Bull. Environm. Contam. Toxicol. 20, 332-339 (1978)

Mercury in Sediments of Lake Päijänne, Finland

Jukka Särkkä[1], Marja Liisa Hattula[2], Jorma Janatuinen[1], and Jaakko Paasivirta[2]
[1]Department of Biology, [2]Department of Chemistry, University of Jyväskylä, SF-40100 Jyväskylä 10, Finland

This investigation is a part of a residue study of food webs of Lake Päijänne, Finland. In this paper in which only the mercury in the sediment is considered, also depth zones and different sediment layers were compared. This material, however, is not big enough to map out the mercury contents in the same manner as has been done in North American or Swedish lakes (THOMAS 1972, 1973, WALTERS et al. 1974, WOLERY et al. 1974, HÅKANSON 1974, 1975, THOMAS & JACQUET 1976).

Mercury has been discharged into Lake Päijänne, especially to stations 1 and 2 (Figure 1) and by a pulp mill situating upstreams into the northern part of the lake. Mercury has been used as slimicides by pulp and paper industry till year 1968 and it appears also as impurity in caustic soda. The losses of mercury into waters from pulp and paper industry in Finland were between 1953 and 1966 about 4.1 tons per year (HÄSÄNEN 1973). On the basis of the production numbers of the industry about 20% of this amount can be estimated to have got into Lake Päijänne. The direction of the flowing of water is from north to south and the greatest inflow is into the most northern end of the lake. The quality of the water has been considered e.g. by SÄRKKÄ (1975).

MATERIALS AND METHODS

The samples were taken in summers 1972, -73 and -74 with a Kajak corer made of plexiglass (HAKALA 1971) having a diameter of 45 mm. For the analyses 5 cm high columns were cut from the surface of the sediment except for 1973 when the sediment column was divided into the layers of 0-2 cm and 2-7 cm from the surface. Samples were taken from sublittoral (2-7 m) and profundal depths, maximum depth was 56 m. In 1974 sampling was done from several depths in lines between the shore and the maximum depth. The samples were conserved frozen. The drying was done in +100°C for 24 hours. The mercury analyses were carried out with a flameless atomic absorption spectrophotometer Coleman MAS-50 by the procedure of HATCH & OTT (1968).

