DEPARTMENT OF CHEMISTRY, UNIVERSITY OF JYVÄSKYLÄ
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ABSTRACT

A biological method based on bioaccumulation and using incubated lake mussels (Anodonta piscinalis) was developed and applied for monitoring organic chlorocompounds originating especially from pulp and paper industry and occurring in the water in very small and fluctuating concentrations. By this method the spreading of the severe PCB-pollution in Lake Kernaalanjärvi was specified, and the limits of the PCB-leakage in the Äänekoski area were defined. Of the other chlorohydrocarbons lindane as well as DDE were detected everywhere in small concentrations. DDT was, on the contrary, very rarely found. Hexachlorobenzene occurred also very commonly, and the highest concentrations were detected in the immediate recipients of pulp mills. Some local pollution cases caused by chlorophenols used in wood preservatives were detected. Airborne chlorophenolics were found everywhere. 2,4,6-Trichlorophenol was found to be the main chlorophenolic in the recipient of the sulphite pulp mill. It was possible to clear up the occurrence and transformation of bleaching remnants (S2PCP-group). In addition, there was proof of the transformation of chlorophenols and chloroguaiacols into chloroanisoles and chloroveratroles in the watercourse. Analysis of the S2PCP-group from incubated mussels seems to be very suitable for the monitoring of organochlorine compounds originating from pulp and paper industry. The introduction of biological effluent treatment caused a significant decrease of chlorophenolic compounds. Chlorinated dibenzo-p-dioxins and dibenzofurans were also found with the help of incubated mussels in areas worst polluted by pulping effluents, although in very small concentrations. It was also found that biological treatment of waste water decreases these compounds considerably and that the components occurring after the purification process were clearly less toxic furans. Practical guidelines of the mussel incubation method are presented.

CONTENTS

1 INTRODUCTION

1.1 Water quality monitoring

A variety of different physical, chemical, biological or microbiological analysis methods may be used in water quality research and monitoring. Usually, a combination of several different methods is required, depending on the particular watercourse characteristics or the part of the overall ecosystem being studied. The type of loading or the nature of other factors affecting the watercourse may also influence the choice of analytical methods.

A watercourse ecosystem can in theory be considered as two parts with completely different characteristics. These parts - the biotope and the biocoenosis - are, however, strongly interdependent. The biotope is the abiotic part of the ecosystem. Its primary quality characteristics are determined by the drainage basin and the hydrological conditions. For example, Finnish inland waters are generally very low in salts, rather poor in nutrients, slightly humic and acidic because the soil and bedrock are poorly soluble but swamps releasing humic compounds occur in large numbers. Increased concentrations of nutrients and toxins observed in watercourses are, however, in most cases anthropogenic in origin.

Direct physical and chemical methods of analysis, such as measurement of concentrations of nutrients and organic materials, are well suited to investigations of the biotope. Many of these methods can be performed according to international standards, and their utilization has provided the basis for watercourse monitoring programmes both in Finland (Heinonen 1989) and elsewhere (Helmer et al. 1987, WMO 1988). Many watercourse utilizability classification systems rely mainly on physical and chemical data (Heinonen and Herve 1987, Newman 1988), as do some eutrophication classification systems (OECD 1982), too.

The living part of the water ecosystem, the biocoenosis, is composed of the different groups of plants, animals and microbes living in the biotope and utilizing its supply of nutrients. Biocoenosis research can be divided into investigations of the amount and species distribution of watercourse organisms, biotests which utilize these organisms, and accumulation investigations carried out using living organisms (see e.g. Miettinen and Heinonen 1988).

The species living in watercourses may be divided into two major groups on the basis of energy utilization: (1) primary producers and (2) consumers. The primary producers include phytoplankton growing in the epilimnion, periphyton growing on submerged surfaces such as stones and water constructions, and macrophytes living mainly in the shore zone. Of these organisms the phytoplankton have been in Finland most investigated for determination of eutrophication (Heinonen 1980). In earlier years the only reliable method for assessing phytoplankton was counting by microscopy. Nowadays, chemical analysis methods can be used for the indirect estimation of phytoplankton biomass by analysing chlorophyll a concentrations in water samples (Sakamoto 1966, Forsberg and Ryding 1980, Marker et al. 1980, see also Herve and Heinonen 1982, 1984). In investigations of species distribution, however, it is still necessary to use the microscopy techniques.

A sufficiently accurate estimate of primary producers growing on submerged surfaces for monitoring purposes can be obtained by measuring periphyton growth either from various natural supports or from special artificial substrates (Wetzel and Hough 1973, Weitzel 1979, Cairns 1982). Estimates of periphyton growth have included assays of e.g. dry weight and chlorophyll per unit of area. In Finland good results have been obtained by periphyton method in the measurement of slow eutrophication in the recipient waters of fish breeding stations, in which the nutrient loading has not yet significantly increased nutrient concentrations (Heinonen 1981, 1984, Heinonen and Herve 1984, Herve and Heinonen 1987). The eutrophication of lakes due to the

pulp and paper industry has also been studied in Finland by the periphyton method (Kettunen 1983). A corresponding incubation method was also used in estimation of sliming of nets (Heinonen et al. 1984).

Macrophytes represent the most visible part of primary production in watercourses, particularly in lakes. In shallow and eutrophic lakes the macrophyte zone may be very wide. Although there are long traditions of macrophyte investigation in Finland (Maristo 1941), no wide-based macrophyte monitoring has been included as a part of general watercourse quality monitoring. Macrophyte investigations are used mainly in watercourse restoration programmes.

Monitoring of the other parts of the food chain - zooplankton, benthic organisms, fish species and particularly the degrading organisms - is also quite deficient in Finland. Organized monitoring of benthic organisms began only in 1989 at the intensive stations of the inland waters biological monitoring programme and a very limited monitoring programme of macrophytes started in the summer of 1990 (National Board of Waters and the Environment 1990, Niemi 1990). Investigations of bacterial activity are also largely lacking.

1.2 Monitoring of harmful substances

The harmful substances discharged into watercourses, and their possible deleterious effects on aquatic organisms, can be analysed by three means: (1) by analysing the concentrations of the compounds from water or from organisms living in watercourses, (2) analysing the environmental transformation products (e.g. DDT vs. DDE), and (3) by biological tests carried out in watercourses or in the laboratory.

Investigations of heavy metals and organic toxins discharged to watercourses have relied mainly on animals, especially fish. Particularly the muscle tissues, gills and internal organs of

animals bioaccumulate many organic compounds so efficiently that their concentrations in tissues may be as much as 1 000 - 10 000 times higher than in the surrounding water. This provides a good possibility of investigating the transport of environmental pollutants present in watercourses in only very low concentrations.

Investigations have been carried out in the case of mercury (Miettinen 1974, Verta 1990), heavy metals (Alliot and Frenet-Piron 1990), chlorinated hydrocarbons, PCB and DDT (Miettinen and Verta 1984, Miettinen et al. 1985) and dioxins and related aromatic chloroethers (Paasivirta et al. 1987c). Zooplankton has been used (Miettinen and Hattula 1978), and aquatic insects have been shown to be efficient accumulators of organic chlorine compounds (Kovats and Ciborowski 1989). Filtering animals appear to accumulate water-soluble compounds strongly, whereas sediment-herbivora species accumulate the less water-soluble, material-bound components (Paasivirta et al. 1985a).

In some investigations various aquatic plants have been studied as bioaccumulators of micropollutants. Of the plants e.g. the bryophytes Fontinalis and Cinclidotus had high concentration factors for heavy metals in fresh waters (Mouvet 1985). The Nordic survey of atmospheric heavy metal deposition by moss analysis (Rühling et al. 1987) is based on an analogous methodology.

In Finland, monitoring of environmental pollution in inland waters is based on the use of different organisms including the lake mussel (Anodonta piscinalis) and the fishes vendace (Coregonus albula), pike (Esox lucius), roach (Rutilus rutilus) and whitefish (Coregonus lavaretus). Coastal marine waters are monitored using the Baltic mussel (Mytilus edulis), mesidotea entomon (Saduria entomon) and the fishes pike (Esox lucius), cod (Gadus morhua) and Baltic herring (Clupea harengus membras) (National Board of Waters and the Environment 1990).

Slowly degrading, long-lived materials and compounds can also be analysed in deposits in lake sediments and in the sediment biota. Investigations have been made of the spreading of heavy metals (Alhonen et al. 1973, Häkkilä 1984, 1985, Verta 1990). Sediments may also contain resistant organochlorine compounds derived from pulp bleaching, and sediment investigations have therefore been used to monitor the diffusion of these effluents over large distances (Paasivirta et al. 1988b, 1990).

Biotests have been carried out in watercourses only on rare occasions. By contrast, waste waters, particularly toxic pulp and paper effluents, have been investigated with biotests in greater detail. The test organisms in Finnish studies included pure cultures of algae and bacteria (e.g. Talsi et al. 1984, Eloranta and Halttunen-Keyriläinen 1985), Daphnia water fleas, Daphnia magna (e.g. Nikunen and Miettinen 1985, Rekolainen 1986) and different species of fishes including rainbow trout (Salmo gairdneri), salmon (Salmo salar) and zebra fishes (Brachydanio rerio).

Fishes have also been caged in recipients of the pulp and paper industry. Caged whitefish have been shown to be good indicators of waste waters when analysing conjugated chlorinated phenolics from bile (Oikari and Holmbom 1986, Lindström-Seppä and Oikari 1989). Resin acids have been analysed from caged rainbow trout (Salmo gairdneri) and from perch (Perca fluviatilis) caught close to a kraft pulp mill (Oikari et al. 1980).

1.3 Mussels in monitoring of harmful substances

Mussels are a widely used test organism in various types of watercourse investigation all over the world. They are readily available for use in tests, in almost all countries and watercourse types. Handling of mussels is easy and they can be incubated in the laboratory. They are long-lived, over ten years, and persist even in unfavorable conditions. For example, mussels (Mytilus edulis) have even been reported to grow in

industrial water cooling systems, where they may cause fouling problems (Jenner 1980).

Mussels have been used in the monitoring of polluted coastal zones of ocean waters (e.g. Anon. 1980, 1989). More frequently, they have been utilized for the estimation of the spreading and effects of heavy metals in recipient waters. Thus for example in the USA the concentrations of copper in river watercourses were investigated with the fresh water mussel Quadrula quadrula (Foster and Bates 1978), whereas the marine species Mytilus edulis was used in an investigation of Norwegian coastal waters (Knutzen 1983) and in waters of the Sound in southern Sweden (Phillips 1979). M. edulis was also used to monitor spreading of the metals Cd, Cu, Pb, Zn, Mn and Fe in Dutch coastal waters (van Eck et al. 1989) and similarly for the metals Cd and Zn in the southern Gulf of Bothnia and the northern Baltic Sea (Broman et al. 1988). Asiatic clams (Corbicula sp.) were used for monitoring chrysotile asbestos in public water supplies (Belanger et al. 1987).

The biological characteristics of mussels, e.g. shell growth and the strength of byssal threads, have also been used in the estimation of effluent effects (Ekelund et al. 1983). The same species was used in an investigation of the energy budget of caged mussels in the vicinity of an industrial centre on the west coast of Sweden (Magnusson et al. 1988). Mussel shell morphology, degree of shell etching and shell growth rates and also the structure of the interfilamentary junction of the mussel gill and its uncoupling have all been used as indicators of environmental stress (Sunila and Lindström 1985, Kollberg et al. 1986, Green et al. 1989). Deformation of mussel shells has also been used as an index of water quality (Lindström 1986).

Mussels of the genera Mytilus and Macoma have been used in marine waters to detect the spreading of PCB (Paasivirta et al. 1985d, Granby and Sørensen 1988), for the monitoring of oil pollution (Mattsson and Notini 1984, Broman and Ganning 1985,

Sinkkonen 1989) and in investigations of sources of contamination by PCDDs and PCDFs in Osaka Bay, Japan (Miyata et al. 1989a, b). Mytilus edulis was used in an investigation of the bioaccumulation of halogenated short-chain hydrocarbons (Wharfe et al. 1981) and polycyclic aromatic hydrocarbons (Kveseth et al. 1982). The green lipped mussel (Perna viridis Linnaeus) was used in waters off Hong Kong for investigating the persistence of the highly toxic coplanar PCBs (Tanabe et al. 1987, Kannan et al. 1989). Mytilus edulis has also been used for monitoring radionuclides in recipients of the Ringhals atomic energy plant in southern Sweden (Notter 1987).

In running waters fresh water mussels were used as biological indicators of pesticide (Bedford et al. 1968, Kauss and Hamdy 1985) and of other organic contaminants (Muncaster et al. 1989). Leard et al. (1980) studied the use of seven species of freshwater bivalves (Pelecypoda) for monitoring organochlorine pesticide residues in the Major Mississippi Stream System as long ago as in 1972 - 1973 by taking water clams directly from the river. The study indicated that some freshwater clams can be effective for pesticide monitoring, although major differences were recorded between the different species in the accumulation of these compounds. Differences between the species Macoma baltica, Mytilus edulis and Unio sp. in the accumulation of metals was also observed by Häkkilä (1984, 1985).

Mussel shells have also been used in investigations of the spreading of heavy metals and of long term pollution in recipients (Lindström et al. 1988a, b, Piepponen and Lindström 1989), although some problems have been reported in analysing the shells (Green et al. 1989).

1.4 Background of the investigations

Characterization of waste water discharges of the wood processing industry has proved to be rather problematic. In the monitoring of waste waters of the Finnish chemical wood

processing industry the variables are usually particulate materials and soluble organic compounds, nutrients, particularly phosphorus, and recently also organic chlorine compounds. The total loading due to organic compounds is measured by BOD-, COD_{Mn}-, COD_{Cr}-, TOC- and AOX-analyses.

The quantitative identification of effluent-derived organic compounds in watercourses is difficult because a major part of the water soluble high-molecular weight material originating from kraft pulping has a structure almost identical to that of lake humus (Knuutinen et al. 1987). The greatest difference is in the amount of total organically bound chlorine (TOCl), which in the case of effluent lignin is of the order of several per cent but which in the case of lake humus is about one per cent or less (Paasivirta 1988b, Paasivirta and Maatela 1988).

Nutrient discharges from industrial plants can be monitored directly. More difficult is the monitoring of discharges of organic chlorine compounds and their distribution in the recipient of the pulping mill. There are several analytical problems in analysing these organic compounds. The recovery of many phenolic compounds in concentrations below 20 µg/l may be between 60 and 70 % and standard deviation percentages of the results for some of these compounds may be between 20 and 50 % (Starck et al. 1985).

Organic chlorine compounds are produced mainly in pulp bleaching plants. Some of these compounds may cause acute toxicity in the recipient near to the point of discharge, whereas others have widespread sub-lethal effects and others tend to be strongly bioaccumulated in biota far from the point source of pollution (Earl and Reeve 1990). Small molecular weight compounds are particularly important because of their possible direct effects on biota (Holmbom 1988). The composition and toxicity of these compounds depend especially on the wood raw material used in the industry. For example, softwood filtrates are twice as mutagenic as hardwood filtrates (Gergov et al. 1988).

Great numbers of different compounds are found in waste waters and only a small part of the total organic chlorine can hitherto be analysed with any accuracy (Håkanson and Jonsson 1989). For this reason there are still considerable problems involved in the estimation of the possible toxic effects of organic chlorine compounds.

The variable best indicating overall concentrations of organic chlorine compounds has been considered to be the TOCl-assay (Maatela and Paasivirta 1989, Manninen 1990). Granberg (1988) used TOCl when modelling the occurrence and spreading of organic chlorine compounds in Lake Päijänne. TOCl appeared to be rather persistent in watercourses. Discharges from the pulp mills at Äänekoski can be detected even in southern Lake Päijänne, some 150 km from the point of discharge.

In some recent investigations assays have been carried out of the concentrations of AOX (adsorbable organic halogens) of effluents (Häsänen 1988, Starck 1988). Both AOX and also EOX (extractable organic halogens) are, however, total variables, the analysis results of which depend to a great extent on various compounds with very different watercourse effects. Furthermore it has recently been reported that AOX can be found even in unpolluted waters in a natural state (Borén et al. 1989, Enell et al. 1989, Enell and Wennberg 1991, Grimvall et al. 1991) and therefore at least AOX would not appear to be a suitable variable for watercourse monitoring. Although AOX may well be applicable for the monitoring and control of total organic chlorine compounds in effluents of the chemical wood processing industry, it is too imprecise to follow their fate in recipient watercourses (Bertmar 1990). In monitoring it is important to obtain data concerning the occurrence and biological reactions of single compounds, too.

A major investigation of the biological effects of pulping effluents was carried out in Sweden in the 1980's. Spreading of the pulping effluents in the recipient was studied in detail and

a series of observations concerning the behaviour of mussels (Macoma baltica) in a brackish water recipient was made (Södergren 1989). At the same time the spreading of EOCl was investigated using samples taken from sediments.

1.5 Aim of the present investigation

The aim of this work was to develop and apply in praxis a bioaccumulation method for the detection and monitoring of low and rapidly changing concentrations of organic chlorine compounds, particularly in the freshwater recipients of the pulp and paper industry. Although they may be of major significance for water quality, both low and rapidly fluctuating concentrations of organic chlorine compounds may be difficult to monitor on the basis of chemical analyses alone.

In this work the whole data base arising from the development of the mussel method was utilized. Some of the results have been published previously, mainly in Finnish mimeographed publications or as abstracts of various congress proceedings. In addition to these, some of the results have also appeared in international journals (Heinonen et al. 1986, Herve et al. 1988b, c, Herve 1989, 1991, Paasivirta et al. 1989a).

2 MATERIALS AND METHODS

2.1 Test-organism, the common mussel (Anodonta piscinalis)

Although some organisms living in water ecosystems have shown to bioconcentrate many organic compounds from surrounding waters better than mussels, e.g. the aquatic leeches (Metcalfe et al. 1984, Metcalfe and Hayton 1989), it was decided to use the lake mussel (Anodonta piscinalis) belonging to molluscs as test animal in these studies. This species of the family of Unionidae, which belongs to filter feeding bivalves (Purchon 1977), is very common in Finland especially in the lake district

in Southern and Central Finland. The lake mussel thrives in shallow waters, sometimes in very dense communities, up to the depth of five metres (Haukioja and Hakala 1974). Besides, there is much research information of its behaviour and characteristics (Haukioja and Hakala 1978a, b), and its use as test organism is easy.

The mussel uses water both in respiration and nutrient uptake. It moves slowly along the bottom, slightly dug in it, in an upright position. It takes up nutrients by mixing the fine components of the sediment with water and by filtering it through its gills. Tens of liters of water may infiltrate through its gills in one day. The mussel uses as nutrients small particles of usually less than 10 µm (Brönmark and Malmqvist 1982), bacteria, algae, and organic relics of macrophytes and corresponding organisms.

Organochlorine compounds were investigated for the first time in Finland from mussels already in 1973 - 1978 (Paasivirta et al. 1976, Paasivirta et al. 1981b), when 2,4,6-trichlorophenol and pentachlorophenol were detected from mussels (Anodonta) in Lake Päijänne in connection with a food chain study.

2.2 The mussels used in the tests

Even though previous studies have proved that the content of contaminants in Anodonta piscinalis is independent of the size of the individual (Särkkä et al. 1978), individuals of approximately uniform size were used in tests. All mussels were obtained from unpolluted watercourses in natural state in Central Finland. During 1984 - 1987 mussels dived by Jyrki Vertanen from Lake Kivijärvi (watercourse area 14.44 according to Seuna 1971) were used. The mussels for the monitoring in 1988 and the winter incubation in 1989 were dived by Jarmo Kivinen from Läsäkoski and Rauhavirta in the Mäntyharju watercourse (watercourse areas 14.92-14.93). The mussels for the monitoring

in 1989 were dived by Jarmo Kivinen from Lake Oulankijärvi (watercourse area 4.15). Läsäkoski, Rauhavirta and Lake Kivijärvi are mesohumic and oligotrophic, whereas Lake Oulankijärvi is clear and oligotrophic (Jarmo Kivinen, Water and Environment District of Mikkeli, pers. com.).

Table 1. Average lengths, ages, and means of total weights, weights without shell, dry weight % (without shells) and fat percentages calculated out of dry weights of mussels (Anodonta piscinalis) used during the years 1984 - 1989.

year	number n	lenght cm	age year	total weight g	weight without shell g	dry weight %	fat-% of dw
1984	34	7.57	6.21	18.95	10.03	10.19	5.63
1985	60	7.46	7.25	19.51	11.05	9.73	6.10
1986	116	7.54	6.01	18.93	10.81	8.47	5.92
1987	147	7.50	9.90	20.86	12.58	9.02	6.20
1988	608	8.00	6.40	23.82	13.19	9.82	6.10
1989W	91	8.44	5.38	26.63	14.06	9.12	6.49
1989M	286	8.40	7.20	20.99	11.65	6.66	7.04

W = winter incubation, M = monitoring

The mussels used in the tests were of a fairly uniform size. Their growth was relatively slow, as they had grown in oligotrophic conditions. In highly eutrophic lakes the mussels may grow quicker but not as long as in oligotrophic conditions (Arter 1989). In this investigation the weight of the shell was high as compared with the length of mussels (see Nagel 1987).

The fat percentage of mussels was on an evenly high level, in average a little over 6 % of the dry weight. The distribution of the fat percentage was almost normal in the whole material.

2.3 Testing arrangements in laboratory

After the diving the mussels were brought quickly to the laboratory of the Water and Environment District of Central Finland, Jyväskylä. They were kept in incubation in a room with the windows covered to prevent direct sunlight to warm up the room. There was no cooling system in the room. No chemical analyses were conducted and no reagents handled in the incubation room. The mussels were kept in aquariums of either 120 or 240 litres. Two respectively four litres of a dilution of Z8 algae cultivation storage solution was added to distilled, ion exchanged water of the aquariums in advance in order to balance nutrient salts and other salts important for production (Källqvist 1973). The situation thus created corresponded rather closely to the concentrations in an eutrophic lake. The lights were on in the aquarium only during working hours five days a week.

Before filling the aquariums a sand bottom of approximately 3-5 cm consisting of cleaned fine gravel was placed in them. There were no water plants and the small amount of algae was mainly due to the algae that were brought in with the slightly pre-rinsed mussels. The mussels were not otherwise fed during this laboratory period. The aeration was on rather effectively during the whole time. The aeration air was not cleaned in any way. In the filtration of water, which was on all the time, common aquarium filters were used (Aquaviva F/42 internal filter Type/32).

There was a long plastic tube system in the aquariums. The water that circulated in it was cooled with refrigeration equipment, and its temperature was about 4-12 °C depending on room temperature. The water of the aquariums was never circulated directly through the refrigeration equipment so that there would not even be a theoretical possibility of a contamination. In order to prevent dust contamination the aquariums were fully covered with glass plates. The possibility of dust contamination was small because people seldom moved in the incubation room during the incubation period.

The mussels were kept in the aquariums 2 - 3 weeks before they were moved to the incubation. The water quality of the aquariums was monitored daily. During this period the temperature in the aquariums varied usually between 15 - 23 °C, the oxygen content between 70 - 100 % of saturation, pH between 6.8 - 7.5, and NH_4-N between 5 - 300 µg/l. The content of especially ammonium nitrogen increased (up to 3600 µg/l) very rapidly, if any of the mussels died.

The condition of the mussels was checked every day. Dead and weak mussels were removed daily. Whenever the oxygen content decreased and the ammonium nitrogen content increased the aeration of the aquariums was increased. However, supersaturation of oxygen was avoided. The chlorophyll a content of the aquariums during the pre-incubation of mussels was low (<1 µg/l).

