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ABSTRACT

In 1988 and 1990 bottom sediment and surface water samples were taken from eight large lakes situated in southern and central Finland. The samples were analysed for gamma-emitting radionuclides and ^{90}Sr. The results of the gammanuclide analyses were reported earlier; this report gives the results for ^{90}Sr.

The ^{90}Sr concentrations in surface waters varied from 14 to 29 Bq m^{-3} in 1988 and from 16 to 23 Bq m^{-3} in 1990. In Lake Pielinen almost all the ^{90}Sr seemed to originate from weapons test fallout, whereas in Lakes Ontojärvi, Näsijärvi and Pyhäjärvi the share of the Chernobyl fallout was equal to that of weapons test fallout. In the sediments, the total amount of ^{90}Sr per square metre varied from 97 to 1060 Bq m^{-2} in 1988 and from 310 to 1160 Bq m^{-2} in 1990. The maximum values occurred in Lake Näsijärvi. The local amount of deposition and the type of sediment were the most important factors affecting strontium values in sediments. In addition, the large variation in total amounts of ^{90}Sr was due to other environmental factors. The total amounts of ^{90}Sr in sediments were generally of the same order of magnitude as the ^{90}Sr deposition on the ground in the area. The concentrations of ^{90}Sr in surface waters also conformed quite well to the distribution pattern of the deposition values. At some stations there was a clear maximum in a deeper sediment layer, which could be construed as a marker of the nuclear weapons tests in the 1960s.

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TIIVISTELMÄ

Vuosina 1988 ja 1990 otettiin pohjasedimentti- ja vesinäytteitä kahdeksasta suuresta Etelä- ja Keski-Suomen järvestä. Näytteistä analysoitiin gammasäteilijät ja strontium-90. Gammanuklidianalyysien tulokset on raportoitu jo aikaisemmin; tässä raportissa esitetään strontium-analyysien tulokset.

Tutkittujen järvien pintaveden strontium-90–pitoisuudet olivat 14 - 29 Bq m^{-3} vuonna 1988 ja 16 - 23 Bq m^{-3} vuonna 1990. Lähes kaikki Pielisen vedessä ollut strontium-90 näytti olevan peräisin ydinasekoelaskeumasta, kun taas Ontojärvessä, Näsijärvessä ja Pyhäjärvessä Tshernobylin laskeuman osuus oli yhtä suuri kuin yhdinasekoelaskeuman. Pohjasedimenteissä strontium-90:n kokonaismäärät olivat 97 - 1060 Bq m^{-2} vuonna 1988 ja 310 - 1160 Bq m^{-2} vuonna 1990. Suurimmat arvot olivat Näsijärvessä. Paikallinen laskeuman määrä ja sedimentin laatu olivat tärkeimmät pohjasedimenttien strontium-arvoihin vaikuttavat tekijät. Sedimenteissä olevien strontium-määrien suureen hajontaan vaikuttivat lisäksi monet muut ympäristötekijät. Yleensä järvien pohjassa olevat strontium-90–määrät olivat samaa suuruusluokkaa kuin kyseisellä alueella maalle tullut laskeuma. Myös järvien pintavesissä olleet strontium-pitoisuudet vastasivat jokseenkin hyvin Tshernobylin laskeuman alueellista jakaumaa. Eräissä havaintopaikoissa löytyi selvä strontium-piikki jostakin syvemmästä sedimenttikerroksesta, jolloin sitä voitiin käyttää 1960-luvulla suoritettujen maanpäällisten ydinasekokeiden ajoitusmerkkinä.

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1 INTRODUCTION

The input of long-lived radionuclides (such as ^{90}Sr and ^{137}Cs) into lakes is due to direct precipitation, discharge from the surface soil in the drainage area, or inflow from the preceding lake upstream in the watercourse. Run-off during the spring snowmelt is an important pathway for Cs and Sr in Finland and other Nordic countries. The Cs isotopes are predominantly transported as colloids, while ^{90}Sr is present in the form of mobile compounds with a low molecular weight (Salbu 1992). ^{90}Sr appears to be removed from lake water primarily by outflow and radioactive decay, whereas rapid settling plays a large role in the case of ^{137}Cs (Tracy 1983). The removal of ^{90}Sr from water into sediment has not been given much attention, because it has been shown that the amount of ^{90}Sr stored in the sediments of terminal lakes (Great Lakes in USA) is only a small fraction (2-6%) of the total amount of ^{90}Sr entering the lake (Lerman 1972).

