^{137}Cs content and distribution in understorey spruces

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Abstract. Understorey spruces *(Picea abies)* grown after the Chernobyl accident were studied in Finland in 1998. Ten trees were sampled from three pine forests on unmanaged mineral soil. ^{137}Cs contamination of the ground, estimated from soil samples, varied from 24 to 66 kBq m^{-2}. Contents and distributions of ^{137}Cs and dry matter were compared by trees of varying age and size. Stemwood contained 19–36% of the dry mass but only 4–7% of the radiocaesium. Needles contained 21-48% of the dry mass and 37–60% of the ^{137}Cs. Roots contributed to the dry mass more than to the ^{137}Cs content of a tree. Activity concentrations in needles and branches were highest in current year growth, and in upper parts of the trees. Also wood and bark had higher ^{137}Cs concentration in upper parts of the stems than in lower parts. Concentrations per unit deposition (m^2 kg^{-1} dry weight) were calculated for comparison of uptake by trees from different sites. They varied by the stage of growth in several tree parts. For instance, in current year needles they were on average 0.098 for older trees and 0.13 m^2 kg^{-1} for younger trees.

1. INTRODUCTION

Concentrations and dynamics of ^{137}Cs in trees vary reflecting differences in the structure and age of forest stands and growth conditions on different sites [1, 2]. At time of study of understorey trees, root uptake from soil and internal translocation of ^{137}Cs have been the main processes in the dynamics of ^{137}Cs in trees.

Understorey spruces *(Picea abies)* grown in heath forests mainly after the Chernobyl accident were studied in central Finland in September 1998. The study area is situated in southern boreal vegetation zone where conifers predominate in overstorey. Contents and distributions of ^{137}Cs and dry matter were compared by trees of varying age and size. Vertical distribution of ^{137}Cs was examined as well. Concentrations of ^{137}Cs in different tree fractions, normalised per unit deposition, described the uptake from soil.

2. MATERIAL AND METHODS

Ten trees were sampled from 25m × 25m plots in three pine forests on unmanaged mineral soil. Number of soil samples collected per plot varied from 2 to 7. Some of the soil samples were collected in August 2000; ^{137}Cs concentrations were then corrected to correspond the activity in September 1998. Information on sampling and some characteristics of the experimental forests are presented in table 1. Dimensions of the trees collected are given in table 2.

All above-ground parts of the trees were sectioned into stemwood, stembark, dead branches/needles, as well as needles and branches/twigs of 3-5 age classes plus older parts. The tallest 5 trees were divided vertically into several parts, and then sectioned into the mentioned compartments. Also lichens growing on stems and branches were sampled and analysed. Needles were separated from branches after drying. Needles growing on stembark were analysed separately. Roots of the smallest 5 trees were collected.

Samples of soil and ground vegetation were collected using a steel auger (Ø 10.6 cm, length 21 cm). Soil columns were subdivided into layers of ground vegetation/litter, humus and 4 layers of mineral soil (0-2, 2-5, 5-10, >10 cm). All samples were weighed, dried (105°C), organic materials were homogenized and mineral soil was sieved (2 mm) prior to gamma-spectrometric measurement.

Table 1: Information on sampling and some characteristics of the experimental forests.

	Site A	Site B	Site C
Deposition, kBq m^{-2} (average and range)	52 (35-66)	37 (24-49)	37 (33 and 42)
Site type	Dryish	Moist	Moist
Soil type	Moraine with podsol solumn	Moraine with podsol solumn	Moraine with podsol solumn
Number of trees collected	5	3	2
Number of soil columns collected	7	5	2

Table 2: Dimensions of the studied 10 trees.

Tree	1	2	3	4	5	6	7	8	9	10
Dry mass, g (above-ground parts)	70	139	142	247	285	762	1126	1179	1492	4401
Length, cm	60	97	85	125	108	176	200	182	236	448
Age, y (1998)	c. 10	c. 10	c. 10	c. 10	c. 10	20	20	20	21	15
Study site	A	A	A	A	A	C	B	B	B	C

Determinations of ^{137}Cs were carried out using a low-background, high-resolution gamma spectrometer with a pure germanium semiconductor detector. The calibration methods and the software for analysis of the gamma spectra were developed for environmental samples at STUK [3]. The ^{137}Cs activities have been given for dried material, and corrected for radioactive decay to correspond the activity on the day of sampling. Measurement uncertainty of single determinations of ^{137}Cs in most cases did not exceed 5 %.

3. RESULTS

3.1 Distributions of ^{137}Cs activity concentrations

^{137}Cs contamination of the ground layer studied, estimated from soil samples, varied on the three sites from 24 to 66 kBq m^{-2}. Activity concentrations in needles and branches were highest in current year growth, and in upper parts of the trees. Also wood and bark had higher ^{137}Cs concentration in upper parts of the stems than in lower parts, although the difference in vertical distribution was not as obvious as for needles and branches.

3.2 ^{137}Cs and dry matter contents

Contents of ^{137}Cs and dry matter in the trees are shown in Fig 1. For the smallest 5 trees from site A the ^{137}Cs content increased with dry weight, whereas at site B in trees No. 7-9 the ^{137}Cs content was almost the same despite different size of the trees.

Relative contributions of the above-ground tree parts to ^{137}Cs and dry matter budgets showed some differences by age and size of the trees. Stemwood contained 19–36 % of the dry mass but only 4–7 % of the radiocaesium of the trees (Fig 2). Needles contained 21–48 % of the dry mass and 37–60 % of the ^{137}Cs. The contribution of branches to ^{137}Cs and dry matter budgets were alike: about 20-27 % for living and 1-15 % for dead branches. Stembark contained 7–13 % of the dry mass and 8–17 % of the ^{137}Cs. Roots of the smallest 5 trees contributed to the dry mass more than to the ^{137}Cs content of a tree (13-19 %

to the dry mass, 7-13 % to the ^{137}Cs content). Current year needles contained 12-28 % of the ^{137}Cs and 2-9 % of the dry matter of the trees.