As the incubation room was not tempered, situations where the temperature of the aquariums tended to rise strongly occurred a few times during the hot spells. It was then necessary to replace the water of the aquariums gradually with precooled water from a cold-storage room. The water used was clean ion exchanged water the temperature of which was approximately +5 °C.

Before the incubation in watercourses started reference mussels were collected from aquariums. They were treated exactly in the same manner as mussels incubated in watercourses.

2.4 Incubation in watercourses

The mussels were transported to the monitoring sites in water tanks of 10 - 20 litres so that the temperature of the water did not rise significantly during the transportation. When necessary, bags containing ice cubes were used for cooling the water. The longest transportations took about 24 hours at the most.

At the incubation site the mussels were immediately moved to plastic traps. The size of one trap was 22 x 15 x 8 cm^3. The traps were tested before incubation that they did not cause any contamination. Altogether 4 - 8 mussels were placed in one trap. The structure of the trap guaranteed an unrestricted change of water for the mussels. The mussels in cages were anchored with floats in the deeper areas of the lakes to be monitored at the depth of about 1 metre, where the effects of the bottom sediments were as non-significant as possible (Fig. 1). Only during the winter incubation programme the incubation depth of five metres was also used.

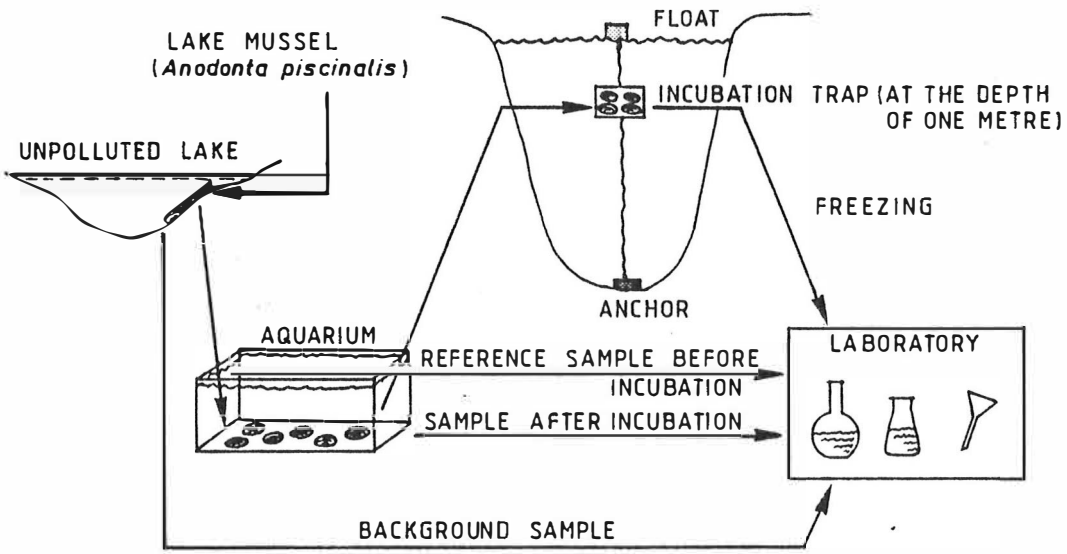

Fig. 1. The principle of the mussel incubation method.

Sixteen mussels in two cages were usually incubated at each monitoring site. The lake mussel is a very resilient test organism, usually surviving even under heavily polluted conditions. Even in the most polluted sites investigated a maximum of only 1 - 2 mussels usually succumbed during the four weeks incubation period.

The incubation time was as a rule four weeks, after which the traps were collected and already in the field each mussel was wrapped as such separately to aluminum foil and transported immediately to the laboratory and frozen at -18 °C. In order to speed up the field work the shell was not removed before freezing as was done by Foster and Bates (1978) and Kauss and Hamdy (1985). In some tests longer incubation times were also used (see Chapters 3.2.1 and 3.2.5).

The incubation cages were not cleaned during the incubation to prevent fouling. That is why the traps and even the shells of the mussels became slimy to a very significant extent at eutrophic sites and close to pulp mills. Despite this the mussels usually survived the incubation. The mussel traps were left relatively well alone in the watercourses and no mischief was done.

In 1984 plastic plates were also incubated in addition to mussels. The same compounds as from the mussels were analysed of the periphyton gathered from them. The size of the plastic plates was 30 cm x 100 cm and there were five of them at each incubation site. The total area from which periphyton was taken and investigated was thus 3 m^2.

2.5 Sample handling

In the laboratory the age of the mussels was estimated on the basis of shell markings. The mussels were weighed and the concentrations of the relevant organic compounds were determined from the soft tissues.

For the laboratory handling of mussels incubated at each sampling site, three composite samples of five mussels were prepared for analyses. This economical method of composite samples (Paasivirta and Paukku, 1989) has been used in mussel

incubation studies in Finland since 1986. The final monitoring result is given as the mean value of these three composite samples prepared from the uniform homogenate of the soft tissues.

2.6 Compounds analysed

Before extraction, known amounts of internal standards were added: 2,4,6-trichlorobiphenyl for chlorohydrocarbons, 2,3,6-trichlorophenol for chlorophenolics, 2,3,6-trichloroanisole for chloroanisoles/veratroles and ^{13}C-labelled 2,3,7,8-dibenzo-p-dioxin for PCDD/PCDFs. The sample was then extracted in a Soxhlet apparatus with hexane-acetone-diethyl ether-petroleum ether (40 - 60°C), 2.2:5.5:1:9 (v/v/v/v) for six hours. The solvent was evaporated first in a Rotavapor and finally in a stream of nitrogen gas and the residue was weighed to determine the fat content (Herve et al. 1988b).

The compounds analysed and their abbreviations are shown in Figs. 2 - 5 (see also Appendix 11).

The compounds available as commercial model compounds were used. The other compounds have been synthesized and their structures verified as described by e.g. Knuutinen 1984, Knuutinen and Klein 1989, Humppi 1985, Soikkeli et al. 1986, Tarhanen et al. 1986, Paasivirta et al. 1987b, Kuokkanen 1989. The detailed analysing procedures are presented in Appendix 1 (Herve et al. 1988b).

The analyses were carried out in 1984-1988 in the Department of Chemistry in the University of Jyväskylä and in 1989 in the Institute for Environmental Research of the University of Jyväskylä.

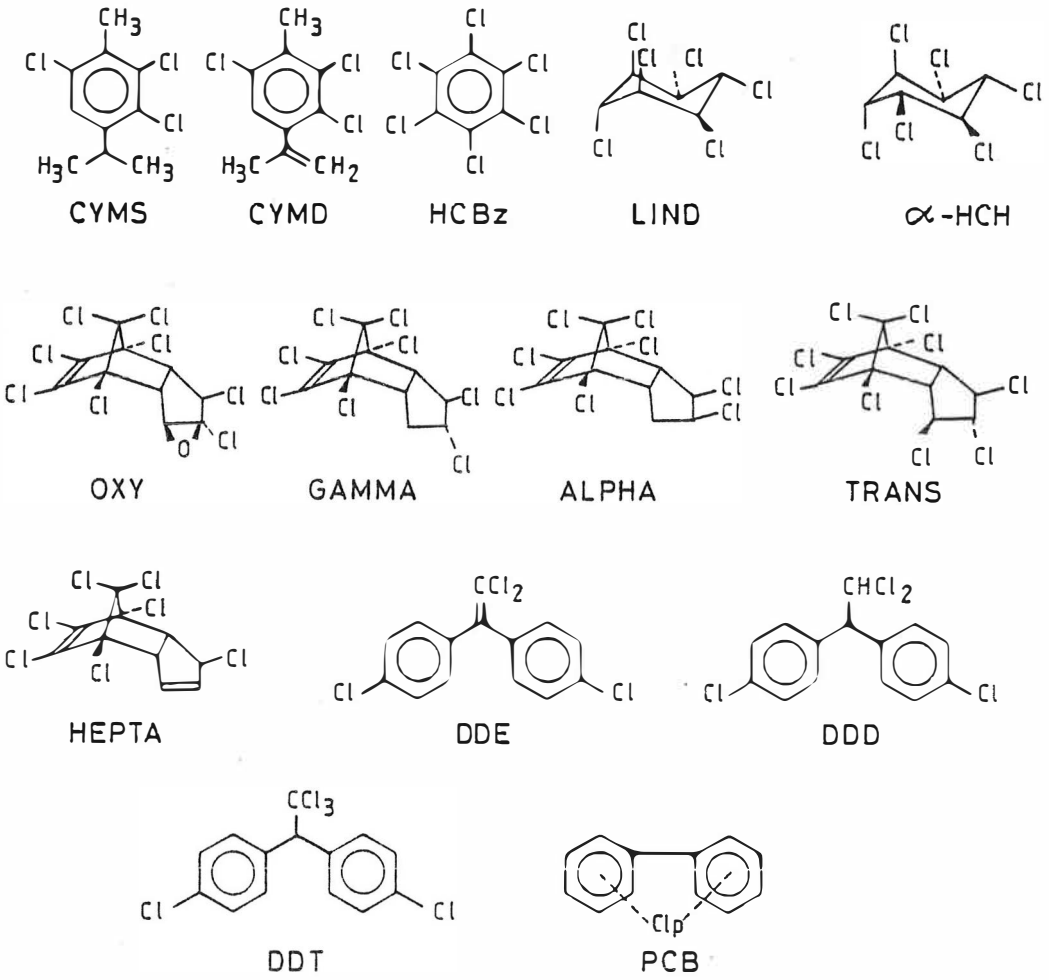

Fig. 2. Structures and abbreviations of the chlorohydrocarbons studied in this work. CYMS = 2,3,6-Trichloro-p-cymene, CYMD = 2,3,6-Trichloro-p-cymenene, HCBz = Hexachlorobenzene, LIND = Lindane, gamma-hexachlorocyclohexane, α-HCH = α-Hexachlorocyclohexane, OXY = Oxychlordane, GAMMA = Gamma-chlordane, ALPHA = Alpha-chlordane, TRANS = Trans-nonachlor, HEPTA = Heptachlor, DDE = p,p'-Dichloro-diphenyl-dichloroethylene, DDD = p,p'-Dichloro-diphenyl-dichloroethane, DDT = p,p'-Dichloro-diphenyl-trichloroethane, PCB = Polychlorinated biphenyls.

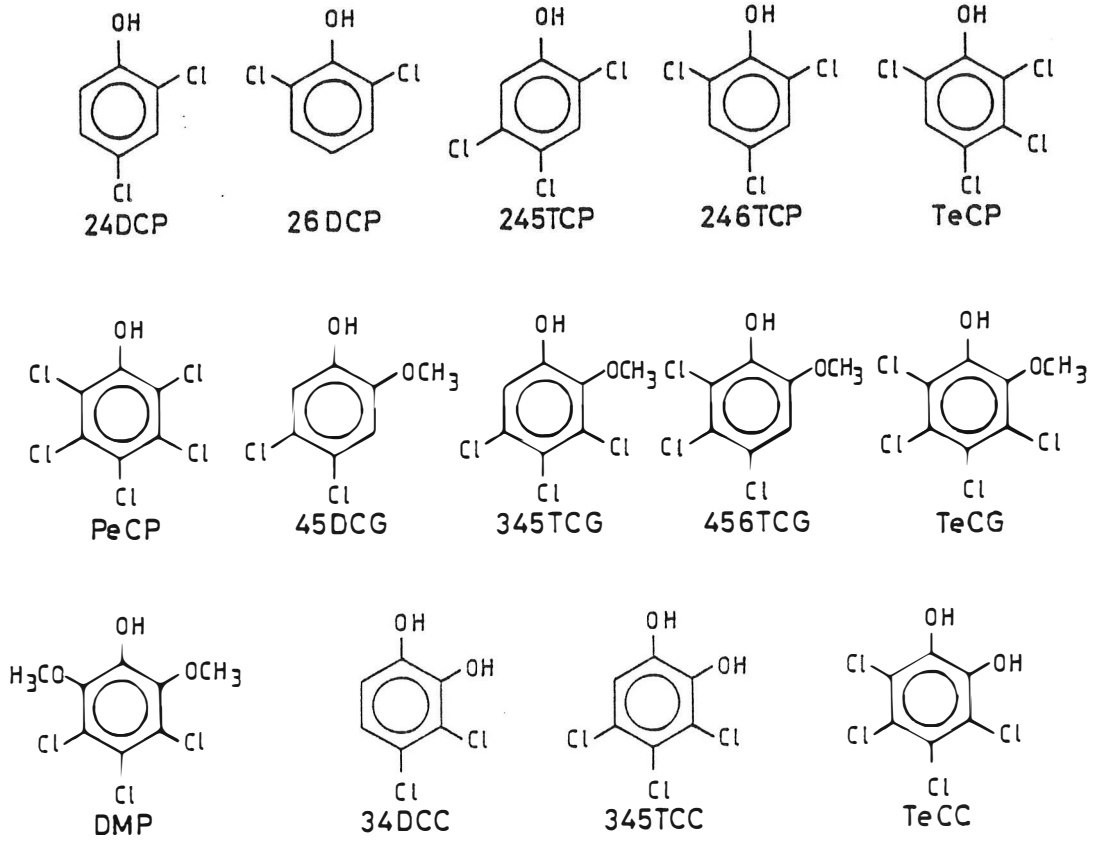

Fig. 3. Structures and abbreviations of the chlorophenolics studied in this work. 24DCP = 2,4-Dichlorophenol, 26DCP = 2,6-Dichlorophenol, 245TCP = 2,4,5-Trichlorophenol, 246TCP = 2,4,6-Trichlorophenol, TeCP = 2,3,4,6-Tetrachlorophenol, PeCP = Pentachlorophenol, 45DCG = 4,5-Dichloroguaiacol, 345TCG = 3,4,5-Trichloroguaiacol, 456TCG = 4,5,6-Trichloroguaiacol, TeCG = Tetrachloroguaiacol, DMP = 2,6-Dimethoxy-trichlorophenol, 34DCC = 3,4-Dichlorocatechol, 345TCC = 3,4,5-Trichlorocatechol, TeCC = Tetrachlorocatechol.

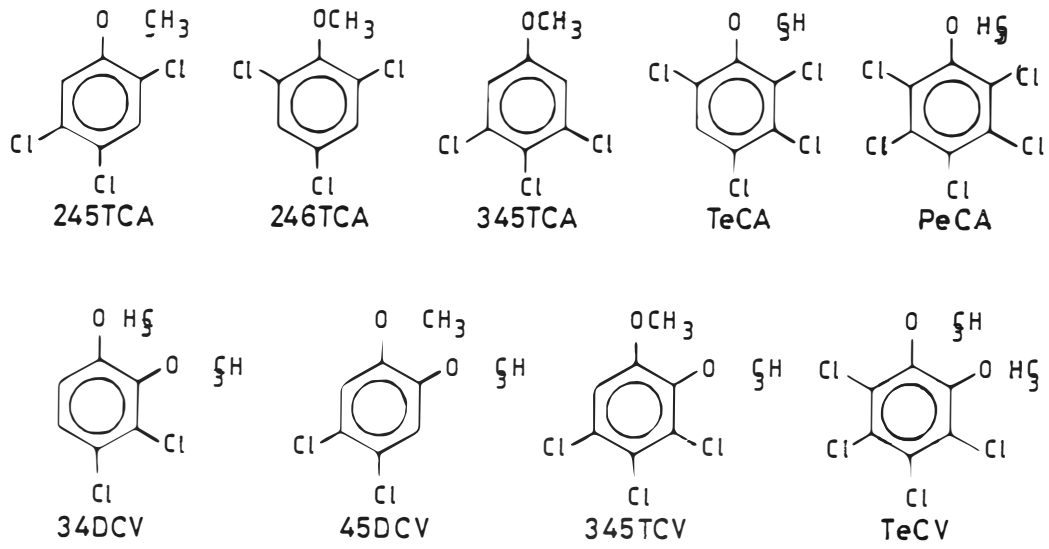

Fig. 4. Structures and abbreviations of the chlorinated anisoles and veratroles studied in this work. 245TCA = 2,4,5-Trichloroanisole, 246TCA = 2,4,6-Trichloroanisole, 345TCA = 3,4,5-Trichloroanisole, TeCA = 2,3,4,6-Tetrachloroanisole, PeCA = Pentachloroanisole, 34DCV = 3,4-Dichloroveratrole, 45DCV = 4,5-Dichloroveratrole, 345TCV = 3,4,5-Trichloroveratrole, TeCV = Tetrachloroveratrole.

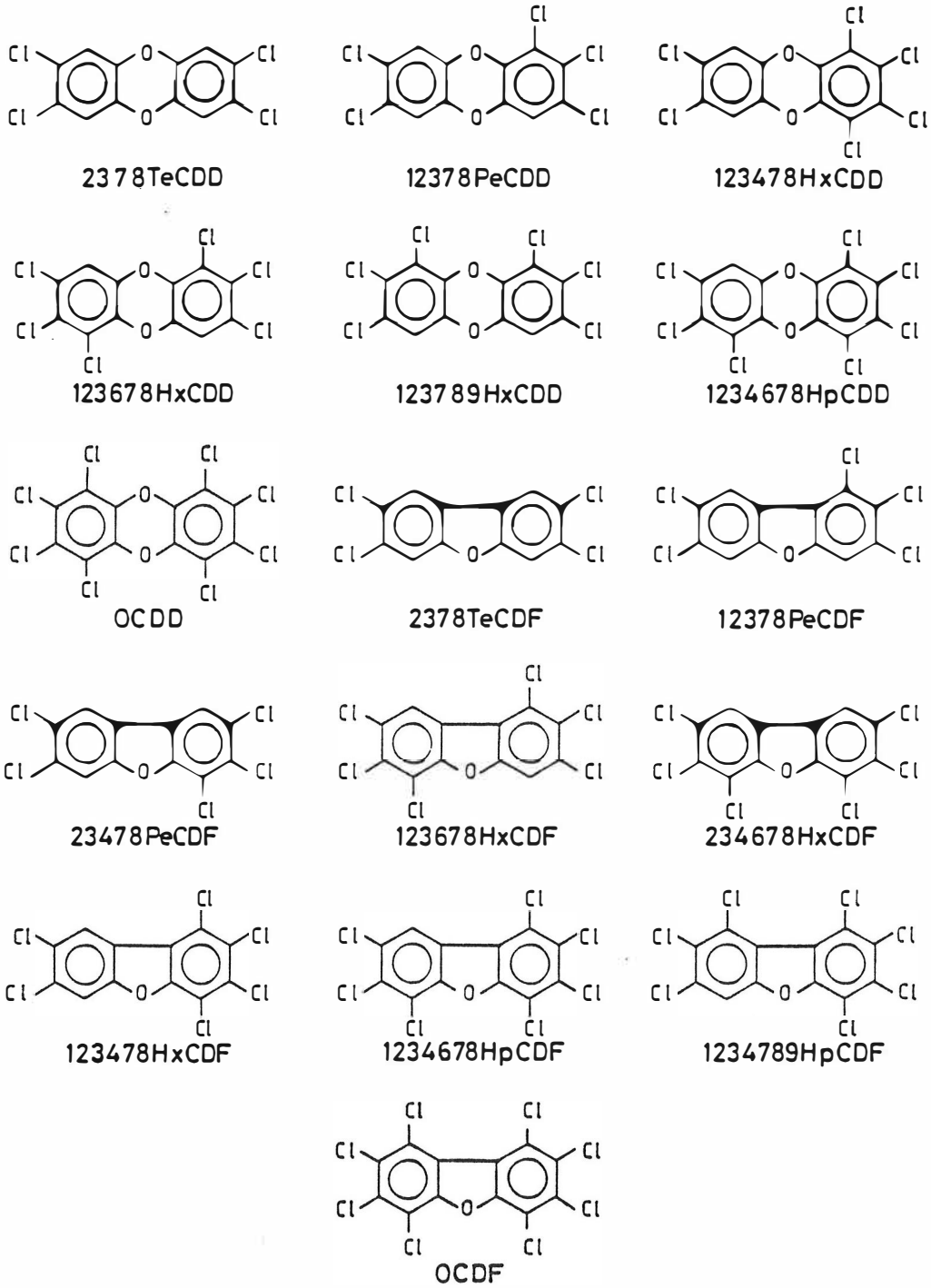

Fig 5. Structures and abbreviations of the chlorinated dibenzo-p-dioxins and dibenzofurans studied in this work. 2378TeCDD =

2,3,7,8-Tetrachlorodibenzo-p-dioxin, 12378PeCDD = 1,2,3,7,8-Pentachlorodibenzo-p-dioxin, 123478HxCDD = 1,2,3,4,7,8-Hexachlorodibenzo-p-dioxin, 123678HxCDD = 1,2,3,6,7,8-Hexachlorodibenzo-p-dioxin, 123789HxCDD = 1,2,3,7,8,9-Hexachlorodibenzo-p-dioxin, 1234678HpCDD = 1,2,3,4,6,7,8-Heptachlorodibenzo-p-dioxin, OCDD = Octachlorodibenzo-p-dioxin, 2378TeCDF = 2,3,7,8-Tetrachlorodibenzofuran, 12378PeCDF = 1,2,3,7,8-Pentachlorodibenzofuran, 23478PeCDF = 2,3,4,7,8-Pentachlorodibenzofuran, 123678HxCDF = 1,2,3,6,7,8-Hexachlorodibenzofuran, 234678HxCDF = 2,3,4,6,7,8-Hexachlorodibenzofuran, 123478HxCDF = 1,2,3,4,7,8-Hexachlorodibenzofuran, 1234678HpCDF = 1,2,3,4,6,7,8-Heptachlorodibenzofuran, 1234789HpCDF = 1,2,3,4,7,8,9-Heptachlorodibenzofuran, OCDF = Octachlorodibenzofuran.

2.7 Data handling

In the handling of results the chlorophenolic compounds were divided into two groups as follows:

(1) S1PCP = 246TCP + TeCP + PeCP; pollutants from wood preservation, combustion, chlorination, and pesticide use,

(2) S2PCP = 24DCP + 26DCP + 245TCP + 34DCC + 345TCC + TeCC + 45DCG + 345TCG + 456TCG + TeCG + DMP; mainly from pulp bleaching.

This grouping is to a great extent based on investigations in Central Finland already in the late 1970's (Paasivirta et al. 1980).

In addition, the following sum variables were used of other compounds:

SANIS = the sum of chloroanisoles and chloroveratroles,

SDDT = DDE + DDD + DDT,

SCHL = OXY + GAMMA + ALPHA + TRANS + HEPTA.

The PCB standard used was usually commercial Clophen A-60, but the standard used in the monitoring sites of HÄM, MIE, VAN, HAT, and KER was Aroclor 1254. Clophen A-60 and a PCB compound aged in the environment usually resemble one another. In the Vanajavesi water system there was a strong younger PCB contamination, and the compound accumulated in the mussels resembled more Aroclor 1254.

In addition to the contents of different compounds the dioxin load was estimated as TCDD-equivalents (NORD 1988).

The concentrations of all compounds were calculated in fat, which can be considered a justified presentation method for organochlorine compounds that are enriched in organism chains (Paasivirta et al. 1983, Paasivirta 1984).

The following descriptions of bioconcentration, bioaccumulation and biomagnification have been used (according to Müller 1987, see also Neumann 1985). The bioconcentration factor (BCF) is described according to the following equation:

$$BCF = \frac{\text{concentration in the organism (µg/g wet weight)}}{\text{concentration in water (dissolved + particulate)(µg/ml)}}.$$

Bioaccumulation occurs when intake rates significantly exceed rates of elimination through metabolism and excretion.

Biomagnification refers to an increase of a given material at successive trophic levels within an ecosystem.

