

Concentration ratios for chemical analogues of key nuclides for different vegetation types at the Olkiluoto site

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INTRODUCTION

Olkiluoto Island on the Finnish coast has been selected as the repository site for spent nuclear fuel produced in Finland. To monitor possible environmental changes during the construction and operation of the repository and to provide the radioecological models with proper site-specific data, an extensive sampling programme on the forest vegetation was implemented in 2005, followed by laboratory analyses. Preliminary results on concentration ratios calculated from the plots including soil, humus, leaf/needle and vegetation samples, will be presented for a selection of chemical analogues of key radionuclides in recent biosphere assessment and for different vegetation types together with a statistical analysis.

MATERIAL AND METHODS

Sampling programme was carried out on 94 permanent monitoring plots each of them being 300 m² in size (Tamminen *et al.*, 2007). The plots were selected from the forest monitoring network (one plot for each hectare of forestry land) on the basis of the forest site type distribution and tree stand characteristics measured on the island during 2002-2004 (Miettinen and Haapanen, 2002; Rautio *et al.*, 2004; Saramäki and Korhonen, 2005).

On the mineral soil sites three composite samples, each consisting of 10 sub-samples, were taken from the organic layer with a cylinder (d = 60 mm). Living vegetation was removed from the top of the sub-sample. Soil samples were also taken from mineral soil layers down to 30 cm. Peat samples were collected for each 0–10 cm, 10–20 cm and 20–30 layer on peatland sites.

Shoot samples of the most abundant or frequent evergreen and deciduous dwarf shrub, herb, grass, bryophyte and lichen species were collected from each plot. Only living above-ground biomass was sampled. Current-year shoots of the dwarf shrubs were separated and the leaves were detached for chemical analysis. For small herbs sample consisted of the whole above-ground shoot, excluding inflorescences, whereas for tall herbs only the leaves were taken. The grass sample consisted of leaves and stems, excluding inflorescences. The bryophyte samples consisted of the three youngest annual segments. For reindeer lichens the upper, light-coloured part was separated from the darker (decomposing) lower part for the sample. Leaf samples of trees were collected at the end of growing season, and needle samples during dormant period.

The element concentrations were determined by wet digestion (HNO₃/H₂O₂) and analysed by ICP-AES. The results were expressed on a dry matter basis (determined by drying at +105 °C).

Sampling, sample pre-treatment and analyses have been reported in more detail by Tamminen *et al.* (2007).

Concentration ratios (CR) were calculated for Ca, K and Ni by dividing nutrient concentration in plant (mg kg^{-1} d.w.) with the concentration in the humus or topmost 10-cm-thick peat layer (mg kg^{-1} d.w.). These CRs can be used as analogues for Sr and Ra, Cs and Ni, respectively. Lognormal distributions were fitted to the data using the EIKOS code (Ekström and Broed, 2006) running on the Matlab version 2007a. The Matlab functions were used to calculate the arithmetic means and standard deviations.

RESULTS AND CONCLUSIONS

CR for deciduous trees (birch and alder) was higher than CR for needles of conifers (Table 1). There was a clear difference between site types in CR of K for the leaves of alder: alder growing on mineral soil had mean CR of 6.1 (range 3.1–8.4) whereas CR was 16.8 (16.1–17.6) for alder on peatland soil. CR of Ni for alder leaves on peatland sites was also significantly higher than CR for birch and conifers (Fig. 1). Results from Olkiluoto for birch on peatland sites and especially for alder were higher than literature values (Avila 2006). These sites are common in potential release areas to biosphere in Olkiluoto, and thus these sites have important role in field studies in the future. Furthermore, CR to the foliage is the most important CR in forest model of Avila (2006); the model determines the element rotation speed through litterfall and subsequent transfer from deeper soil layers to the topsoil. Foliage is also an important food source for many of herbivores.

Table 1. Concentration ratios of Ca, K and Ni. Reference values according to Avila (2006) for the analogous Sr, Cs and Ni, respectively.