The retention of ^{137}Cs in lakes can be substantial, i.e. more than 50%, while more than 90% of all ^{90}Sr can be transported downstream through the lake system (Salbu 1992). Manjón et al. (1997) showed that in some Swedish lakes at least 50% of the ^{90}Sr initially deposited in the water does not accumulate in the lake basin. In our earlier studies, we noticed that most of the ^{90}Sr deposited on the water surface remains in the water phase and does not get deposited onto the bottom as much as ^{137}Cs, which gets bound to clay particles and deposited on the bottom of lakes and rivers. The amounts of ^{90}Sr removed from catchment areas correlate very well with the percentage of lakes in the area. The removal rates of ^{137}Cs per unit area were lowest in catchment areas where the proportion of clay in soil was large and highest in catchment areas with a large proportion of bog. It has been suggested that ^{137}Cs could be adsorbed on colloidal humus substances and carried by them. A considerable proportion of ^{90}Sr was removed by runoff from land to watercourses, while ^{137}Cs was not (Salo et al. 1984).

Details of ^{90}Sr distribution in sediment cores suggest that ^{90}Sr diffuses from water into interstitial water in sediment and that it is taken up by solid phases in the sediment (Lerman, Taniguchi 1972). Since a large amount of ^{137}Cs is in a fixed state, and is less mobile than ^{90}Sr, the latter isotope is more easily washed out of the surface of the bottom deposits, leading to an increase in the Cs/Sr ratio. Irlweck (1985) stated that ^{90}Sr deposited in the

sediment has to be assigned to two fractions with differing behaviour. One part is strongly fixed in or on the sediment particles (behaviour similar to ^{137}Cs). The other part of ^{90}Sr is fairly mobile. It can be released from the sediment particles and can leave the sediment layer in which it was originally deposited through a diffusion and/or an elution process. The first result of such a process is depletion of ^{90}Sr in the lower sediment layers and its enrichment in the upper layers. Such dislocation of ^{90}Sr may be due to the action of complexing agents. HCO_3^- carboxylic acids and other degradation products of organic material in the sediments could promote desorption of radionuclides from the sediment by forming complexes; these agents would then diffuse out from the sediment into the lake water (Irlweck 1985).

This paper is part of a study reported by us earlier (STUK-A112, 1993). The amounts of radionuclides in the bottom sediments of some large Finnish lakes were studied in the late 1960s and late 1970s (Ilus, Puhakainen 1987). In 1988 and 1990 the study was repeated in the same lakes. The concentrations of gamma-emitting radionuclides in surface water and bottom sediment samples were given in our previous report. The most important factors affecting Cs values in the sediments were the local amount of deposition and the type of sediment. In 1988, the maximum concentrations of ^{137}Cs and ^{134}Cs were in the uppermost layer of the sediment (0-2cm) at almost all stations. In 1990, the Cs peaks already occurred at many stations in the second layer (2-5cm). The present report gives the results for ^{90}Sr in the same samples. It makes a valuable addition to our knowledge because only a few data have been published on Sr in sediments since the Chernobyl accident.

We are indebted to Pertti Palanne, Tero Laiho and Mirja Rosenberg for assistance in sampling, to Ulla Yli-Arvo for radiochemical analyses of the ^{90}Sr in water samples and to Irja Putkonen, Tarja Heikkinen, Taru Niskanen and Marika Ridell for ^{90}Sr analysis of the sediment samples.

2 MATERIAL AND METHODS

2.1 Sampling

In 1988 and 1990, samples of bottom sediments and surface water were taken from eight large Finnish lakes, i.e. Lakes Ontojärvi, Pielinen, Kallavesi, Konnevesi, Päijänne, Keurusselkä, Näsijärvi and Pyhäjärvi (Fig. 1). These lakes belong to four large watercourses discharging into the Baltic Sea. The locations of the sampling stations in the eight lakes are shown in Figs 2 and 3. The methods used for sampling and to describe the lakes and sediment types are explained in detail in our previous report (STUK-A112, 1993). In 1988 the sediment samples were taken by a STUK corer (tube diameter 64 mm) and in 1990 by a Limnos sampler (tube diameter 94 mm). At each station, six parallel cores were taken by the STUK corer and two parallel cores by the Limnos sampler.

The cores were sectioned into an uppermost slice of 0-2 cm, a second slice of 2-5 cm, and then into 5 cm slices down to a depth of 10-40 cm, depending on the compactness of the sediment. After each slicing the sectioning apparatus was washed with local lake water with a wash-bottle and the water was let run into the samples. The equivalent slices of the parallel cores were combined for analysis. The samples were frozen and stored in plastic bags and then freeze-dried before analysis.

The water samples were taken directly from the surface and placed in large plastic kegs. The volumes of the samples were 30 L.

