VESIENTUTKIMUSLAITOKSEN JULKAISUJA
PUBLICATIONS OF THE WATER RESEARCH INSTITUTE 7

PENTTI ALHONEN & VEIJO MIETTINEN & ERKKI HÄSÄNEN

# MERCURY IN AQUATIC SEDIMENTS OF THREE POLLUTED AREAS IN FINLAND

Seloste

**Pohjan elohopeapitoisuus eräillä likaantuneilla vesialueilla**

VESIHALLITUS — NATIONAL BOARD OF WATERS, FINLAND
Helsinki 1973

CONTENTS


Abstract

1. Introduction

2. Methods

3. Description of the investigated areas
3.1 Oulu
3.2 Pihlavanlahti
3.3 Tammijärvi

4. Description of the cores and their mercury content
4.1 Oulu
4.2 Pihlavanlahti
4.3 Tammijärvi

5. Conclusions and discussion

6. Mercury content in fish

References

Seloste



ISBN 951-46-0688-4

Helsinki 1973. Valtion painatuskeskus

ABSTRACT

The vertical distribution of mercury in recent sediments was studied on 24 cores from three polluted sites in Finland. The material indicates that the maximum thickness of the mercury-contaminated layer is about 5 cm in the sea area off Oulu, 8 cm in the bay Pihlavanlahti and 10 cm in the lake Tammijärvi. The mercury content per kilo dry matter in the uppermost analysed surface samples varied from 1.3 to 98 mg in the cores of the Oulu area, from 0.1 to 3.7 mg in those of Pihlavanlahti and from 0.5 to 3.0 mg in those of Tammijärvi. The greatest mercury values in Oulu were found in the immediate vicinity of the outfall of factory effluent and clearly declined with distance from the drain. In Pihlavanlahti and Tammijärvi the mercury content of the surface sample is more evenly distributed. A declining tendency can be observed in the amounts of mercury outside Oulu, probably reflecting a decrease of mercury in industrial effluents. The deposition of mercury in Pihlavanlahti and Tammijärvi does not show any notable fluctuations. Attention is paid to the significance of the mercury-polluted sediments as a potential substrate for the methylation activity of certain micro-organisms. The mean mercury contents of pike, perch and burbot in 1967, 1968 and 1970 are also given in this report.

## 1. INTRODUCTION

The main purpose of the present report is to study the vertical distribution of mercury in the surface sediments of three mercury-polluted areas in Finland, and at the same time to give some quatitative data on its deposition. In these three types of sites mercury is discharged to the waters with industrial wastes, and the previous Finnish investigations have concentrated on the mercury contents in fishes and some other animals (see e.g. Häsänen and Sjöblom 1968; Helminen, Karppanen and Koivisto 1968; Sjöblom and Häsänen 1969; Nuorteva and Häsänen 1971, 1972). This report is intended to contribute to the information on the behaviour of mercury in aquatic media, particularly in the bottom sediments. It is also a geological approach to an interesting and significant problem of environmental science: the toxic effects on Man of waterborne mercury are now well known under the name "Minamata Disease" (e.g. Kurland, Faro and Siedler 1960).

14169–73

Norrman (1971) has reported high mercury contents in the sediments in the south of Lake Vättern in Sweden, and important investigations on the relation between mercury distribution and the sedimentological environment have recently been made by Axelsson and Håkanson (1972) and Håkanson (1972) in Lake Ekoln, situated some 10 km south of the town Uppsala.

Pentti Alhonen [1.] is responsible for the geological part of the study, Veijo Miettinen [2.] wrote the mercury content in fish and Erkki Häsänen [3.] made the mercury determinations of this material.

## 2. METHODS

Cores were obtained with the gravity sampler (length of plexiglass tube 50 cm, diameter 5 cm). Small samples were taken from them and put into plastic bottles for analysis. The identifications of the bottom sediments were made during the field work. A sampler of the Ekman-Birge type was also used outside Oulu. The mercury determination was performed by neutron activation analysis in the Reactor Laboratory, Technical Research Centre of Finland, Otaniemi, on the basis of the principles described in detail by Häsänen (1970). The results are given as mg/kg dry matter.

## 3. DESCRIPTION OF THE INVESTIGATED AREAS

Fig. 1 shows the investigated areas.

### 3.1 OULU

Fig. 2 shows the sampling sites in the brackish water area off Oulu. The area receives fresh water from the river Oulujoki. The salinity in the northern parts of the Gulf of Bothnia is about 3 o/oo. The study area receives various industrial wastes and domestic

---

1. Department of Geology and Palaeontology, University of Helsinki and Water Research Institute, National Board of Waters, Helsinki
2. Water Research Institute, National Board of Waters, Helsinki
3. Reactor Laboratory, Technical Research Centre of Finland, Otaniemi

sewage. The extent of the heavily polluted area is about 25 $km^2$ and indications of pollution can be found over an area of 60 $km^2$ (Karimo, Leskelä, Mikola and Ryhänen 1970, p. 193). In summer 1969 a mass death of fish was observed. The distribution of the pollution is shown in the map in Fig. 2.

In summer 1970 the oxygen saturation near the bottom in the main part of the investigated area was 79-88 per cent. The primary productivity at this time ranged from 62 to 849 mg $C_{ass.}/m^3$ per day. The greatest value measured is from the bay Kempeleenlahti, where the conductivity near the bottom was 2 610-2 620 µS (Oy Keskuslaboratorio Ab, 1971. Oulun kaupungin ja teollisuuslaitosten jätevesien vaikutusalueen seuraamustutkimus 1970. Mimeographed report.).

The main mercury source at this site is the chlorine-alkali factory of Oulu Oy, the yearly mercury discharge of which has been about 100 kg since 1970.

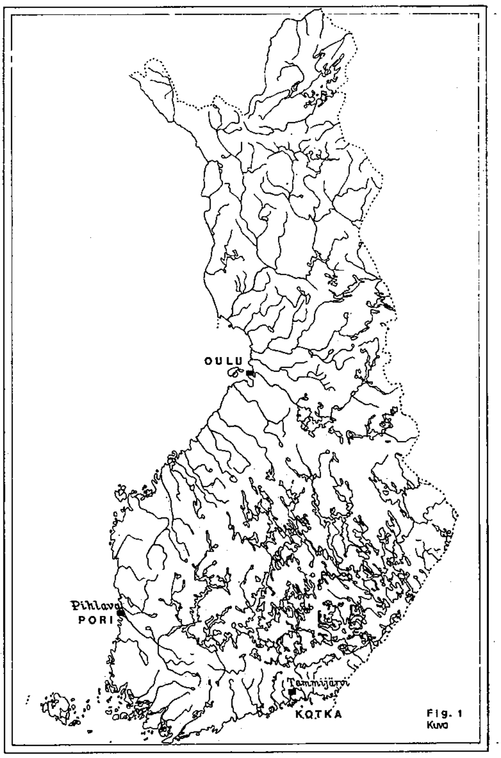



Fig. 1. Investigation areas.
Kuva 1. Tutkimusalueet

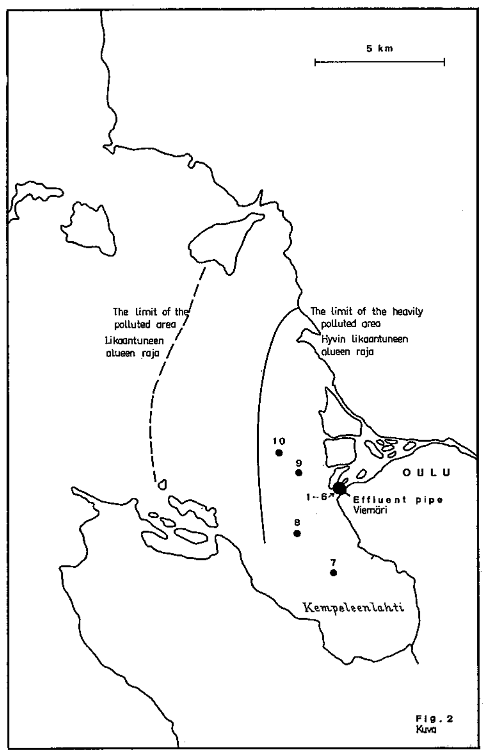



Fig. 2. The sampling sites in the sea area off Oulu
Kuva 2. Näytteenottopaikat Oulun edustan merialueell