Concentration ratio	Ca					K					Ni				
	Mean	Std	Min	Max	N	Mean	Std	Min	Max	N	Mean	Std	Min	Max	N
To needles (all conifers)	0.84	0.41	0.17	2.51	69	4.6	1.2	1.6	8.7	69	0.12	0.04	0.05	0.21	69
Reference	0.5 ^{a)}		0.03 ^{a)} 24 ^{a)}			3.4 ^{c)}		0.8 ^{c)} 14 ^{c)}			d)		0.09 0.23		
To birch leaves	1.4	0.75	0.53	2.81	10	6.2	2.2	3.3	9.1	10	0.15	0.05	0.08	0.27	10
To alder leaves	1.2	0.40	0.80	1.80	6	9.7	5.9	3.1	18	6	0.24	0.10	0.13	0.38	6
Reference	7 ^{b)}		0.3 ^{b)} 11 ^{b)}			5.8 ^{c)}		0.4 ^{c)} 910 ^{c)}			d)				
To mosses	0.75	0.43	0.19	2.67	87	4.8	2.2	1.4	14	87	0.42	0.24	0.10	1.6	87
To evergreen plants and blueberries	1.4	0.83	0.15	4.53	115	6.0	2.9	1.8	22	115	0.08	0.04	0.03	0.21	115
To other understorey	0.67	0.62	0.07	4.19	134	16.6	8.1	0.6	38	134	0.19	0.10	0.06	0.60	134
Reference: to understorey	0.7 1.1 ^{e)}		0.06 ^{e)} 110 ^{e)}			2.3 ^{f)}		0.01 ^{f)} 240 ^{f)}			0.13 ^{g)}		0.01 4.7		

a) For Sr and nominal for pine, range for coniferous. b) For Sr and birch, range for deciduous. c) For Cs. d) Lack of data, Avila (2006) assumes same nominal value as for understorey. e) For Sr, mean value for grasses and herbs | scrubs. f) For Cs, mean value for grasses and herbs. g) Mean value for blueberries. h) For Ra.

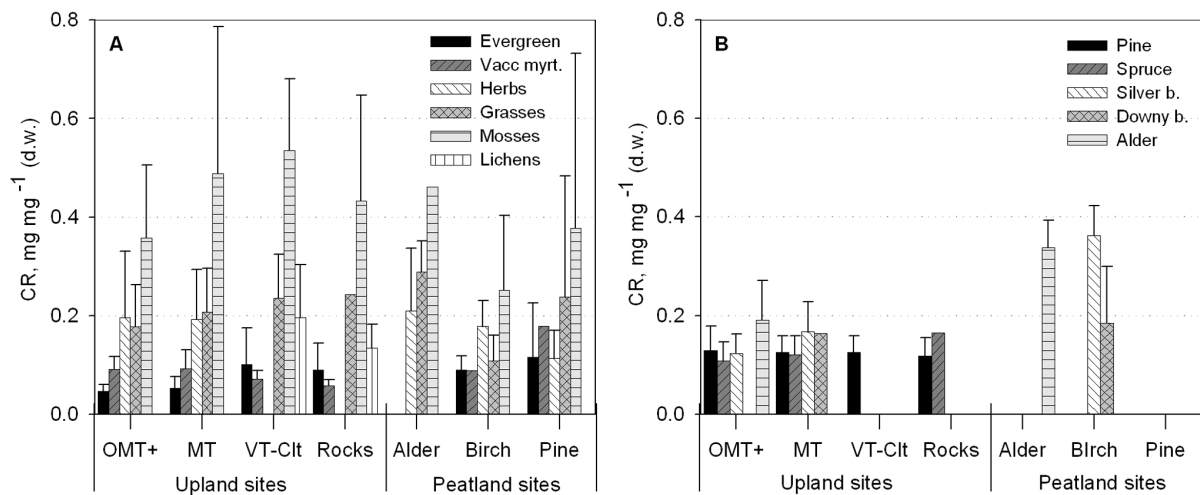


Fig. 1. Site type specific CRs of Ni to the understorey in different plant groups (A) and to the foliage in tree species (B) at Olkiluoto. The forest site types (Cajander 1949): OMT+ = the most fertile, herb-rich sites and *Oxalis acetosella*-*Vaccinium myrtillus* types, MT= *V. myrtillus* type, VT-CIT= *V. vitis-idaea*, *Calluna vulgaris* and *Cladina* types, and Rocks= bedrock sites with no or very shallow mineral soil layer. Peatlands were classified according to the dominant tree species. Tree species: Pine= *Pinus sylvestris*, Spruce=*Picea abies*, Silver birch=*Betula pendula*, Downy birch=*B. pubescens*, Alder= *Alnus glutinosa*.