2.2 Method for ^{90}Sr analysis in water

Water samples were acidified with nitric acid to pH 1-2 soon after reaching the laboratory. Before pre-treatment and analysis a known amount (20 mg) of stable Sr was added to each sample, in order to determine the chemical yield of the Sr separation. The samples were concentrated by evaporating them to a dry state. The evaporation residue was ashed at 450°C to remove any organic material. The ashed sample was dissolved and alkaline earth elements were separated by carbonate precipitation. Various precipitations were used to purify Sr from other elements in the sample matrix. Finally, after a standing period of 15 days to reach an equilibrium with ^{90}Y (the

daughter nuclide of ^{90}Sr), ^{90}Sr was determined by means of ^{90}Y by precipitating it as oxalate and measuring it with a low background beta counter. The chemical yield of Sr was obtained by determining the amount of Sr in the final solution using the atomic absorption spectrophotometric method, and comparing the result with the amount of Sr carrier added to the sample. The chemical yield for ^{90}Y was determined using a titrimetric method (EDTA - $ZnSO_4$).

2.3 Method for ^{90}Sr analysis in sediment

50-150 g of freeze-dried sediment was used to analyse ^{90}Sr. The samples were ashed at 450°C and stable Sr-carrier was added. The samples were extracted twice with 18% HCl at room temperature. The analysis method was based on the separation of ^{90}Sr through oxalate, nitrate, chromate and carbonate precipitations. ^{90}Sr was determined by means of its daughter nuclide ^{90}Y, by precipitating it as oxalate and measuring with a low background beta counter, or then ^{90}Sr and ^{90}Y were measured together after ingrowth of ^{90}Y, using a Quantulus liquid Scintillation Spectrometer and a Lumagel scintillation cocktail. The measuring time was 300 min. The DL obtained for ^{90}Sr using a Quantulus is 0.03 Bq per sample (0.2 Bq kg^{-1} for 150 g dried sample).

3 RESULTS

The concentrations of ^{90}Sr in surface water are given in Table I. In 1988, the ^{90}Sr concentrations in the water samples varied from 14 to 29 Bq m^{-3} and in 1990, from 16 to 23 Bq m^{-3}. The decrease in ^{90}Sr activity over the two years was thus 5-44%.

The activity concentrations (Bq kg^{-1}) and the amounts (Bq m^{-2}) of ^{90}Sr in different sediment layers at different sampling stations are presented in Table II, together with the depth of the sampling stations and the sampling dates. In 1988, the maximum concentration of ^{90}Sr was found in the topmost sediment layer (0-2 cm) at all the sampling stations. In 1990, the maximum concentration occurred in the second slice (2-5 cm) in Lakes Keurusselkä and Pyhäjärvi. At the other stations, the maximum concentration was still in the topmost layer.

At some stations the highest amounts of ^{90}Sr per square metre found in 1988 were in the 2-5 cm slice (Pyhäjärvi) or the 5-10 cm slice (Ontojärvi, Mulkkusaaret; Konnevesi; Päijänne, Ristiselkä; Figs 4-7). At some stations (Pielinen; Kallavesi; Päijänne, Ristiselkä and Souselkä) there were two maxima: the first maximum in the topmost layer and the other in a deeper one. In 1990, the maximum at most stations was in the second (2-5 cm) or third (5-10 cm) slice.

Table III presents the total amounts of ^{90}Sr in the sediments at different stations in different years. The total amounts of ^{90}Sr per square metre varied from 140 to 440 Bq m^{-2} in 1969 and from 210 to 960 Bq m^{-2} in 1978. In 1988, the corresponding ranges were from 97 to 1060 Bq m^{-2}, and in 1990 from 310 to 1160 Bq m^{-2}. Each year the maximum value was recorded in Lake Pyhäjärvi.

The $^{137}Cs/^{90}Sr$ ratios in surface water and bottom sediments at different sampling stations in 1988 and 1990 are given in Table IV.

4 DISCUSSION

Comprehensive data are available on ^{137}Cs deposition in Finland since the Chernobyl accident (Arvela et al. 1990). No corresponding data on ^{90}Sr are available, but a rough distribution estimate can be made, based on the results of deposition at 17 permanent sampling stations in Finland (STUK-A75, 1990). In 1986, the deposition of ^{90}Sr was highest (590 Bq m^{-2}) at Kuhmo, the station nearest to Lake Ontojärvi. In the regions of Lakes Kallavesi and Pielinen, the deposition might have been much lower, because in Kuopio ^{90}Sr deposition was about 180 Bq m^{-2} and in Joensuu only 30 Bq m^{-2}. The nearest deposition stations to the other lakes studied were Niinisalo (420 Bq m^{-2}) for Lakes Keurusselkä, Näsijärvi and Pyhäjärvi, and Jyväskylä (280 Bq m^{-2}) for the northern part of Lake Päijänne. More exact data are available only for the southern part of Lake Päijänne. Based on lichen samples taken in August 1986 from the catchment of the lake (Saxén et al. 1996) the ^{90}Sr deposition was estimated to be about 400 Bq m^{-2} there. Rantavaara and Kostiainen (1992) have reported that in Padasjoki in 1988-1989, the total amount of ^{90}Sr in mineral soil ranged from 530 to 1030 Bq m^{-2}. The deposition of ^{90}Sr caused by the Chernobyl accident was 0.7-10% of that of ^{137}Cs at various stations in Finland (STUK-A75, 1990).

