration (in Bq/L) is the same in all aqueous parts of the environment (including the combustion water of dry matter, which accounts for OBT).

Sediment partition coefficient (K_d) values were used as effective CRs to derive no-effect levels for sediments from the levels for water. The K_d values were chosen to be the best-estimate values from the IMPACT database. Dose conversion coefficients (DCCs) were taken from FASSET (Table 1).

We considered four generic organisms in our analysis (terrestrial plant and animal; and aquatic plant and animal), each of which was treated conservatively. For a given radionuclide and pathway, the CR for each generic organism was chosen to be the largest among all the reported FASSET CRs for all organisms in that category. We compared aquatic CRs further with IMPACT values and used whichever was higher. Similarly, the DCCs were chosen to be the largest among all the reported FASSET DCCs. In this way, our generic organisms are conservative with respect to both environmental transfer and dose, and our calculated no-effect concentrations will protect all organisms in each generic category.

The dose rate benchmarks were selected as 1 mGy/d for terrestrial animals, and 10 mGy/d for terrestrial plants, aquatic animals and aquatic plants (aquatic benchmarks are for the maximum exposed individual because large enough sample size was available but the remaining benchmarks are for average population because large sample sizes are not usually available).

The calculations started with a unit concentration (C_e) in the environmental compartment. The concentration in a given reference organism (C_o) was then calculated from

$$C_o = CR \quad C_e \tag{1}$$

where CR is the concentration ratio for the given radionuclide, organism and pathway. The external dose to the organism (D_e) is given by

$$D_e = DCC_e \quad C_e \tag{2}$$

where DCC_e is the external dose conversion coefficient. The internal dose to the organism (D_i) was calculated from

$$D_i = DCC_i \quad C_o \tag{3}$$

where DCC_i is the internal dose conversion coefficient. The no-effect level concentration (C_{nel}) was then found from

$$C_{nel} = \frac{DRB}{D} \tag{4}$$

where DRB is the dose rate benchmark and D is either the internal or external dose from a unit concentration in the respective environmental compartment. The generic no-effect concentration for a given radionuclide in a given compartment was then found as the minimum no-effect value among the concentrations for external and internal doses to plants and animals. The no-effect concentrations for sediments were found by multiplying the no-effect level concentration for water by the appropriate K_d value.

RESULTS AND CONCLUSIONS

Generic no-effect concentrations for nine CANDU radionuclides and six environmental compartments are shown in Table 2. These results are the environmental concentrations of radionuclides below which no detrimental effects are expected to non-human biota at Canadian CANDU sites. A comparison of the calculated no-effects levels with present and past measurements of environmental radionuclide concentrations at Canadian CANDU sites indicates that the measured concentrations are orders of magnitude below the generic no-effect levels. Therefore, non-human biota are being well protected from the effects of release of ionizing radiations under past and current operations at the CANDU sites.

Table 1. Selected input parameters used in calculating generic no-effect level concentrations.

