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Transfer and behaviour of ^{137}Cs in two Finnish lakes and their catchments

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ABSTRACT

The long-term behaviour of ^{137}Cs was studied in two freshwater ecosystems in southern Finland in an area most loaded by the Chernobyl fallout in 1986. Samples were taken from water, sediments, aquatic plants and fish in the lakes and from soil, mushrooms and seed plants in the catchments. The activity concentrations of ^{137}Cs in fish have remained at a relatively high level and decreased much more slowly in these two lakes than in other lakes studied by us. One reason for the continuously high concentrations in fish is evidently the prolonged stay of caesium at a relatively high level in the water of these lakes, which is associated with a slow sedimentation rate. The hydrographical properties of the lakes, i.e. the oligotrophic character associated with a deficiency of potassium in water and a low pH are other reasons for the effective uptake and long retention time of ^{137}Cs in fish. The effect of humic substances on the uptake and delay of caesium in fish could not be proved clearly in this study. The swampy soil type of the catchment associated with a more oligotrophic status and lower pH of the water in Lake Siikajärvi explain at least partly the difference in activity concentrations and transfer of ^{137}Cs between the two lakes studied. This refers to the higher transfer from the catchment to the lake and the higher uptake of ^{137}Cs by fish and other biota in Lake Siikajärvi than in Lake Vehkajärvi. Perch and pike were more efficient accumulators of caesium than the best indicators among the aquatic plants. In the terrestrial environment, caesium was most effectively accumulated by mushrooms.

1. Introduction

The deposition of ^{137}Cs from the Chernobyl accident was very unevenly distributed in Finland and raised activity concentrations of ^{137}Cs in the aquatic environment significantly. Large variations in the activity concentrations in fish and lake water were still being observed in the 1990s and even in the 2000s (Saxén, 2007). Much higher activity concentrations in lake water and fish and in the concentration factors were found in two lakes in particular, Siikajärvi and Vehkajärvi, which are located quite near to each other in southern Finland (Saxén and Koskelainen, 2005). These two lakes were included in our study on the role of sedimentation processes in the changes of ^{137}Cs activity concentrations in Finnish lakes (Ilus and Saxén, 2005). The results showed that the sedimentation rate in these two lakes was lower than in the other lakes studied, and that the activity concentrations in water and fish continued to be higher than in other lakes in an area with the same deposition level.

This study focused not only on the lakes themselves but also on their catchments. The objective was to study the distribution of ^{137}Cs also in other aquatic organisms, besides fish, and in soil and biota of the catchments in order to find reasons for the continuously high activity concentrations of ^{137}Cs in water and fish.

The behaviour of Chernobyl-derived ^{137}Cs in different types of the Finnish lakes, in their fish, water and sediments, was

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Table 1 – Some hydrographical characteristics of the surface water (0–1 m) in lakes Siikajärvi and Vehkajärvi in 2000–2005 (mean and range of values) based on the data from the Water Quality Register of Pirkanmaa Regional Environment Centre

Parameter (unit)	Siikajärvi	Vehkajärvi
Total phosphorus (μg l^{-1})	6.6±1.2 (5–10)	6.9±1.4 (3–10)
Total nitrogen (μg l^{-1})	270±22 (170–490)	270±15 (220–370)
pH	5.9±0.1 (5.5–6.3)	6.9±0.1 (6.6–7.1)
Colour number (mg Pt l^{-1})	24±4 (15–35)	10±2 (5–15)
Turbidity (TUA/FNU)	0.5±0.1 (0.15–0.8)	0.5±0.1 (0.15–0.9)

considered widely in several papers in the years soon after the Chernobyl accident (e.g. Kansanen et al., 1991; Penttilä et al., 1993; Saxén et al., 1996, 1998; Saxén and Koskelainen, 2005; Suutarinen et al., 1991; Särkkä et al., 1991, 1993, 1995, 1996). The present study illustrates the fate of caesium in the long-term in two lakes with specific characteristics.