The activity concentrations of ^{90}Sr in the surface water of the lakes conformed quite well to the above distribution pattern of deposition values. In 1988, the highest concentrations were 29 Bq m^{3} in Lakes Ontojärvi and Näsijärvi and 27 Bq m^{-3} in Lake Pyhäjärvi (Table I). On the other hand, the lowest concentrations were 14 Bq m^{-3} in Lake Pielinen and 19 Bq m^{-3} in Lake Kallavesi. Before the Chernobyl accident, ^{90}Sr concentrations in surface waters were 13-15 Bq m^{-3}, thus almost all the ^{90}Sr in Lake Pielinen seems to have originated from weapons test fallout. This was also reflected in the $^{137}Cs/^{90}Sr$ ratios, which were 1.4 and 1.9 in Lakes Pielinen and Kallavesi, but 13 in Lakes Kerusselkä and Päijänne at Asikkalanselkä (Table IV). The concentrations of ^{90}Sr in the water of the lakes studied decreased most rapidly in Lake Ontojärvi, with an ecological half-life of about 2 years in 1988-1990, and far more slowly in the other lakes. In 1990, the highest value in our material was 23 Bq m^{-3} in Lake Pyhäjärvi and the lowest 16 Bq m^{-3} in Lake Ontojärvi. At all the sampling stations, the $^{137}Cs/^{90}Sr$ ratio was lower in 1990 than in 1988. An example of the decreasing activity concentrations of ^{90}Sr in

bulked surface water from northeastern Finland since the Chernobyl deposition is shown in Fig. 8.

As in the case of ^{137}Cs, the water/sediment ratio of ^{90}Sr was highest in Lake Konnevesi in 1988. This was probably due to some failure in sampling, because the radionuclide concentrations in the top sediment layer were very low (STUK-A112, 1993). On the other hand, the ratio was lowest in Lake Pyhäjärvi, which could indicate rapid sedimentation of both radionuclides there. In 1990, the ratios at all the stations were much lower than in 1988, the highest value being at Asikkalanselkä in Päijänne. The total amounts of ^{90}Sr in sediments (Table III) also conformed quite well to the deposition values. In 1990 the highest values occurred in the sediments of Lakes Näsijärvi, Pyhäjärvi, Keurusselkä and Ontojärvi. In 1988, the lowest values were found in Lakes Konnevesi, Päijänne (Souselkä), Kallavesi and Pielinen.

The total amounts of ^{90}Sr in sediments were generally at the same level as the ^{90}Sr deposition on the ground. In contrast, the amounts of ^{137}Cs were almost twice as high as the corresponding deposition values at most stations (STUK-A112, 1993). Consistently, the total amounts of ^{90}Sr were generally only slightly higher in 1988-1990 than in the late 1960s and 1970s, whereas the amounts of ^{137}Cs were increased by a factor of 5 to 70 by the Chernobyl fallout. Thus, the deposition of Cs into sediments has been much more efficient than that of ^{90}Sr. This is also demonstrated by the $^{137}Cs/^{90}Sr$ ratios in sediments, which were significantly higher than those in water (Table IV). At its peak, this ratio was 240 in the sediment of Lake Pyhäjärvi, in 1990. Lake Pyhäjärvi is heavily loaded by industrial effluents and sewage from the city of Tampere. In our previous report we assumed that the type of sediment was the main reason why the highest amounts of ^{137}Cs have regularly occurred in Lake Pyhäjärvi. The same reason may also be valid in the case of ^{90}Sr, although the total amounts in Lake Näsijärvi were estimated to be somewhat higher.

The vertical profiles of ^{90}Sr (Figs 4-7) show that in 1988 there was a clear maximum in the uppermost sediment layer (0-2 cm) at many stations. In general, Sr was found in much deeper layers than Cs; i.e. down to 30 or 35 cm. This is partly due to the lower detection limit of the Sr analysis, but it may also be due to downwards diffusion, because Sr is more mobile in sediments than Cs. At some stations there was a clear maximum in deeper layers, and this could be construed as a marker of the weapons test fallout in

the 1960s. In 1990, a distinct Sr peak already occurred at many stations in the second (2-5 cm), or even third (5-10 cm), sediment layer, indicating a high sediment accumulation rate (e.g. Lake Pyhäjärvi).