Transfer parameter description		**Transfer parameter values for nine radionuclides**								
Name (unit)	**Sub Category**	**H-3**	**C-14**	**Co-60**	**Sr-90**	**Zr-95**	**Nb-95**	**I-131**	**Cs-134**	**Cs-137**
CRs from air to terrestrial organism (Bq/kg FW* organism per Bq/m3 in air)	Animal	143	944							
	Plant	143	1530							
CRs from soil to terrestrial organism (Bq/kg FW organism per Bq/kg DW[#] soil)	Animal			8.0E-2	4.2E-2	3.8E-3	5.4E-11	4.3E-5	7.1E-3	1.8E+0
	Plant			2.2E-1	2.2E+0	2.9E-2	2.9E-6	1.6E-5	2.7E-4	2.6E+0
CRs from water to aquatic organisms (Bq/kg FW organism per Bq/L of water for all nuclides except C-14; Bq/kg FW per Bq/g dissolved organic carbon in water for C-14)	Freshwater Animal	1	170	5.2E+2	1.0E+3	3.0E+2	3.0E+4	7.0E+3	3.5E+3	2.1E+4
	Freshwater Plant	1	144	6.0E+3	2.8E+2	3.0E+3	3.0E+3	1.3E+3	2.4E+2	5.2E+3
	Marine Animal	1	170	2.0E+4	2.8E+2	5.0E+3	1.0E+3	3.0E+3	3.1E+2	5.3E+2
	Marine Plant	1	144	6.0E+3	1.8E+2	3.0E+3	3.0E+3	1.0E+4	2.4E+2	2.0E+2
CRs from fresh water to terrestrial animals (Bq/kg FW organism per Bq/L water for all nuclides except C-14; Bq/kg FW per Bq/g dissolved inorganic carbon in water for C-14)		1	170	1.3E-1	3.1E+1	3.1E-2	not available	1.4E+0	3.0E+0	3.4E+0
SA CR from sediment to aquatic organism. For H-3, Bq/kg FW organism per Bq/L sediment water; for C-14, Bq/kg FW organism per Bq/g total organic carbon in sediment	Freshwater	1 (plant and animal)	170 (animal)	n/a‡	n/a	n/a	n/a	n/a	n/a	n/a
	Marine	1 (plant and animal)	170 (animal)	n/a	n/a	n/a	n/a	n/a	n/a	n/a
SA CR from freshwater sediment to terrestrial animal. Bq/kg FW organism per Bq/L sediment water	Freshwater	1	†	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Sediment K_d values (L/kg DW)	Freshwater	n/a	n/a	600	130	6000	1600	76	2700	2700
	Marine	n/a	n/a	600	130	6000	1600	10	2700	2700
External DCCs for terrestrial organisms (mGy/d per Bq/kg DW soil)	Animal	0	0	3.6E-5	2.6E-12	2.3E-5	3.9E-6	1.9E-6	7.7E-6	2.9E-6
	Plant	0	0	3.6E-5	2.6E-12	2.3E-5	3.9E-6	1.8E-6	7.4E-6	2.6E-6
External DCCs for freshwater organisms (mGy/d per Bq/L water)	Animal	0	0	3.6E-5	1.6E-5	1.2E-5	1.1E-5	7.9E-6	2.4E-5	1.1E-5
	Plant	0	0	3.6E-5	1.6E-5	1.2E-5	1.1E-5	7.9E-6	2.4E-5	1.1E-5
External DCCs for marine organisms (mGy/d per Bq/L water)	Animal	0	0	3.6E-5	1.6E-5	1.2E-5	1.1E-5	7.9E-6	2.4E-5	1.1E-5
	Plant	0	0	3.6E-5	1.6E-5	1.2E-5	1.1E-5	7.9E-6	2.4E-5	1.1E-5
Internal DCCs for terrestrial organisms (mGy/d per Bq/kg FW organism)	Animal	7.9E-8	7.0E-7	1.7E-5	1.6E-5	6.7E-6	5.8E-6	6.2E-6	1.6E-5	8.6E-6
	Plant	7.9E-8	7.0E-7	3.8E-6	1.5E-5	2.4E-6	1.4E-6	3.1E-6	3.8E-6	4.1E-6
Internal DCCs for freshwater organisms (mGy/d per Bq/kg FW organism)	Animal	7.9E-8	7.0E-7	8.6E-6	1.5E-5	4.1E-6	3.1E-6	4.1E-6	7.4E-6	5.3E-6
	Plant	7.9E-8	5.8E-7	8.6E-7	1.5E-6	9.1E-7	5.3E-7	1.0E-6	7.9E-7	1.0E-6
Internal DCCs for marine organisms (mGy/d per Bq/kg FW organism)	Animal	7.9E-8	7.0E-7	1.7E-5	1.6E-5	6.7E-6	5.8E-6	5.5E-6	1.3E-5	7.4E-6
	Plant	7.9E-8	7.0E-7	3.8E-6	1.5E-5	2.4E-6	1.4E-6	3.1E-6	3.8E-6	4.1E-6

*FW Fresh weight.[#] DW Dry weight.

n/a‡ Sediment K_d values are not applicable to H-3 and C-14 and SA CRs are not applicable to other nuclides.

† Since C-14 in sediment may not be in equilibrium with C-14 in water, a link cannot be assumed between C-14 in sediment and terrestrial animals, and no number is provided.

Table 2. Generic radionuclide concentrations below which no radiation effects are expected on non-human biota in Canada.

Nuclide	Air concentration (Bq/m3)	Soil Concentration (Bq/kg dry weight soil)	Fresh water concentration (Bq/L water)‡	Marine water concentration (Bq/L water)‡	Freshwater sediment concentration (Bq/kg dry weight sediment)†	Marine sediment concentration (Bq/kg dry weight sediment)†
H-3	8.84E+04	*	1.26E+07	1.26E+08	1.26E+07†	1.26E+08†
C-14	1.52E+03	*	8.45E+03‡	8.45E+04‡	8.45E+04†	8.45E+04†
Co-60		2.81E+04	1.93E+03	2.98E+01	1.16E+06	1.79E+04
Sr-90		3.11E+05	6.49E+02	2.29E+03	8.44E+04	2.98E+05
Zr-95		4.35E+04	3.65E+03	2.98E+02	2.19E+07	1.79E+06
Nb-95		2.56E+05	1.07E+02	1.74E+03	1.71E+05	2.78E+06
I-131		5.41E+05	3.50E+02	3.21E+02	2.66E+04	3.21E+03
Cs-134		1.30E+05	3.84E+02	2.48E+03	1.04E+06	6.70E+06
Cs-137		6.29E+04	9.24E+01	2.54E+03	2.49E+05	6.85E+06

* In most cases, the air concentrations of HTO and C-14 are available and can be used to ensure the protection of biota. In rare cases, if soil concentrations are required, they can be calculated using the specific activity model.

‡ Unit is Bq/g dissolved inorganic carbon in water for C-14.

† Units are Bq/L of sediment water for HTO; and Bq/g total organic carbon in sediment for C-14.

ACKNOWLEDGEMENT

We would like to thank the COG (CANDU Owners Group) partners for funding this study.

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