0007-4861/78/0020-0332 $01.60

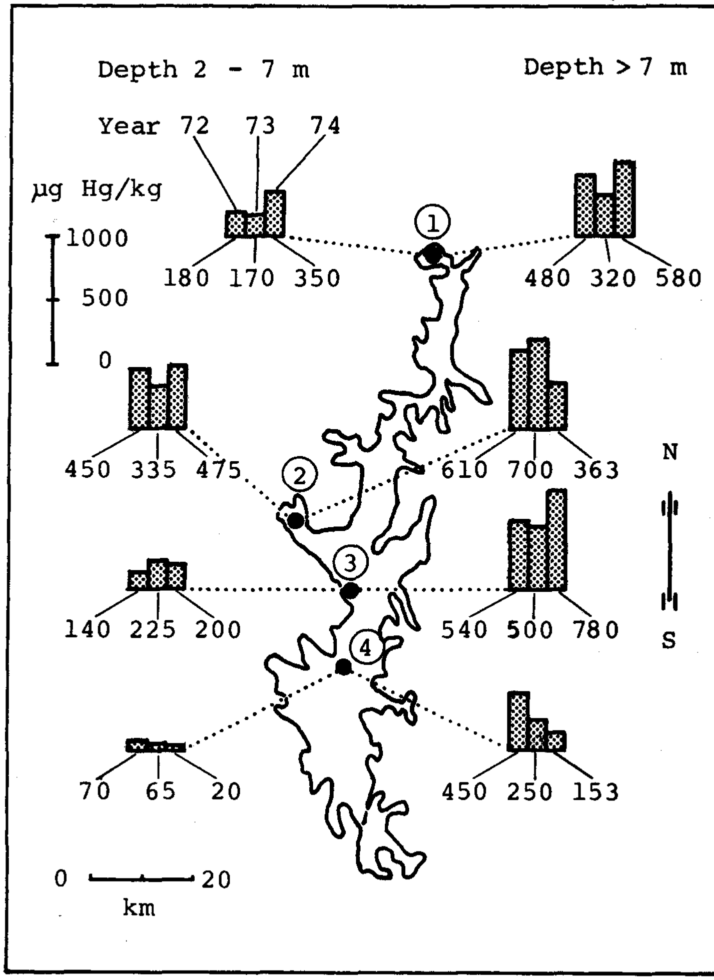

FIGURE 1. Lake Päijänne with the sampling stations (1-4) and the regional average contents of mercury µg/kg dry weight in different years (1972-74) in depth zones 2-7 m (left) and 8 m or more (right).

RESULTS

The mercury contents for the whole material is presented in Table 1 as wet and dry weight values. In Figure 1 is presented the average contents of mercury for each of the four stations, in three years of investigation in the sublittoral zone (2-7 m) and deeper (8 m or more) zone. The differences between the years which are shown in Figure 2, however, are not significant according to Kruskal-Wallis one-way analyses of variance and t-tests. The regional differences shown in Figure 1, on the contrary, are significant according to the Kruskal-Wallis test in the sublittoral zone on the significance level of $p < 0.01$, in the deeper zone with $p < 0.005$. The data from different years were combined to a series of parallel samples for each of the stations. According to t-tests, particularly the mean of sublittoral zone of stat. 2 differed significantly from the corresponding values of the other stations: from stat. 1 and 2 ($p < 0.05$) and from stat. 4 ($p < 0.001$). Also the difference between stat. 1 and 4 was significant ($p < 0.05$). In the deeper zone the only significant regional difference was found between stat. 3 and 4 ($p < 0.01$).

In Table 2 are presented the maximum and minimum values, means and standard deviations for the whole material. When the means of the contents in shallow (< 8 m) and deep water were compared with each other (Table 3), it was seen that according to t-test the mercury concentration was on an average in the deeper zone significantly greater than in the shallower zone except for stat. 2.

For the material sampled in 1974 from vertical lines regression coefficient and its significance was calculated for the dependence of the mercury contents on the depth. This dependence was significant on stat. 1 only ($p < 0.01$) where the mercury contents was increasing with the depth. A corresponding increasing with depth or when the sediment becomes finer has been shown e.g. by THOMAS (1972, 1973), VERNET & THOMAS (1972a) and THOMAS & JACQUET (1976).

In Figure 2 the contents of the uppest 2 cm and the deeper layers has been compared. In this figure also the average rate of sedimentation in different stations, nearest in the profundal depths, is presented according to GRANBERG & LAPPALAINEN (1974), MÄKINEN et al. (1975) and MÄKINEN (1976). On the basis of these numbers it can be calculated that the two uppest centimeters correspond at stat. 1 the sedimentation which occurred only during 3-4 years before the sampling year (1973), at stat. 2 about 5-6 years, at stat. 3 about 15 years and at stat. 4 about 60-200 years, respectively. Thus, at stat. 1 the whole upper layer of the profundal depths represents a period at which time mercury was not discharged into the lake, according to the own report of the industry. Considering this, the contents observed can be regarded as high. The mercury contents at stat. 2 seems already to be decreasing. At stat. 3 and 4 the uppest layer includes the sediment originating from the period of the most powerful usage which obviously has resulted in the greater contents in the upper than lower layer.

TABLE 1

Contents of mercury in the sediment samples from Lake Päijänne. Stations see Figure 1.