5 CONCLUSIONS

The local amount of deposition and the type of sediment were the most important factors affecting the Sr values in sediments. In addition, the large variation in total amounts of ^{90}Sr at various stations was due to other environmental factors. The total amounts of ^{90}Sr in sediments were generally of the same magnitude as the ^{90}Sr deposition on the ground in the area. The concentrations of ^{90}Sr in surface waters also conformed quite well to the distribution pattern of the deposition values. At some stations there was a clear maximum in a deeper sediment layer, which could be construed as a marker of the nuclear weapons test fallout in the 1960s.

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Figure 1. *Location of the lakes studied. A = Ontojärvi, B = Pielinen, C = Kallavesi, D = Konnevesi, E = Päijänne, F = Keurusselkä, G = Näsijärvi, H = Pyhäjärvi.*

Figure 2. *Location of the sampling stations in Lakes Ontojärvi, Pielinen, Kallavesi and Konnevesi.*

Figure 3. *Location of the sampling stations in Lakes Päijänne, Keurusselkä, Näsijärvi and Pyhäjärvi (on the left).*

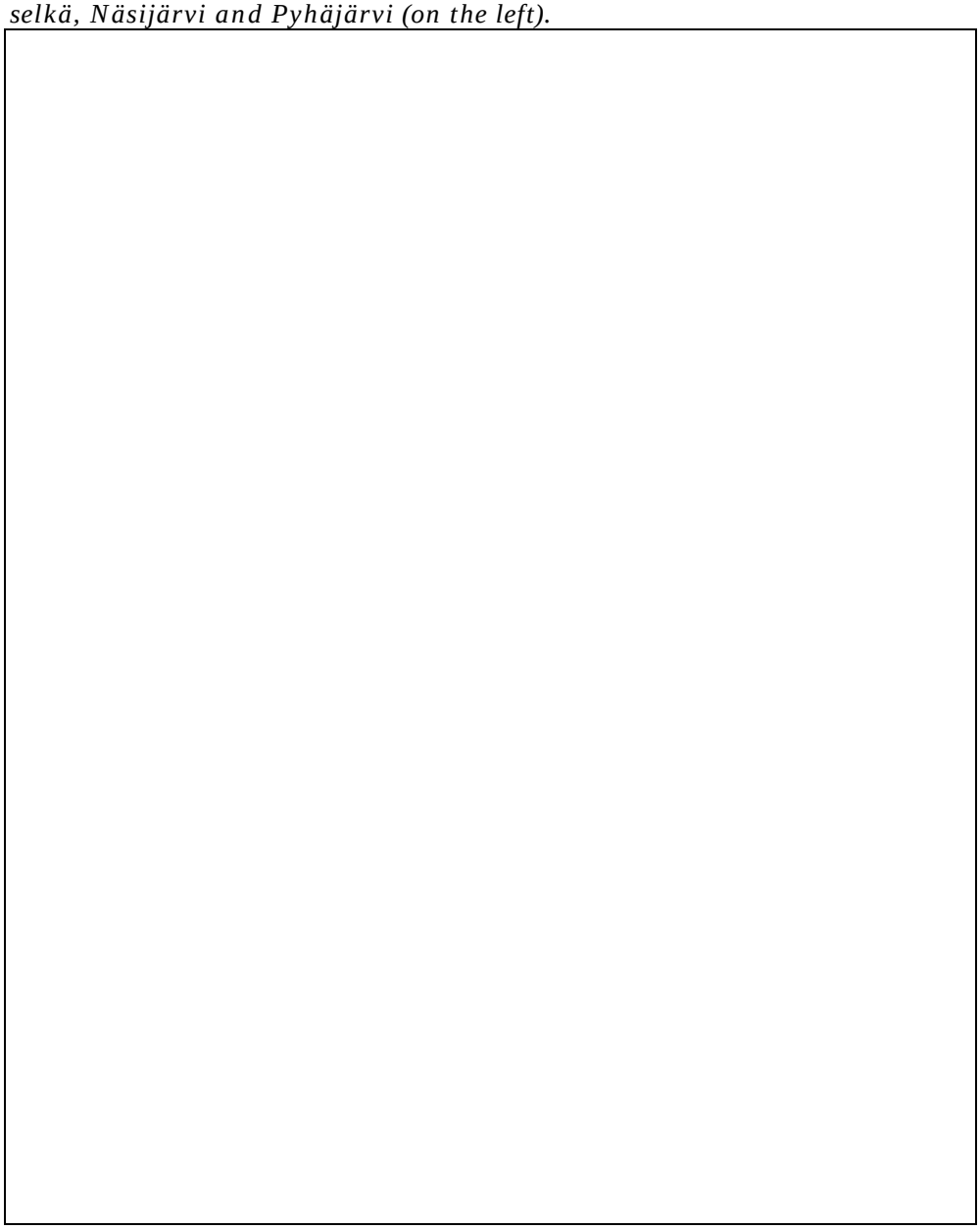

Figure 4. *Vertical distribution of ^{90}Sr (Bq m^{-2}) in bottom sediments at stations 3, 4, 6, 7, 8 and 12 in 1988.*