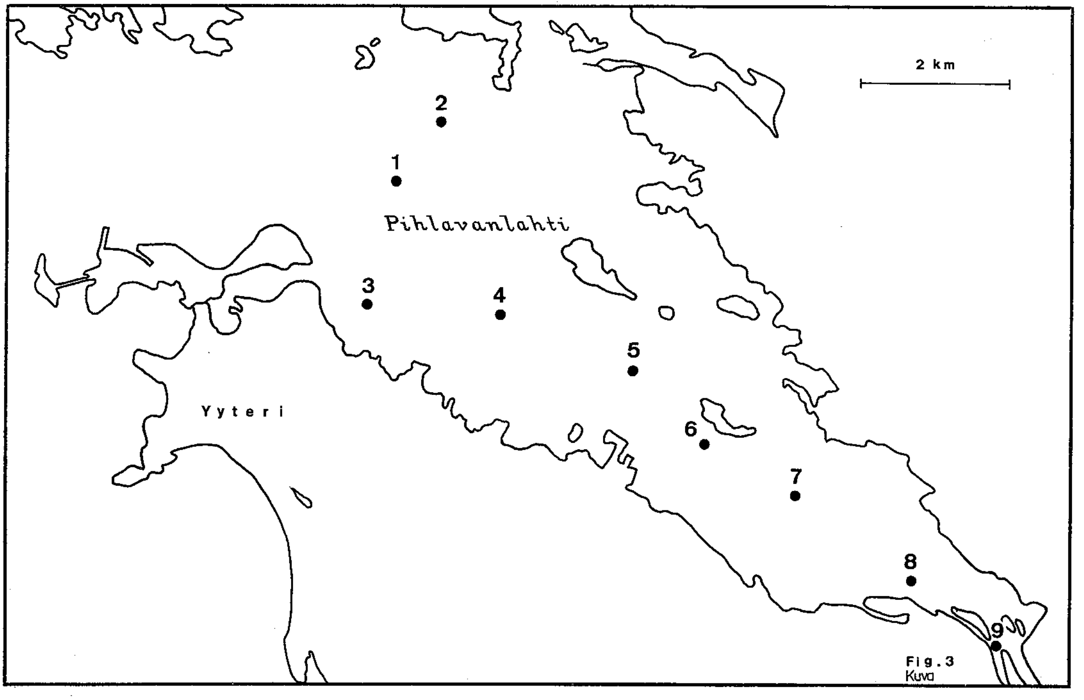



Fig. 3. The sampling sites in Pihlavanlahti.
Kuva 3. Näytteenottopaikat Pihlavanlahdella

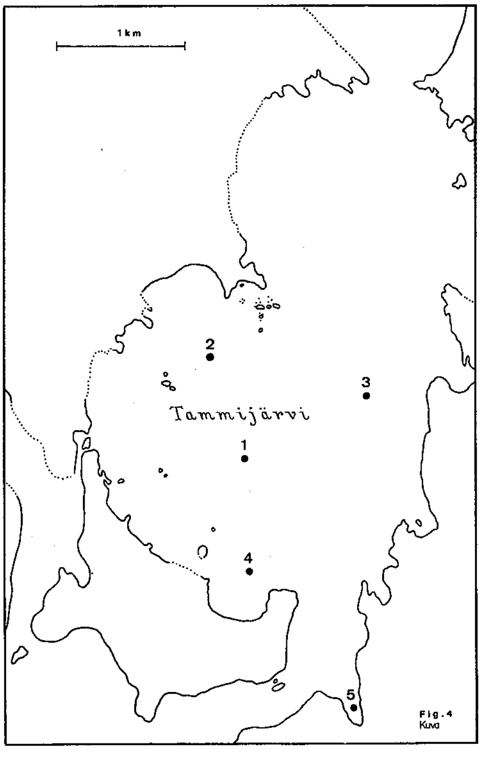



Fig. 4. The sampling sites in Tammijärvi
Kuva 4. Näytteenottopaikat Tammijärvellä

## 3.2 PIHLAVANLAHTI

A map of Pihlavanlahti at the mouth of the river Kokemäenjoki is shown in Fig. 3. The maximum depth in the study area is 6 m, but the mean depth is only 3-4 m. In the southeast of Pihlavanlahti and in parts of the river the bottom is covered with bark and fibres originating from timber-floating and the pulp and paper industry (Särkkä 1969, p. 276 and Fig. 2). Here the water of the Kokemäenjoki mixes with the brackish water of the Gulf of Bothnia. The zone with a salinity range of 0.5-3 o/oo is restricted to the shallowest part of Pihlavanlahti, whereas the 3-5 o/oo salinity zone occasionally extends far into the bay (Särkkä 1969, Fig. 3). In 1964 the oxygen content near the bottom in the middle of Pihlavanlahti was found to be 41 per cent of saturation in the winter and 91 per cent in late summer (Särkkä, op. cit.,

Table 1; for the oxygen situation see also Ryhänen 1962a, 1962b). The bottom fauna has been studied by Särkkä (1969).

The source of industrial mercury is the chlorine-alkali factory of Finnish Chemicals Oy at Äetsä, Keikyä, the yearly mercury discharge of which has been about 10 kg since 1970 according to the inspection work done by the Water Administration, and before 1968 also the pulp and paper industry upstream along the watercourse.

### 3.3 TAMMIJÄRVI

The lake Tammijärvi (see Fig. 4) is 6.3 km long and measures 2.7 km at its widest point. The greatest recorded depths are 12 m in the main basin, and 15.4 m in Laitsalmi. The mean depth is 7.2 m. The river Kymijoki runs through the lake. The hydrogeochemical data available show that the oxygen saturation near the bottom was 82 per cent, the conductivity 75 uS, pH 6.4, colour 87 mg Pt/l, total nitrogen 0.01 mg/l and total phosphorus 0.04 mg/l (data for 18.IV.1972).

The source of industrial mercury is the chlorine-alkali factory of Kymin Oy, at Kuusankoski, the yearly mercury discharge of which has been about 10 kg since 1970 according to the inspection work done by the Water Administration, and also the pulp and paper industry upstream along the watercourse.