2.8 Composite samples

When contents are very low, even near determination limits, the deviation is not normal but it resembles a lg-normal. Due to

this the method of composite samples was usually used when analysing the mussels, as this decreases the deviation of the results significantly (Paasivirta et al. 1988c, Flores Baez and Galindo Bect 1989, Paasivirta and Paukku 1989).

In 1984 four or eight mussels were incubated at each monitoring site, and individual mussels were analysed (usually four individuals). An arithmetic mean was calculated on the basis of these results. In 1985 four mussels were incubated at each site, and two homogenates were formed out of them. The result used was the mean value of these two homogenates. In 1986 and 1987 15 mussels divided in two cages were incubated at each site. In the analysis homogenates of three mussels were formed of them. Thus the final result was the mean of five such homogenates. In the monitoring of 1988 and 1989 15 mussels were also incubated at each monitoring site, and the homogenates were formed of five mussels. The final result was thus the mean of three such homogenates.

3 RESULTS AND DISCUSSION

3.1 Results of chemical analyses

Mussel incubation method was used in the years 1984-1989. Altogether seven different trials were carried out. Usually the mussels were incubated during summer stratification time, only once in wintertime. Investigations were carried out in many watercourses in Finland (Fig. 6).

All results of these incubation trials are presented in the original form received from the analysing laboratories (Appendices 2-8). All the abbreviations used are presented in Appendix 11. The primary results of the investigations in 1984-1987 were published earlier in the mimeographed reports of the National Board of Waters and the Environment (Heinonen et al. 1985, Paasivirta et al. 1986a, 1987a and 1988c).

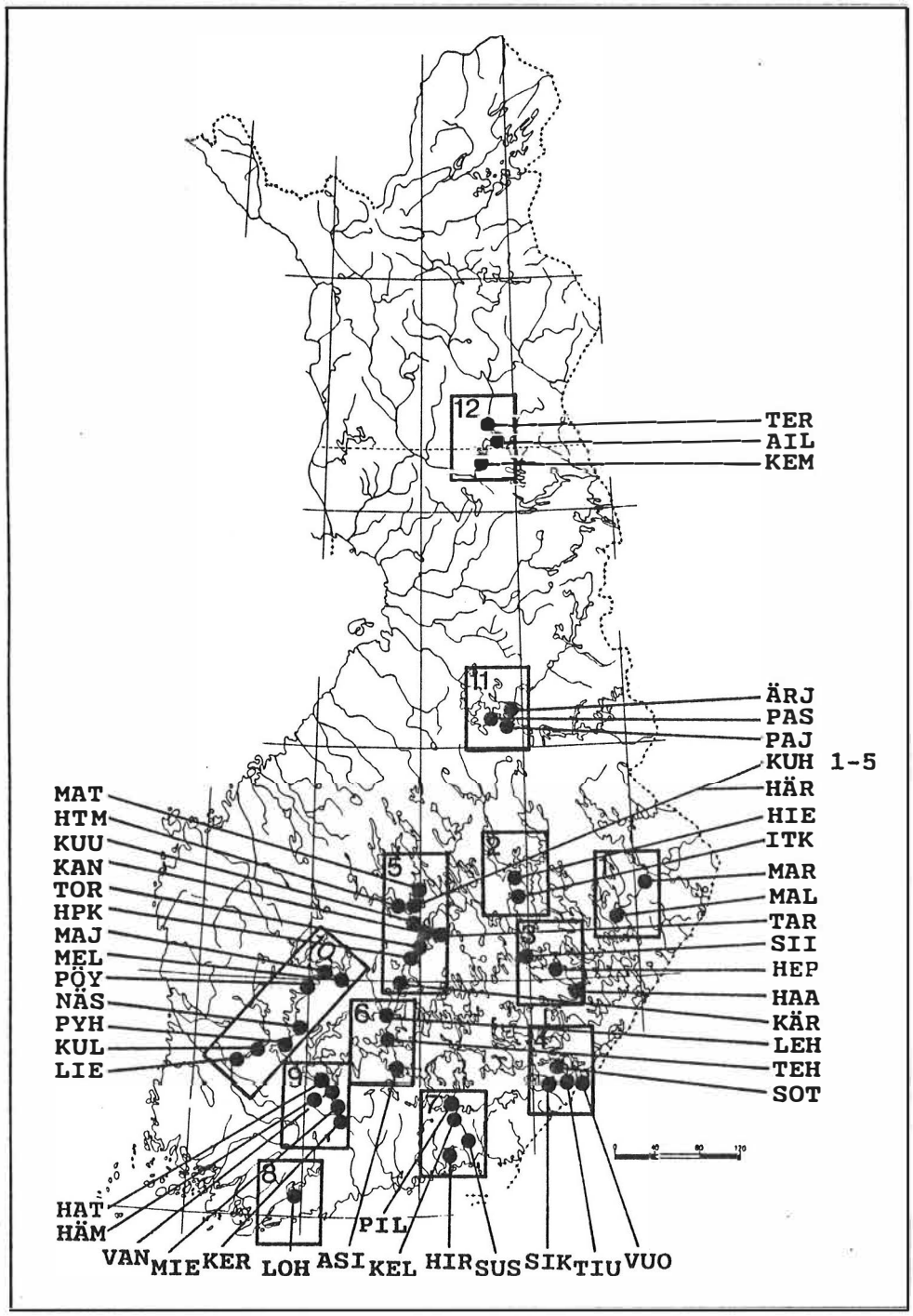

Fig. 6. The mussel incubation stations used in these investigations (abbreviations in Appendix 11).

3.2 Incubation trials

3.2.1 The Äänekoski area in 1984 - 1985

The development of the monitoring method of organochlorine compounds started in 1984. The watercourse stretching down to Kärkistensalmi in Lake Päijänne in the Kymijoki river basin below the City of Äänekoski (Map 5 in Appendix 9) was chosen as the field site for the investigations in the first phase. The hydrologic properties including the retention time are well known. The area is influenced by the pulp and paper industry in Äänekoski. The lowest monitoring site - Kärkistensalmi (KÄR) in Lake Päijänne - is influenced by the City of Jyväskylä near-by (population over 66 000 inhabitants, effective biological and chemical treatment of waste water) and the waste water from communities and small-scale industry in its vicinity. The monitoring station TAR (in 1984) was to a certain extent influenced by the diluted load from the sulphite pulp mill at Lake Lievestuoreenjärvi. This mill was run down in 1985. In 1984 the kraft pulp production of the pulp industry in Äänekoski was about 100 000 t/a and the estimated TOCl-discharge about 260 t/a (Paasivirta et al. 1986b).

There were altogether six incubation sites for mussels (Map 5, Appendix 9). The incubations were carried out in two periods in 1984. During the first period the incubation started on 2-3 August and ended four weeks later on 29-30 August 1984. The second incubation period started on 29-30 August and ended about five weeks later on 8-9 October 1984. The results are presented in Appendix 2.

In 1984 organochlorine compounds were analysed also from incubated periphyton plates. The results of these analyses have been presented by Heinonen et al. (1985).

In 1985 the investigation was repeated in the same recipient. The incubation started on 23 July. In addition to four week

incubation, periods of two, six, and eight weeks were also used in 1985 in order to define and check the ideal length of incubation. The results are presented in Appendix 3.

After 1984 there had been a significant change in the waste water load on the area, which also affected discharges of organochlorine compounds. In January 1984 the production of sulphite pulp and yeast stopped, and in May 1985 the old sulphate pulp mill was closed. In March 1985 the new activated sludge waste water treatment plant for the purification of the new sulphate pulp mill and its waste water went into operation, due to which the organic load on the watercourse decreased significantly. The load from the sulphite pulp mill to Lake Lievestuoreenjärvi was small in the summer 1985 before the mill was finally closed at the beginning of September (Paasivirta et al. 1986b).

In this first investigation it was found that the periphyton incubation method was very laborious and inaccurate especially at the field stage. Due to small concentrations it was necessary to use many very large gathering plates, the handling of which was laborious both at the incubation stations and in the laboratory. The possibility of mistakes was thus evident. The periphyton that was developed especially in eutrophic areas could come loss from plate even before the end of the incubation period and thus reduce the real amount. In the areas where the influence of pulp waste waters was strongest the primary production could be inhibited, and the amount of algae necessary to accumulate the organic compounds to be investigated did not develop. This is why the use of periphyton method in this context was given up, and the studies were hereafter concentrated solely on the mussel method.

At the reference station (MAT) small amounts of lindane and DDE, a metabolite of DDT were detected in both 1984 (0.26-0.31 µg/g fat and 0.16-0.28 µg/g fat respectively) and 1985 (0.10 µg/g fat and 0.07 µg/g fat respectively). Other chlorohydrocarbons were

not found in detectable concentrations at this incubation station that was in a completely natural state according to ordinary monitoring of watercourses.

At the monitoring station KUU which is strongly affected by the chemical pulp and paper industry in Äänekoski there was in 1984 in addition to lindane and DDE a relatively significant amount of PCB (1.73-2.36 µg/g fat). High concentrations of PCB (2.22-3.06 µg/g fat) in incubated mussels were found in the following year 1985, too. The lindane-concentrations were also approximately of the same level as in 1984, but the DDE-concentrations had decreased considerably. New compounds detected from the mussels incubated in 1985 were CYMS (0.31-2.06 µg/g fat) and HCBz (0.05-0.11 µg/g fat).

The effects of the pulp and paper industry in Äänekoski reduce rapidly as the water flow grows and the mixing becomes more effective. Also reduction of organochlorines in mussels as a function of time and distance in the successive incubation stations KAN and TOR (Map 5 in Appendix 9) is clearly seen. Lindane, DDE, and PCB occurred at these sites in both 1984 and 1985. In 1985 small amounts of CYMS and HCBz were also found. Lindane also occurred (0.30 µg/g fat) at the monitoring station KÄR at Lake Päijänne in 1984.

Of chlorophenolics only TeCP and PeCP were detected both years at the reference station MAT (0.53-1.91 µg/g fat and 0.52-2.61 µg/g fat respectively). In 1985 246TCP (0.68 µg/g fat) was also detected. 345TCG, 456TCG, TeCG, and DMP were detected in the mussels incubated at sites downstream from pulp and paper industry. The highest concentrations were detected in KUU (S2PCP 2.20-16.4 µg/g fat), the closest incubation station to pulp and paper discharge. The concentrations were already much smaller at the incubation station TOR (S2PCP 1.61-3.01 µg/g fat).

The chlorocatechols were analysed in 1984 and 1985. The only

clearly positive results were from 345TCC in the year 1984 in the incubation stations KUU and KÄR (both 1.00 µg/g fat).

3.2.2 The Kymijoki river basin in 1986

In 1986 the use of the mussel method was expanded to the whole Kymijoki river basin. There were, however, only seven incubation stations (Maps 5-7, Appendix 9). The reference station MAT was the same as in 1984 and 1985, as also the monitoring stations KUU, TOR, and KÄR. The incubation station LEH in Central Lake Päijänne was chosen because the pulp and paper industries in the Jämsä district had a dominating effect on that part of the lake. The results from River Kymijoki, incubation station HIR, describe the effluents of organochlorine compounds from the chemical pulp and paper industry at Kuusankoski and Anjalankoski. Due to the short retention time it also describes relatively well the water quality of River Kymijoki that flows to the Gulf of Finland. The reference station for this was the station PIL in the least polluted area of River Kymijoki.

The incubation time was from 4-6 August to 1-3 September 1986. Chlorohydrocarbons, chlorophenolics, and for the first time in these investigations chloroanisoles and chloroveratroles, were analysed of the samples. The results are presented in Appendix 4.

Of chlorohydrocarbons PCB (0.55 µg/g fat) and small amounts of lindane (0.03 µg/g fat) and DDE (0.02 µg/g fat) were detected at the reference station MAT. In addition small amounts of DDT and HCBz were also found from the mussels. No chlordanes OXY, GAMMA, ALPHA, and TRANS were detected at the reference station.

In the monitoring sites KUU and TOR downstream from Äänekoski exceptionally high PCB-concentrations (2.74 and 2.03 µg/g fat respectively) were detected. CYMS-concentrations increased considerably (from 0.01 to 0.30 µg/g fat) as compared KUU with

the reference station MAT. Gamma-chlordane (0.03 µg/g fat) was also found from the immediate recipient of pulp industry, KUU.

In Lake Päijänne small amounts of CYMS, HCBz, and lindane were found from the incubation sites KÄR and LEH. GAMMA and PCB were detected in addition to these from the reference area (PIL) of the River Kymijoki.

From the part of River Kymijoki with pulp and paper industry (HIR) CYMS (0.72 µg/g fat), HCBz (0.05 µg/g fat) and GAMMA (0.11 µg/g fat) were detected. This incubation place was exceptional in that no lindane was detected. The PCB-concentrations were also below the detection limit.

Of chlorophenolics only TeCP (0.30 µg/g fat) and PeCP (0.11 µg/g fat) were detected at the reference station in Matilanvirta (MAT).

The bleaching effluents of pulp and paper industry changed the picture of the chlorophenolics detected in incubated mussels at the stations KUU and TOR so that higher concentrations of 345TCG (1.99 and 0.54 µg/g fat respectively) and TeCG (0.53 and 0.18 µg/g fat respectively) were detected. 246TCP and 456TCG were also found nearer the discharge place of waste water at the incubation station KUU. The sum of chlorophenolics originating from bleaching (S2PCP) was high at the station KUU (3.12 µg/g fat) but decreased clearly downstream in the water system (TOR 0.73 and KÄR 0.35 µg/g fat).

At the incubation stations KÄR and LEH in Lake Päijänne the highest concentrations of chlorophenolics were determined of 345TCG. In addition to it 246TCP, TeCP, PeCP, and TeCG were detected from incubated mussels.

The highest concentrations of chlorophenolics found from mussels incubated at the reference station PIL in River Kymijoki were of TeCP (0.33 µg/g fat) and PeCP (0.38 µg/g fat). Small concentra-

tions of 246TCP (0.09 µg/g fat) were also detected. The highest concentrations of chlorophenolic compounds (as sum concentration) of this monitoring of the Kymijoki river basin were found from River Kymijoki itself (HIR), which is heavily loaded by chemical pulp and paper industry. The most common single chlorophenolic compounds detected were 345TCG (2.79 µg/g fat), 246TCP (1.57 µg/g fat), TeCP (1.15 µg/g fat) and TeCG (0.94 µg/g fat). The concentrations of PeCP (0.42 µg/g fat), 456TCG (0.35 µg/g fat) and DMP (0.31 µg/g fat) were also high as compared with the other stations.

The chlorocatechols were also analysed from all incubation stations but not detected anywhere.

In the monitoring of the Kymijoki river basin also chloroanisoles and chloroveratroles were analysed. The highest concentrations of TeCV were found at the closest recipients downstream from the pulp mills, incubation station HIR at River Kymijoki (0.27 µg/g fat) and KUU at Kuusaankoski in the immediate recipient of the mills in Äänekoski (0.14 µg/g fat). Small concentrations were, however, also found in the reference station MAT (0.03 µg/g fat). In addition, small concentrations of 246TCA, TeCA, and PeCA were detected at different stations. 345TCA, 34DCV, 45DCV and 345TCV were not detected in any sample.

3.2.3 The PCB-investigation in 1987

Already in the preliminary studies using the mussel method in 1984 and 1985, and in the monitoring of the Kymijoki river basin in 1986 relatively high PCB-concentrations had been detected regularly at the incubation stations KUU and TOR downstream from Äänekoski. In addition, clearly increased concentrations of PCB had also been detected earlier in pikes from the area (Paasivirta et al. 1981a, 1983) and a slightly increasing PCB-trend had been detected from the perches of Lake Päijänne that is further away already towards the end of 1970's (Paasivirta and Linko 1980). Also Miettinen and Verta (1984) found increased concen-

trations of PCB in pikes in Lake Leppävesi in 1978 - 1979. Clearly increased PCB-concentrations were also found in the sediment of Lake Jyväsjärvi (near the City of Jyväskylä), which, however, did not alone explain the relatively high PCB-concentrations in the pikes of Lake Päijänne (Paasivirta et al. 1986c). For this reason it was decided in 1987 to investigate closer the possible origins of the PCB.

Mussels were incubated at ten monitoring stations in the watercourse between Matilanvirta (MAT) and Torronselkä (TOR), and the situations near the mills were investigated more closely (Map 5 in Appendix 9). In order to achieve comparisons in time, mussels were incubated also at the incubation sites Kuusaankoski (KUU) and Torronselkä (TOR). For the same reason other chlorohydrocarbons and chlorophenolics as well as chloroanisoles and chloroveratroles were investigated. In addition, polychlorinated dibenzo-p-dioxins (PCDD) and dibenzofurans (PCDF) were analysed from incubated mussels at the monitoring sites KUH3 and KUH4.

The incubation of mussels started on 4-5 August and ended on 1-2 September 1987. The results are presented in Appendix 5.

The PCB-concentration in incubated mussels was at its highest and on the same level as in the previous investigations in the incubation sites KUU (1.77 µg/g fat) and TOR (1.76 µg/g fat). High concentrations were also detected at the stations KUH2 (1.16 µg/g fat), KUH3 (0.95 µg/g fat), and KUH4 (1.66 µg/g fat). The most likely origin of PCB was thus clearly limited to the waters near the mills of Metsä-Serla Co. and Metsä-Sellu Co., above the main waste water discharge point used then, and it was not possible that the leak could originate from the Keitele (HÄR) or Saarijärvi (HTM) water systems. PCB did not come to the water system with waste water effluent either, but it probably originated from other sources in the mill area (Herve et al. 1988a).

Of other chlorohydrocarbons only small concentrations of lindane (0.02-0.14 µg/g fat) and hexachlorobenzene (0.03-0.07 µg/g fat) occurred in the whole area. In the reference area MAT there were still small amounts of DDE (0.03 µg/g fat). In the areas close to pulp industry, and especially in the incubation sites below it (KUH2, KUH3, KUH4, KUU and TOR) CYMS (0.59, 1.20, 0.48, 0.43 and 0.28 µg/g fat respectively), CYMD (0.11, 0.46, 0, 0.06 and 0.09 µg/g fat respectively) and HCBz (0.04, 0.03, 0.07, 0.04 and 0.04 µg/g fat respectively) were detected. Cymene and cymenene were not found at the stations MAT, HÄR, HTM, KUH1 and KUH5.

The highest concentrations of chlorophenolics in the reference areas (MAT, HÄR, HTM, KUH1) were detected from TeCP (0.36, 0.20, 0.15 and 1.58 µg/g fat respectively) and PeCP (0.13, 0.03, 0.24 and 0.54 µg/g fat respectively). The highest concentrations of chlorophenolic compounds S2PCP were detected in the immediate recipient of waste waters from mills, at the incubation station KUH3 (21.4 µg/g fat). The major part of this S2PCP was 345TCG (14.2 µg/g fat). TeCG-concentrations were also high (4.39 µg/g fat). At the stations KUU and TOR high concentrations of chlorophenolics of the S2PCP-group still occurred in the incubated mussels (1.77 and 1.94 µg/g fat respectively).

The chlorocatechols were also analysed but not detected at any incubation station.

Especially high concentrations of chloroanisoles and chloroveratroles that cause major flavour defects in fish (Veijanen 1990) were detected in the incubation station KUH3. The highest concentrations were detected of 3,4,5-trichloroveratrole (2.51 µg/g fat) and tetrachloroveratrole (1.88 µg/g fat). Chloroanisole concentrations were much lower than these (0.07-0.27 µg/g fat). A corresponding situation was also analysed from mussels incubated at the monitoring sites KUU and TOR. 245TCA and 345TCA of chloroanisoles and 34DCV and 45DCV of chloro-

veratroles were detected in no samples.

The PCDD- and PCDF-concentrations were very low in the mussels, due to which it was necessary to even further combine samples for the analysis. One structually non-identified tetrachlorodibenzo-p-dioxin was detected at station KUH4. Its content was measured to be 1.9 ng/g in fat. One tetrachlorodibenzofuran that was not further identified was also detected at the incubation station KUH3 (Paasivirta et al. 1988c).

3.2.4 The monitoring in 1988

The systematic monitoring of organochlorine compounds in the freshwater recipients of pulp and paper industry by this mussel incubation method was started in Finland in the summer 1988 as a part of the inland monitoring programme of the National Board of Waters and the Environment. The total number of incubation stations was altogether 40.

The incubation sites were placed in watercourses downstream from all inland pulp mills that produce or had produced bleached pulp during the past few years. In the most polluted recipient waters of pulp and paper industry there were several incubation sites for finding out how bleaching effluents spread and degrade. There is a map of the monitoring sites (Fig. 6) and also more detailed maps (Maps 1 - 12 in Appendix 9). The loading of the pulp and paper mills concerned are presented in Appendix 10. The results are presented in Appendix 6.

The incubation was carried out simultaneously at all stations. All mussels were first kept 2 - 3 weeks in the laboratory of the Water and Environment District of Central Finland in aquariums, whereafter they were transported to the incubation stations with the help of the local Water and Environment Districts. The incubation started on 9-10 August and the mussels were taken from the incubation four weeks later on 6-7 September 1988.

Chlorohydrocarbons and chlorophenolic compounds were analysed of the incubated mussels. Chloroanisoles and chloroveratroles were also measured. At the ten stations that had been estimated in advance as the worst in this respect polychlorinated dibenzo-p-dioxins (PCDD) and dibenzofurans (PCDF) were also analysed.

Of chlorohydrocarbons the highest concentrations in incubated mussels were analysed of PCB. Its concentrations were remarkably high (30 - 40 µg/g fat) at Lake Kernaalanjärvi (KER) in the Kokemäenjoki water system. The effects of this lake that has been badly polluted by the waste water and PCB from a paper mill stretches far downstream so that clearly increased PCB-concentrations (0.85 µg/g fat) could be detected as far as Hattulanselkä in Vanajavesi (HAT, Map 9 in Appendix 9).

Another area where the PCB-concentrations were clearly increased was the waterway below Äänekoski (Map 5 in Appendix 9). PCB-concentrations were still high in the sampling stations KUU (1.27 µg/g fat) and TOR (0.94 µg/g fat), which had also been detected in the previous investigations in 1984 - 1987. PCB-concentrations that were clearly higher than the background values were also found in mussels incubated in River Vuoksi (VUO), River Kymijoki (KEL, SUS, HIR), and Lake Kulovesi (KUL).

The highest concentrations of the metabolites of DDT, especially DDE, were detected in the badly polluted Lake Kernaalanjärvi, KER (0.55 µg/g fat) and Lake Vanajavesi, MIE and VAN (0.08 and 0.11 µg/g fat respectively) downstream from it. The sum of DDT and its metabolites (SDDT) was also clearly increased in Lake Ruovesi, MAJ (0.08 µg/g fat).

Gamma-chlordane was detected in Lake Kernaalanjärvi, KER (0.16 µg/g fat). Downstream from it, in Lake Vanajavesi (MIE, VAN), the chlordane-concentrations were high, but here they were alpha-chlordane (0.22 and 0.14 µg/g fat respectively). GAMMA was also detected in River Kymijoki, KEL, SUS and HIR (0.17, 0.06

and 0.11 µg/g fat respectively) and Lake Kallavesi, HIE and ITK (0.08 and 0.12 µg /g fat respectively).

High concentrations of CYMS were detected in Lake Melasjärvi, MEL (0.69 µg/g fat), Lake Majavesi, MAJ (0.38 µg/g fat), in Southern Lake Saimaa, SIK and SOT (0.41 and 0.58 µg/g fat respectively), in Lake Haukivesi in Siitinselkä, SII (0.56 µg/g fat) and Heposelkä, HEP (0.16 µg/g fat), and in Lake Vanajavesi, HÄM and HAT (0.21 and 0.50 µg/g fat respectively). The CYMS-concentrations in River Kymijoki were also detectable up to 0.22 µg/g fat.