Figure. 5. *Vertical distribution of ^{90}Sr (Bq m^{-2}) in bottom sediments at stations 1, 2 and 5 in 1988 and 1990.*

Figure 6. *Vertical distribution of ^{90}Sr (Bq m^{-2}) in bottom sediments at stations 9, 10 and 11 in 1988 and 1990.*

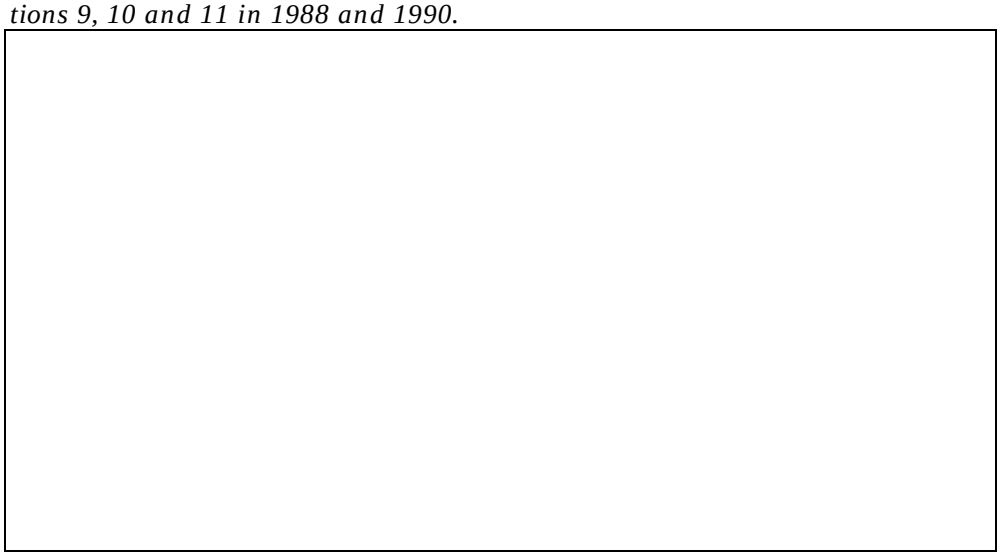

Figure 7. *Vertical distribution of ^{90}Sr (Bq m^{-2}) in bottom sediments at station 13 in 1988 and 1990.*

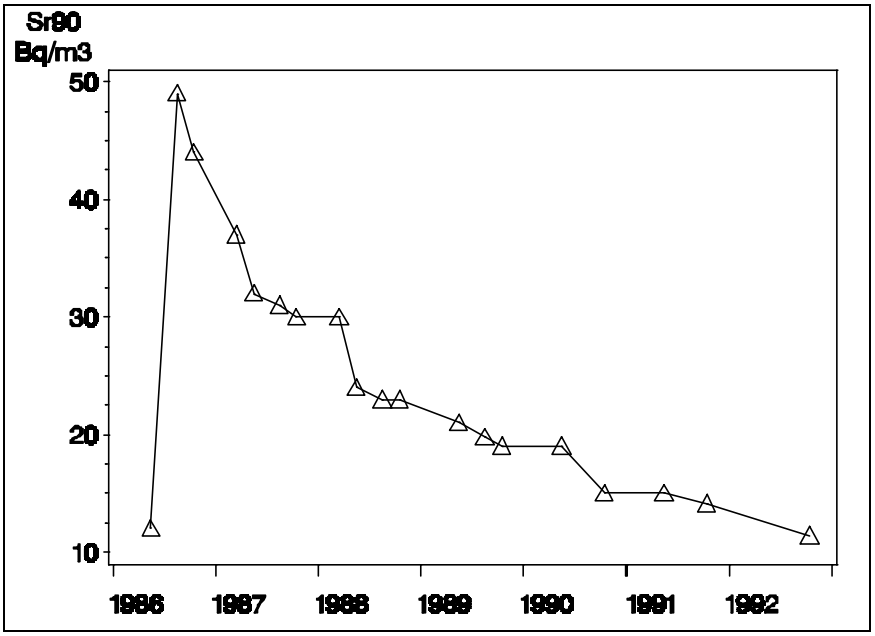

Figure 8. *Changes in activity concentrations of ^{90}Sr (Bq m^{-3}) in bulked surface water samples taken from northeastern Finland (includes Lake Ontojärvi) since the Chernobyl fallout.*

