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A pilot study on the distribution of ^{137}Cs between vegetation and soil in an industrial pollution gradient at the Kola peninsula

Abstract

The activity concentration of radiocaesium in dwarf shrubs, mosses, organic and inorganic soil was studied in an industrial pollution gradient from the Monchegorsk smelter at the Kola peninsula. As expected the highest values for vegetation was found in mosses/lichens followed by dwarf shrubs. The transfer factor between organic soil and vascular vegetation was ten times higher in the control area (100 km from the smelter) than in the affected areas (7 to 31 km from the smelter).

Key words

chemical pollutions, vegetation, soil

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Dokumentets titel En pilotstudie om fördelningen av ^{137}Cs mellan vegetation och jord i en industriell föroreningsgradient på Kolahalvön.	
Sammanfattning Innehållet av radiocesium i dvärgbuskar, mossor/lavar, organisk och oorganisk jord har undersökts i en föroreningsgradient från smältverket i Monchegorsk på Kolahalvön. Aktivitetskoncentrationen av ^{137}Cs i vegetation var, som väntat, högre i mossor och lavar än i dvärgbuskar. Kvoten mellan aktivitetskoncentrationen i dvärgbuskar och jord var tio gånger högre i kontroll området (ca 100 km från Monchegorsk) än i de kemiskt förorenade områdena (7 till 31 km).	
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Table of contents

Introduction

This report contains the main results from a pilot study undertaken in 1996 in the Kola Peninsula. The aim is to get a first indication of the distribution of ^{137}Cs in coniferous forests subjected to air pollution and to provide some basic data for the planning of the EPORA Project within the Nuclear Fission Safety of EU. The experimental sample plots have been chosen in a gradient of increasing impact of chemical pollution from the Monchegorsk smelter. Results of ^{137}Cs are compared for dwarf shrubs, mosses, lichens humus and illuvial soil horizons. A rough assessment of the expected concentration of ^{137}Cs in water is also made, based on these data, to indicate the volume of water expected to be appropriate for the low level analysis of ^{137}Cs in samples in the coming runoff study.

Materials and methods

The forests in the sampling plots have been classified as background with no influence from the smelter (more than 60 to 70 km from the smelter), defoliating forests (20 to 70 km from the smelter) and sparse forests or industrial barren's (less than 20 km from the smelter). Plant and soil samples were taken during August 1996, at the locations shown in figure 1 and Table 1 (Nikonov and Lukina, 1996).

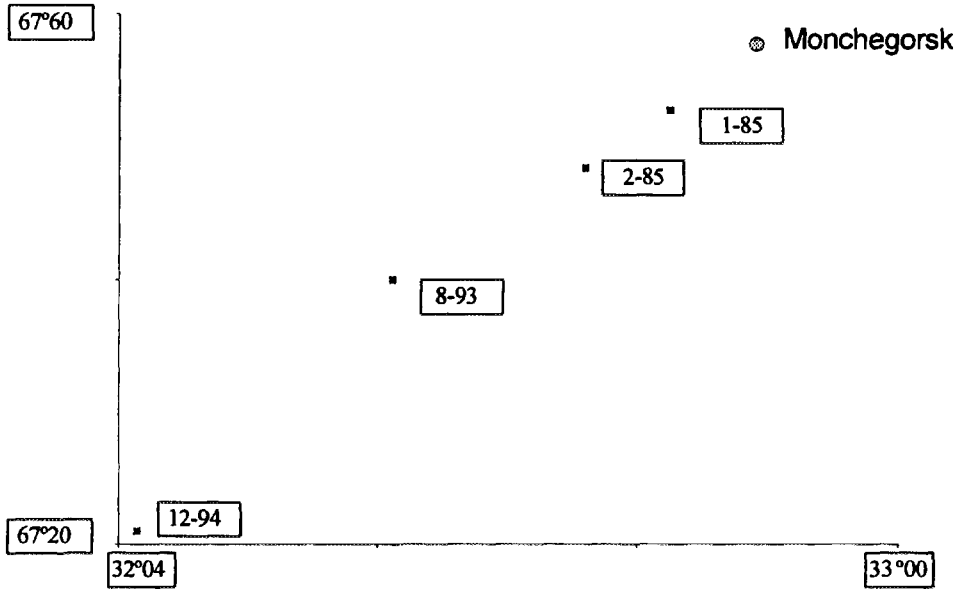

Figure 1. The positions for vegetation and soil samplings (Nikonov and Lukina, 1996).

The plots were established in both spruce and pine forests during 1990 and include collectors of atmospheric deposition, litterfall and lysimeters at different depth (under the humus layer, B and BC horizons). The sample plots have served as areas for long time studies of atmospheric deposition and soil migration of chemical elements, organic matter dynamics, soil acidity and element uptake by plants (Nikonov and Lukina, 1996).