Small concentrations of lindane (<0.05 µg/g fat) occurred in almost all incubation stations.

Chlorophenols of the S1PCP-group were detected in all incubation sites. The highest sum concentrations were found from Lake Vanajavesi, near the City of Hämeenlinna, HÄM (9.77 µg/g fat). from Lake Kallavesi, ITK (5.61 µg/g fat) near the City of Kuopio, and Lake Paltajärvi, PAJ (3.88 µg/g fat) near the City of Kajaani. At all these incubation stations the major component in S1PCP was TeCP, the main component of a wood preservative.

The S1PCP-concentrations were rather high in Lake Melasjärvi, MEL (2.97 µg/g fat) as well, which is the only recipient of waste waters from a sulphite pulp mill in Finland. The most common component in S1PCP was 246TCP (1.78 µg/g fat), but TeCP was also found (0.99 µg/g fat). In Lake Vanajavesi Hattulanselkä (HAT) the major component of S1PCP (3.01 µg/g fat) was TeCP (2.50 µg/g fat), whereas in Lielahti (NÄS) in Lake Näsijärvi near the City of Tampere the fairly high concentration of S1PCP (2.31 µg/g fat) was due to almost even amounts of TeCP (1.00 µg/g fat) and PeCP (1.10 µg/g fat).

The highest concentrations of chlorophenolic compounds of the S2PCP-group occurred in mussels incubated in River Kymijoki, KEL, SUS and HIR (3.28, 5.20 and 5.56 µg/g fat respectively) and

in Lake Kemijärvi, TER, AIL and KEM (6.41, 3.21 and 1.61 µg/g fat respectively). The concentrations were also high in Kuusaankoski, KUU (1.84 µg/g fat) and Torronselkä, TOR (2.82 µg/g fat), in River Vuoksi, VUO (2.34 µg/g fat), in Lake Saimaa in the vicinity of Island Sikosalo, SIK (2.89 µg/g fat) and in Lake Melasjärvi, MEL (1.77 µg/g fat). In all these recipients that are heavily polluted by pulp industry 345TCG was the major component of S2PCP. The second most common component was tetrachloroguaiacol.

The highest DMP-concentration (0.53 µg/g fat) was analysed from Lake Vanajavesi (MIE). Rather high DMP-concentrations were also found from mussels incubated at the stations in River Kymijoki KEL, SUS and HIR (0.21, 0.31 and 0.38 µg/g fat respectively). DMP-concentrations almost as high as these were also determined from River Pielisjoki, MAR (0.21 µg/g fat). There DMP was actually the most common component in the S2PCP-group, which can be due to the more extensive use of birch as raw material for pulp (see also Petänen and Oikari 1987).

The sum concentration of chloroanisoles and chloroveratroles (SANIS) was the highest in the vicinity of pulp industry in Lake Kemijärvi, KEM (4.23 µg/g fat). In Kemijärvi the main components of the SANIS-group were 345TCA and 345TCV. Clearly increased SANIS-concentrations were also observed in Lake Kallavesi, HIE (2.66 µg/g fat) where there were high TeCA-concentrations in addition to 345TCA and 345TCV. In Southern Lake Saimaa (SIK) the relatively high SANIS-concentration (2.01 µg/g fat) was mainly due to 345TCA. In Lake Ruovesi (MAJ, PÖY) in the recipient of sulphite pulp industry the increase in the SANIS-concentration (2.76 and 1.68 µg/g fat respectively) was mainly attributable to TeCV.

In River Kymijoki the SANIS-concentrations were the highest in the lower course of Kymijoki (HIR) where 345TCV and TeCA were the largest components of SANIS (2.55 µg/g fat). The SANIS-concentration consisting mostly of 345TCV and TeCV was also high

(1.95 µg/g fat) in Lake Lohjanjärvi (LOH). The remarkable feature in Lake Lohjanjärvi as compared with all other monitoring sites was that no TeCA was detected. A corresponding situation was analysed in Southern Lake Päijänne (TEH).

The highest concentrations of polychlorinated dibenzo-p-dioxins and dibenzofurans were detected in the incubation sites of River Kymijoki. The highest toxic load as TCDD-equivalents was accumulated in the incubation station Keltti (KEL), in the immediate recipient of the pulp and paper mills in Kuusankoski area. Especially dibenzofurans, but also small amounts of 123678HxCDD and 1234678HpCDD were accumulated in the mussels incubated at this station. As TCDD-equivalents (NORD 1988) the total dioxin and furan concentrations at the incubation station Keltti (KEL) corresponded to 510 pg/g fat. At the next incubation station downstream in River Kymijoki (SUS) the chlorinated dibenzofuran concentrations were still high, but the 123678HxCDD- and 1234678HpCDD-concentrations were clearly lower, which is why the result was only 218 pg/g fat as TCDD-equivalents. At the lowest incubation station in River Kymijoki (HIR) it was no longer possible to find dioxins, which is why the TCDD-equivalent was only 189 pg/g fat even though considerable furan concentrations were still found from the mussels.

At the other seven incubation stations of mussels where dioxins and furans were defined dioxins were found only in the incubation station of River Vuoksi (VUO). The TCDD-equivalents remained, however, under 50 pg/g fat in all incubation stations.

3.2.5 The winter incubation in 1989

As the method of incubating mussels was being developed it was always carried out when the water was warm, usually in August-September. The vital functions of mussels are then active and the incubation including the acquisition of the mussels and the field stage are easier to carry out than in the winter when the watercourses are covered with ice. The proportion of auto-

chthonous material in the nutrition of the mussels is higher in the summer than in the winter. A monitoring programme that is repeated at the same time each year has also the advantage that possible changes in bioaccumulation due to the life cycle of the mussel do not affect the results. The behaviour of chlorophenolics during warm water seasons and cold water seasons may also be quite different. It has been shown that the concentrations of chlorophenolics are strongly reduced by transformation processes during warm water seasons (Seppälä and Kansanen 1988).

Winter conditions have a theoretical effect on at least the respiration and nutrition intake of mussels, and as the behaviour of different chlorophenolics is different in cold waters, a test was also performed during winter time. A good monitoring method must be applicable during all seasons. Elsewhere the metal accumulation in shrimps in a seawater area (Alliot and Frenet-Piron 1990) has been investigated in the winter.

The winter incubation was carried out in the Kuusaankoski station (KUU, map 5 in Appendix 9) from 16 February to 30 March 1989, the incubation time being six weeks. The mussels were incubated below falls in an ice-free area. The weather was mild during the incubation, and no problems due to the winter occurred.

Chlorohydrocarbons, chlorophenolics, chloroanisoles, and chloroveratroles were analysed of the incubated mussels. The results are presented in Appendix 7.

The concentrations of the chlorohydrocarbons were small. The highest concentration detected was of PCB (0.06 µg/g fat), but even it was only a fraction of the concentrations detected at the same incubation station the summer before and during the previous years (see e.g. Appendix 6).

On the other hand, remarkably high concentrations of chlorophenolic compounds were found from incubated mussels. The

highest concentrations detected were of 345TCG (2.67 µg/g fat) belonging to the S2PCP-group and TeCP (1.85 µg/g fat) belonging to the S1PCP-group. The bioaccumulation of 246TCP (0.99 µg/g fat), PeCP (0.60 µg/g fat) and TeCG (0.51 µg/g fat) was also remarkably high. Small amounts of chlorocatechols, 345TCC and TeCC, were also detected.

From the group of chlorinated anisoles and veratroles the highest concentration found in winter incubation was of tetrachloroveratrole (0.14 µg/g fat).

3.2.6 The monitoring in 1989

In the summer 1989 the monitoring of organochlorine compounds in the freshwater recipients of pulp and paper mills was repeated on twenty stations. The incubation stations were picked up on the basis of the results in the summer 1988. These stations and the mussel incubation carried out on them were a part of the monitoring of environmental toxins in inland waters presented in the programme of the National Board of Waters and the Environment (National Board of Waters and the Environment 1990). The abbreviations of the incubation sites can be found in the list of results (Appendix 8). There is also a general map of the monitoring sites (Fig. 6) and more detailed maps (Appendix 9).

The incubation was carried out simultaneously at all the stations. The mussels were incubated for four weeks starting on 8-9 August 1989.

Chlorohydrocarbons and chlorophenolics were analysed. Dibenzo-p-dioxins and dibenzofurans were also analysed from mussels incubated at six of these incubation stations. The results have been presented in Appendix 8.

PCB was detected at all monitoring stations, the highest concentrations in Lake Kernaalanjärvi, KER (76.0 µg/g fat) and in Lake Vanajavesi near the City of Hämeenlinna, HÄM (4.50 µg/g

fat). The concentrations at the incubation stations of Kuusaankoski, KUU (2.36 µg/g fat) and Torronselkä, TOR (1.41 µg/g fat) in the recipient downstream from Äänekoski mills continued to be rather high. Concentrations exceeding the background values in this study were also detected in all incubation stations of the River Kymijoki , KEL, SUS and HIR (0.89, 1.00 and 1.07 µg/g fat respectively). Similarly, downstream of the City of Tampere in Lake Pyhäjärvi (PYH) the concentration was remarkable (0.97 µg/g fat).

Lindane was detected in most incubation stations, but only in very small concentrations (<0.05 µg/g fat).

Of other chlorohydrocarbons chlordanes, especially GAMMA, were detected in all three incubation stations of River Kymijoki KEL, SUS and HIR (0.33, 0.22 and 0.18 µg/g fat respectively). Chlordanes were also detected in Lake Kallavesi , ITK (SCHL 0.14 µg/g fat) and in Lake Haukivesi, SII (SCHL 0.20 µg/g fat) downstream from the City of Varkaus, but in addition to ALPHA and GAMMA, trans-nonachlor was also detected in them.

The highest concentrations of 2,3,6-trichloro-p-cymene (CYMS), occurred in Lake Melasjärvi, MEL (0.34 µg/g fat) and in Lake Haukivesi, SII (0.26 µg/g fat). In the Kymijoki river basin the highest CYMS-concentrations were detected in the incubation stations downstream from the mills in Äänekoski, KUU and TOR (0.18 and 0.11 µg/g fat respectively) and in the River Kymijoki itself, KEL, SUS and HIR (0.18, 0.20 and 0.19 µg/g fat respectively). In the Southern Lake Saimaa (TIU) and in the River Vuoksi (VUO) the cymene concentrations were also elevated (0.11 and 0.10 µg/g fat respectively).

Only in Lake Vanajavesi (HÄM) a little elevated DDE-concentration (0.08 µg/g fat) was detected.

The highest concentration of chlorophenols of the S1PCP-group was detected in Lake Vanajavesi in the area of the City of

Hämeenlinna, HÄM (10.1 µg/g fat). The major component was TeCP (8.64 µg/g fat), which is the main component of a wood preservative, (Ky-5).

Rather high S1PCP-concentrations were also found at the incubation station TOR downstream from Äänekoski (1.64 µg/g fat) and in Lake Päijänne, KÄR (1.39 µg/g fat), where the major component was PeCP, and from Lake Melasjärvi, MEL (1.06 µg/g fat), where the major component was 246TCP. In the Lake Paltajärvi near the City of Kajaani (PAJ) the rather high S1PCP-concentration (1.01 µg/g fat) was mainly due to TeCP.

The highest S2PCP-concentrations were detected in Lake Kemijärvi (TER) where S2PCP (7.27 µg/g fat) mostly consisted of 345TCG and TeCG. The concentrations were much lower in the outlet of the Lake Kemijärvi, KEM (S2PCP 1.33 µg/g fat). In the Lake Melasjärvi (MEL) in the recipient of a sulphite pulp mill the high S2PCP-concentration (4.58 µg/g fat) consisted of 345TCG, 456TCG and TeCG. The same components also caused the high S2PCP-concentration (3.00 µg/g fat) in River Vuoksi (VUO). In the incubation stations downstream of Äänekoski mills (KUU, TOR) the high S2PCP-concentrations (3.60 and 3.13 µg/g fat respectively) were mainly due to 345TCG and TeCG, while the proportion of 456TCG was smaller. A similar situation was also found at the incubation stations of the River Kymijoki (KEL, SUS, HIR), where the S2PCP-concentrations (0.68, 1.07 and 1.23 µg/g fat respectively) were clearly lower than one year before. The chlorocatechols were analysed, but not detected in any incubation station.

Polychlorinated dibenzo-p-dioxins and dibenzofurans were investigated from mussels incubated at six monitoring stations. Dioxins were not found in any samples, even though the following compounds were analyzed: 2378TeCDD, 12378PeCDD, 123478HxCDD, 123678HxCDD, 123789HxCDD, 1234678HpCDD, and OCDD. The highest concentrations of polychlorodibenzofurans were detected in the River Kymijoki (KEL). The furan compounds detected were

1234678HpCDF and OCDF. The value of the TCDD-equivalent (NORD 1988) was 59.6 pg/g fat. In addition, 1234678HpCDF was detected in River Vuoksi (VUO), the value of its TCDD-equivalent being 9.5 pg/g fat, and 2378TeCDF in Lake Kernaalanjärvi (KER), its TCDD-equivalent being 97.3 pg/g fat.

3.3 Observations

3.3.1 Chlorohydrocarbons

There are several sources of chlorohydrocarbons, and some of them can be found everywhere as they spread globally by air, and they have been found in the air of strongly industrialized areas but also areas that are considered to be in a completely natural state like Arctic and Antarctic areas (several authors referred by Södergren et al. 1990). The most important chlorohydrocarbons are polychlorinated biphenyls, PCBs. These are still considered to be some of the most dangerous environmental toxins (e.g. Paasivirta 1988a, Kannan et al. 1989). PCB is persistent and ubiquitous, and it has been found in water, air, soil, and sediment (Dunnivant et al. 1989). In nature PCB may also spread by air bound with particles (Södergren 1972).

PCB in a water ecosystem binds itself to particles and especially sediments (Paasivirta et al. 1986c) and phytoplankton (Södergren 1984b). It takes a long time for e.g. a sediment polluted by it to become clean, and thus it can have effects on large areas of a water ecosystem by e.g. bioaccumulating in organisms or in connection with dredgings (Södergren 1973, 1984a, Södergren and Larsson 1982, Larsson and Södergren 1987). A similar release of PCB may be caused by dumps and polluted landfills (Richardson and Waid 1982).

The highest PCB-concentrations were found in mussels incubated in Lake Kernaalanjärvi (KER) (Chapters 3.2.4, 3.2.6 and Fig. 7). Maximum concentrations were in 1988 39.2 µg/g fat and in 1989 76.0 µg/g fat. These values are high found from living organ-

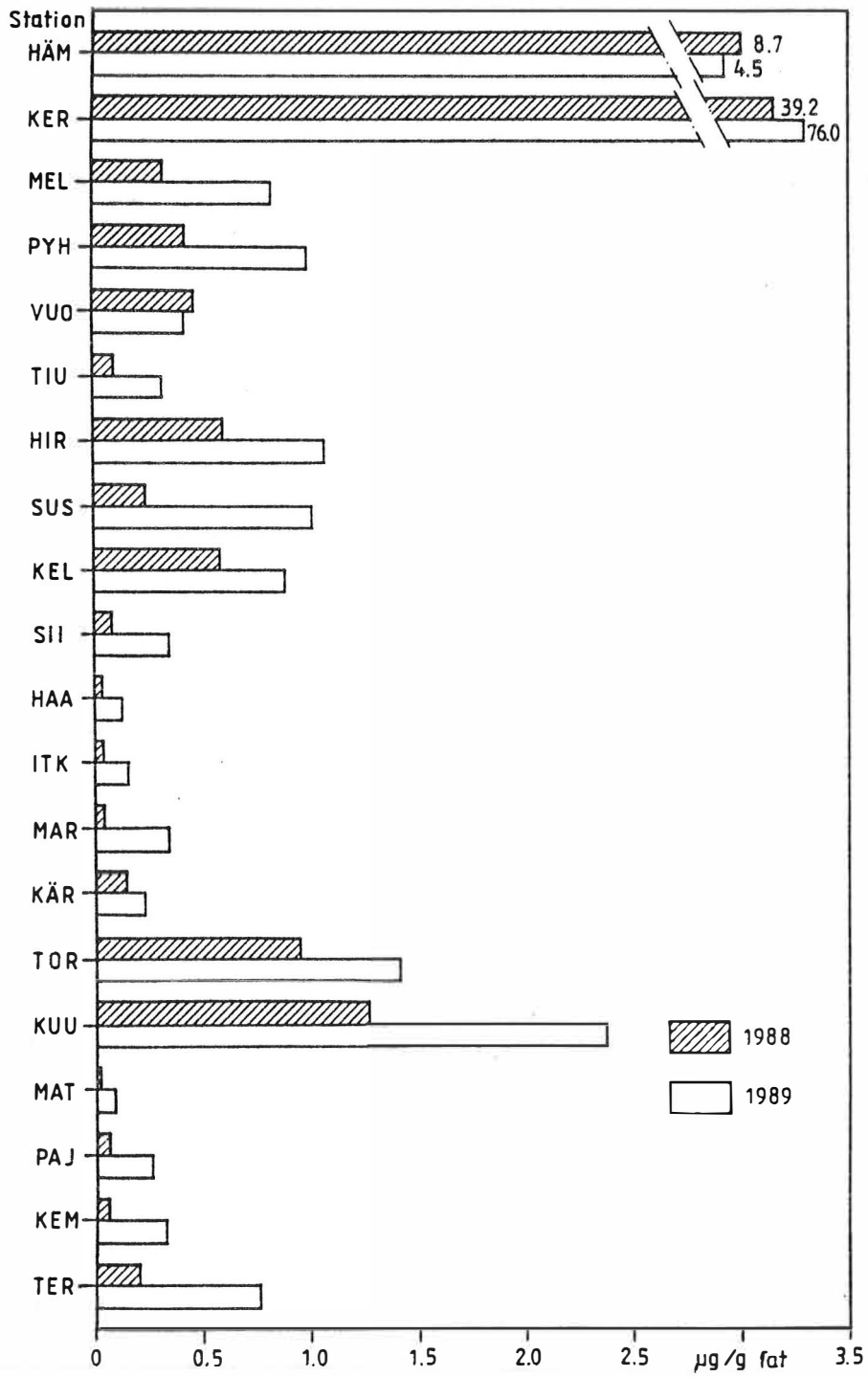

Fig. 7. PCB-concentrations in mussels incubated in 1988 and 1989 (abbreviations, see Appendix 11).

isms. In connection with the PCB pollution of long duration in Lake Kernaalanjärvi the highest PCB-concentrations measured in pikes caught from the lake were about 6.2 µg/g PCB in fresh muscles (Koistinen et al. 1989a, b). The polluting influence of Lake Kernaalanjärvi was felt very widely in Lake Vanajavesi (MIE, VAN, HÄM).

Another important PCB-area was the recipient of the industry in the City of Äänekoski (stations KUU, TOR) where the PCB-concentrations have remained on a level of 2 µg/g fat during the whole investigation period (1984 - 1989). The only statistically significant deviation is the low concentration of PCB during the winter incubation in 1989. Even though it is known that the discharge of PCB from sediment to water is clearly slower in the winter than in the summer (Larsson and Södergren 1987), this does not probably wholly account for the very low PCB-concentration. Rather, this result strengthens the hypothesis that the origin of PCB is not waste water or sediment, but possibly the earth layers on shore that freeze in the winter and from which PCB can spread to the water only in the summer.

In the recipient of the sulphite pulp mill of Mänttä in Lake Melasjärvi the PCB-concentrations were also elevated, especially in 1988. In the River Kymijoki PCB-concentrations were significantly lower in 1989 than in the earlier years.

Of the other chlorohydrocarbons small concentrations of lindane that is used as forest insecticide could be found in almost all monitoring sites. It is spread to water ecosystems mostly by air, and its occurrence does not necessarily have to be connected with the effluents from pulp and paper industry (Paasivirta 1988a). The concentrations of lindane also depend on the humus content in watercourse (Carlberg et al. 1986).

CYMS and CYMD were found to bioaccumulate to mussels in the recipients of pulp mills. Consequently, these particular compounds are indicators of the pollution of water especially

from chlorobleaching. Kuokkanen and Paasivirta (1980), Kuokkanen et al. (1988) and Kuokkanen (1989) have shown that at least 2-chloro-p-cymene, 2,5-dichloro-p-cymene and 2,3,6-trichloro-p-cymene appear in the neutral fraction of the waste waters of pulp bleaching plants, even after biological treatment of the spent bleach liquor.

Kuokkanen (1989) showed that chlorinated cymenenes were more abundant compounds in the pulping effluent than cymenes. On the contrary, more 2,3,6-trichloro-p-cymene than 2,3,6-trichloro-p-cymenene was found in fish and mussels in the recipient below the effluent point. This finding indicated that chlorocymenes are more persistent or they bioaccumulate more readily than chlorocymenenes (see also Herve et al. 1988b).

In 1987 CYMS and CYMD were not detected in reference stations MAT, HÄR and HTM nor in western Lake Kuhnamo (KUH1 and KUH5) upstream of pulp and paper mill but very clearly in eastern Lake Kuhnamo in the recipient of kraft pulp mill (KUH3 and KUH2). CYMS (but not CYMD) were found also in KUH4, upstream of the pulp mill. This could be explained by an old depot of CYMS from the previous bleaching plant at Äänekoski (stopped in 1985) and by its persistency in the depot (Herve et al. 1988b).

Hexachlorobenzene occurred very commonly, even though the highest concentrations were found in the immediate recipients of pulp industry. During both the monitoring years of 1988 and 1989 the highest concentrations were found in mussels incubated in the River Kymijoki. HCBz seems to spread on one hand by air and on the other hand clearly with effluents from pulp mills. Hexachlorobenzene was found in the pikes of Lake Päijänne for the first time already in 1980. Concentrations were then very small, only slightly above the detection level (Paasivirta et al. 1981a).

The insecticide DDT is a chlorohydrocarbon that is enriched in

food chains, and there is a lot of information of its occurrence in different organisms. Of different fish species e.g. in Barbus sp. Södergren et al. (1978) have found from Kupor River in Iran DDT-values up to 600 µg/g fat. In this area DDT has been used abundantly for the prevention of malaria inside houses. In another area in Iran 3.2 - 88 µg/g fat was detected in Salmo gairdneri.

From Lake Päijänne there is information on the occurrence of DDT and its metabolites in fish as early as at the beginning of the 1970's (Paasivirta et al. 1976, 1981c, Paasivirta 1983). In connection with this investigation DDT was found in incubated mussels only in very few stations. Metabolites of DDT, especially DDE, which is the most universally distributed in the environment (Södergren 1973) but also DDD occurred, however, rather often. Their concentrations were small.

3.3.2 Chlorophenolic compounds

Toxic chlorophenolics, that are enriched in food chains, are a central environmental toxin risk. The bioaccumulation of chlorophenolic compounds into biota corresponds rather well with the log $P_{(o/w)}$-values of these compounds (Mäkelä and Oikari 1989). Chlorophenolic compounds are volatile, lipid soluble and for that reason also more toxic to biota in an acid environment (Kotilainen 1985). However, the bioaccumulation and enrichment capacity of chlorophenolic compounds is significantly lower than that of the persistent chlorohydrocarbons like PCB and DDT residues (Landner et al. 1977, Paasivirta et al. 1985a). Also the natural humus water can significantly reduce the bioconcentration of organic micropollutants for instance of 2,4,6-trichlorophenol towards biological material (Carlberg et al. 1986).