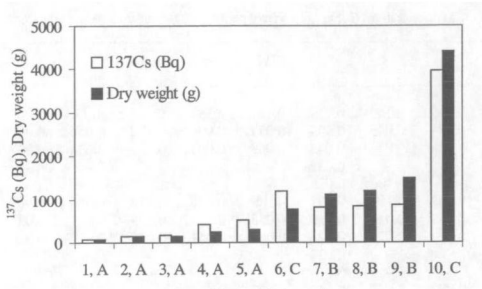

Figure 1: ^{137}Cs and dry matter contents of above-ground parts of the studied trees. For site A the ^{137}Cs content was corrected to correspond the ground contamination estimated for sites B and C (37 kBq m^{-2}).

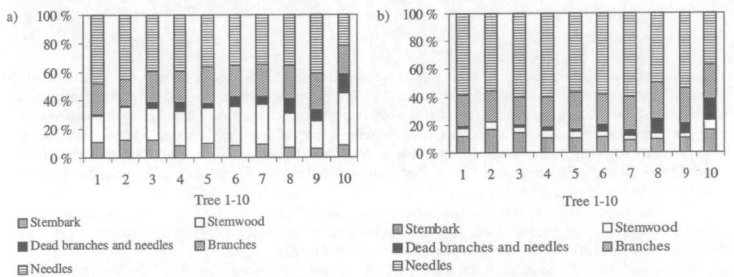

Figure 2: Percentage distribution of dry matter (a) and ^{137}Cs content (b) in above-ground parts of the trees.

3.3 Uptake of ^{137}Cs by different tree parts

Normalised ^{137}Cs concentrations (Bq kg^{-1} dry weight per Bq m^{-2}) were calculated using dry matter weighted average concentrations for tree fractions and average ground contamination for each site. These normalised concentrations varied by the stage of growth in several tree parts. For instance, in current year needles they were on average 0.098 for older trees and 0.13 m^2 kg^{-1} for younger trees, and the range for current year needles was from 0.05 to 0.16 m^2 kg^{-1} (Table 3). In stemwood the concentration varied from 0.01 m^2 kg^{-1} for a 10-year-old tree to 0.003 m^2 kg^{-1} for 20-year-old trees. The uptake to stemwood was 3-9 % of the uptake to current year needles.

The uptake to a whole tree, calculated from the total content of ^{137}Cs of a tree, varied from 0.016 to 0.046 m^2 kg^{-1}, being smallest for older trees.

The normalised concentration decreased from younger to older needles and branches in every studied tree (Table 3). The decrease was most obvious from current year growth to C+1 year growth.

The normalised concentration seemed to decrease with increasing dry weight, but the correlation was not statistically significant for any of the studied tree fractions.

Table 3: Normalised ^{137}Cs concentrations (Bq kg^{-1} dry weight per Bq m^{-2}) for different parts of the trees.

Tree	1	2	3	4	5	6	7	8	9	10
C needles	0.095	0.103	0.114	0.161	0.154	0.163	0.11	0.069	0.051	0.124
C+1 needles	0.031	0.045	0.054	0.077	0.096	0.109	0.055	0.035	0.027	0.068
C+2 needles	0.028	0.028	0.043	0.063	0.064	0.086	0.034	0.027	0.02	0.052
C+3 needles	-	-	0.032	-	-	-	-	-	0.016	-
C+4 needles	-	-	0.030	-	-	-	-	-	0.016	-
C branches	0.108	0.104	0.091	0.15	0.195	0.174	0.086	0.069	0.060	0.157
C+1 branches	0.043	0.055	0.039	0.055	0.073	0.095	0.041	0.037	0.027	0.071
C+2 branches	0.023	0.025	0.027	0.042	0.041	0.045	0.027	0.026	0.016	0.046
C+3 branches	-	-	0.023	-	-	-	-	-	0.014	-
C+4 branches	-	-	0.018	-	-	-	-	-	0.012	-
Dead branches/needles	0.032	0.017	0.010	0.022	0.018	0.028	0.014	0.02	0.014	0.028
Stemwood	0.009	0.007	0.006	0.010	0.009	0.006	0.003	0.003	0.003	0.005
Stembark	0.033	0.037	0.035	0.053	0.046	0.048	0.017	0.025	0.023	0.042
Roots	0.018	0.015	0.021	0.024	0.028	-	-	-	-	-
Whole tree	0.03	0.029	0.031	0.044	0.046	0.042	0.020	0.020	0.016	0.024

4. CONCLUSIONS

^{137}Cs deposited on forests transfers from soil to trees still when more than a decade has passed after the release to the environment. In boreal forests, most of the radiocaesium in the soil is found in organic and in uppermost layers of mineral soil, where it is available for uptake by plants years after deposition.

The decrease in radiocaesium concentration with aging of needles is in agreement with findings made already after the Chernobyl accident [4, 5, 6]. The observed normalised concentrations for the studied understorey trees were only a bit higher than reported earlier for stemwood of 44-year-old spruces [7] and for debarked spruce timber [8].

The uncertainty of ground contamination used for uptake calculations may not be negligible. Observed variability in tree-specific findings includes also influence of growth conditions. However, these factors do not affect relative distributions in individual trees.

Stemwood was the least contaminated part of all trees, showing 3-9 % of the contamination of current year needles. The new growth showed the highest uptake of ^{137}Cs in all tree parts studied.

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