Table 1 Samples taken during the autumn of 1996.

Sample	Distance	Sample plot	Sample	Date
1	110	M1K1	Lichens	16.08.96
2	110	M1K1	Mosses	16.08.96
3	100	12-94	Mosses	16.08.96
4	100	12-94	Empetrum hem	16.08.96
5	100	12-94	Vaccinium myrt	16.08.96
6	31	8-93	Lichens	17.08.96
7	31	8-93	Mosses	17.08.96
8	31	8-93	Vaccinium myrt	17.08.96
9	31	8-93	Empetrum hem	17.08.96
10	22	2-85	Vaccinium myrt	17.08.96
11	22	2-85	Empetrum hem	17.08.96
12	100	12-94	Organic soil	16.08.96
13	100	12-94	Illuvial soil	16.08.96
14	31	8-93	Organic soil	17.08.96
15	31	8-93	Illuvial soil	17.08.96
16	22	2-85	Organic soil	17.08.96
17	22	2-85	Illuvial soil	17.08.96
18	7	1-85	Empetrum hem	25.08.96
19	7	1-85	Vaccinium myrt	25.08.96
20	7	1-85	Vaccinium vitis	25.08.96
21	7	1-85	Organic soil	25.08.96
22	7	1-85	Illuvial soil	25.08.96

* Distance in km from the Monchegorsk smelter

Results and discussion

The activity concentration of ^{137}Cs was higher in organic than in illuvial soil (Table 2). This is partly explained by the higher density in the latter but also reflects the shallow distribution of ^{137}Cs in soil. The ratio between ^{137}Cs in organic and illuvial soil is highest in defoliating forests.

Table 2 The activity concentration in vegetation and soil taken in an industrial pollution gradient at the Kola Peninsula.

Sample plot	Distance* km	^{137}Cs Bq/kg D.W.	Species	Class
1-85	7	6,6	Empetrum	Ind Barrent
1-85	7	9,4	Illuvial	Ind Barrent
1-85	7	60	Organic	Ind Barrent
1-85	7	28	Vaccinium m	Ind Barrent
1-85	7	20	Vaccinium v	Ind Barrent
2-85	22	14	Empetrum	Defoliating
2-85	22	2,3	Illuvial	Defoliating
2-85	22	140	Organic	Defoliating
2-85	22	31	Vaccinium m	Defoliating
8-93	31	6,2	Empetrum	Defoliating
8-93	31	0,5	Illuvial	Defoliating
8-93	31	93	Lichens	Defoliating
8-93	31	36	Mosses	Defoliating
8-93	31	110	Organic	Defoliating
8-93	31	29	Vaccinium m	Defoliating
12-94	100	38	Empetrum	Control
12-94	100	2,8	Illuvial	Control
12-94	100	83	Mosses	Control
12-94	100	34	Organic	Control
12-94	100	80	Vaccinium m	Control
M1K1	110	110	Lichens	Control
M1K1	110	250	Mosses	Control

* Distance from the Monchegorsk smelter

The level of ^{137}Cs in Vaccinium is lower than in the Swedish boreal region (Nylén, 1996) and suggests a deposition of 700 to 3000 Bq m^{-2} in the region (the aggregated transfer factor is about 0.03 Bq kg^{-1} Bq m^{-2} in the Swedish forests). The activity concentration in Vaccinium is higher than in Empetrum which seems to be a general trend in coniferous forests.

The transfer factor (Tf) is defined as Bq kg^{-1} in vegetation divided by Bq kg^{-1} in organic soil. The range of Tf for Vaccinium myrtillus is 0.2 to 2 and for Empetrum hermaphroditum 0.06 to 1. Reported values of Tf in Vaccinium for boreal soils in middle Sweden are in the range of 1 to 1.2 (Fawaris, 1995). The mean value for Northern Sweden was 0.6 +/- 0.1 (S.E.) during 1990. The transfer factors are similar in the polluted areas, but ten times higher in the control area. This trend is similar for the two species of dwarf shrubs (Figure 2 and Table 3).

Table 3. Transfer factors between Cs-137 in soil and dwarf shrubs.