## 4. DESCRIPTION OF THE CORES AND THEIR MERCURY CONTENT

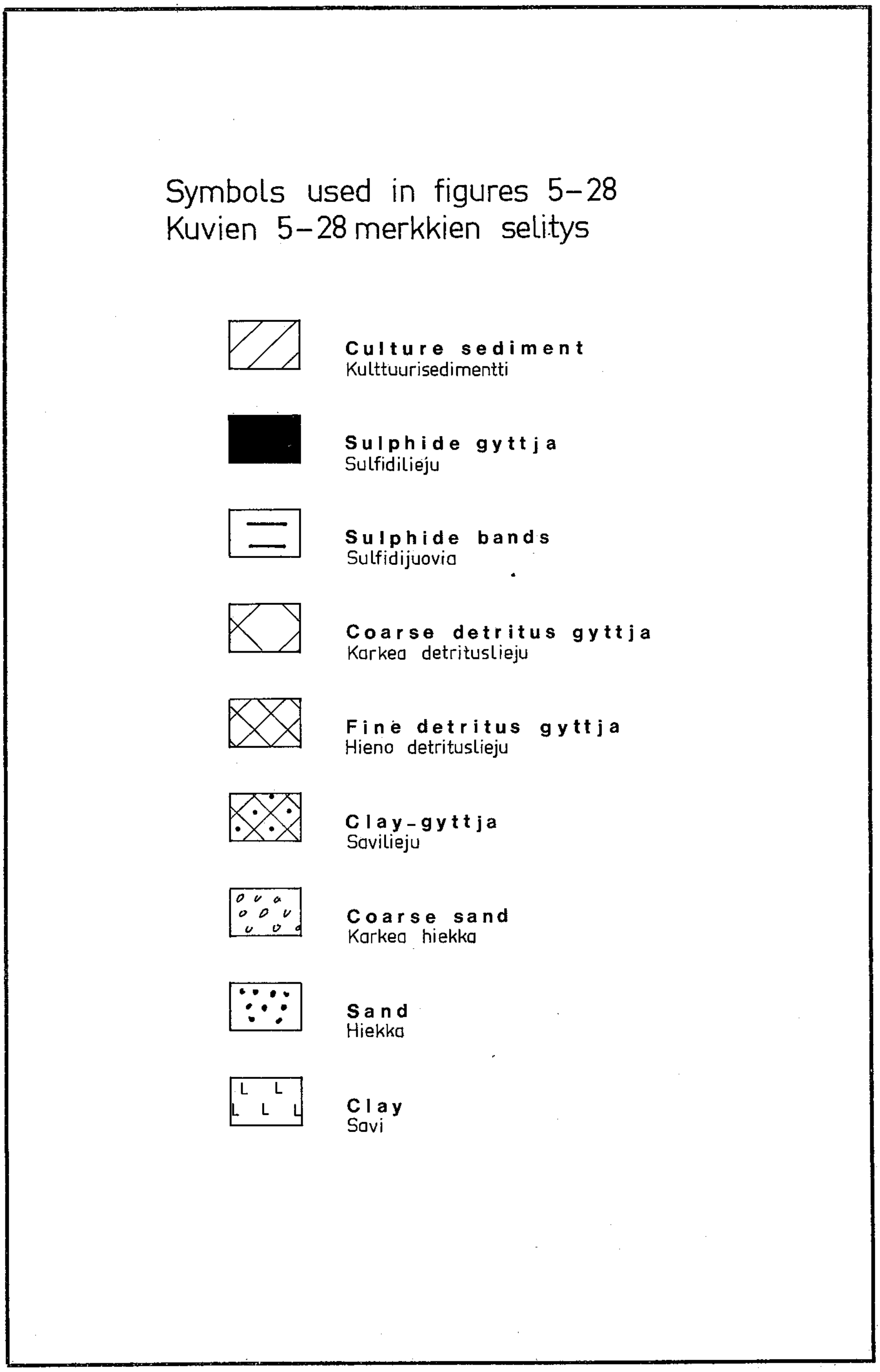
### 4.1 OULU

Core 1, water depth 2 m (Fig. 5).

The core, whose sediment showed evidence of human influence, was taken at a distance of 70 m from the outfall of the effluent of the chlorine-alkali factory of Oulu Oy. The mercury content shows a gradual decrease from 171 to 98 mg Hg/kg dry matter.

Core 2, water depth 2 m (Fig. 6).

The core site lies at about the same distance from the effluent outfall as core 1. The mercury content first shows a clear increase to a maximum of 81 mg Hg/kg and then decreases to 45 mg Hg/kg in the top sample (0-1 cm).


Symbols used in figures 5–28
Kuvien 5–28 merkkien selitys
Culture sediment
Kulttuurisedimentti
Sulphide gyttja
Sulfidilieju
Sulphide bands
Sulfidijuovia
Coarse detritus gyttja
Karkea detrituslieju
Fine detritus gyttja
Hieno detrituslieju
Clay-gyttja
Savilieju
Coarse sand
Karkea hiekka
Sand
Hiekka
Clay
Savi

Oulu

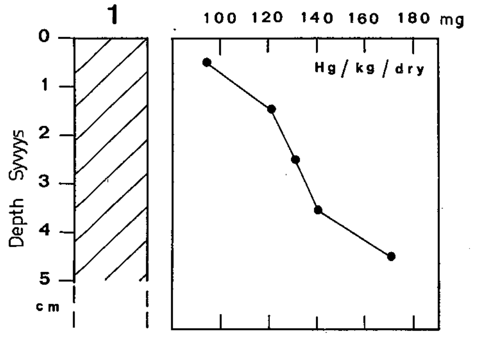



Fig. 5
Kuva

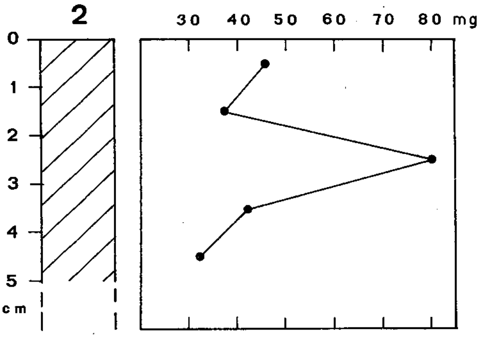



Fig. 6
Kuva

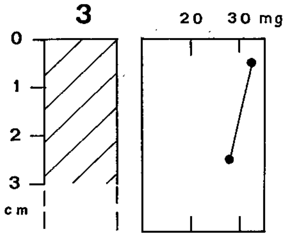



Fig. 7
Kuva

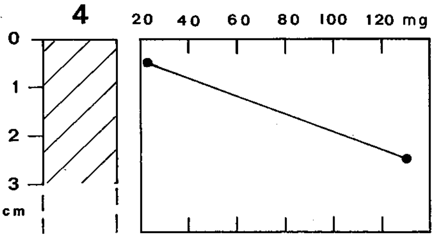
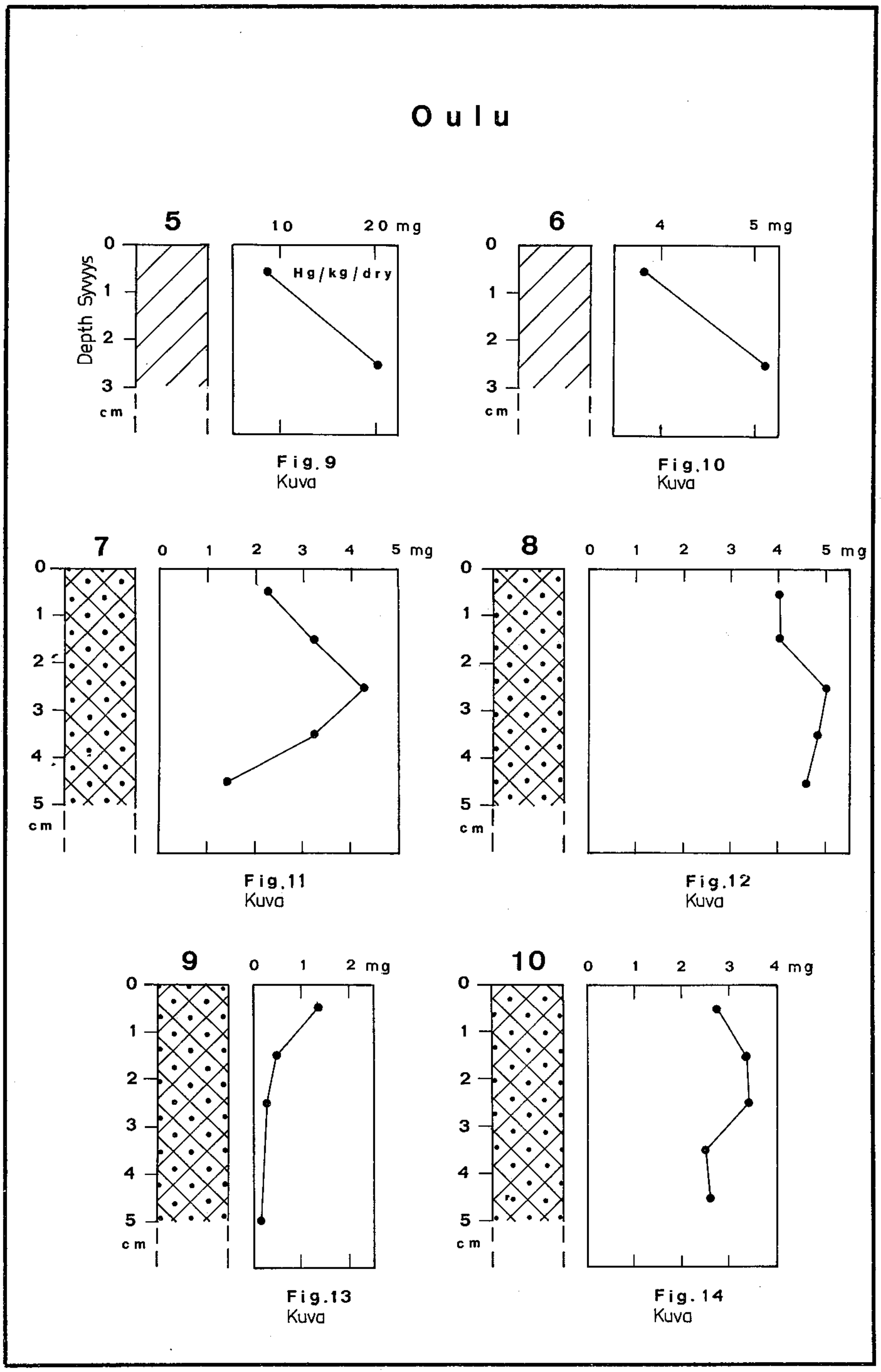



Fig. 8
Kuva

Figs. 5-8. The vertical distribution of mercury in the cores of the sampling sites 1-4 in the sea area off Oulu.