Table I. *^{90}Sr in lake water samples (Bq m^{-3}) in 1988 and 1990. Samples were taken in August - September.*

Lake	**Sampling station**	**^{90}Sr**	
		1988	**1990**
Ontojärvi	Mulkkusaaret	29	16
Pielinen	Suurselkä	14	
Kallavesi	Muuraissaaret	19	
Konnevesi	Konneselkä	28	20
Päijänne	Ristiselkä	22	
Päijänne	Asikkalanselkä	22	21
Keurusselkä	Vuolleselkä	24	19
Näsijärvi	Näsiselkä	29	21
Pyhäjärvi	Lehtisaari	27	23

Table II. *The concentration (Bq kg^{-1} dry weight) and amount (Bq m^{-2}) of ^{90}Sr in sediment samples at different sampling stations in 1988 and 1990.*

Lake **Sampling station**	**Layer**	**^{90}Sr** **1988**		**1990**	
	cm	**Bq kg^{-1}**	**Bq m^{-2}**	**Bq kg^{-1}**	**Bq kg^{-2}**
Ontojärvi					
Merjanselkä	0-2	65	150	44	85
12.3 m	2-5	18	120	34	180
2.8.88	5-10	13	120	11	130
	10-15	8.1	63	7.2	56
12.5 m	15-20	4.3	29	3.6	26
21.8.90	20-25	1.4	9.6	1.0	8.2
	25-30	0.39	2.9	0.06	1.1
	total		**490**		**490**
Ontojärvi					
Mulk-	0-2	27	41	300	230
kusaaret	2-5	19	49	120	230
24.4 m	5-10	11	53	41	170
2.8.88					
	10-15	8.4	38	10	59
25.0 m	15-20	3.7	16	6.1	34
21.8.90	20-25	1.3	5.9	5.0	26
	25-30	0.58	2.7	1.8	9.0
	total		**205**		**760**
Pielinen					
Suurselkä	0-2	25	67	-	-
29.5 m	2-5	3.0	20	-	-
3.8.88	5-10	3.3	49	-	-
	10-15	2.8	41	-	-
	15-20	2.3	33	-	-
	20-25	0.94	13	-	-
	25-30	0.53	8.1	-	-
	30-35	0.05	0.8	-	-
	total		**230**		

Table II *cont.*

Lake	Layer	^{90}Sr			
Sampling		1988		1990	
station	cm	Bq kg^{-1}	Bq m^{-2}	Bq kg^{-1}	Bq kg^{-2}
Kallavesi					
Muurais-	0-2	27	49	-	-
saaret	2-5	9.7	38	-	-
32.2 m	5-10	2.2	20	-	-
4.8.88					
	10-15	4.0	36	-	-
	15-20	4.9	40	-	-
	20-25	1.6	12	-	-
	25-30	0.78	5.6	-	-
	30-35	0.30	2.1	-	-
	total		**200**		
Konnevesi					
Konneselkä	0–2	12	18	71	52
40.0 m	2-5	10	26	-	(62)
4.8.88	5-10	8.1	31	22	71
	10-15	2.6	9.8	12	51
50.0 m	15-20	1.6	5.8	8.2	37
22.8.90	20-25	0.89	3.3	5.5	25
	25-30	0.85	3.1	2.8	13
	30-35	-	-	-	-
	total		**97**		**310**
Päijänne					
Ristiselkä	0-2	27	55	-	-
45.0 m	2-5	10	41	-	-
7.9.88	5-10	5.6	60	-	-
	10-15	2.1	45	-	-
	15-20	1.1	35	-	-
	20-25	0.83	21	-	-
	25-30	0.79	14	-	-
	30-35	0.37	5.6	-	-
	total		**280**		

Table II *cont.*

Lake	Layer	^{90}Sr			
Sampling		1988		1990	
station	cm	Bq kg^{-1}	Bq m^{-2}	Bq kg^{-1}	Bq kg^{-2}
Päijänne					
Souselkä	0-2	17	48	-	-
41.0 m	2-5	3.1	20	-	-
5.8.88	5-10	2.3	41	-	-
	10-15	2.0	36	-	-
	15-20	2.3	26	-	-
	20-25	1.4	14	-	-
	25-30	0.63	6.2	-	-
	30-35	0.17	1.8	-	-
	35-40	-	-	-	-
	total		**190**		
Päijänne					
Tehinselkä	0-2	170	290	-	-
35.2 m	2-5	25	130	-	-
6.9.88	5-10	4.6	44	-	-
	10-15	5.1	41	-	-
	15-20	3.6	31	-	-
	20-25	1.1	10	-	-
	25-30	0.70	6.6	-	-
	30-35	0.23	2.4	-	-
	total		**550**		
Päijänne					
Asikkalan-	0-2	61	130	86	140
selkä	2-5	14	83	30	140
40.0 m	5-10	4.3	68	7.0	110
6.9.88					
	10-15	3.2	44	3.8	46
41.0 m	15-20	2.2	23	2.3	22
24.8.90	20-25	0.97	8.7	-	-
	25-30	0.38	3.2	-	-
	30-35	0.08	0.7	-	-
	total		**360**		**450**