These chlorophenolic compounds are manufactured industrially and the reason for the production is always the biocide effect.

Chlorophenolic compounds have thus been the effective substance in several bactericides, insecticides, fungicides, wood preservatives, and herbicides (Paasivirta 1978).

In kraft pulp mills waste water chlorophenolics together with fatty acids and resin acids have for a long period been known to be the main toxic and potentially toxic and bioaccumulating compounds (Seppovaara and Hattula 1977, Holmbom 1980). The occurrence of chlorophenolic compounds in bleaching effluents depends on the ratio of chlorine and chlorine dioxide in bleaching (Kringstad and Lindström 1984) and also on the ratio of soft and hard wood used in production (Petänen and Oikari 1987, Kitunen 1990).

Typical chlorophenolic compounds in the effluents of a mill producing bleached pulp are polychlorinated quaiacols and catechols. The chloroguaiacols originate from the effluents of the first alkaline extraction step and the chlorocatechols from the first chlorination step (Landner et al. 1977). Knuutinen (1984) found 3,4-dichlorocatechol, 3,4,5-trichlorocatechol, 3,4,6-trichlorocatechol and tetrachlorocatechol in the chlorination stage effluent. Large amounts of chlorinated guaiacols (in concentration order 3,4,5-trichloroguaiacol, tetrachloroguaiacol, 4,5-dichloroguaiacol and 4,5,6-trichloroguaiacol) have been found in the extraction stage effluent of a pine kraft pulp mill.

The chloroguaiacols and chlorocatechols seem to get partially through a biological waste water treatment plant as well so that they can also be found in recipients below a mill both in the water and in the sediment (Remberger et al. 1986). These compounds are very strongly bonded to sediment which must be taken into account when analysing chloroguaiacols and chlorocatechols (Hakala et al. 1989). Chloroguaiacols have been observed to spread very far in the recipient from the discharging point (Kierkegaard and Renberg 1988, Grimvall et al. 1991).

Chloroguaiacols have shown to be more toxic under limnic conditions than in marine or brackish water systems. In both cases they should, however, be classified as highly toxic (Renberg et al. 1980).

Regarding these compounds it is discussed that under aerobic conditions in sediment, O-methylation of chloroguaiacols may take place with the synthesis of chloroveratroles. Under anaerobic conditions instead de-O-methylation of chloroguaiacols and chloroveratroles occurs with the formation of chlorocatechols (Allard et al. 1988). For the reactions in the aquatic phase, the bacteria generally are the most significant agents (Neilson et al. 1988). Organochlorine compounds that are preserved in sediment may be harmful to the organisms in the sediment. Especially the early development phases of organisms are sensitive (Ekelund et al. 1989).

This study was focused on chlorophenolics originating from pulp bleaching. The sum variable used was the S2PCP-concentration. The highest concentrations of these compounds in incubated mussels were found in the near vicinity of pulp and paper mills with no biological waste water treatment (Fig. 8). This was noticed in the vicinity of the pulp and paper mills in Äänekoski area (KUU, TOR) in 1984 and in waters downstream from Kuusankoski pulp and paper mills in the River Kymijoki (KEL, SUS, HIR) in 1986 and 1988. In Lake Kemijärvi, where the local sulphate pulp mill discharges its waste waters only after an aerated lagoon, the S2PCP-concentrations were also relatively high in the years 1988 - 1989.

In the River Vuoksi where very large pulp mills discharge their waste waters directly only after a pond treatment, the S2PCP-values were elevated, but still clearly lower than in the recipients of Äänekoski and Kemijärvi mills. This is mainly due

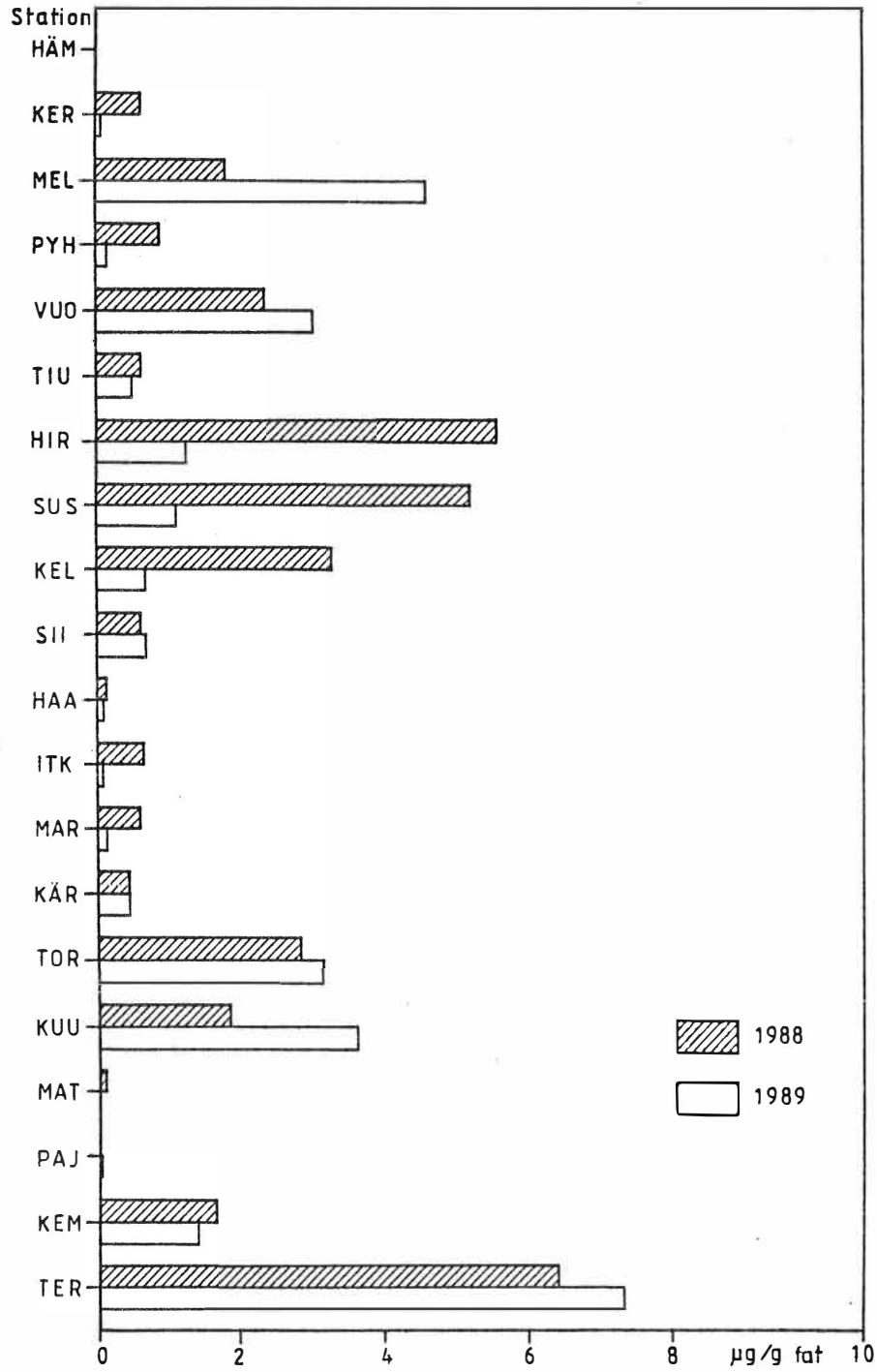

Fig. 8. The S2PCP-concentrations in mussels incubated in 1988 and 1989 (abbreviations, see Appendix 11).

to the greater flow in the River Vuoksi (MQ about 554 m^3/s, National Board of Waters and the Environment 1987), which together with the water-power station dilutes and mixes the waste water discharged to the river to about one hundredth. Harmful effects are thus small despite the great daily load (Appendix 10).

In Lake Melasjärvi (MEL) the situation was quite different. The flow of the watercourse in the recipient of the Mänttä sulphite pulp mill is very small, in Vilppulankoski some 10 km downstream of mills the MQ is only 18.7 m^3/s (National Board of Waters and the Environment 1987). This is why the S2PCP-concentrations were rather high despite the smaller load of organic compounds from the mill. Especially in 1989, when the flow was relatively low, the S2PCP-concentrations in incubated mussels were doubled. Similarly high concentrations of chlorophenolic compounds were found in the sediments of the same area earlier by Krogerus (1988). Because water in that recipient has been acid the effects of chlorophenolic compounds have been more toxic (Voss et al. 1980, Saarikoski and Viluksela 1981). That may explain the higher mortality of mussels incubated in Lake Melasjärvi than at other incubation stations.

The results showed that the typical discharge of a sulphite pulp mill was 246TCP which could be a useful variable in monitoring sulphite pulping recipients.

The results of these mussel incubation investigations showed that the chlorophenolic compounds originating from bleaching degrade in the recipient, although rather slowly. Flow of the recipient, mixing conditions of the effluent at the point of release to the watercourse and the molecular size of the organic chlorine compounds released all have a significant effect on the nature and amounts of the compounds recovered from the recipient watercourse.

The influence of residence time on the occurrence and degradation of organochlorine compounds was great. In the River Kymijoki where the mean flow is almost 300 m^3/s, and where the residence time of water from the incubation station (KEL) to the downstream incubation station (HIR) was only 2 - 3 days, no significant change in S2PCP-concentrations was detected in the analysis results of mussels incubated at stations KEL and HIR. However, in Lake Kemijärvi, where the effluent is discharged to a river-like lake with a residence time of several weeks, the corresponding decrease in S2PCP-concentrations was of the order of 50 - 70 %.

The chlorophenolics are degradated increasingly with increased residence time of waste waters and also diluted and sedimented. When the residence time exceeds one year in the recipient downstream it becomes practically impossible to detect individual chlorophenolic compounds originating from bleaching. This indicated that the majority of pulp and paper mills situated alongside Finnish inland watercourses have no significance as sources of organic chlorine compounds in the Baltic Sea.

Polychlorocatechols which are common in pulp mill recipient water, sediment, and fish (Paasivirta et al. 1985a, 1988a, b) were not regularly detected in incubated mussels not even in Lake Kemijärvi where the overall discharge of chlorophenols is rather high and where the waste water is only treated in an aerated lagoon, where the decrease of chlorocatechols is especially low (Gergow et al. 1988). This is why the monitoring of chlorocatechols must be carried out by analysing for example fish or water.

According to the results of this investigation a particularly sensitive indicator of bleaching effluents in recipients was the sum of 3,4,5-trichloroguaiacol and tetrachloroguaiacol. The maximum combined sum of these compounds in incubated mussels

exceeded 5 µg/g fat. Of the two compounds, it appears that 3,4,5-trichloroguaiacol extended further into the recipient (Herve 1991).

The sum parameter SlPCP consists of chlorophenols that do not originate from kraft pulp bleaching. Compounds belonging to this group are often also found in reference areas (Fig. 9), which proves that the compounds are at least partly spread by air, too (Paasivirta et al. 1980). The typical values for these compounds in incubated mussels in natural or only slightly polluted areas were in these studies 1 µg/g fat or less. These organochlorine pollutants have been found also in snow samples, especially in urban areas (Paasivirta et al. 1985c, e).

The compounds of the SlPCP-group originate mainly from wood preservation, combustions, chlorinations and pesticide uses (Paasivirta 1978). Clearly elevated concentrations of these chlorophenols were found especially in mussels incubated in the recipients of the cities of Hämeenlinna, Kuopio, and Kajaani (Herve et al. 1989a). In Lake Kallavesi near the City of Kuopio and in Lake Paltajärvi near the City of Kajaani the concentrations decreased significantly in 1989 compared with the values of the year 1988. In Lake Vanajavesi near the City of Hämeenlinna high concentrations were detected in both years.

The dominating part of SlPCP-concentrations in incubated mussels was 2,3,4,6-tetrachlorophenol, the main component in wood preservative Ky-5, commonly used earlier (Fig. 10). The background concentration in this investigation seemed to be ca. 0.5 µg/g fat.

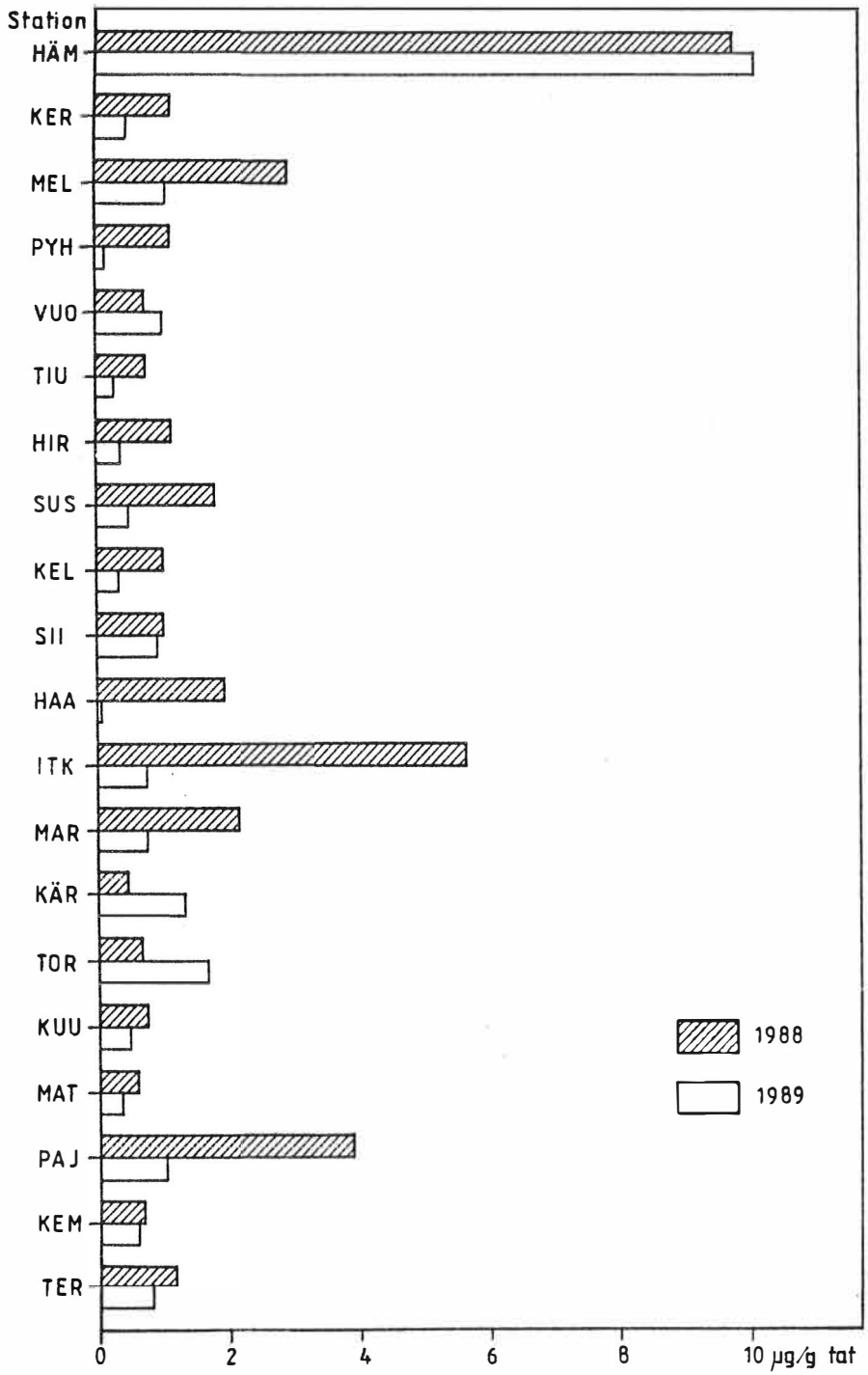

Fig. 9. The S1PCP-concentrations in mussels incubated in 1988 and 1989 (abbreviations, see Appendix 11).

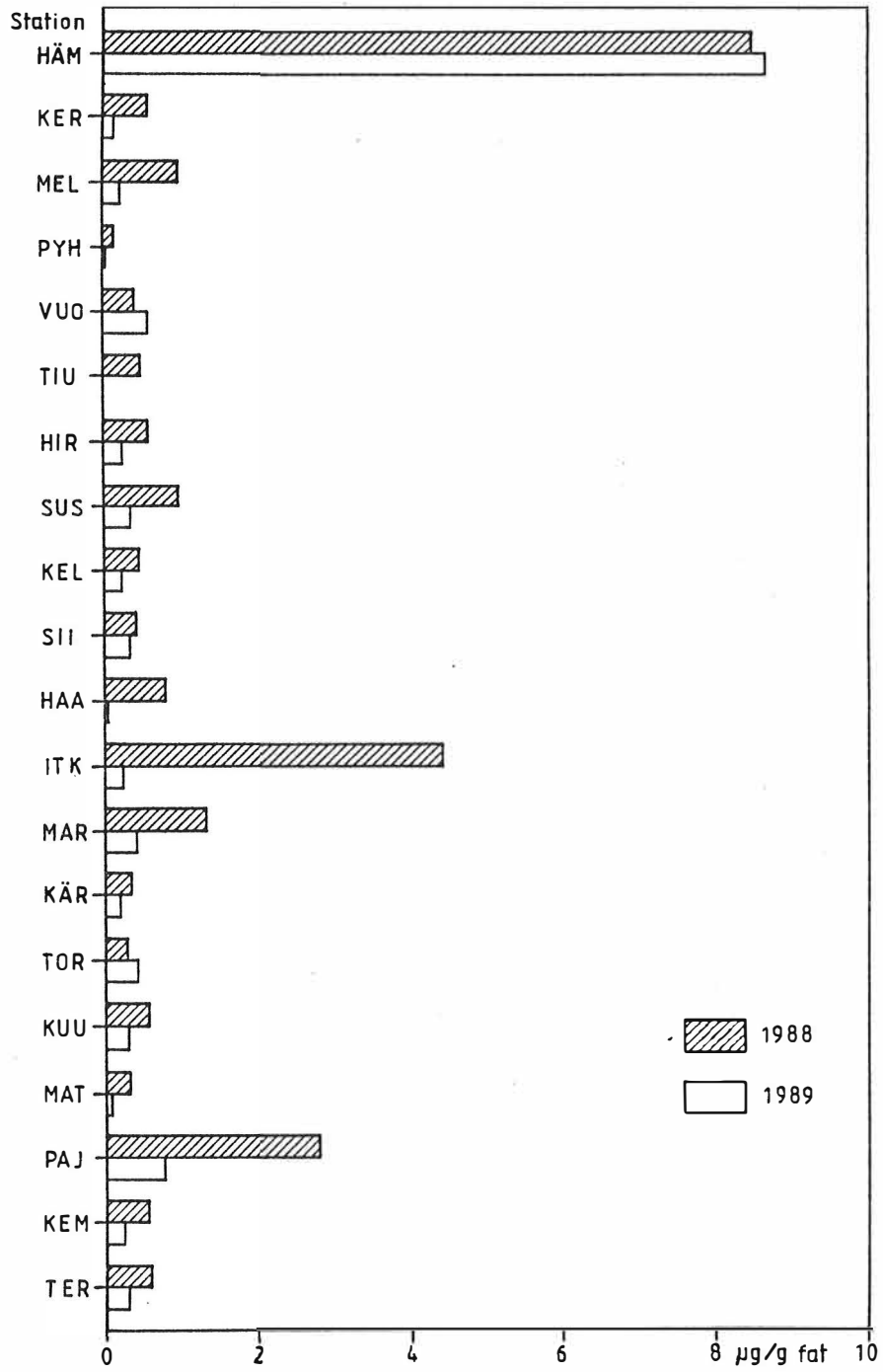

Fig. 10. The concentrations of 2,3,4,6-tetrachlorophenol in mussels incubated in 1988 and 1989 (abbreviations, see Appendix 11).

3.3.3 Chloroanisoles and chloroveratroles

Chloroanisoles and chloroveratroles were found from incubated mussels in 1986, 1987 and 1988. These compounds are among the most problematic compounds of pulping industry. They are biomethylation products of chlorophenols, chlorocatechols, and chloroguaiacols originating from bacterial activity, and they cause bad taste in fish in watercourses polluted by pulp and paper industry (Paasivirta et al. 1986d, Remberger et al. 1986, Paasivirta 1987a, 1988a, Veijanen et al. 1988, Herve 1989, Veijanen 1990). The toxicity of chloroanisoles and chloroveratroles is lower than that of chlorocatechols and chloroguaiacols (Nordiska Ministerrådet 1989).

The concentrations of chloroanisoles and chloroveratroles are very low in the water, but their bioconcentration to fish and mussels is more effective than that of chlorocatechols and chloroguaiacols, bioconcentration factor must be over 10 000 (Paasivirta et al. 1987b, Nordiska Ministerrådet 1989). Thus these substances have been shown to be the main factor causing bad taste in fish.

In these investigations chloroanisoles and chloroveratroles were found nearly in all incubation stations, especially in the same areas as chlorophenolics. The most common of the chloroanisoles found in the monitoring of 1988 were usually 345TCA and TeCA. The highest concentrations were found in Lake Melasjärvi below a sulphite pulp mill, in Southern Lake Saimaa, and in Lake Kemijärvi. Of chloroveratroles 345TCV was the most common. The occurrence of 345TCV and TeCV in the recipients of pulp and paper mills but not in reference areas proves them as possible metabolites of chlorocatechols and chloroguaiacols. The highest sum of chloroanisoles and chloroveratroles (SANIS) was detected in Lake Kemijärvi, KEM (4.23 µg/g fat). The following figure can be presented on the concentrations of S2PCP and SANIS in incubated mussels from Lake Kemijärvi, where there were three incubation sites in the watercourse below the mill (Fig. 11).

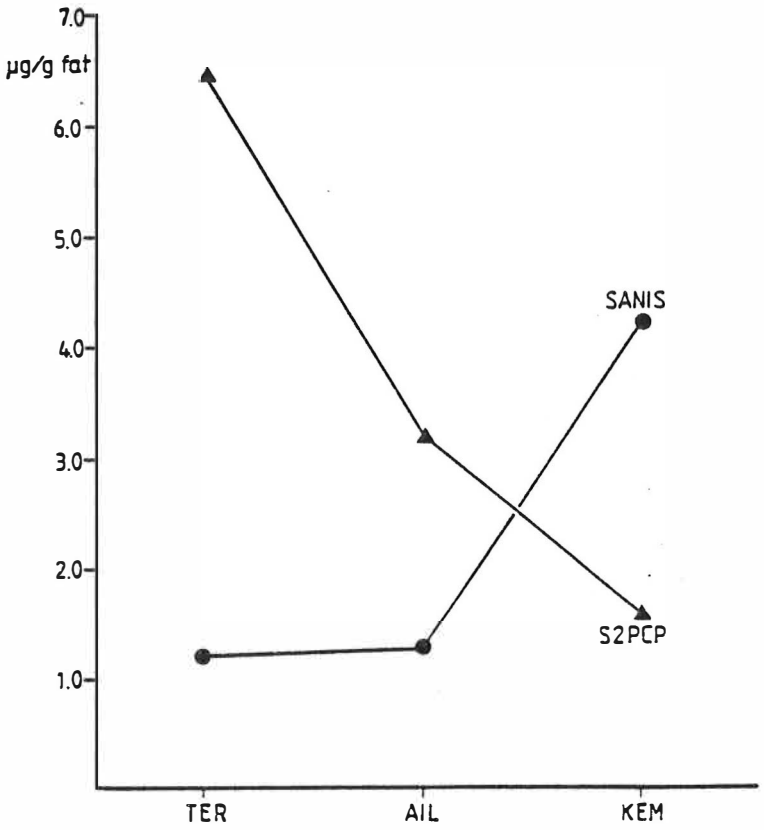

Fig. 11. S2PCP (▲) and SANIS (●) concentrations in incubated mussels in Lake Kemijärvi (TER, AIL, and KEM) in 1988.