Kuvat 5-8. Pohjakerrostumanäytteiden elohopeapitoisuus (mg Hg/kg kuivap.) eri syvyyksillä Oulun edustan näytteenottopaikoilla 1-4




Figs. 9-14. The vertical distribution of mercury in the cores of the sampling sites 5-10 in the sea area off Oulu.

Kuvat 9-14. Pohjakerrostumanäytteiden elohopeapitoisuus (mg Hg/kg kuivap.) eri syvyyksillä Oulun edustan näytteenottopaikoilla 5-10

Cores 3, 4 and 5, water depth 3 m (Figs. 7-9).

These cores were taken at a distance of 100 m from the outfall. The mercury content is clearly decreasing in cores 4 and 5, but slightly increasing in core 3.

Core 6, water depth 3 m (Fig. 10).

The core site is 130 m from the outfall. Only two samples were analysed. They show a decrease from 5.2 to 3.6 mg Hg/kg dry matter.

Core 7, water depth 4 m (Fig. 11).

This core, which consists of clay-gyttja, was taken from the bay Kempeleenlahti (see Fig. 2). The mercury curve first rises to 4.4 mg Hg/kg and then declines gradually towards the topmost sample (0-1 cm).

Core 8, water depth 5 m.

This core site lies in the same area as core 7. The sediment is clay-gyttja. The mercury curve (see Fig. 12) does not show any great fluctuations.

Core 9, water depth 6.5 m (Fig. 13).

The core was taken off the island Vihreäsaari and consists of clay-gyttja. A gradual increase is seen in the mercury curve.

Core 10, water depth 9.5 m (Fig. 14).

The core consisting of clay-gyttja was taken near the island Nuottasaari. The mercury content does not show any significant changes.

## 4.2 PIHLAVANLAHTI

The core sites are presented in Fig. 3.

Core 1, water depth 2 m (Fig. 15).

The core stratigraphy is as follows:

| | | |
|---|---|---|
| 0-1.5 | cm | dark brown fine detritus gyttja |
| 1.5-10 | cm | gray clay-gyttja with black sulphide bands |

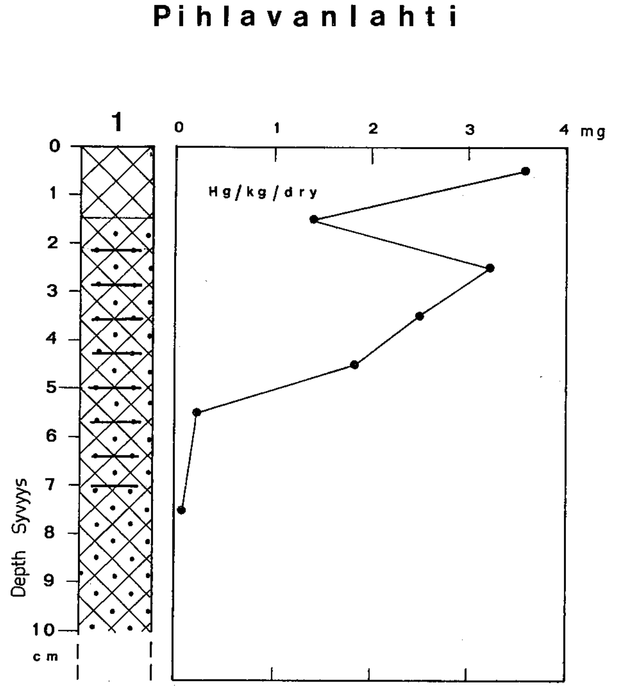



Fig.15
Kuva

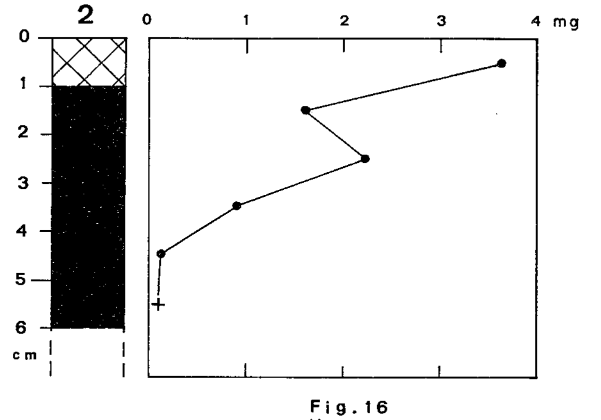
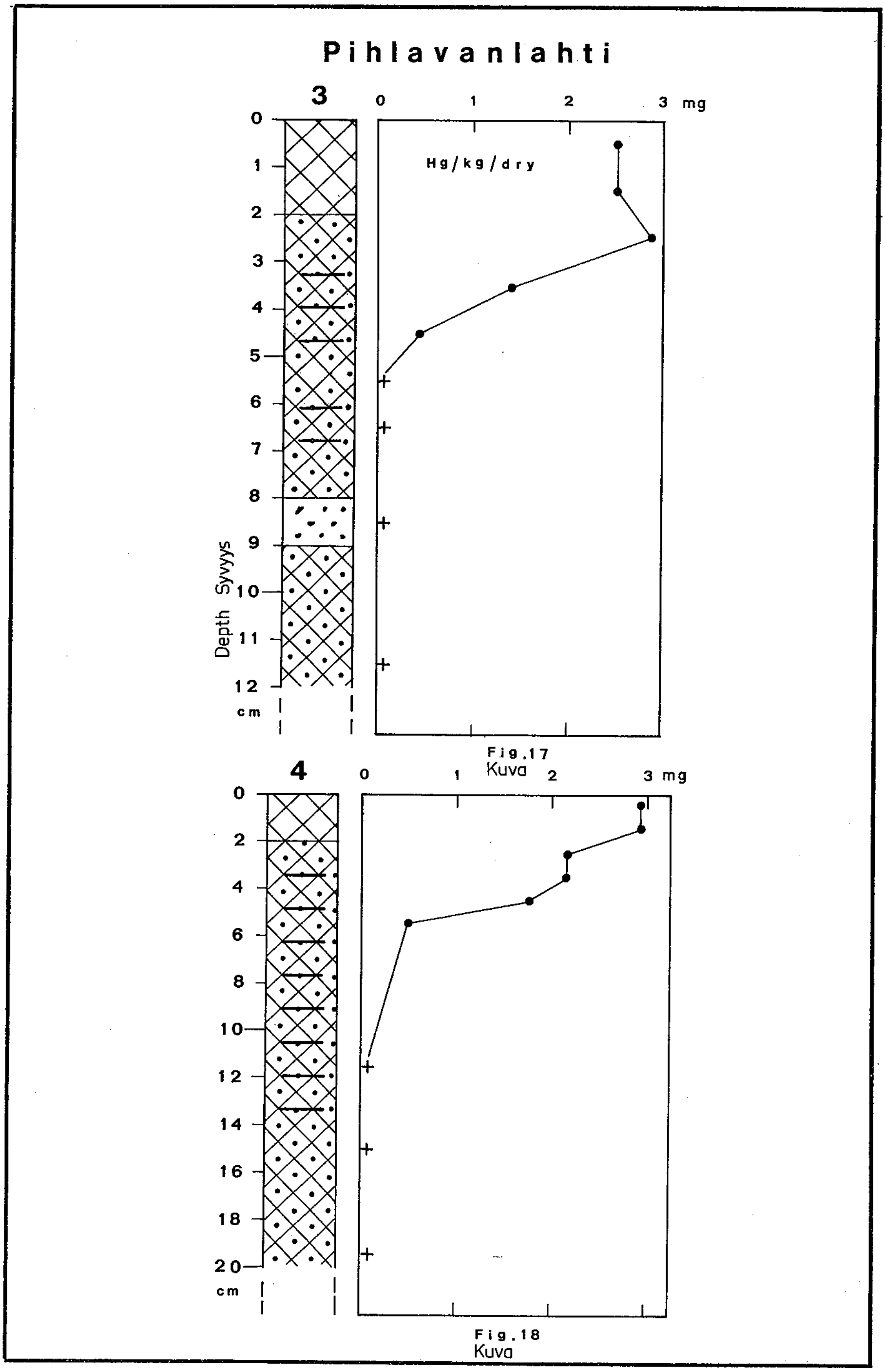



Fig.16
Kuva

Figs. 15-16. The vertical distribution of mercury in the cores of the sampling sites 1-2 in Pihlavanlahti.