Table II *cont.*

Lake	Layer	^{90}Sr			
Sampling		1988		1990	
station	cm	Bq kg^{-1}	Bq m^{-2}	Bq kg^{-1}	Bq kg^{-2}
Keurus-selkä					
Vuolleselkä	0-2	77	96	70	57
16.1 m	2-5	23	68	250	510
13.7.88	5-10	8.6	68	45	240
	10-15	4.9	45	6.1	52
15.2 m	15-20	2.6	22	3.6	34
3.8.90	20-25	1.1	6.7	3.1	29
	25-30	0.32	1.9	-	-
	total		**310**		**920**
Näsijärvi					
Näsiselkä	0-2	380	650	240	270
31.0 m	2-5	-	(180)	-	(690)
8.9.88	5-10	17	110	18	100
	10-15	4.6	57	4.3	46
30.0 m	15-20	2.7	31	2.5	25
23.8.90	20-25	1.9	20	2.2	22
	25-30	1.2	10	1.5	12
	30-35	0.32	3.0	-	-
	total		**(1060)**		**(1160)**
Näsijärvi					
Siilinkari	0-2	130	270	-	-
18.0 m	2-5	31	180	-	-
8.9.88	5-10	3.6	42	-	-
	10-15	4.0	46	-	-
	15-20	2.4	26	-	-
	20-25	2.4	20	-	-
	25-30	1.4	12	-	-
	total		**600**		

Table II *cont.*

Lake	Layer	^{90}Sr			
Sampling		1988		1990	
station	cm	Bq kg^{-1}	Bq m^{-2}	Bq kg^{-1}	Bq kg^{-2}
Pyhäjärvi					
Lehtisaari	0-2	120	310	52	110
26.0 m	2-5	62	430	70	440
9.9.88	5-10	11	140	37	490
	10-14	7.1	150	-	-
27.0 m	**total**		**1030**		**1040**
23.8.90					

Values in parentheses are calculated using the estimated ^{90}Sr/^{137}Cs ratios.

***Table III**. The total amounts of ^{90}Sr in bottom sediments (Bq m^{-2}) in 1969, 1978, 1988 and 1990.*

Lake Sampling station	Bq m^{-2} 1969	1978	1988	1990
Ontojärvi				
Merjanselkä	330	340	490	480
Mulkkusaaret	-	210	205	760
Pielinen				
Suurselkä	-	-	230	-
Kallavesi				
Muuraissaaret	-	-	200	-
Konnevesi				
Konneselkä	-	-	97	(310)
Päijänne				
Ristiselkä	200	300	280	-
Souselkä	140	300	190	-
Tehinselkä	140	310	550	-
Asikkalanselkä	340	220	360	450
Keurusselkä				
Vuolleselkä	-	-	310	920
Näsijärvi				
Näsiselkä	190	470	(1060)	(1160)
Siilinkari	-	320	600	-
Pyhäjärvi				
Lehtisaari	440	960	1030	1040

Values in parentheses are calculated using the estimated $^{90}Sr/^{137}Cs$ ratios.

***Table IV**. The ratio of ^{137}Cs to ^{90}Sr in surface waters (Bq m^{-3}) and in total bottom sediments (Bq m^{-2}) in 1988 and 1990.*

Lake Sampling station	$^{137}Cs/^{90}Sr$ ratio In water		In sediment	
	1988	**1990**	**1988**	**1990**
Ontojärvi				
Merjanselkä	-	-	20	29
Mulkkusaaret	5.6	4.8	11	18.5
Pielinen				
Suurselkä	1.4	-	12	-
Kallavesi				
Muuraissaaret	1.9	-	19	-
Konnevesi				
Konneselkä	10	7.7	11	(150)
Päijänne				
Ristiselkä	7.7	-	43	-
Souselkä	-	-	20	-
Tehinselkä	-	-	29	-
Asikkalanselkä	13	7.7	140	200
Keurusselkä				
Vuolleselkä	13	9.1	62	140
Näsijärvi				
Näsiselkä	10	7.7	(100)	(95)
Siilinkari	-	-	180	-
Pyhäjärvi				
Lehtisaari	9.1	6.7	160	240

Values in parentheses are calculated using the estimated $^{90}Sr/^{137}Cs$ ratios.

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