Stat. no	Depth m	Layer cm	Day	Month	Year	Hg mg/kg Wet weight	Hg mg/kg Dry weight
1	5	0-5	11	8	72	0.07	0.18
1	18	0-5	11	8	72	0.09	0.48
2	7	0-5	1	8	72	0.22	0.45
2	34	0-5	1	8	72	0.26	0.61
3	5	0-5	2	8	72	0.05	0.14
3	32	0-5	2	8	72	0.13	0.54
4	5	0-5	2	8	72	0.07	0.07
4	37	0-5	2	8	72	0.45	0.45
1	4	0-2	3	9	73	0.05	0.12
1	4	2-7	3	9	73	0.11	0.21
1	16	0-2	3	9	73	0.07	0.32
1	16	2-7	3	9	73	0.09	0.32
2	5	0-2	2	8	73	0.13	0.32
2	5	2-7	2	8	73	0.16	0.35
2	31	0-2	2	8	73	0.08	0.31
2	31	2-7	2	8	73	0.42	1.09
3	5	0-2	2	8	73	0.08	0.37
3	5	2-7	2	8	73	0.03	0.08
3	35	0-2	2	8	73	0.07	0.54
3	35	2-7	2	8	73	0.11	0.46
4	5	0-2	31	7	73	0.04	0.11
4	5	2-7	31	7	73	0.01	0.02
4	32	0-2	31	7	73	0.08	0.37
4	32	2-7	31	7	73	0.03	0.13
1	2	0-5	23	8	74	0.06	0.48
1	5	0-5	23	8	74	0.10	0.22
1	8	0-5	23	8	74	0.08	0.58
1	12	0-5	23	8	74	0.08	0.40
1	18	0-5	23	8	74	0.12	0.76
2	2	0-5	19	8	74	0.14	0.45
2	4	0-5	19	8	74	0.20	0.50
2	8	0-5	19	8	74	0.11	0.30
2	11	0-5	19	8	74	0.11	0.43
2	12	0-5	19	8	74	0.09	0.27
2	17	0-5	19	8	74	0.09	0.28
2	18	0-5	19	8	74	0.12	0.40
2	20	0-5	19	8	74	0.10	0.38
2	25	0-5	19	8	74	0.10	0.42
2	33	0-5	19	8	74	0.12	0.42
3	5	0-5	21	8	74	0.07	0.20
3	30	0-5	21	8	74	0.19	0.70
3	56	0-5	21	8	74	0.22	0.86
4	5	0-5	21	8	74	0.01	0.02
4	10	0-5	21	8	74	0.03	0.07
4	20	0-5	21	8	74	0.04	0.11
4	29	0-5	21	8	74	0.06	0.28