In the nearest recipient to the mill (TER) S2PCP was at its highest, and its concentration in incubated mussels decreased clearly further away from the mill. The situation with the SANIS-values was the opposite as smaller values were found in the nearest recipient. Thus the sum of S2PCP and SANIS was of the same order in the whole Lake Kemijärvi. This result indicates that the biomethylation of chlorophenolics takes place already before the bioaccumulation in mussels.

3.3.4 Dioxins and furans

Polychlorinated dibenzo-p-dioxins and dibenzofurans are one potential environmental risk. The National Environmental Protection Board in Sweden has started a special project to determine the sources and environmental levels of highly toxic organic contaminants, especially dioxins (de Wit et al. 1989, 1990). In many respects the data about dioxins and furans are still insufficient. Especially the relative importance of their sources in watercourses needs more studies.

Dioxins have been found to bioaccumulate highly to lake trout primarily through the food chain and secondarily through contact with the contaminated sediment (Batterman et al. 1989). Similarly, PCDDs and PCDFs were found in cod, herring and white fish from different fishing grounds in the seas round Sweden (Bergqvist et al. 1989). PCDDs and PCDFs were found in seal blubber samples which were collected in waters around the Scandinavian peninsula and from the Antarctic (Bignert et al. 1989). Similar results were analysed from cod liver fat on the Arctic coast of Norway, and Baltic salmon (Koistinen et al. 1989a, b) and in Baltic seals (Koistinen 1990).

The time trend of dioxin pollution curves follows the production of industrial organochlorine compounds (Paasivirta 1988a). Metallurgical processes, especially the production of magnesium and nickel (Rappe 1988, Brevik et al. 1989) and in Finland especially the chlorobleaching of pulp (Kitunen 1990) may be significant sources of these compounds. The dominating toxic isomers of PCDDs and PCDFs in pulping effluents are 2378TeCDF, 2378TeCDD, 23478PeCDF and 12378PeCDD (Kjeller et al. 1990). Rappe (1988) stated that pulp bleaching is the only direct source of PCDDs and PCDFs into the water. On the other hand, Paasivirta (1988b) has shown that the concentrations of PCDDs and PCDFs in bleaching liquor were always below the concentration level 1 ng/l.

In pulp bleaching the consumption of molecular chlorine (Cl_2), expressed as the ratio between chlorine and the lignin content, is a very important variable in estimating the PCDD- and PCDF-discharges from pulp bleaching. The formation of the dibenzo-p-dioxins and the dibenzofurans increased drastically above a certain critical level (Axegård and Renberg 1989, Kringstad et al. 1989). Especially poor brownstock washing has lead to increased levels of PCDDs and PCDFs in softwood pulps after the chlorination stage and in the final effluent (Hise and Hintz 1990).

Inefficient burning of urban wastes and other organic chlorine containing materials may cause chlorobenzenes and chlorophenols to be formed in much higher amounts than from fossil fuels or wood (containing inorganic chlorine) and, consequently, leads to high emissions of PCDDs and PCDFs (Paasivirta et al. 1985a, b, Rappe 1988, Miyata et al. 1989b, Rappe et al. 1989). The main toxic congeners in the heated PCBs were shown to be PCDFs which were also recognized as hazard in PCB capacitor fires (Paasivirta 1989b). Car exhausts have also been identified to be a relatively remarkable source of PCDDs and PCDFs into the air (Rappe 1988).

The occurrence of polychlorinated dibenzo-p-dioxins and dibenzofurans was also clarified in this investigation. All the concentrations found in incubated mussels were very low, generally below 50 pg/g fat as total chlorinated TCDD-equivalents (NORD 1988). The highest concentrations, 200 - 500 pg/g fat were recorded in 1988 in mussels incubated in the River Kymijoki. Biological waste water treatment apparently efficiently reduces bioavailable dioxin concentrations in pulp and paper effluents, which was indirectly detected from the results of the year 1989.

Polychlorinated dioxins and furans bioaccumulate strongly. The highest concentrations ever reported in Finnish wild life (1-13 ng/g for PCDD/Fs in fresh muscle) were detected in adult eagle samples, in the liver of a juvenile eagle, and in eagle

eggs from southern Finland 1984 - 1985 (Tarhanen et al. 1989). In this investigation the amounts found from mussels were very low as compared with these. In the Rainy River in Canada they have used a quite similar method in monitoring PCDDs (Hayton et al. 1990). They incubated mussels (Elliptio complanata) for a period of 21 ± 1 days. The highest concentration of chlorinated dioxins found was 58 pg/g of OCDD (wet weight). Several sources of PCDD were identified including two kraft pulp and paper mills, a wood waste disposal site and a sewage treatment plant.

3.3.5 Incubation of mussels

The developing of this mussel incubation method started in 1984. The method has been used by water authorities in Finland for monitoring purposes since 1988. The method has proved to be practical for monitoring the state of the environment despite the fact that the exact biological background of the method has not yet been fully cleared up.

The mussels function as excellent bioaccumulators of organochlorine compounds. They seem to survive even in the most polluted areas, which increases the application area of the method. In exceptionally polluted areas, areas where even acutely toxic effluents are possible, the method with solvent filled dialysis membrane might be used (Södergren 1987, Södergren and Okla 1988). In this method dialysis membranes filled with hexane accumulate different organochlorine pollutants for instance PCBs, DDE and DDT. Preliminary results obtained in investigations in Central Finland show, however, that the accumulation of organochlorine compounds in dialysis membranes is significantly smaller than in bioaccumulation carried out by mussels.

In this investigation the incubation depth was one metre which guaranteed that the mussels were incubated in epilimnion and no bottom effect was present. The incubation depth and the incubation time are important factors which affect the results. Foster and Bates (1978) used already in 1978 caged freshwater

bivalves but they incubated mussels in hardware cages above the river bottom as also Hayton et al. (1990). Korhonen and Oikari (1987) used the incubation depth of 3 - 4 metres in their investigations in Southern Lake Saimaa.

The incubation time, four weeks, was sufficient in bioaccumulating the organic chlorocompounds and also practical in monitoring the watercourses. Korhonen and Oikari (1987) have also used a similar incubation time in Finland. Hayton et al. (1990) used 21 ± 1 days incubation time but they suggested that further work is required to determine the optimum exposure period.

The average age of the mussels in this investigation varied from six to ten years. Foster and Bates (1978) used juvenile mussels (less than four years old) in their tests, as they had noticed in their preliminary tests that smaller mussels accumulate higher concentrations of copper than the larger. No correlations were found between the analysis results of this investigation and the age of the mussels used.

The fat percentage of mussels is important in bioaccumulation of organic chlorocompounds: the greater the fat concentration, the higher the concentrations of organic chlorocompounds in animal (Castro et al. 1990).

The seasonal variations in fat concentration, which e.g. in the investigations of Castro et al. (1990) with the Portuguese oyster (Crassostrea angulata) were remarkably great, could not occur to any greater extent in this material, as all tests, except for the winter incubation conducted with a fairly small number of mussels, were conducted in the summer.

No reduction of fat concentrations in the winter (see Södergren et al. 1972) was observed. Such a clear reduction of fat percentage, 40 % at its largest, due to pollution that Farrington et al. 1989 have reported was not observed in these investigations. Some interference, however, was indicated in

1987 at the very strongly polluted stations KUH3 and KUH4 (map 5 in Appendix 9) where fat contents were slightly lowered, but statistically not significantly according to Q-test (Herve et al. 1988b). Thus the biological variation was expected not to interfere significantly with the results of monitoring trace pollutants.

In principle, if the fat content decreases in the winter, wintertime would be the best time for finding out e.g. the longest spreading distances in the recipient of chlorocompounds originating from pulp bleaching. More data should therefore be obtained from winter incubation.

Composite samples of mussels were used for the analysis. Altogether fifteen mussels were incubated and three homogenates of five mussels were used for analyses. In the extensive National Mussel Watch Programme 15 mussels have also been used in each single sample (Anon. 1980). Certain studies conducted in Mexico with Mytilus edulis investigating the bioaccumulation of DDT, which also especially investigated the importance of a suitable sample size for the result, came to the conclusion that 20 mussels is the optimum number of individuals to homogenize in a single sample in order to find the least analytical variability (Flores Baez and Galindo Bect 1989). In Finland, Korhonen and Oikari (1987) have used composite samples of three mussels. The final result in their investigation was the mean of three composite samples.

In addition to minimizing the deviation the economy of the investigations also has an effect on the optimal sample size, especially when defining different chlorocompounds extensively.

The method can also be used for investigating the watercourse effects of other industrial plants, sawmills, power stations, waste tips, scrap yards, mining and agriculture (Herve et al. 1989b).

3.3.6 Correlations and trends

In handling the incubation results two kinds of correlations were calculated. First, correlations between some of the biological properties of the incubated mussels (age, length, total weight, tissue weight, dry weight percentage, and fat percentage) and all the chemical results were calculated. On the other hand, correlations between all different compounds were estimated. Because of the great variations observed usually in the results of the biological material, only the statistically very significant correlations are presented here.

The most important property of the mussels in bioaccumulation investigations is the fat percentage. When calculating the correlation coefficients between fat percentage and all chemical variables analysed in these investigations, as a rule no significant values were observed in the monitoring results. Only once, the correlation coefficient (0.778) to the TeCV-concentration in winter incubation in Kuusaankoski (KUU) station was statistically significant. This result guarantees that the differences detected in concentrations of organic chlorocompounds in incubated mussels were real and affected only by the differences in water quality at the incubation stations, not by the possible differences in fat percentages of the mussels used in incubation.

The correlations between different chemical compounds can be used e.g. for estimating or ensuring the origin of these compounds. The most significant correlations were found between compounds which already in the first investigations in 1984 - 85 were assumed to originate mostly from pulp bleaching. The correlation matrixes for the results of these compounds in 1988 (n = 119) and 1989 (n = 56) were as follows:

year 1988	345TCG	456TCG	TeCG	DMP
45DCG	0.159*	0.113	0.093	0.071
345TCG	-	0.622***	0.951***	0.371***
456TCG	-	-	0.561***	0.614***
TeCG	-	-	-	0.376***

year 1989	345TCG	456TCG	TeCG	DMP
45DCG	0.668***	0.431***	0.796***	0.470***
345TCG	-	0.757***	0.908***	0.341***
456TCG	-	-	0.736***	0.321**
TeCG	-	-	-	0.399***

Except for the 45DCG-values in 1988 the correlations between these compounds were very significant.

Outside this S2PCP-group hexachlorobenzene (HCBz) had a very strong correlation to the S2PCP-group and especially to all chloroguaiacols. However, hexachlorobenzene correlated also statistically significantly with lindane and alpha-chlordane. This indicates that HCBz does not only originate from pulp bleaching but also from airborne pollution sources.

Of other compounds, TeCP correlated very significantly with PeCP, indicating the same source i.e. wood preservation, combustion etc.

The very short monitoring period, in most incubation stations only two years, has made it impossible to calculate any time trends. Only in the recipient of the industry situated in the Äänekoski area (map 5 in Appendix 9) tests have been carried out

in all the six years. The decrease in chlorophenolics, especially those of the S2PCP-group, was connected with the water protection control measurements and process changes carried out in the pulp and paper industry of the Äänekoski area.

A decreasing trend of many organic chlorocompounds was observed in many areas, which was a consequence of the decrease in the use of these compounds in Finland. There are good examples of this e.g. in the DDT- and PCB-concentrations of starlings (Paasivirta et al. 1985f) and in the biota of the Baltic Sea.

In these investigations decreasing trends for S1PCP and lindane in incubation stations Kuusaankoski (KUU) and Torronselkä (TOR) were also detected. The concentrations of hexachlorobenzene and cymene (CYMS) in the same stations decreased as well from the year 1985 to 1989.

3.3.7 The effect of waste water treatment

It has been demonstrated that the close up of the sulphite mills, modification of the kraft mills and introduction of the biological waste water treatment decreased lignosulphonates and chloroform considerably in addition to other organic compounds (Paasivirta 1987b, 1989a, Paasivirta et al. 1988a, Kuokkanen and Koistinen 1989). In this investigation it was possible to make indirect conclusions of the effects of waste water treatment plants of pulp mills on discharges of organic chlorocompounds in two different recipients. One of these is situated in the recipient downstream from Äänekoski at incubation sites KUU and TOR. Mussels were incubated at these sites for the first time in 1984 when the treatment of waste water in the old pulp industry of Äänekoski only took place mechanically. At the sulphate pulp mill in Äänekoski that was renewed just then an activated sludge plant treating all waste waters from the mill was built in 1985. The positive effects of this plant could already be seen in the watercourse in the mussel incubations during the summer 1985.

The significance of biological waste water treatment in the removal of organic chlorine compounds from effluents can clearly be seen from the results at the observation station Kuusaankoski (KUU) in the recipient of the Äänekoski pulp and paper industry during the period 1984 - 1989:

year	S2PCP (µg/g fat) in incubated mussels
1984	10.68
1985	3.62
1986	3.12
1987	1.77
1988	1.84
1989	3.60

Biological waste water treatment was introduced at the factory in the spring of 1985. At the same time considerable process alterations were made at this kraft mill.

A similar reduction in S2PCP-concentrations was observed in the River Kymijoki between 1988 and 1989 (Fig. 12). In 1988, when the waste waters of this large pulp and paper mill were still treated only by mechanical means, the S2PCP-concentration of incubated mussels was nearly 5 µg/g in fat. The new activated sludge water treatment plant started up in the spring of 1989 and by August of the same year the corresponding concentration

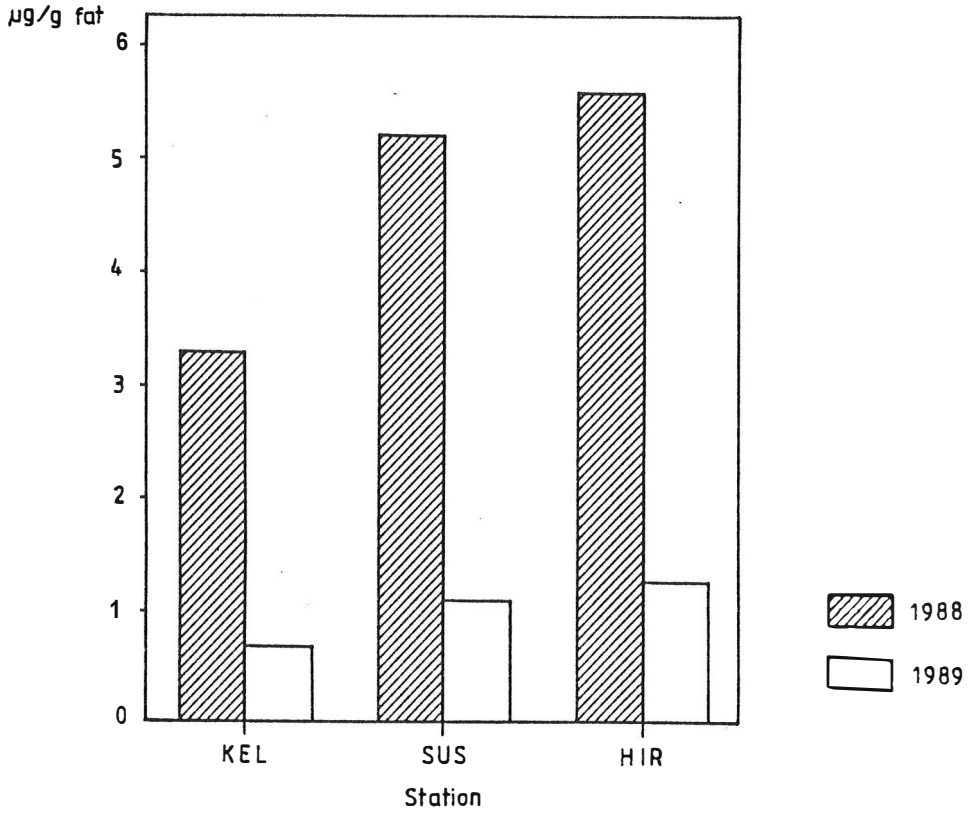

Fig. 12. S2PCP-concentrations in incubated mussels in River Kymijoki in 1988 (before biological treatment plant) and in 1989 (biological treatment plant operating), (abbreviations, see Appendix 11).

in mussels had decreased to only about 1.0 µg/g fat. As compared with the results of the previous year, the greatest changes occurred in the chlorophenolics of the S2PCP-group (Fig. 12) and in the concentrations of dibenzo-p-dioxins and dibenzofurans (Fig. 13). The concentrations of all these compounds decreased in incubated mussels by about 80 % due to the waste water treatment plant.

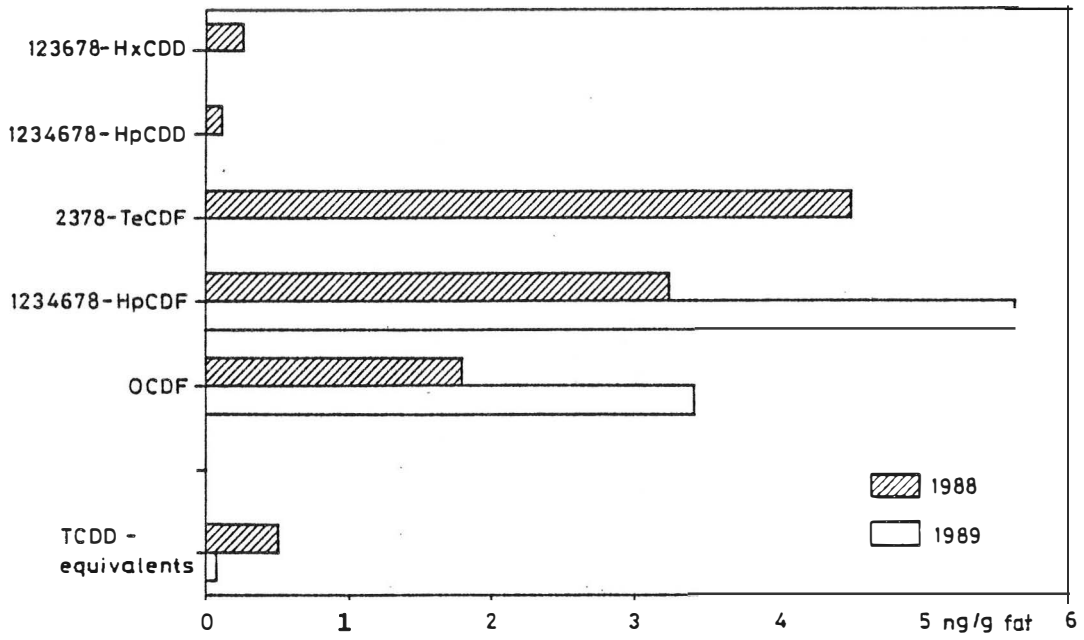

Fig. 13. The concentrations in incubated mussels in River Kymijoki (KEL) in 1988 (before biological treatment plant) and in 1989 (biological treatment plant operating), (abbreviations, see Appendix 11, TCDD-equivalents calculated according to NORD 1988).

It may, however, be at least partly only apparent that activated sludge treatment plants could decrease the amount of chlorocompounds so significantly (measured as AOX about 50 %, Jussila and Ek 1990), as it is known that organic chlorocompounds, e.g. chlorophenolics, bind themselves to biosludge and are possibly released from it in different ways depending on the continued treatment of the sludge. It is known that the burning of biosludge releases in fly ash the same polychlorinated aromatic compounds as other combustions. Main chloroaromatics formed in combustions are chlorophenolic compounds and chlorobenzenes which are intermediates to PCDDs and PCDFs (Mäntykoski et al. 1989a, b, Paasivirta et al. 1989b). These compounds absorbed physically to some extent into the activated sludge biomass may

easily be discharged to watercourses (Leuenberger et al. 1983). That is why it is very important to take care of all the discharges of suspended solids from any pulp and paper industry (Folke 1991).

4 CONCLUSIONS AND RECOMMENDATIONS

4.1 Conclusions

As a result of the method development started in 1984 and continued yearly it has been able to create a biological research method based on bioaccumulation in which it is possible to monitor by using incubated lake mussels (Anodonta piscinalis) the spreading and degradation of organic chlorocompounds that originate from pulp and paper industry and occur in the water in very small and fluctuating concentrations.

At first the investigations were only carried out in Central Finland in the recipient of one pulp and paper mill, but already in 1988 they were extended to cover the whole country, as the monitoring of the effluents from pulp mills along inland waters was started as a part of the monitoring of toxins in inland waters.

With the help of the method the spreading and extension of the PCB-pollution in Lake Kernaalanjärvi was specified, and the limits of the PCB-leakage that polluted the watercourse in the Äänekoski area for a long time were rather precisely defined.

Of the other chlorohydrocarbons lindanes as well as DDE, the metabolite of DDT, could be detected everywhere in small concentrations with the method. DDT was, on the contrary, very rarely found. Hexachlorobenzene occurred also very commonly everywhere, even though the highest concentrations were detected in the immediate recipients of pulp mills.

Local pollution cases caused by chlorophenols used in wood preservatives (246TCP, TeCP, and PeCP) were detected in the recipients of the cities of Hämeenlinna, Kuopio and Kajaani. Airborne chlorophenolics were found at all incubation stations.

2,4,6-Trichlorophenol was found to be the main chlorophenolic in mussels incubated in recipients of sulphite pulp mills.

It was possible to clear up the occurrence and transformation of bleaching remnants from wood processing industry in watercourses, especially chlorophenolics of the S2PCP-group, with the incubated mussels. In addition, there was proof of the transformation of chlorophenols and chloroguaiacols into chloroanisoles and chloroveratroles. The highest S2PCP-concentrations were measured in the recipients of pulp industry from which their total amount decreased as a function of time, distance, and degradation. For the monitoring of organochlorine compounds originating from pulp and paper industry the analysis of the S2PCP-group from incubated mussels seems to be a better alternative than e.g. the analyses of the sum variable AOX from water samples.

With the help of incubated mussels chlorinated dibenzo-p-dioxins and dibenzofurans were also found in areas worst polluted by pulping effluents, although in very small concentrations. It was also found that biological treatment of waste water decreases these compounds considerably and that the components occurring after the purification process were also clearly less toxic especially furans.

The introduction of biological effluent treatment caused a significant decrease of chlorophenolic compounds in mussels incubated in recipients.

4.2 Recommendations

The mussel incubation method has proved to be a very suitable monitoring method for investigating the spreading, transformation, and degradation of organic chlorocompounds. In addition to monitoring the effluents from chemical pulp and paper industry the method may be used in other corresponding situations, e.g. for investigating the harmful effects of other industrial plants, sawmills, power stations, waste tips, scrap yards, mining and agricultural loading on watercourses. The following guidelines are recommended when the method is applied:

(1) The mussels needed must be acquired from areas that are as clean as possible and preferably in natural state. The size of the mussels incubated should be as even as possible.

(2) Before the incubation starts the mussels to be incubated should be preincubated in an aquarium in a laboratory. This will quarantee the cleanness of the mussels, and on the other hand, any weak individuals can be eliminated due to chocks caused by the transportation.

(3) The transportation of the mussels to the incubation site must be carried out carefully so that the temperature of the water in the transportation tanks cannot rise or the quality of the water otherwise deteriorate significantly.

(4) The incubation period of exactly four weeks has proved to be sufficient. The mussels must be incubated so that they cannot take nutrition directly from the sediment. A suitable incubation site is in the epilimnion at the depth of one metre.

(5) After the incubation the mussels must be transported to the laboratory each separately wrapped in foil and frozen immediately.