Kuvat 15-16 Pohjakerrostumanäytteiden elohopeapitoisuus (mg Hg/kg kuivap.) eri syvyyksillä Pihlavanlahden näytteenottopaikoilla 1-2




Figs. 17-18. The vertical distribution of mercury in the cores of the sampling sites 3-4 in Pihlavanlahti.

Kuvat 17-18 Pohjakerrostumanäytteiden elohopeapitoisuus (mg Hg/kg kuivap.) eri syvyyksillä Pihlavanlahden näytteenottopaikoilla 3-4

The mercury content shows a gradual increase from 5-6 cm upwards. The maximum value (3.7 mg Hg/kg dry matter) is in the topmost sample in the fine detritus gyttja.

Core 2, water depth 4 m (Fig. 16).

The core stratigraphy is as follows:

0-1 cm brown fine detritus gyttja
1-6 cm black sulphide gyttja

The mercury curve of this core is more or less similar to that of core 1.

Core 3, water depth 3 m (Fig. 17).

The core stratigraphy is as follows:

0-2 cm brown fine detritus gyttja
2-8 cm gray clay-gyttja with black sulphide bands
8-9 cm pale gray sand
9-12 cm gray clay-gyttja

The mercury content of the sediments shows an increase in the clay-gyttja with sulphide bands and a slight decrease in the transition between the clay-gyttja and fine detritus gyttja.

Core 4, water depth 2.5 m (Fig. 18).

The core stratigraphy is as follows:

0-2 cm brown fine detritus gyttja
2-20 cm gray clay-gyttja, the upper part of which contains black sulphide bands

The curve of the mercury content of the sediment shows an abrupt rise towards the top samples.

Core 5, water depth 1.8 m (Fig. 19).

The core, which descends to 8 cm, consists of coarse sand. The mercury curve does not show any great fluctuations.

Core 6, water depth 1.5 m (Fig. 20).

In the stratigraphy of this core a layer of thin clay-gyttja (1 cm) overlies pale gray sand.

The content of mercury shows values under 1 mg Hg/kg dry matter.

Core 7, water depth 1 m (Fig. 21).

The core stratigraphy is as follows:

0-2 cm brown coarse detritus gyttja
2-7 cm dark brown fine detritus gyttja with black sulphide bands
7-10 cm pale gray sand

A slight increase can be seen in the mercury curve of this core.

Core 8, water depth 1.5 m (Fig. 22).

The core stratigraphy is as follows:

0-4 cm black sulphide gyttja
4-10 cm dark brown fine detritus gyttja

A gradual decrease in the mercury content of the sediment is seen in the upper part of the core.

Core 9, water depth 1 m (Fig. 23).

The core stratigraphy is as follows:

0-7 cm dark brown fine detritus gyttja
7-10 cm gray sand
10-16 cm blue clay, which continues downwards

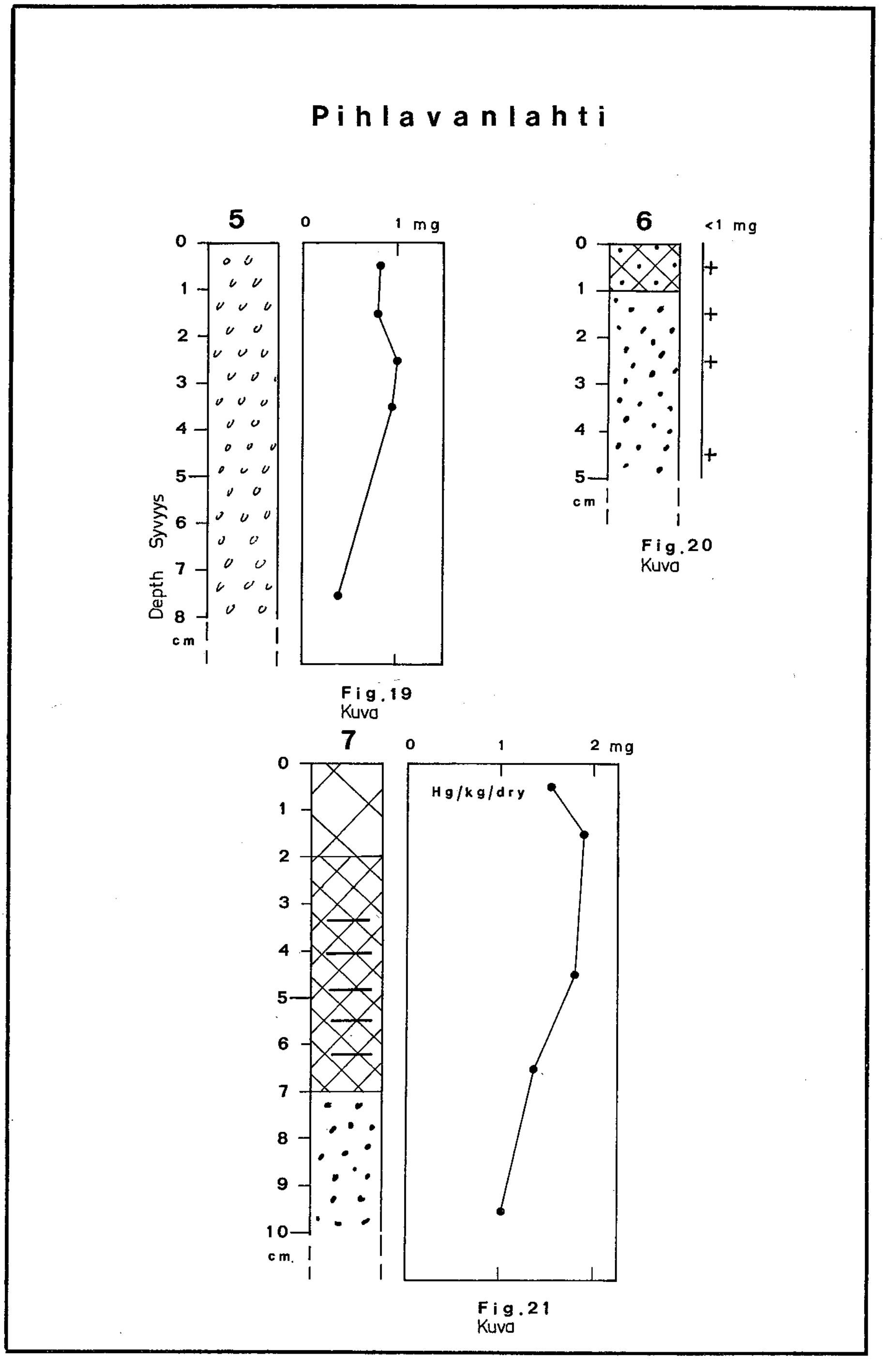
According to the diagram the mercury curve rises in the sand layer and shows a maximum in the sample of 5-6 cm. Thereafter it declines towards the surface of the sediment.

## 4.3 TAMMIJÄRVI

The core sites are presented in Fig. 4.

Core 1, water depth 4 m (Fig. 24).

This core consists of pale brown fine detritus gyttja. In the uppermost sample a slight




Figs. 19-21. The vertical distribution of mercury in the cores of the sampling sites 5-7 in Pihlavanlahti.