2. Description of the lakes and their catchments

Lake Siikajärvi is a small (area 0.9 km^2), quite deep (max. depth 22 m), oligotrophic wilderness lake in a natural state. The area is sparsely populated and full of small lakes surrounded with forests. The surroundings of Lake Siikajärvi are characterized by kilometres of peat bogs. The lake water is brownish and somewhat acid (Table 1).

Lake Vehkajärvi is a larger (area 25 km^2), clear-watered, oligotrophic lake with a relatively abundant rural population (farms and summer houses) in the surroundings. It is located in a watershed area between two large water systems. The acidity of the water is close to neutral and the nutrient level and turbidity are about the same as in Lake Siikajärvi (Table 1).

According to the classification based on the EC Water Framework Directive, lakes Siikajärvi and Vehkajärvi belong to the type 'Small and middle-sized low-humic lakes'. According to the Finnish usability classification of lakes, Vehkajärvi belongs to the class 'excellent'; Siikajärvi has not been classified (Pirkanmaa Regional Environment Centre). The average values of certain characteristics of the surface water (Table 1) show that the lakes are in a natural state; they are oligotrophic and clear-watered. The pH value is much lower and the colour number much higher in Siikajärvi, which indicates a greater impact of humic substances there.

The municipalities surrounding both lakes belong to the category of the highest surface activity of Chernobyl-derived ^{137}Cs in Finland (Arvela et al., 1990). The municipal average values of ^{137}Cs deposition in the four municipalities: Kuhmalahti, Kuhmoinen, Luopioinen and Padasjoki, which surround Lake Vehkajärvi, were 55700, 58000, 41200 and 77000 Bq m^{-2}, respectively (1 October 1986). In the Siikajärvi area, which is part of the town of Orivesi, the average deposition was 51400 Bq m^{-2} in 1986. However, these figures are averages for the whole municipalities, and, in fact, include a considerable

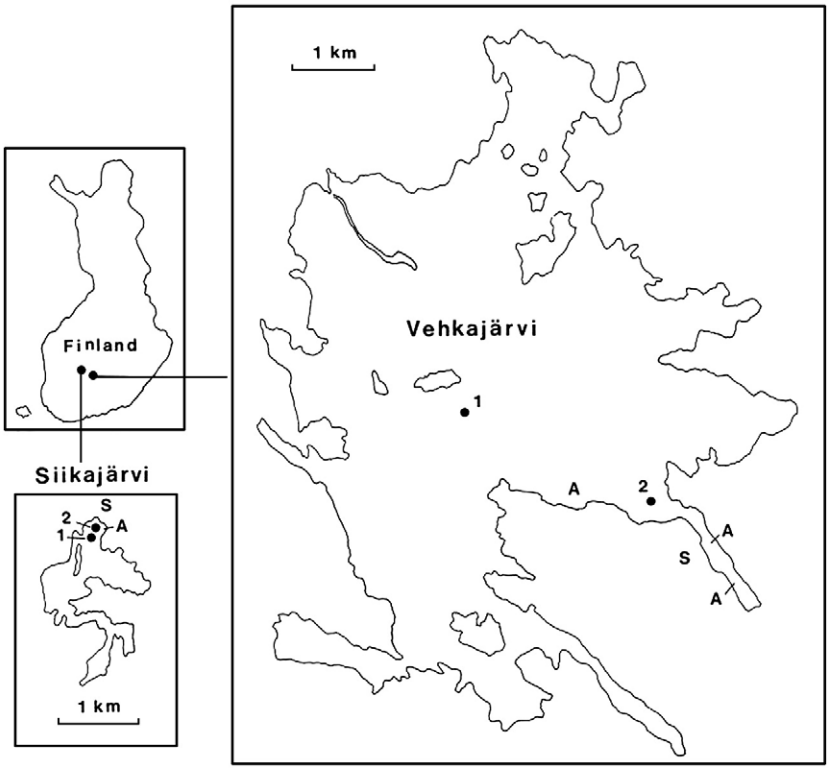

Fig. 1 – Location of Siikajärvi and Vehkajärvi in Finland and the sampling sites in the areas of the lakes (1 and 2 = sediment sampling stations, S = sampling areas of soil and terrestrial plants, A = sampling areas of aquatic plants).