(6) Composite samples should be used in the analyses of the mussels in order to achieve the required accuracy with minimum costs. In this investigation 15 mussels were incubated at one incubation site, and at the analysis stage three parallel samples of five mussels were formed of them. The final result is the mean value of these three samples.

(7) The results of the organochlorine compounds must be given as suitable weight units calculated per fat.

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Sirpa Herve

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APPENDICES

1. Analysis methods used
2. The chemical results of mussels incubated in Äänekosi area in 1984
3. The chemical results of mussels incubated in Äänekoski area in 1985
4. The chemical results of mussels incubated in the Kymijoki river basin in 1986
5. The chemical results of mussels incubated in Äänekoski area for PCB-investigation in 1987
6. The chemical results of mussels incubated in the monitoring programme in 1988
7. The chemical results of mussels incubated in winter 1989 (16.2. - 30.3.) in Kuusaankoski station (KUU)
8. The chemical results of mussels incubated in the monitoring programme in 1989
9. The locations of the incubation stations
10. The waste water load of pulp and paper mills concerned, according to the data of the National Board of Waters and the Environment
11. The abbreviations used

Appendix 1

Analysis methods used

In analysing chlorohydrocarbons fat is weighed and dissolved in 4 ml of hexane. Two ml of this hexane solution I is shaken with 2 ml of concentrated sulphuric acid to remove fat and non-persistent compounds. Samples are analysed with GC/ECD for chlorohydrocarbons. The hexane solution (II) is separated and divided for different analyses. One µl of concentrated or diluted (depending on original PCB level) hexane solution II is injected in MICROMAT HRGC 412 gas chromatograph equipped with two quartz capillary columns (OV-1701 and SE-54) 25 m long, i.d. 0,25 mm and with two Ni-63 EC detectors at temperature of 350 °C. The columns are fit to the single injector kept at 250 °C. Carrier gas is helium 1 ml/min and make up gas for detector argon/methane 95:5 (v/v). Temperature programme is 150 °C + 5 °/min to 250 °C and hold there 20 min. Identity of the peaks is obtained by comparing their retention times at both channels to the dual chromatograms of authentic standard compound mixtures and quantitation by using response factors towards the internal standard peaks.

To analyse chlorophenols two ml of the hexane solution I is shaken with 50 ml of 0.1 M potassium carbonate solution for 5 minutes. The water layer is washed three times with 20 ml of hexane. The combined hexane layers are collected for PCA/PCV analysis. One ml of acetic acid anhydride is added to the water layer and shaken for 5 min. Then 5 ml of hexane is added and shaken for a minute. The hexane layer is evaporated to small volume and sample of it injected to a gas chromatograph MICROMAT HRGC 412 with dual column operation. The columns are of fused silica coated with SE-54 and OV-1701. Ni-63 EC detectors are used in temperature-programmed run helium as carrier gas 1 ml/min. The temperature programme is 100 °C + 4°/min to 250°C and hold there 20 min. Chlorophenol acetates are identified comparing to the authentic reference standard mixture and quantified using response factors against the internal standard.

In analysing chloroanisoles and chloroveratroles a column of 2 g of alumina (deactivated with 5% of water) is constructed into a Pasteur pipette. The wash hexane solutions from chlorophenol determination (see before) are evaporated to 1 ml and transferred to column and eluted with 3 ml of dichloromethane-hexane 1:1 (v/v). Effluent is concentrated for the analysis and 1 µl injected in two channel MICROMAT HRGC 412 gas chromatograph equipped with 25 m fused silica capillary columns OV-1701 and SE-54 and EC detectors. Temperature programme is 100 °C + 4°/min to 220 °C and then + 8°/min to 260 °C and hold there for 20 min. Carrier gas is helium 1 ml/min and make up gas is argon-methane 95:5 (v/v). The PCAs and PCVs are identified with comparing to authentic reference standard mixture and quantified using response factors against the internal standard.

In PCDD and PCDF analyses an activated carbon column is prepared as follows. A 10 cm long 6 mm o.d., 4 mm i.d. glass tube having a small pump at 4 cm from the top is filled starting from bottom with a small plug of hexane-washed cotton wool, then with 50 mg of activated carbon (80/100 mesh, SK-4 Alltech) and again with a small cotton wool plug. The total length of the packing is 15 mm. The pump at the top keeps the packing material on its place during fractionation.

One ml of the hexane solution II (washed with sulphuric acid, see before) is transferred to the dry carbon column with a Pasteur pipette. Non-planar organochlorine compounds are removed from the column by elution with 10-15 ml of hexane-methylene chlorine 1:1 (v/v). Then the column is turned upside down and the planar and coplanar compounds are eluted out with 10 ml of toluene. Toluene is evaporated to small volume (not to dryness) with nitrogen gas stream. The residue might also contain polychlorinated diphenyl ethers (PCDE) which interfere PCDF-analyses. If PCDEs are found, they are removed by transferring the residue with hexane into a Pasteur pipette column containing 2 g of basic alumina (activity class I) and eluting out the PCDEs with 10 ml of hexane-methylene dichloride 98:2 (v/v). Then the

PCDD/F fraction is collected by eluting with 10 ml of hexane-methylene chloride 1:1 (v/v). This PCDE removal can be done also before the carbon column treatment and also with activated Florisil PR column.

The mixture is analysed with GC/MS using HP 5970 mass selective detector system. The column used is quarz capillary , 25 m long, i.d. 0.2 mm coated with SE-54. Helium is used as carrier gas 1 ml/min. Temperature programme: 100 °C, hold 1 min, then + 20°/min to 180 °C and then + 5°/min to 270 °C and stay there 10 min.

PCDDs and PCDFs (P=4-8) are determined by GC/SIM using two selected molecular ions for each isomer group and two for the internal standard (^{13}C-labelled 2378TeCDD). If the intensity ratio of the ions is the same as calculated from chlorine isotope abundances for the assumed compound and if no interference from higher molecules is observed, the compound is accepted to be the assumed PCDD/F compound or its isomer. Provided authentic reference standard compound is available, also the exact structure of the congener can be identified if its separation from other isomers is sufficient.

The determination limits were as follows:

- PCB	6-10 ng/g fat (1984-88)
	30 ng/g fat (1989)
- Other chlorohydrocarbons	1-2 ng/g fat
- Dichlorophenols	10-15 ng/g fat
- Other chlorophenolics	1-3 ng/g fat
- Chloroanisoles and chloroveratroles	1 ng/g fat (1986-88)
	1-5 ng/g fat (1989)
- Chlorinated dibenzo-p-dioxins and dibenzofurans	70 pg/g fat.

Appendix 2

The chemical results of mussels incubated in Äänekoski area in 1984.

Incubation station period	fat %	Chlorohydrocarbons (µg/g fat) CYMS	HCBz	LIND	OXY	GAMMA	ALPHA	TRANS	SCHL	DDE	DDD	DDT	SDDT	PCB
MAT 2.-29.8.84	6.60	0.00	0.00	0.62	0.00	0.00	0.00	0.00	0.00	0.14	0.00	0.00	0.14	0.00
	5.50	0.00	0.00	0.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	5.50	0.00	0.00	0.35	0.00	0.00	0.00	0.00	0.00	0.15	0.00	0.00	0.15	0.00
	7.27	0.00	0.00	0.07	0.00	0.00	0.00	0.00	0.00	0.34	0.00	0.00	0.34	0.00
$\bar{x}$	6.22	0.00	0.00	0.31	0.00	0.00	0.00	0.00	0.00	0.16	0.00	0.00	0.16	0.00
MAT 29.8.-8.10.84	4.26	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.16	0.00	0.00	0.16	0.00
	7.28	0.00	0.00	0.29	0.00	0.00	0.00	0.00	0.00	0.29	0.00	0.00	0.29	0.00
	8.86	0.00	0.00	0.35	0.00	0.00	0.00	0.00	0.00	0.27	0.00	0.00	0.27	0.00
	4.66	0.00	0.00	0.39	0.00	0.00	0.00	0.00	0.00	0.39	0.00	0.00	0.39	0.00
$\bar{x}$	6.26	0.00	0.00	0.26	0.00	0.00	0.00	0.00	0.00	0.28	0.00	0.00	0.28	0.00
KUU 2.-29.8.84	9.57	0.00	0.00	0.14	0.00	0.00	0.00	0.00	0.00	0.08	0.00	0.00	0.08	2.28
	7.99	0.00	0.00	0.16	0.00	0.00	0.00	0.00	0.00	0.25	0.00	0.00	0.25	2.77
	6.75	0.00	0.00	1.97	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.55
	8.46	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.86
$\bar{x}$	8.19	0.00	0.00	0.57	0.00	0.00	0.00	0.00	0.00	0.08	0.00	0.00	0.08	2.36
KUU 29.8.-8.10.84	7.30	0.00	0.00	0.23	0.00	0.00	0.00	0.00	0.00	0.36	0.00	0.00	0.36	1.47
	7.66	0.00	0.00	0.16	0.00	0.00	0.00	0.00	0.00	0.21	0.00	0.00	0.21	2.40
	4.81	0.00	0.00	0.21	0.00	0.00	0.00	0.00	0.00	0.17	0.00	0.00	0.17	1.33
	4.78	0.00	0.00	0.23	0.00	0.00	0.00	0.00	0.00	0.21	0.00	0.00	0.21	1.72
$\bar{x}$	6.14	0.00	0.00	0.21	0.00	0.00	0.00	0.00	0.00	0.24	0.00	0.00	0.24	1.73
TAR 29.8.-8.10.84	3.56	0.00	0.00	0.56	0.00	0.00	0.00	0.00	0.00	0.17	0.00	0.00	0.17	0.00
	2.30	0.00	0.00	0.48	0.00	0.00	0.00	0.00	0.00	0.39	0.00	0.00	0.39	0.00
	1.95	0.00	0.00	0.56	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	3.76	0.00	0.00	0.32	0.00	0.00	0.00	0.00	0.00	0.21	0.00	0.00	0.21	0.00
$\bar{x}$	2.89	0.00	0.00	0.48	0.00	0.00	0.00	0.00	0.00	0.19	0.00	0.00	0.19	0.00
TOR 29.8.-8.10.84	2.93	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.56
	2.09	0.00	0.00	0.43	0.00	0.00	0.00	0.00	0.00	0.24	0.00	0.00	0.24	3.64
	6.16	0.00	0.00	0.10	0.15	0.00	0.00	0.00	0.15	0.31	0.00	0.00	0.31	1.72
	3.45	0.00	0.00	0.29	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
$\bar{x}$	3.66	0.00	0.00	0.20	0.04	0.00	0.00	0.00	0.04	0.14	0.00	0.00	0.14	1.98
HPK 3.-30.8.84	7.93	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	6.92	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
$\bar{x}$	7.42	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
HPK 30.8.-9.10.84	6.08	0.00	0.00	0.91	0.00	0.00	0.00	0.72	0.72	0.00	0.00	0.00	0.00	0.00
	7.08	0.00	0.00	0.37	0.00	0.00	0.00	0.00	0.00	0.28	0.00	0.00	0.28	0.00
	6.23	0.00	0.00	1.01	0.00	0.00	0.00	0.00	0.00	0.29	0.00	0.00	0.29	0.00
	5.02	0.00	0.00	1.04	0.00	0.00	0.00	0.00	0.00	0.92	0.00	0.00	0.92	0.00
$\bar{x}$	6.10	0.00	0.00	0.83	0.00	0.00	0.00	0.18	0.18	0.37	0.00	0.00	0.37	0.00
KÄR 30.8.-9.10.84	3.96	0.00	0.00	0.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	7.98	0.00	0.00	0.44	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	3.86	0.00	0.00	0.21	0.00	0.00	0.00	0.00	0.00	0.21	0.00	0.00	0.21	0.00
	3.04	0.00	0.00	0.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
$\bar{x}$	4.71	0.00	0.00	0.30	0.00	0.00	0.00	0.00	0.00	0.05	0.00	0.00	0.05	0.00

Incubation	Chlorophenolics (µg/g fat)												
Station period	24DCP	246TCP	245TCP	TeCP	PeCP	345TCC	TeCC	345TCG	456TCG	TeCG	DMP	S1PCP	S2PCP
MAT 2.-29.8.84	0.00	0.00	0.00	1.94	4.62	0.00	0.00	0.00	0.00	0.00	0.00	6.56	0.00
	0.00	0.00	0.00	0.98	2.38	0.00	0.00	0.00	0.00	0.00	0.00	3.36	0.00
	0.00	0.00	0.00	1.51	3.09	0.00	0.00	0.00	0.00	0.00	0.00	4.60	0.00
	0.00	0.00	0.00	0.65	0.36	0.00	0.00	0.00	0.00	0.00	0.00	1.01	0.00
$\bar{x}$	0.00	0.00	0.00	1.27	2.61	0.00	0.00	0.00	0.00	0.00	0.00	3.88	0.00
MAT 29.8.-8.10.84	0.00	0.00	0.00	0.54	0.47	0.00	0.00	0.00	0.00	0.00	0.00	1.01	0.00
	0.00	0.00	0.00	0.47	0.41	0.00	0.00	0.00	0.00	0.00	0.00	0.88	0.00
	0.00	0.00	0.00	0.47	0.62	0.00	0.00	0.00	0.00	0.00	0.00	1.09	0.00
	0.00	0.00	0.00	0.64	0.58	0.00	0.00	0.00	0.00	0.00	0.00	1.22	0.00
$\bar{x}$	0.00	0.00	0.00	0.53	0.52	0.00	0.00	0.00	0.00	0.00	0.00	1.05	0.00
KUU 2.-29.8.84	0.00	1.79	0.00	0.97	0.33	0.00	0.00	0.71	1.30	0.00	0.59	3.09	2.60
	0.00	1.49	0.00	1.29	0.51	0.00	0.00	1.20	0.00	1.05	0.59	3.29	2.84
	0.00	1.75	0.00	1.42	0.82	0.00	0.07	1.33	1.16	1.11	1.62	3.99	5.29
	0.00	0.98	0.00	1.12	0.05	0.00	0.00	0.79	3.07	0.85	2.23	2.15	6.94
$\bar{x}$	0.00	1.50	0.00	1.20	0.43	0.00	0.02	1.01	1.38	0.75	1.26	3.13	4.42
KUU 29.8.-8.10.84	0.00	2.69	0.00	3.82	3.43	2.71	0.00	3.10	6.58	2.66	3.77	9.94	18.82
	0.00	2.89	0.94	2.09	2.21	0.00	0.00	2.09	4.31	1.85	1.98	7.19	11.17
	0.00	4.57	10.19	3.70	1.95	0.00	0.00	3.24	3.74	2.29	6.82	10.22	26.28
	0.00	2.03	0.00	1.49	0.54	1.30	0.00	2.24	2.47	0.96	2.47	4.06	9.44
$\bar{x}$	0.00	3.04	2.78	2.78	2.03	1.00	0.00	2.67	4.28	1.94	3.76	7.85	16.43
TAR 29.8.-8.10.84	1.57	0.00	3.37	1.46	1.32	0.00	0.00	0.7.	0.00	0.14	0.00	2.78	5.87
	0.00	0.00	0.00	2.00	1.83	0.00	0.00	0.00	0.00	0.00	0.00	3.83	0.00
	0.00	0.00	0.00	1.23	1.23	0.00	0.00	0.00	0.00	2.62	0.00	2.46	2.62
	0.00	0.00	0.00	4.12	1.20	0.00	0.00	0.00	0.00	1.38	0.00	5.32	1.38
$\bar{x}$	0.39	0.00	0.84	2.20	1.40	0.00	0.00	0.20	0.00	1.04	0.00	3.60	2.47
TOR 29.8.-8.10.84	0.00	2.22	0.00	1.74	0.00	0.00	0.00	0.00	0.00	2.46	0.00	3.96	2.46
	0.00	3.25	0.00	4.21	2.54	0.00	0.00	3.97	0.00	0.00	0.00	10.00	3.97
	0.00	1.25	0.00	1.01	0.13	0.00	0.00	1.33	0.00	0.00	0.00	2.39	1.33
	0.00	2.06	0.00	1.71	0.00	0.00	0.00	1.83	0.00	0.00	0.00	3.77	1.83
$\bar{x}$	0.00	2.20	0.00	2.17	0.67	0.00	0.00	1.78	0.00	0.62	0.00	5.03	2.40
HPK 3.-30.8.84	0.00	1.88	0.00	7.20	0.56	0.00	0.00	0.00	0.00	0.00	0.00	9.64	0.00
	0.00	0.74	0.00	0.68	0.85	0.00	0.00	0.00	0.00	0.00	0.00	2.27	0.00
$\bar{x}$	0.00	1.31	0.00	3.94	0.70	0.00	0.00	0.00	0.00	0.00	0.00	5.96	0.00
HPK 30.8.-9.10.84	0.00	2.73	0.00	1.43	0.61	0.00	0.00	0.30	0.00	0.15	0.00	4.77	0.45
	0.00	2.27	0.00	1.36	1.05	0.00	0.00	0.59	0.00	0.37	1.05	4.68	2.01
	0.00	0.98	0.00	1.33	0.34	0.00	0.00	0.48	0.00	0.00	0.58	2.65	1.06
	0.00	0.00	0.00	0.42	0.28	0.00	0.00	0.00	0.00	0.00	0.00	0.70	0.00
$\bar{x}$	0.00	1.50	0.00	1.14	0.57	0.00	0.00	0.34	0.00	0.13	0.41	3.20	0.88
KÄR 30.8.-9.10.84	0.00	0.00	0.00	2.60	1.24	1.87	0.00	2.05	0.00	1.11	4.87	3.84	9.90
	0.00	0.58	0.00	2.71	1.02	2.12	0.00	1.02	0.00	2.21	4.95	4.31	10.30
	0.00	0.00	0.00	2.18	1.35	0.00	0.00	0.00	0.00	0.00	7.46	3.53	7.46
	0.00	0.00	0.00	1.28	0.00	0.00	0.00	0.00	0.00	0.63	0.00	1.28	0.63
$\bar{x}$	0.00	0.14	0.00	2.19	0.90	1.00	0.00	0.77	0.00	0.99	4.32	3.24	7.07

26DCP, 45DCG and 34DCC were analysed but not detected.

The chemical results of mussels incubated in Äänekoski area in 1985.

Incubation station	period	fat %	Chlorohydrocarbons (µg/g fat) CYMS	HCBz	LIND	DDE	PCB
MAT	23.7.-5.8.1985	9.57	0.000	0.010	0.084	0.084	0.000
		5.21	0.000	0.038	0.115	0.058	0.000
		$\bar{x}$ 7.39	0.000	0.024	0.100	0.071	0.000
KUU	23.7.-5.8.1985	4.70	1.660	0.128	0.511	0.000	1.957
		5.38	2.454	0.093	0.009	0.000	2.491
		$\bar{x}$ 5.04	2.057	0.110	0.260	0.000	2.224
KUU	23.7.-19.8.1985	5.30	1.057	0.094	0.189	0.000	2.962
		6.05	1.223	0.083	0.165	0.000	2.793
		$\bar{x}$ 5.68	1.140	0.088	0.177	0.000	2.878
KUU	23.7.-2.9.1985	6.13	0.522	0.065	0.033	0.000	2.708
		4.81	0.852	0.083	0.062	0.000	3.410
		$\bar{x}$ 5.47	0.687	0.074	0.048	0.000	3.059
KUU	23.7.-16.9.1985	7.83	0.307	0.064	0.026	0.000	2.490
		7.98	0.313	0.038	0.125	0.025	2.870
		$\bar{x}$ 7.90	0.310	0.051	0.076	0.012	2.680
KAN	23.7.-5.8.1985	5.09	1.591	0.059	0.010	0.000	1.415
		4.60	-1	0.109	0.011	0.000	1.674
		$\bar{x}$ 4.84	1.591	0.084	0.010	0.000	1.544
KAN	23.7.-19.8.1985	6.43	0.762	0.047	0.078	0.008	1.680
		9.05	0.906	0.066	0.221	0.006	1.724
		$\bar{x}$ 7.74	0.834	0.056	0.150	0.007	1.702
KAN	23.7.-2.9.1985	5.16	0.601	0.039	0.174	0.010	1.880
		6.26	0.367	0.048	0.128	0.000	1.869
		$\bar{x}$ 5.71	0.484	0.044	0.151	0.005	1.874
KAN	23.7.-16.9.1985	7.29	0.329	0.041	0.041	0.055	1.824
		7.27	0.220	0.055	0.110	0.028	1.994
		$\bar{x}$ 7.28	0.274	0.048	0.076	0.042	1.909
TOR	23.7.-5.8.1985	7.68	0.872	0.065	0.007	0.000	1.133
		4.78	0.879	0.063	0.209	0.000	1.318
		$\bar{x}$ 6.23	0.876	0.064	0.108	0.000	1.226
TOR	23.7.-19.8.1985	4.69	1.684	0.011	0.011	0.000	2.111
		4.26	1.080	0.070	0.164	0.000	2.277
		$\bar{x}$ 4.48	1.382	0.040	0.088	0.000	2.194
TOR	23.7.-2.9.1985	5.65	0.301	0.035	0.195	0.035	1.752
		5.90	0.559	0.051	0.051	0.034	1.966
		$\bar{x}$ 5.78	0.430	0.043	0.123	0.034	1.859

Incubation			Chlorohydrocarbons (µg/g fat)				
station	period	fat %	CYMS	HCBz	LIND	DDE	PCB
TOR	23.7.-16.9.1985	7.35	0.286	0.027	0.027	0.000	1.633
		6.94	0.288	0.043	0.043	0.058	1.801
		$\bar{x}$ 7.14	0.287	0.035	0.035	0.029	1.717

OXY, GAMMA, ALPHA, TRANS, DDD and DDT were analysed but not detected.

