Regional variation of ^{137}Cs in freshwater fishes in Finland

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Abstract. The aim of this study was to see if differences in the transfer and behaviour of ^{137}Cs in fishes can be found in large fishery areas. Based on watercourses the country can be divided into eight large areas. The study is focused mainly to four of these areas, most important for freshwater fishing in Finland and based on long-term analysing programmes of freshwater fishes carried out after the Chernobyl deposition in each area. Deposition from Chernobyl was distributed most unevenly in Finland. Average depositions of ^{137}Cs to the areas studied varied from 4 kBq/m^2 to 34 kBq/m^2. The transfer of ^{137}Cs into fishes differed somewhat in various areas. Regional averages of ^{137}Cs in fishes per unit deposition varied between 0.04 to 0.2 m^2/kg. Average concetration ratios of ^{137}Cs in predatory, non-predatory and intermediate fish and water were 7000, 2400 and 6200, respectively, in 1998. After peak values ^{137}Cs in fishes decreases with a half-life of 2.2 - 7.5 years in the four large fishery areas. The type of the catchment plays an important role in the long-term behaviour of ^{137}Cs both in surface water and in fishes.

1. INTRODUCTION

The deposition caused by the Chernobyl accident in 1986 raised markedly the activity concentrations in freshwater fishes in Finland. The deposition was most unevenly distributed in the country (Fig. 1)[1]. Based on watercourses Finland can be divided into eight large areas, which also represent the fishery statistical areas (Fig. 2). Results of the study from 1986-1999 on ^{137}Cs both in surface water and in fishes in the large drainage areas give a chance to estimate the recovery times of the areas after an accidental contamination by ^{137}Cs.

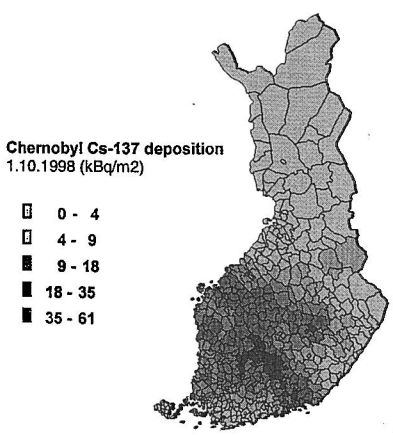

Figure 1. Distribution of ^{137}Cs from the Chernobyl deposition in Finland 1.10.1998 (kBq/m^2) (1).

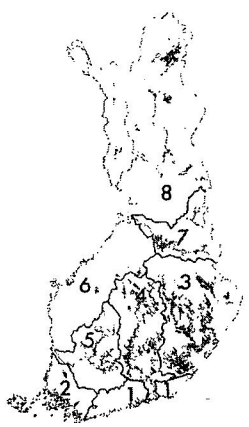

Figure 2. Large drainage areas in Finland. Areas 3, 4, 5 and 7 were included in this study.

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2. MATERIAL AND METHODS

During 1986-1999 somewhat more than 6 700 fish samples were analysed from lakes located in different large drainage areas (Table 1) [2-5]. About 10 most important fish species (perch *(Perca fluviatilis)* , pike *(Esox Lucius)*, vendace *(Coregonus albula)*, roach *(Rutilus rutilus)*, bream *(Abramis brama)*, burbot *(Lota lota)*, pike-perch *(Stizostedion lucioperca)*, whitefish *(Coregonus lavaretus)*, etc.), typical for the catches in each area, were included in the samples. In 1998 water samples were analysed from the same 24 lakes that were sampled for fishes. To discover the impact of environmental factors on the behaviour of ^{137}Cs and possible differences between various areas, the regional annual averages of activity concentrations per unit deposition in water and in fish were compared. Concentration factors (CF) of ^{137}Cs in three types of fishes with different feeding habits (predators, non-predators and intermediate) and in water in each area were compared.

Table 1. Number of lakes and fish samples included in the study and the average deposition of ^{137}Cs in each area.

	Average deposition of ^{137}Cs in 1986, kBq/m^2	Number of lakes for fish samples in 1986-1999	Number of fish samples analysed in 1986-1999
Area 3	6.7	40	894
Area 4	29.9	140	2692
Area 5	34.1	105	2736
Area 7	3.8	50	417

3. RESULTS

Regional differences existed in the decrease rate of ^{137}Cs in fishes (Fig. 2). Variation in ^{137}Cs in fishes was large in each area, it was large even in lake a few years after the deposition. The decrease of ^{137}Cs in fishes after the peak values had been reached was slowest in area 4 and fastest in area 5 (Fig. 2). After the peak values in fishes, which were reached in 1987 or 1988, regional annual average values of ^{137}Cs decreased according to the equation of the following form $\mathbf{C_f = a * e^{-b*t}}$, where t is the time since the Chernobyl deposition (in 1986 t = 0). Coefficients of determination for various areas were astonishingly good, except for area 7, although the material was classified neither by fish type nor by lake type (cf. Fig. 3 and Table 2).

Table 2. Ecological halflives of ^{137}Cs in fishes in the four large drainage areas determined after the peak values up to 1999, and the coefficients of the determinations.