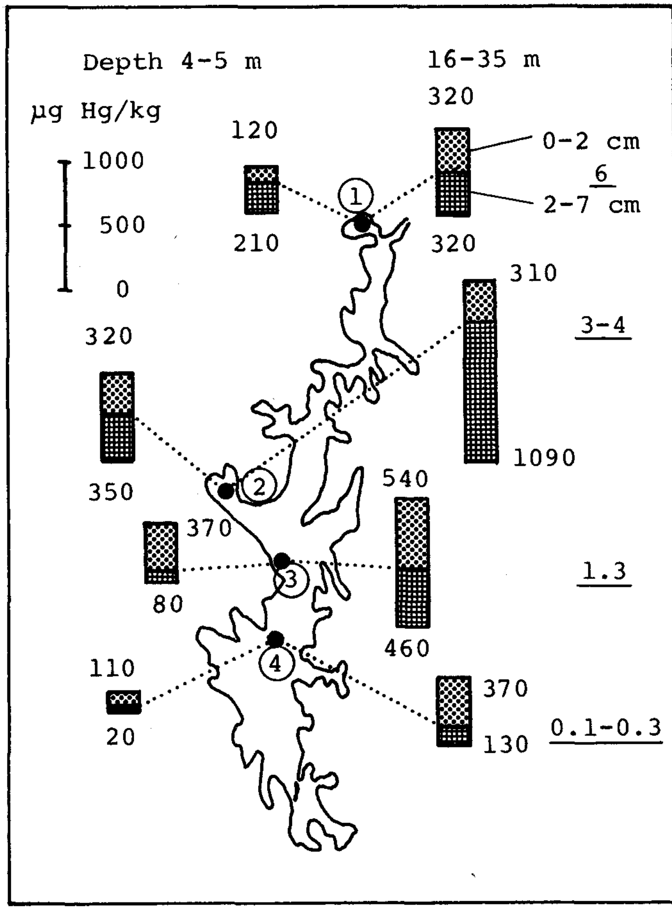

FIGURE 2. Contents of mercury µg/kg dry weight in layers of 0-2 cm and 2-7 cm below the surface of the sediment at different stations and in two depth zones. The underlined numbers on the right indicate the sedimentation rates mm/year.

TABLE 2

Maximum and minimum values, means and standard deviations (S.D.) of the contents of mercury in the sediment samples from Lake Päijänne.

	mg Hg/kg wet weight	mg Hg/kg dry weight
Max.	0.42	1.09
Min.	0.01	0.02
Mean	0.104	0.360
S.D.	0.073	0.222
n	46	46

TABLE 3

Average regional contents of mercury mg/kg dry weight in sediment of sublittoral (2-7 m) and profundal (8-56 m) depth zones. Stations as in Figure 1.

		Stations			
		1	2	3	4
	Mean	0.24	0.41	0.20	0.06
Sublittoral	S.D.	0.14	0.08	0.13	0.04
	n	5	5	4	4
	Mean	0.48	0.45	0.62	0.24
Profundal	S.D.	0.17	0.23	0.16	0.16
	n	6	11	5	6

DISCUSSION

As background mercury contents of lake sediments are generally regarded concentrations of the order of about 10-100 µg/kg dry weight (e.g. HASSELROT 1968, VERNET & THOMAS 1972b, SYERS et al. 1973, WALTERS et al. 1974). In Lake Päijänne the contents of this order of magnitude can be found nearest at stat. 4 in sublittoral depths (Figure 1) and in the deeper layer of sublittoral zone of stat. 3 and 4 (Figure 2). Also the value of the deeper layer of the profundal sample from stat. 4 (Figure 2) probably indicates the natural level in this lake. The highest contents in Päijänne (maximum 1 090 µg/kg) is smaller than the high contents in several other investigations in polluted regions which usually vary approximately between 2 800 and 86 000 µg/kg dry weight (HASSELROT 1968, JERNELÖV & LANN 1971, HOLDEN 1972, PILLAY et al. 1972, BLACKBURN 1973, SYERS et al. 1973, HÅKANSON 1975). In Japan the maximum was even 801 000 µg/kg (HOLDEN 1972). Very many other investigations from the mercury contents of the bottom sediments have been carried out but unfortunately it is not often clear whether the results concern dry or wet values.

The mercury contents of the upper layer at the regions of strong sedimentation (stat. 1 and 2, Figure 2) which are much higher than the natural contents can be to a certain extent also a consequence of the transferring of mercury from the deeper sediment layers towards the surface. This kind of phenomenon was observed experimentally by JERNELÖV (1970). In the considering of these layers, however, also the fact should be noted that the division of the material into thinner layers could perhaps reveal still higher contents. On the basis of the sedimentation rates the highest contents in the profundal depth zone ought to be found at stat. 1 about in depth of 3-13 cm, at stat. 2 in 2-8 cm, at stat. 3 in 1-3 cm and at stat. 4 about in 0.1-0.6 cm depth. The profundal values in Figure 2 agree with these depths with the exception of stat. 1.