Kuvat 19-21. Pohjakerrostumanäytteiden elohopeapitoisuus (mg Hg/kg kuivap.) eri syvyyksillä Pihlavanlahden näytteenottopaikoilla 5-7

Pihlavanlahti

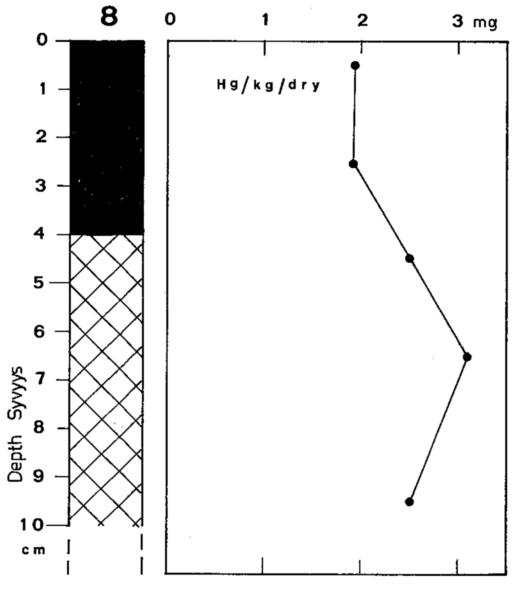



Fig. 22
Kuva

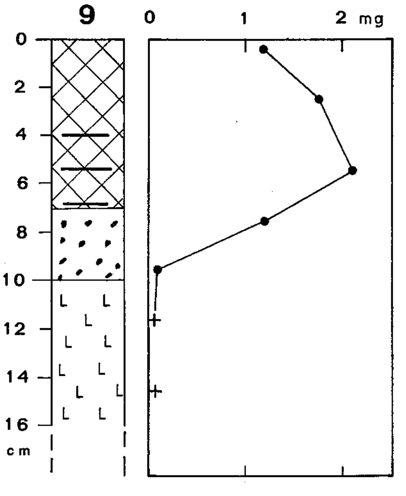
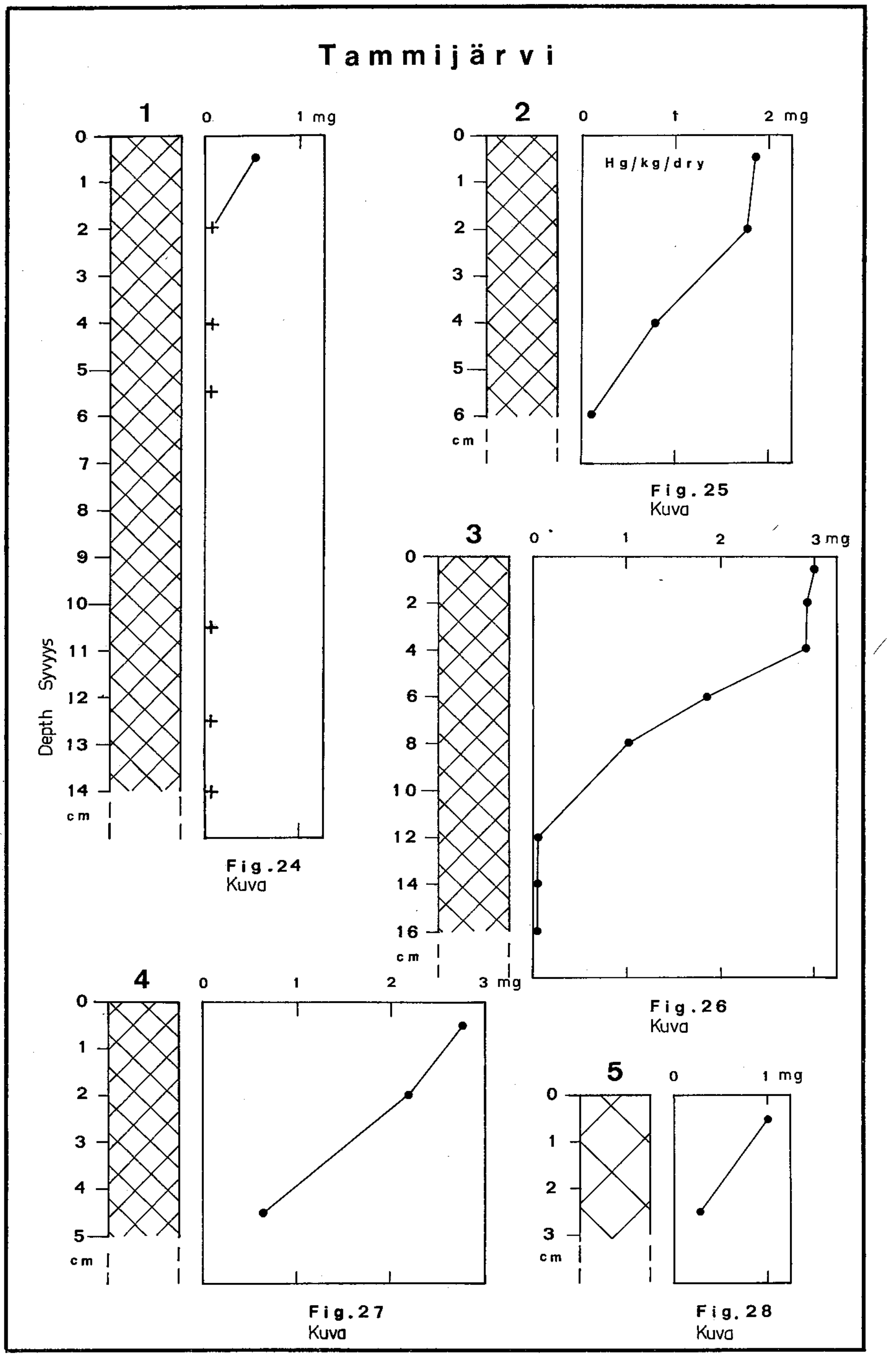



Fig. 23
Kuva

Figs. 22-23. The vertical distribution of mercury in the cores of the sampling sites 8-9 in Pihlavanlahti.

Kuvat 22-23. Pohjakerrostumanäytteiden elohopeapitoisuus (mg Hg/kg kuivap.) eri syvyyksillä Pihlavanlahden näytteenottopaikoilla 8-9




Figs. 24-28. The vertical distribution of mercury in the cores of the sampling sites 1-5 in Tammijärvi.

Kuvat 24-28. Pohjakerrostumanäytteiden elohopeapitoisuus (mg Hg/kg kuivap.) eri syvyyksillä Tammijärven näytteenottopaikoilla 1-5 increase of the mercury content can be seen.

Core 2, water depth 2.5 m (Fig. 25).

The core consists of fine detritus gyttja. The mercury curve rises evenly towards the surface of the sediment.

Core 3, water depth 2.5 m (Fig. 26); also fine detritus gyttja. A clear rise in the mercury content of the sediment can be seen in the diagram.

Core 4, water depth 3 m (Fig. 27); fine detritus gyttja. A clear increase in the mercury content is visible in the uppermost sample of this core.

Core 5, water depth 1 m (Fig. 28); coarse detritus gyttja. Only two samples were analysed, but these showed the same tendency as the other cores of Tammijärvi.

## 5. CONCLUSIONS AND DISCUSSION

The thickness of the "mercury-contaminated" layer can be determined from the results, since its lower limit is indicated by a clear rise in the mercury curve. It is very thin in all these cases, but varies with the deposition rate. The present material indicates that the maximum thickness of the mercury-polluted layer is about 5 cm in the sea area off Oulu, 8 cm in the bay Pihlavanlahti and 10 cm in the lake Tammijärvi. The mercury content per kg dry matter in the uppermost analysed surface sample varied from 1.3 to 98 mg in the cores from Oulu, from 0.1 to 3.7 mg in those of Pihlavanlahti and from 0.5 to 3.0 mg in those of Tammijärvi. The greatest values in Oulu were found in the immediate vicinity of the mouth of the drain-pipe of the chlorine-alkali factory (see Figs. 5-9) declining with distance from the outfall. In Pihlavanlahti and Tammijärvi the mercury content of the surface sediments shows a more uniform horizontal distribution than in the sea area off Oulu.

The vertical distribution of the mercury suggests a declining tendency in the case of Oulu, probably reflecting the decrease of mercury in the industrial effluents. This result, if it is real, is in agreement with the mollusk studies made by E. Lindgren (pers. com.) in the same area. The deposition of mercury in Pihlavanlahti and Tammijärvi seems to be fairly constant.