CR of Ni was higher in mosses than in other plants (Table 1, Fig. 1). For K in plants, CR was significantly highest in other understorey plants, i.e. herbs and grasses. This can be explained by the differences in K uptake of different plant species. However, CRs for plants are rather consistent with values presented by Avila (2006); it seems that higher end of literature values are due to mosses (Fig. 2). Also comparison of the elements measured and the analogous radionuclide data does not appear problematic, even though it is expected that the uptake cannot be totally similar. For Ni, it can be explained by the different plant groups and site types (Figs. 1, 2).

CRs for elements are not commonly used in plant nutrition related studies since they depend on original data, sampling and its processing. There is a multitude of ways to derive the CR values from the site data, meaning that suitably low or high value can always be defended. In Olkiluoto, however, knowledge on distribution of different key elements in forest ecosystems is needed for the safety assessments where forests tend to dominate the dose (Broed, 2007; Broed *et al.*, 2007). Before more specific analyses of radionuclides are available, currently used non-radioactive elements will provide a sound base for those analyses, especially because data is collected from the prevailing forests on Olkiluoto.

Results were only based on element concentrations in surface soil excluding part of the rooting zone of trees or other plants. Therefore, more CR values using different thickness of soil layers and weights for trees and plants (e.g. age, tree size) will be presented and possible dependencies (age of plant, site properties) will be studied thoroughly before definitive conclusions. On the basis of these first experiences with real site data, it seems that the current CR-based approach on the radionuclide modeling in the forest ecosystems seems problematic due to the large variation in possible parameter values and in their practical definition. A more mechanistic model would

be preferred, but acknowledging the efforts required, the CR-based approach can be still judged viable if the data basis is built profoundly.

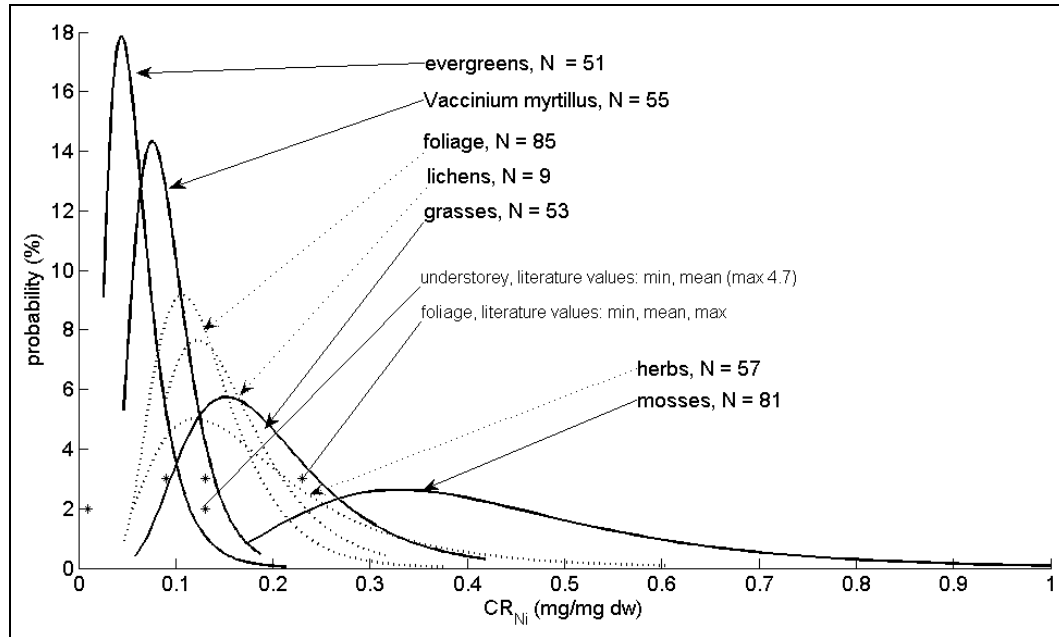


Fig. 2. Lognormal distributions (probability density functions of the CR value) fitted to the site data on concentration ratios for Ni. For comparison, nominal, minimum and maximum values from (Avila 2006) are marked with *.

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