If it is assumed that during the period when mercury was used in slimicides (1953-1968), 20% of 4.1 tons, about 820 kg Hg has been discharged yearly into Lake Päijänne. If the amount is calculated evenly over the whole area (1 090 km^2) of the lake this is equal to 750 µg Hg/m^2/year. A rough estimate of the average rate of sedimentation for the whole lake is about 0.6 mm/year or 600 g/m^2/year as wet weight. In the present material dry weight corresponds on an average 0.32 times wet weight which corresponds the sedimentation of 192 g/m^2/year as dry weight. These sediment layers ought to contain mercury if it were distributed evenly, 750 µg/192 g = 3.9 µg/g = 3 900 µg/kg. The mean for the whole material was, however, 360 µg/kg (Table 2), the mean for the upper layer in profundal depths was 340 µg/kg (Figure 2) and for the lower layer 610 µg/kg. The results show that the average contents and even the maximum values observed are much smaller than this "approximated" mean. The highest contents of mercury was expected to be found in the lower layers of station 1 and 2. This was the case but the maximum level found was only 1 090 µg/kg. Thus a great part of the mercury released into this lake obviously has not settled into the sediment. The more or less high contents of mercury in different levels of food chain, in plankton, zoobenthos, aquatic plants, fish and birds which are considered in papers to be published later, support the assumption that only a part of the total mercury flow has got into the sediment.

The high contents with regard to the probable natural level found in profundal depths (Figure 1, Figure 2 surface layer) at stat. 3 and 4, however, show that mercury has been transferred in Lake Päijänne into the sediment considerable far from the origin of pollution from the stations 1 and 2.

ACKNOWLEDGEMENTS

This study was financed by the Academy of Finland, Council of the Natural Sciences.

REFERENCES

BLACKBURN, T.R.: Schweiz. Ztschr. Hydrol. 35, 201 (1973).

GRANBERG, K. and M. LAPPALAINEN: Hydrobiol. Res. Inst. Jyväskylä Rep. 51, 1 (1974).

HAKALA, I.: Ann. Zool. Fenn. 8, 422 (1971).

HÅKANSON, L.: Ambio 3, 37 (1974).

HÅKANSON, L.: SNV PM S63 NLU Rep. 80, 1 (1975).

HÄSÄNEN, E.: Limnologisymposion 1969, 33 (1973).

HASSELROT, T.B.: Rep. Inst. Freshw. Res. Drottningholm 48, 102 (1968).

HATCH, W.R. and W.L. OTT: Anal. Chem. 40, 2085 (1968).

HOLDEN, A.V.: IAEA Techn. Rep. Ser. 137, 143 (1972).

JERNELÖV, A.: Limnol. Oceanogr. 15, 958 (1970).

JERNELÖV, A. and H. LANN: Oikos 22, 403 (1971).

MÄKINEN, P., K. GRANBERG and M.K. LAPPALAINEN: Hydrobiol. Res. Inst. Jyväskylä Rep. 53, 1 (1975).

MÄKINEN, P.: Hydrobiol. Res. Inst. Jyväskylä Rep. 69, 1 (1976).

PILLAY, K.K.S., C.C. THOMAS, Jr., J.A. SONDEL and C.M. HYCHE: Environ. Res. 5, 172 (1972).

SÄRKKÄ, J.: Aqua Fenn. 1975, 3 (1975).

SYERS, J.K., J.K. ISKANDER and D.R. KEENEY: Water, Air, Soil Pollut. 2, 105 (1973).

THOMAS, R.L.: Can. J. Earth Sci. 9, 636 (1972).

THOMAS, R.L.: Can. J. Earth Sci. 10, 194 (1973).

THOMAS, R.L. and J.-M. JACQUET: J. Fish. Res. Board Can. 33, 404 (1976).

VERNET, J.-P. and R.L. THOMAS: Eclogae Geol. Helv. 65, 307 (1972a).

VERNET, J.-P. and R.L. THOMAS: Eclogae Geol. Helv. 65, 293 (1972b).

WALTERS, L.J., Jr., T.L. KOVACIK and C.E. HERDENDORF: Ohio J. Sci. 74, 1 (1974).

WOLERY, T.J. and L.J. WALTERS, Jr.: Proc. 17th Conf. Great Lakes Res. 1974, 235 (1974).