It is now known (cf. Jensen and Jernelöv 1969) that mercury compounds are converted to methyl mercury by micro-organisms. Most of this biological methylation of mercury in aquatic ecosystems, e.g. in lakes, is assumed to take place in the uppermost centimetres of the bottom sediments. It is interesting to speculate on the extent of this process in the deposits of the investigated sites, which with their store of mercury represent a potential substrate for the methylation activity of micro-organisms. Jernelöv (1970) showed that in a system without macro-organisms formation and release of methyl mercury occurs almost entirely in the upper few centimetres of the sediment. High population densities of Tubificidae affect the mercury situation, but especially Anodonta changes it considerably (see Jernelöv 1970, p. 960). As concerns the methylation problem in Finnish conditions, it can be mentioned that Rissanen, Erkama and Miettinen (1970) have made methylation experiments in the laboratory. Most of their mud samples showed no significant difference between the rates of methylation under aerobic and anaerobic conditions and, in general, the rate of methylation depends on the content of organic matter being fastest in muds with a high content. At 12$^{o}$C no methylation was found under aerobic conditions, but under anaerobic conditions some methylation occurred in sediments with a high organic content. At 19-20$^{o}$C the methylation of mercury was higher than at 12$^{o}$C and equal both in aerobic and anaerobic conditions. Rissanen, Erkama and Miettinen (1970) concluded that the methylation of mercury in Finnish waters is presumably rather weak, since the mean annual water temperature is approximately 5$^{o}$C.

The form of the mercury and the pH of the sedimentation environment are also significant factors in the methylation process. Fagerström and Jernelöv (1971) found that in aerobic organic sediments the rate of formation of methyl mercury was considerably lower with pure mercuric sulphide than with inorganic divalent mercury. It should also be noted that mildy reducing conditions, which are sometimes common in the bottom deposits of lakes, can cause the mercury to be precipitated as sulphide, which has an extremly low solubility. Very strongly reducing conditions may increase the solubility by converting the mercuric ion to free metal (see Hem 1970, p. 21).

In attempts to assess the probability of mercury being released into the water, it must be kept in mind that dredging in the areas where mercury-polluted sediments are found can lead to serious changes in the mercury situation.

## 6. MERCURY CONTENT IN FISH

The mercury content in fish in Finland was first investigated by Sjöblom and Häsänen (1969). In 1967 and 1968 about 500 fish were analysed by neutron activation analysis. Some large water areas, along which the majority of the Finnish pulp, paper and chlorine factories are located, have fish, especially pike, perch and burbot, with mercury contents over 1 ppm.

In 1970 the National Board of Waters began to study the mercury pollution of Finnish watercourses. In 1970 261 fish were subjected to neutron activation analysis (Häsänen 1970), and 100 fish were analysed by the oxygen combustion-ditizon method (Karppanen, pers. com.). Thus altogether 361 fish, of which 217 were pike, were analysed. The fish were caught in January - May, mainly in May. The samples for analysis were taken from the axial muscle of each fish ventrally to the dorsal fin and immediately above the horizontal septum.

The mean mercury contents of pike, perch and burbot in 1967, 1968 and 1970 are presented in table 1.

The most important indicator fish has been found to be the pike (Esox lucius L.). Its advantages are: 1. its stationary habit, thanks to which it provides information on a definite area; 2. its life span of several years, which serves to integrate temporal variations in the occurrence of accumulativa substances in the environment and 3. its wide distribution, which permits comparative studies over extensive geographic areas.

Variations have been observed in the mercury content of pike from the same locality. Comparisons were facilitated by determining the mercury content of "standard pike" weighing one kilogram for each locality and year (see Table 2.). The mercury content of the "standard pike" was obtained by simple graphic interpolation. The mercury content was related to the weight of the pike, because determinations of the age of a pike based on scale reading are not very reliable.

The areas in table 2. are identical to the sites at which the bottom sediment was sampled except in the case of the sea area off Oulu, where the pike were caught at the most polluted area only in 1968.

Statistical examination of the mean values in table 1. did not show any significant change in the mercury content of pike in 1970 compared with the previous research period.

Table 1. Mean content of mercury in fish in 1967-68 and 1970.
Taulukko 1. Kalojen elohopeapitoisuuksien keskiarvot vuosina 1967-68 ja 1970.

| Research locality<br>Tutkimusalue | | 1967-68<br>n | <br>mg Hg/kg | 1970<br>n | <br>mg Hg/kg |
|---|---|---|---|---|---|
| Sea area off Oulu<br>Oulun edustan merialue | pike hauki | 16 | 0.98 | 18 | 1.15 |
| | perch ahven | 3 | 1.45 | 12 | 1.53 |
| | burbot made | 2 | 1.07 | 12 | 1.32 |
| The bay of Pihlavanlahti<br>Pihlavanlahti | pike hauki | 13 | 0.91 | 14 | 1.13 |
| | perch ahven | 2 | 1.53 | 3 | 1.23 |
| | burbot made | 5 | 1.16 | | |
| Lake Tammijärvi<br>Tammijärvi | pike hauki | 5[x] | 3.32 | 4 | 4.05 |

[x]1968-69

n = number of fish investigated
n = tutkittujen kalojen lukumäärä

Table 2. Mercury content of "standard pike" weighing one kilogram.
Taulukko 2. Yhden kilon painoisen "vakiohauen" elohopeapitoisuus

| Research locality and year<br>Tutkimusalue ja vuosi | | mg Hg/kg | n |
|---|---|---|---|
| Sea area off Oulu<br>Oulun edustan merialue | 1967 | 0.77 | 10 |
| | 1968 | 1.32 | 6 |
| | 1970 | 1.05 | 18 |
| The bay of Pihlavanlahti<br>Pihlavanlahti | 1967 | 0.90 | 10 |
| | 1968 | 1.00 | 3 |
| | 1970 | 1.07 | 14 |
| Lake Tammijärvi<br>Tammijärvi | 1968-69 | 2.93 | 5 |
| | 1970 | 3.52 | 4 |

n = number of pike in sample
n = tutkittujen kalojen lukumäärä

Seloste

Pohjan elohopeapitoisuus eräillä likaantuneilla vesialueilla

Tutkimuksessa käsitellään Oulun edustan merialueen, Kokemäenjoen suualueen Pihlavanlahden ja Kymijoen Tammijärven nuorien pohjakerrostumien elohopeapitoisuuksien vaihtelua sekä annetaan tietoja näiltä alueilta pyydystettyjen kalojen elohopeapitoisuuksista. Tutkimusta varten kerättiin pohjanoutimella 24 näytesarjaa (10 Oulun edustalta, 9 Pihlavanlahdelta ja 5 Tammijärveltä) elohopean pystysuoran jakautumisen selvittämiseksi pohjan pintakerrostumassa. Näytesarjojen paksuus vaihteli 3-20 cm:iin. Tämä paksuus osoittautui riittäväksi teollisuudesta peräisin olevien elohopeamäärien vaihteluiden osoittamiseksi tutkimusalueilla. Näytesarjoista määritettiin tihein välein kerrostumaelohopean pitoisuus, ja kaikkiaan 118 analyysia tehtiin Teknillisen Korkeakoulun reaktorilaboratoriossa fil. tohtori Erkki Häsäsen johdolla.

Saaduista tuloksista ilmeni, että elohopean saastuttaman kerroksen paksuus kerrostumisnopeudesta riippuen on Oulun edustalla noin 5 cm, Pihlavanlahdella 8 cm ja Tammijärven pohjassa 10 cm. Samalla osoitettiin, että ylimmän analysoidun pintanäytteen elohopeamäärä vaihteli Oulun edustan merialueella 1,3:sta 98 mg:aan, Pihlavanlahden näytesarjoissa 0,1:stä 3,7 mg:aan ja Tammijärvessä 0,5:stä 3,0 mg:aan kilossa kuivaa ainetta. Suurimmat arvot olivat Oulu Osakeyhtiön klooritehtaan viemärin välittömässä läheisyydessä 70-100 m:n etäisyydellä siitä elohopeapitoisuuden selvästi pienetessä tämän vyöhykkeen ulkopuolella. Pihlavanlahdella ja Tammijärvellä pohjan pinnan elohopeamäärä oli alueellisesti tasaisemmin jakaantunut kuin Oulun edustalla.

Eräänä mielenkiintoisena tuloksena voidaan pitää Oulun merialueen kerrostumaelohopean vähenemistä siirryttäessä nuorempiin pohjanäytteisiin. Tämä saattaisi selittyä elohopeapitoisten jätevesien puhdistuksen tehostumisesta. Vastaavaa ilmiötä ei sensijaan voitu selvästi osoittaa Pihlavanlahden ja Tammijärven näytesarjoissa.