Species	Distance	Tf
Empetrum hermaphroditum	7	0,11
Empetrum hermaphroditum	22	0,10
Empetrum hermaphroditum	31	0,059
Empetrum hermaphroditum	100	1,1
Vaccinium vitis-idaea	7	0,34
Vaccinium myrtillus	7	0,46
Vaccinium myrtillus	22	0,23
Vaccinium myrtillus	31	0,27
Vaccinium myrtillus	100	2,3

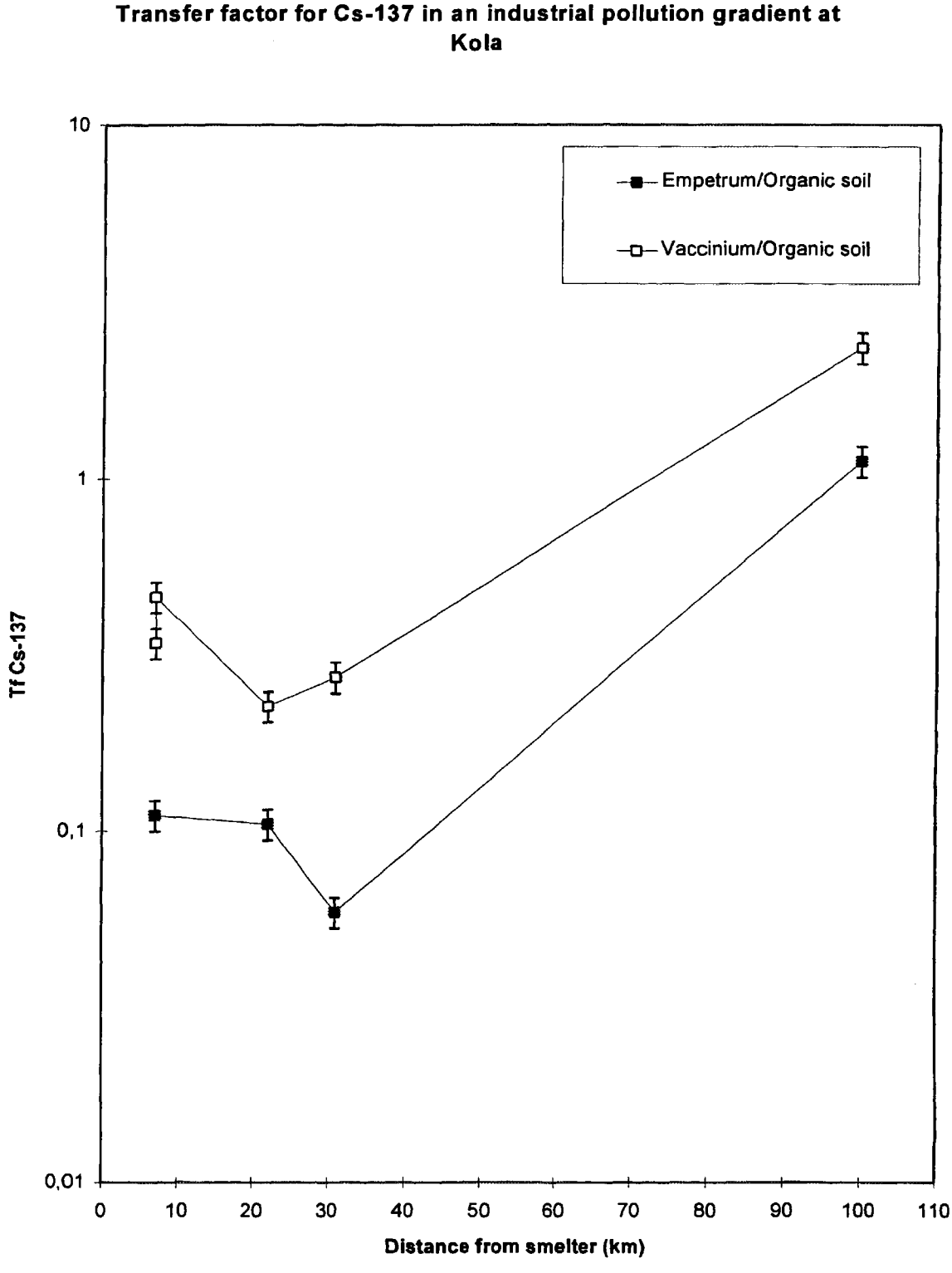

Figure 2 Transfer factors for ^{137}Cs in Vaccinium spp in relation to the distance from the Ni-Cu melter in Monchegorsk.

The results can also be used for a first calculation of the amount of water needed for the run off studies (EPORA). In this part of the project ^{137}Cs and ^{90}Sr will be studied. Due to the lower Kd and higher mobility for Strontium in soil, ^{137}Cs will probably determine the amount of water needed. The estimated deposition is 700 to 3000 Bq m^{-2}. The relative activity (m^{-1}) in Swedish stream water is about 0.0003 in bog-free catchments and higher in streams originating in bogs. This can be translated to about 0.2 to 0.9 Bq m^{-3} of ^{137}Cs in stream water in the pilot study area. Our conclusion is, given the current detection limits at our radiometry lab, that about 200 l of water per sample is necessary to perform a reliable analysis of ^{137}Cs.

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