	$T_{1/2\ ecol}$ (1987 or 1988 - 1999)	R^2
Area 3	4.6 y	0.79
Area 4	7.5 y	0.68
Area 5	2.2 y	0.90
Area 7	3.8 y	0.33

The ^{137}Cs in fishes per unit deposition in areas 3 and 4 behaved almost equally (Fig. 4). Highest lake specific values of ^{137}Cs in fish per unit deposition (up to 1.7 m^2/kg) were found in area 7, whereas the regional annual averages varied from 0.04 to 0.2 m^2/kg.

Table 3. Concentration ratios CF, CF = ^{137}Cs in fish (Bq/kg)/ ^{137}Cs in water (Bq/kg), in three types of fishes: predators, non-predators and intermediate, in 1998.

	Predatory fish	Non-predatory fish	Intermediate fish
Area 3	6030	2200	4100
Area 4	7660	3030	5680
Area 5	6620	2030	4930
Area 7	7860		9930

In 1998 CF for predators (pike, pike-perch, burbot, etc.) was on the average about 7000 and that for non-predators (vendace, roach and other roach related fishes, etc.) about 2 400.

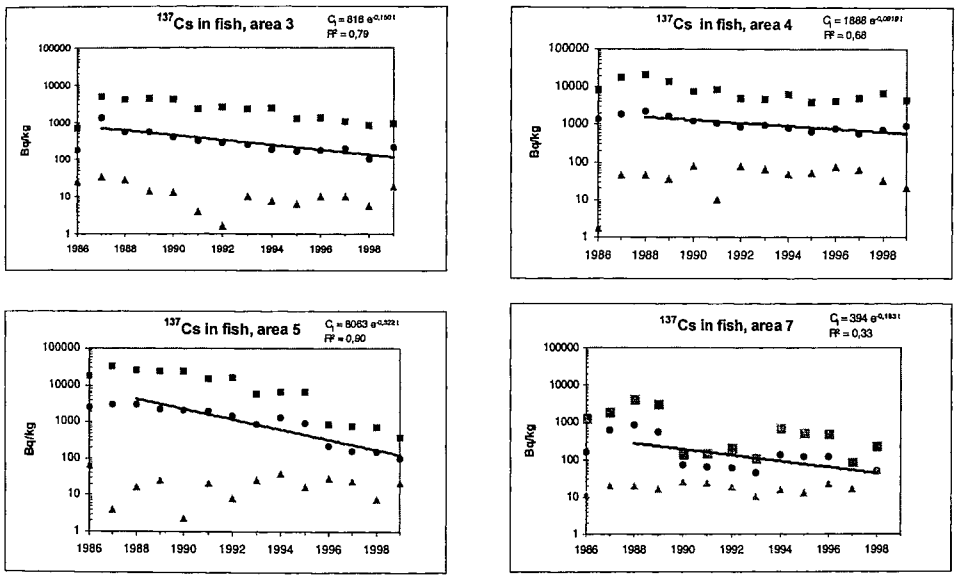

Figure 3. Annual averages of ^{137}Cs (Bq/kg fresh weight) with variation in fishes in areas 3, 4, 5 and 7 in 1986 - 1999. Effective ecological halflives of ^{137}Cs in fishes in the areas 3, 4, 5 and 7 were, 4.6 y, 7.5 y, 2.2 y and 3.8 y, respectively, between 1987 or 1988 and 1999.

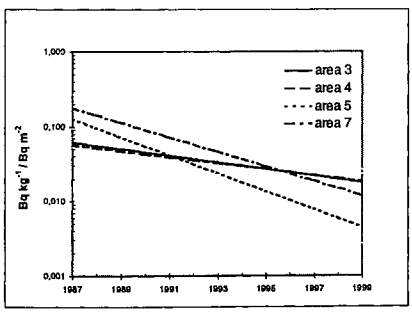

Figure 4. ^{137}Cs in freshwater fishes per unit deposition (Bq kg^{-1}/ Bq m^{-2}) in four large areas in Finland 1987-1999.

4. DISCUSSION

Results show that regional differences in the long-term behaviour of ^{137}Cs in fishes can be found, because large number of samples were included in the study. High coefficients of determination in the fittings strengthen the reliability of the results. Assumptions made on the representativeness of the sample material and limited number of samples in some areas are sources of uncertainty in the estimations. The recovery of freshwater fish from contamination by ^{137}Cs is slowest in area 4, and most rapid in area 5. Clay soils prevailing in this area binds ^{137}Cs tightly and decreases the runoff from the catchment area to the lake thus reducing the availability of ^{137}Cs to fishes.

Inside each of the areas there is large variation in ^{137}Cs in fishes from various lakes, but the figures given here express the large areas as a whole. Assumption that all the lake types, typical of each of the large areas, are included in the study, representing a variety of lake specific factors affecting transfer of ^{137}Cs, such as nutrition level, K, pH, humic status, etc. causing variation, and fish species with different feeding habits are equally and well represented in the sample material, is made. Particularly in area 7, there are not enough lakes sampled. This causes large variation in annual averages and regional results, and hence coefficients of the determinations are far more worse than in the other areas.

The study gives a generalized picture for the decrease of ^{137}Cs in fishes in various regions in Finland after the fallout based on field data. A study by Smith J.T. et al. [6] concerning lakes in Cumbria shows that parameter values of an empirical model are related to the physical characteristics of the system, in particular water residence time and mean lake depth.

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