Tutkimuksessa pohditaan myös kerrostuneen elohopean mahdollista muuttumista mikro-organismien toiminnan vaikutuksesta metyylielohopeaksi, joka tunnetusti on myrkyllistä ja rikastuu esimerkiksi kaloihin. Tämän biologisen metyloitumisen on todettu tapahtuvan pohjakerrostumien ylimmissä osissa, mistä sitä voi vapautua veteen mm. tiettyjen pohjaeläinten (Tubificidae, Anodonta) toiminnan tuloksena. Missä määrin metyloitumista tapahtuu Suomen oloissa ja nimenomaan tutkittujen alueiden pohjilla ei erikseen ole selvitetty. Tässä on tyydytty ainoastaan viittaamaan eräisiin kokeellisiin tutkimuksiin, jotka ovat osoittaneet, että metyylielohopean syntyminen maamme vesissä näyttää olevan jokseenkin vähäistä johtuen alhaisesta vesien vuotuisesta keskilämpötilasta. Pohjakerrostuman orgaanisen aineksen määrällä oli näiden kokeiden mukaan merkitystä metyloitumisen nopeudessa sen kasvaessa runsaasti orgaanista ainesta sisältävissä sedimenteissä.

Arvioitaessa elohopean säilymistä tutkituissa kerrostumissa on lisäksi huomioitava mahdollisten ruoppausten vaikutus. Ruoppaukset voivat nimittäin ilmeisesti johtaa elohopeatilanteen vakaviinkin häiriöihin alueilla, missä tavataan elohopean likaamia pohjakerrostumia.

Elohopean pysyvyyteen pohjakerrostumissa tiedetään myös vaikuttavan sen kemiallinen muoto, kerrostumisympäristön pH ja pohjanläheisten vesikerrosten happitilanne. Edelleen elohopean likaamilla kerrostumilla erilaisissa vesielinympäristöissä voidaan katsoa olevan aina tärkeä ekologinen ja samalla ympäristötutkimuksellinen merkitys, varsinkin kun ne muodostavat enemmän tai vähemmän muutosherkän ja suhteellisen pitkäaikaisen "elohopeavaraston", joka muodostaa laajuutensa, paksuutensa ja pitoisuutensa puolesta tärkeät taustatiedot erilaisille käytännön toimenpiteille.

Tutkimuksessa käsitellään myös kalojen elohopeapitoisuutta tutkimusalueilla. Kaloille vesistön pohja, sen pohjakerrostumat ovat yhtä olennaista ympäristöä kuin niitä ympäröivä vesikin. Vesistössä vallitsee jatkuva aineiden kierto veden ja pohjan sekä niissä elävien eliöiden välillä. Erityisen selvästi tällainen kierto on osoitettavissa eliöihin ja niiden ympäristöön kerääntyvillä ja vaikeasti muuttuvilla aineilla, kuten elohopealla. Pohjakerrostumien ylempien osien sisältämä elohopea kerääntyy kaloihin paitsi kalojen ravintoeläinten välityksellä myös suoraan vedestä kalan kidusten ja ihon kautta. Näiden kahden eri kerääntymistavan keskinäistä merkittävyyttä ei vielä tarkoin tunneta. Kerääntyminen vaihtelee kalalajeittain ja siihen vaikuttavista ulkoisista tekijöistä on tärkein vesistön tila.

Tässä tutkimuksessa on määritetty vain kalojen elohopeapitoisuus. Useissa eri tutkimuksissa on kuitenkin todettu kalojen lihaksien elohopeasta 80-100 % olevan elohopeaa vaarallisempaa metyylielohopeaa. Tästä metyylielohopeasta on ainakin osa muodostunut vesistön pohjalla mikrobien toiminnan seurauksena.

Kalojen elohopeapitoisuudesta on tutkituilta vesialueilta tietoja vuodesta 1967 lähtien. Tärkeimpinä tutkimuskohteina ovat olleet petokalat made, ahven ja erityisesti hauki, jonka elohopeapitoisuus parhaiten kuvaa melko suppeankin vesialueen elohopeatasoa. Vuonna 1970 haukien keskimääräinen elohopeapitoisuus oli Oulun edustan merialueella 1,15 mg/kg, Pihlavanlahdella 1,13 mg/kg ja Tammijärvellä 4,05 mg/kg kalojen tuorepainoa kohti. Oulun edustan merialueelta ja Pihlavanlahdelta tutkituilla ahvenilla ja mateilla keskimääräinen elohopeapitoisuus oli suurempi kuin hauilla.

Ennen vuotta 1970 tehtyihin tutkimuksiin verrattuna haukien keskimääräinen elohopeapitoisuus ei ole tutkituilla alueilla merkittävästi muuttunut.

REFERENCES

Axelsson, W. & L. Håkanson, 1972. Sambandet mellan kvicksilverförekomst och mentologisk miljö i Ekoln. Del 2. Sedimentens egenskaper och kvicksilverinnehåll (English Summary). UNGI Rapport 14, 33 pp.

Fagerström, T. & A. Jernelöv, 1971. Formation of methyl mercury from pure mercuric sulphide in aerobic organic sediment. Swedish Water and Air Pollution Research Laboratory, Ser. B., 99, 1-6.

Helminen, M., E. Karppanen & I. Koivisto, 1968. Saimaan norpan elohopeapitoisuudesta 1967. Suomen Eläinlääkärilehti 74:87-89.

Hem, J. D., 1970. Chemical behavior of mercury in aqueous media. Geological Survey, Professional Paper 713:19-24.

Håkanson, L., 1972. Sambandet mellan kvicksilverförekomst och sedimentologisk miljö i Ekoln. Del 3. Transport och deposition av kvicksilver (English Summary). UNGI Rapport 15, 56 pp.

Häsänen, E. & V. Sjöblom, 1968. Kalojen elohopeapitoisuus Suomessa vuonna 1967. (English Summary). Suomen Kalatalous 36:1-24.

Häsänen, E., 1970. Determination of mercury in biological material by neutron activation analysis. Suomen Kemistilehti B 43:251-254.

Jensen, S. & A. Jernelöv, 1969. Biological methylation of mercury in aquatic organisms. Nature 223:753-754.

Jernelöv, A., 1970. Release of methyl mercury from sediments with layers containing inorganic mercury at different depths. Limnol. Oceanogr. 15:958-960.

Karimo, K., H. Leskelä, P. Mikola & R. Ryhänen, 1970. Vesien pilaantuminen ja sen ehkäiseminen. Maa- ja vesiteknillisiä tutkimuksia 18, 309 pp.

Kurland, L. T., S. N. Faro & H. Siedler, 1960. Minamata disease. Wld. Neurol. 1:370-395.

Norrman, J. O., 1971. Höga kvicksilverhalter i sediment från södra Vättern. FoF 1:9-12.

Nuorteva, P. & E. Häsänen, 1971. Observations on the mercury content of Myoxocephalus quadricornis (L.) (Teleostei, Cottidae) in Finland. Ann. Zool. Fennici 8:331-335.

Nuorteva, P. & E. Häsänen, 1972. Transfer of mercury from fishes to Sarcosaprophagous flies. Ann. Zool. Fennici 9:23-27.

Rissanen, K., J. Erkama & J. K. Miettinen, 1970. Experiments on microbiological methylation of mercury (2+) ion by mud and sludge under aerobic and anaerobic conditions. FAO Technical Conference on Marine Pollution and its Effects on Living Resources and Fisheries 1970. FIR:MP/70/E 61, 1970, 6 pp.

Ryhänen, R., 1962a. Über den Zustand der Gewässer im südlichen Einzugsgebiet des Kokemäenjoki (Finnland) III. A. Ergebnisse der chemischen und physikalischen Winteruntersuchungen. Ann. Acad. Scient. Fennicae A. III. 64, 82 pp.

Ryhänen, R., 1962b. Über den Zustand der Gewässer im südlichen Einzugsgebiet des Kokemäenjoki (Finnland) III. B. Ergebnisse der chemischen und physikalischen Sommeruntersuchungen. Ann. Acad. Scient. Fennicae A. III. 65, 41 pp.

Sjöblom, V. & E. Häsänen, 1969. Kvicksilverhalten i fisk i Finland. Nord. Hyg. Tidskr. 50:37-53.

Särkkä, J., 1969. The bottom fauna at the mouth of the river Kokemäenjoki, southwestern Finland. Ann. Zool. Fennici 6:275-288.