Incubation			Chlorophenolics (µg/g fat)							
station	period	246TCP	TeCP	PeCP	345TCG	456TCG	TeCG	DMP	S1PCP	S2PCP
MAT	23.7.-5.8.1985	0.261	1.369	0.502	0.000	0.000	0.000	0.000	2.132	0.000
		1.094	2.457	0.653	0.000	0.000	0.000	0.000	4.204	0.000
		$\bar{x}$ 0.678	1.913	0.578	0.000	0.000	0.000	0.000	3.168	0.000
KUU	23.7.-5.8.1985	2.085	0.468	1.404	0.404	0.000	0.957	1.553	3.957	2.914
		1.654	1.264	0.149	0.446	0.297	2.621	0.836	3.067	4.200
		$\bar{x}$ 1.870	0.866	0.776	0.425	0.148	1.789	1.194	3.512	3.557
KUU	23.7.-19.8.1985	0.472	0.245	0.000	1.434	0.000	0.509	0.000	0.717	1.943
		1.174	0.331	1.107	1.355	0.116	0.711	0.628	2.612	2.810
		$\bar{x}$ 0.823	0.288	0.554	1.394	0.058	0.610	0.314	1.664	2.376
KUU	23.7.-2.9.1985	0.636	0.261	0.212	1.126	0.114	0.245	0.326	1.109	1.811
		0.894	0.665	1.060	6.071	0.686	2.037	2.079	2.619	10.873
		$\bar{x}$ 0.765	0.463	0.636	3.598	0.400	1.141	1.202	1.864	6.342
KUU	23.7.-16.9.1985	1.124	0.217	0.473	1.034	0.294	0.332	1.405	1.814	3.065
		1.328	0.125	0.902	0.777	0.075	0.351	0.125	2.355	1.328
		$\bar{x}$ 1.226	0.171	0.688	0.906	0.184	0.342	0.765	2.084	2.196
KAN	23.7.-5.8.1985	0.314	1.906	0.472	0.806	0.079	0.255	0.000	2.692	1.140
		1.130	1.587	1.978	2.783	0.783	-1	0.000	4.695	3.566
		$\bar{x}$ 0.722	1.746	1.225	1.794	0.431	0.255	0.000	3.694	2.353
KAN	23.7.-19.8.1985	0.327	0.202	0.653	0.762	0.000	0.591	0.000	1.182	1.353
		0.453	0.320	0.343	0.829	0.000	0.796	0.000	1.116	1.625
		$\bar{x}$ 0.390	0.261	0.498	0.796	0.000	0.694	0.000	1.149	1.489
KAN	23.7.-2.9.1985	0.504	0.426	0.271	1.453	0.000	0.388	0.000	1.201	1.841
		0.319	0.335	0.144	1.038	0.000	0.351	0.000	0.798	1.389
		$\bar{x}$ 0.412	0.380	0.208	1.246	0.000	0.370	0.000	1.000	1.615
KAN	23.7.-16.9.1985	0.974	0.357	0.370	0.658	0.000	1.015	0.000	1.701	1.673
		1.417	0.248	0.440	0.990	0.000	1.224	0.000	2.105	2.214
		$\bar{x}$ 1.196	0.302	0.405	0.824	0.000	1.120	0.000	1.903	1.944
TOR	23.7.-5.8.1985	0.456	0.612	0.443	2.214	0.000	0.612	0.000	1.511	2.826
		0.879	0.628	0.795	2.762	0.000	0.439	0.000	2.302	3.201
		$\bar{x}$ 0.668	0.620	0.619	2.488	0.000	0.526	0.000	1.906	3.014

Incubation station	period	Chlorophenolics (µg/g fat) 246TCP	TeCP	PeCP	345TCG	456TCG	TeCG	DMP	S1PCP	S2PCP
TOR	23.7.-19.8.1985	0.512	1.386	0.384	2.324	0.000	1.130	0.000	2.282	3.454
		0.798	1.831	1.925	1.009	0.000	0.728	0.000	4.554	1.737
	$\bar{x}$	0.655	1.608	1.154	1.666	0.000	0.929	0.000	3.418	2.596
TOR	23.7.-2.9.1985	0.814	1.009	0.690	2.177	0.000	0.973	0.000	2.513	3.150
		0.644	0.661	0.237	1.966	0.000	0.610	0.000	1.542	2.576
	$\bar{x}$	0.729	0.835	0.464	2.072	0.000	0.792	0.000	2.028	2.863
TOR	23.7.-16.9.1985	0.952	0.599	0.286	0.830	0.000	0.558	0.000	1.837	1.388
		1.542	0.548	0.720	1.066	0.000	0.764	0.000	2.810	1.830
	$\bar{x}$	1.247	0.574	0.503	0.948	0.000	0.661	0.000	2.324	1.609

24DCP, 26DCP, 245TCP, 34DCC, 345TCC, TeCC and 45DCG were analysed but not detected.
-1 = no results

Appendix 4

The chemical results of the mussels incubated in the Kymijoki river basin in 1986.

Incubation station period	fat %	Chlorohydrocarbons (µg/g fat) CYMS	HCBz	LIND	OXY	GAMMA	ALPHA	TRANS	SCHL	DDE	DDD	DDT	SDDT	PCB
MAT	5.490	0.018	0.055	0.036	0.000	0.000	0.000	0.000	0.000	0.018	0.000	0.018	0.036	0.510
4.8.-1.9.	5.290	0.000	0.038	0.038	0.000	0.000	0.000	0.000	0.000	0.019	0.000	0.019	0.038	0.397
	6.130	0.008	0.049	0.016	0.000	0.000	0.000	0.000	0.000	0.016	0.000	0.016	0.032	0.571
	4.400	0.011	0.045	0.023	0.000	0.000	0.000	0.000	0.000	0.023	0.000	0.023	0.046	0.432
	6.080	0.000	0.000	0.033	0.000	0.000	0.000	0.000	0.000	0.016	0.000	0.016	0.032	0.822
$\bar{x}$	5.478	0.008	0.037	0.029	0.000	0.000	0.000	0.000	0.000	0.019	0.000	0.019	0.037	0.546
KUU	6.220	0.305	0.080	0.032	0.000	0.048	0.000	0.000	0.048	0.000	0.016	0.032	0.048	2.814
4.8.-1.9.	6.430	0.373	0.047	0.062	0.000	0.031	0.000	0.000	0.031	0.000	0.000	0.000	0.000	2.862
	5.510	0.200	0.018	0.018	0.000	0.018	0.000	0.000	0.018	0.000	0.000	0.000	0.000	2.868
	5.930	0.320	0.034	0.034	0.000	0.034	0.000	0.000	0.034	0.000	0.000	0.000	0.000	2.496
	6.590	0.288	0.061	0.030	0.000	0.030	0.000	0.000	0.030	0.000	0.000	0.000	0.000	2.686
$\bar{x}$	6.136	0.297	0.048	0.035	0.000	0.032	0.000	0.000	0.032	0.000	0.003	0.006	0.009	2.745
TOR	6.290	0.143	0.064	0.032	0.000	0.000	0.000	0.000	0.000	0.016	0.000	0.016	0.032	1.320
4.8.-1.9.	5.100	0.078	0.059	0.020	0.000	0.000	0.000	0.000	0.000	0.020	0.000	0.020	0.040	2.706
	5.220	0.153	0.096	0.019	0.000	0.000	0.000	0.000	0.000	0.019	0.000	0.019	0.038	1.973
	5.170	0.097	0.039	0.039	0.000	0.000	0.000	0.000	0.000	0.019	0.000	0.019	0.038	2.515
	5.040	0.139	0.099	0.060	0.000	0.000	0.000	0.000	0.000	0.020	0.000	0.020	0.040	1.627
$\bar{x}$	5.364	0.122	0.071	0.034	0.000	0.000	0.000	0.000	0.000	0.019	0.000	0.019	0.038	2.028
KÄR	5.550	0.072	0.018	0.018	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
6.8.-3.9.	5.450	0.037	0.018	0.018	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	5.740	0.009	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.009	0.000	0.017	0.026	0.000
	5.450	0.018	0.000	0.055	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	6.490	0.015	0.031	0.031	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
$\bar{x}$	5.736	0.030	0.013	0.024	0.000	0.000	0.000	0.000	0.000	0.002	0.000	0.003	0.005	0.000
LEH	4.650	0.065	0.022	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
6.8.-3.9.	4.850	0.021	0.000	0.021	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	5.370	0.056	0.000	0.019	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	5.400	0.074	0.000	0.019	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	5.200	0.077	0.019	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
$\bar{x}$	5.094	0.058	0.008	0.012	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
PIL	6.670	0.060	0.315	0.075	0.000	0.030	0.000	0.000	0.030	0.000	0.000	0.000	0.000	0.630
5.8.-2.9.	6.380	0.063	0.078	0.047	0.000	0.063	0.000	0.000	0.063	0.000	0.000	0.000	0.000	0.737
	6.460	0.077	0.139	0.031	0.000	0.015	0.000	0.000	0.015	0.000	0.000	0.000	0.000	0.991
	6.920	0.058	0.087	0.058	0.000	0.058	0.000	0.000	0.058	0.000	0.000	0.000	0.000	0.737
	5.830	0.086	0.086	0.051	0.000	0.069	0.000	0.000	0.069	0.000	0.069	0.034	0.103	0.806
$\bar{x}$	6.452	0.069	0.141	0.052	0.000	0.047	0.000	0.000	0.047	0.000	0.014	0.007	0.021	0.780
HIR	7.720	0.635	0.052	0.000	0.000	0.117	0.000	0.000	0.117	0.000	0.000	0.000	0.000	0.000
5.8.-2.9.	6.440	0.745	0.047	0.000	0.000	0.109	0.000	0.000	0.109	0.000	0.000	0.000	0.000	0.000
	5.750	0.748	0.052	0.000	0.000	0.122	0.000	0.000	0.122	0.000	0.000	0.000	0.000	0.000
	8.180	0.746	0.061	0.000	0.000	0.086	0.000	0.000	0.086	0.000	0.000	0.000	0.000	0.000
	7.050	0.723	0.043	0.000	0.000	0.113	0.000	0.000	0.113	0.000	0.000	0.000	0.000	0.000
$\bar{x}$	7.028	0.719	0.051	0.000	0.000	0.109	0.000	0.000	0.109	0.000	0.000	0.000	0.000	0.000

Incubation		Chlorophenolics (µg/g fat)												
station	period	24DCP	26DCP	246TCP	245TCP	TeCP	PeCP	45DCG	345TCG	456TCG	TeCG	DMP	S1PCP	S2PCP
MAT	4.8.-1.9.86	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
		0.000	0.000	0.000	0.000	0.378	0.170	0.000	0.000	0.000	0.000	0.000	0.548	0.000
		0.000	0.000	0.000	0.000	0.212	0.228	0.000	0.000	0.000	0.000	0.000	0.440	0.000
		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
		0.000	0.000	0.000	0.000	0.888	0.148	0.000	0.000	0.000	0.000	0.000	1.036	0.000
	$\bar{x}$	0.000	0.000	0.000	0.000	0.296	0.109	0.000	0.000	0.000	0.000	0.000	0.405	0.000
KUU	4.8.-1.9.86	0.129	0.000	0.225	0.000	0.000	0.000	0.000	1.913	0.402	0.450	0.032	0.225	2.926
		0.591	0.000	0.809	0.000	0.467	0.000	0.000	2.364	0.342	0.591	0.047	1.276	3.935
		0.127	0.000	0.309	0.000	0.000	0.000	0.000	1.760	0.363	0.490	0.018	0.309	2.758
		0.067	0.000	0.337	0.000	0.000	0.000	0.000	1.855	0.253	0.506	0.017	0.337	2.698
		0.106	0.000	0.395	0.000	0.000	0.000	0.000	2.079	0.486	0.592	0.015	0.395	3.278
	$\bar{x}$	0.204	0.000	0.415	0.000	0.093	0.000	0.000	1.994	0.369	0.526	0.026	0.508	3.119
TOR	4.8.-1.9.86	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.477	0.000	0.079	0.000	0.000	0.556
		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.647	0.000	0.176	0.000	0.000	0.823
		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.594	0.000	0.172	0.000	0.000	0.766
		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.445	0.000	0.193	0.000	0.000	0.638
		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.556	0.000	0.298	0.000	0.000	0.854
	$\bar{x}$	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.544	0.000	0.184	0.000	0.000	0.727
KÄR	6.8.-3.9.86	0.000	0.000	0.000	0.000	0.162	0.162	0.000	0.234	0.000	0.054	0.000	0.324	0.288
		0.000	0.000	0.055	0.000	0.055	0.000	0.000	0.294	0.000	0.055	0.000	0.110	0.349
		0.000	0.000	0.087	0.000	0.139	0.000	0.000	0.279	0.000	0.052	0.122	0.226	0.453
		0.000	0.000	0.092	0.000	0.440	0.037	0.000	0.220	0.000	0.055	0.000	0.569	0.275
		0.000	0.000	0.000	0.000	0.062	0.000	0.000	0.262	0.000	0.077	0.031	0.062	0.370
	$\bar{x}$	0.000	0.000	0.047	0.000	0.172	0.040	0.000	0.258	0.000	0.059	0.031	0.258	0.347
LEH	6.8.-3.9.86	0.000	0.000	0.065	0.000	0.344	0.430	0.000	0.215	0.000	0.022	0.000	0.839	0.237
		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.165	0.000	0.021	0.000	0.000	0.186
		0.000	0.000	0.019	0.000	0.000	0.000	0.000	0.186	0.000	0.019	0.000	0.019	0.205
		0.000	0.000	0.093	0.000	0.000	0.000	0.000	0.278	0.000	0.037	0.000	0.093	0.315
		0.000	0.000	0.019	0.000	0.038	0.000	0.000	0.308	0.000	0.038	0.000	0.057	0.346
	$\bar{x}$	0.000	0.000	0.039	0.000	0.077	0.086	0.000	0.230	0.000	0.027	0.000	0.202	0.258
PIL	5.8.-2.9.86	0.000	0.000	0.105	0.000	0.810	1.919	0.000	0.000	0.000	0.000	0.000	2.834	0.000
		0.000	0.000	0.125	0.000	0.361	0.000	0.000	0.016	0.000	0.000	0.000	0.486	0.016
		0.000	0.000	0.077	0.000	0.279	0.000	0.000	0.000	0.000	0.000	0.000	0.356	0.000
		0.000	0.000	0.043	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.043	0.000
		0.000	0.000	0.120	0.000	0.206	0.000	0.000	0.000	0.000	0.000	0.000	0.326	0.000
	$\bar{x}$	0.000	0.000	0.094	0.000	0.331	0.384	0.000	0.003	0.000	0.000	0.000	0.809	0.003
HIR	5.8.-2.9.86	0.350	0.000	1.231	0.000	1.256	1.308	0.000	3.187	0.402	1.140	0.363	3.795	5.442
		0.093	0.000	1.708	0.062	1.304	0.000	0.000	2.826	0.342	0.870	0.280	3.012	4.473
		0.070	0.000	1.757	0.087	0.870	0.000	0.000	2.609	0.348	0.730	0.261	2.627	4.105
		0.183	0.000	1.687	0.073	1.467	0.819	0.000	2.812	0.293	1.161	0.391	3.973	4.913
		0.284	0.000	1.475	0.000	0.865	0.000	0.000	2.539	0.355	0.780	0.255	2.340	4.213
	$\bar{x}$	0.196	0.000	1.571	0.044	1.153	0.425	0.000	2.794	0.348	0.936	0.310	3.149	4.629

34DCC, 345TCC and TeCC were analysed but not detected.

Incubation station	period	Chlorinated anisoles and veratroles (ng/g fat) 246TCA	TeCA	PeCA	TeCV	SANIS
MAT	4.8.-1.9.1986	0.00	9.11	0.00	18.21	27.32
		0.00	0.00	0.00	37.81	37.81
		0.00	0.00	0.00	48.94	48.94
		0.00	0.00	0.00	22.73	22.73
		0.00	0.00	0.00	32.89	32.89
	$\bar{x}$	0.00	1.82	0.00	32.12	33.94
KUU	4.8.-1.9.1986	16.08	0.00	8.04	144.69	168.81
		0.00	0.00	15.55	124.42	139.97
		18.15	0.00	0.00	145.19	163.34
		0.00	0.00	16.86	151.77	168.63
		15.17	0.00	15.17	136.57	166.91
	$\bar{x}$	9.88	0.00	11.13	140.53	161.53
TOR	4.8.-1.9.1986	47.69	15.90	0.00	0.00	63.59
		0.00	0.00	0.00	0.00	0.00
		38.31	0.00	38.31	0.00	76.62
		0.00	0.00	19.34	0.00	19.34
		0.00	0.00	0.00	0.00	0.00
	$\bar{x}$	17.20	3.18	11.53	0.00	31.91
KÄR	6.8.-3.9.1986	0.00	18.02	36.04	72.07	126.13
		0.00	5.50	18.35	55.05	78.90
		0.00	0.00	17.42	8.71	26.13
		0.00	0.00	36.70	73.39	110.09
		0.00	15.41	30.82	61.63	107.86
	$\bar{x}$	0.00	7.79	27.86	54.17	89.82
LEH	6.8.-3.9.1986	0.00	0.00	0.00	0.00	0.00
		0.00	0.00	0.00	0.00	0.00
		0.00	0.00	0.00	0.00	0.00
		0.00	0.00	0.00	0.00	0.00
		0.00	0.00	0.00	0.00	0.00
	$\bar{x}$	0.00	0.00	0.00	0.00	0.00
PIL	5.8.-2.9.1986	0.00	0.00	0.00	0.00	0.00
		0.00	0.00	0.00	0.00	0.00
		0.00	0.00	0.00	0.00	0.00
		0.00	0.00	0.00	0.00	0.00
		0.00	0.00	0.00	0.00	0.00
	$\bar{x}$	0.00	0.00	0.00	0.00	0.00
HIR	5.8.-2.9.1986	0.00	0.00	0.00	297.93	297.93
		15.53	0.00	0.00	263.98	279.51
		52.17	0.00	0.00	243.48	295.65
		36.67	0.00	0.00	268.95	305.62
		28.37	0.00	0.00	297.87	326.24
	$\bar{x}$	26.55	0.00	0.00	274.44	300.99

345TCA, 34DCV, 45DCV and 345TCV were analysed but not detected.

Appendix 5

The chemical results of mussels incubated in Äänekoski area for PCB-investigation in 1987.

Incubation station period	fat %	Chlorohydrocarbons (µg/g fat) CYMS	CYMD	HCBz	LIND	GAMMA	SCHL	DDE	DDD	SDDT	PCB
MAT 4.8.-1.9.1987	6.640	0.000	0.000	0.030	0.151	0.000	0.000	0.015	0.000	0.015	0.000
	6.250	0.000	0.000	0.080	0.144	0.000	0.000	0.064	0.000	0.064	0.000
	5.850	0.000	0.000	0.051	0.051	0.000	0.000	0.034	0.000	0.034	0.000
	6.170	0.000	0.000	0.065	0.194	0.000	0.000	0.016	0.000	0.016	0.000
	7.100	0.000	0.000	0.028	0.155	0.000	0.000	0.014	0.000	0.014	0.000
$\bar{x}$	6.402	0.000	0.000	0.051	0.139	0.000	0.000	0.029	0.000	0.029	0.000
HÄR 5.8.-2.9.1987	6.760	0.000	0.000	0.044	0.059	0.000	0.000	0.000	0.000	0.000	0.000
	7.340	0.000	0.000	0.054	0.082	0.000	0.000	0.000	0.000	0.000	0.000
	7.070	0.000	0.000	0.057	0.099	0.000	0.000	0.000	0.000	0.000	0.000
	5.930	0.000	0.000	0.034	0.067	0.000	0.000	0.000	0.000	0.000	0.000
	6.110	0.000	0.000	0.016	0.049	0.000	0.000	0.000	0.000	0.000	0.000
$\bar{x}$	6.642	0.000	0.000	0.041	0.071	0.000	0.000	0.000	0.000	0.000	0.000
HTM 5.8.-2.9.1987	6.110	0.000	0.000	0.033	0.065	0.000	0.000	0.000	0.000	0.000	0.000
	5.410	0.000	0.000	0.018	0.111	0.000	0.000	0.000	0.000	0.000	0.000
	6.580	0.000	0.000	0.015	0.076	0.000	0.000	0.000	0.000	0.000	0.000
	6.140	0.000	0.000	0.049	0.065	0.000	0.000	0.000	0.000	0.000	0.000
	6.210	0.000	0.000	0.032	0.048	0.000	0.000	0.000	0.000	0.000	0.000
$\bar{x}$	6.090	0.000	0.000	0.029	0.073	0.000	0.000	0.000	0.000	0.000	0.000
KUH 1 5.8.-2.9.1987	8.740	0.000	0.000	0.046	0.011	0.000	0.000	0.023	0.000	0.023	0.000
	5.040	0.000	0.000	0.040	0.020	0.000	0.000	0.040	0.000	0.040	0.000
	6.610	0.000	0.000	0.030	0.015	0.000	0.000	0.030	0.000	0.030	0.000
	6.080	0.000	0.000	0.033	0.016	0.000	0.000	0.016	0.000	0.016	0.000
	6.470	0.000	0.000	0.015	0.031	0.000	0.000	0.015	0.000	0.015	0.000
$\bar{x}$	6.588	0.000	0.000	0.033	0.019	0.000	0.000	0.025	0.000	0.025	0.000
KUH 2 5.8.-2.9.1987	6.130	0.375	0.033	0.033	0.033	0.016	0.016	0.000	0.000	0.000	1.305
	6.250	0.480	0.048	0.048	0.032	0.016	0.016	0.000	0.000	0.000	0.848
	5.400	0.704	0.222	0.056	0.037	0.019	0.019	0.000	0.000	0.000	1.019
	5.320	0.714	0.113	0.038	0.019	0.038	0.038	0.038	0.000	0.038	1.391
	6.850	0.657	0.117	0.044	0.029	0.029	0.029	0.015	0.000	0.015	1.255
$\bar{x}$	5.990	0.586	0.106	0.044	0.030	0.024	0.024	0.010	0.000	0.010	1.164
KUH 3 5.8.-2.9.1987	5.980	0.920	0.619	0.050	0.033	0.050	0.050	0.000	0.000	0.000	0.987
	6.860	1.035	0.423	0.044	0.044	0.029	0.029	0.000	0.000	0.000	0.787
	5.980	1.338	0.401	0.017	0.000	0.033	0.033	0.000	0.000	0.000	0.936
	4.560	1.404	0.548	0.022	0.000	0.022	0.022	0.000	0.000	0.000	0.987
	5.720	1.294	0.297	0.000	0.000	0.070	0.070	0.000	0.000	0.000	1.049
$\bar{x}$	5.820	1.198	0.458	0.027	0.015	0.041	0.041	0.000	0.000	0.000	0.949
KUH 4 5.8.-2.9.1987	5.420	0.387	0.000	0.092	0.018	0.000	0.000	0.055	0.000	0.055	1.568
	5.120	0.410	0.000	0.078	0.039	0.000	0.000	0.020	0.000	0.020	2.109
	5.600	0.554	0.000	0.054	0.036	0.000	0.000	0.018	0.000	0.018	1.714
	5.790	0.518	0.000	0.086	0.035	0.000	0.000	0.035	0.000	0.035	1.675
	5.610	0.535	0.000	0.053	0.036	0.000	0.000	0.036	0.000	0.036	1.230
$\bar{x}$	5.508	0.481	0.000	0.073	0.033	0.000	0.000	0.033	0.000	0.033	1.659

Incubation station period	fat %	Chlorohydrocarbons (µg/g fat) CYMS	CYMD	HCBz	LIND	GAMMA	SCHL	DDE	DDD	SDDT	PCB
KUH 5 5.8.-2.9.1987	5.650	0.000	0.000	0.071	0.035	0.000	0.000	0.018	0.000	0.018	0.000
	7.400	0.000	0.000	0.081	0.081	0.000	0.000	0.041	0.000	0.041	0.000
	6.060	0.000	0.000	0.066	0.050	0.000	0.000	0.033	0.000	0.033	0.000
	5.640	0.000	0.000	0.053	0.018	0.000	0.000	0.035	0.018	0.053	0.000
	5.810	0.000	0.000	0.069	0.052	0.000	0.000	0.017	0.000	0.017	0.000
$\bar{x}$	6.112	0.000	0.000	0.068	0.047	0.000	0.000	0.029	0.004	0.032	0.000
KUU 5.8.-2.9.1987	7.240	0.276	0.041	0.041	0.014	0.041	0.041	0.014	0.000	0.014	2.224
	6.890	0.377	0.015	0.029	0.029	0.029	0.029	0.000	0.000	0.000	1.684
	5.860	0.478	0.085	0.034	0.017	0.034	0.034	0.017	0.000	0.017	1.672
	7.160	0.475	0.070	0.042	0.014	0.014	0.014	0.014	0.000	0.014	1.439
	5.590	0.537	0.089	0.036	0.018	0.018	0.018	0.018	0.000	0.018	1.825
$\bar{x}$	6.548	0.429	0.060	0.036	0.018	0.027	0.027	0.013	0.000	0.013	1.769
TOR 5.8.-2.9.1987	6.400	0.328	0.000	0.047	0.047	0.047	0.047	0.063	0.000	0.063	2.031
	5.550	0.198	0.108	0.036	0.072	0.054	0.054	0.036	0.000	0.036	1.532
	5.250	0.286	0.076	0.038	0.038	0.057	0.057	0.038	0.000	0.038	1.829
	6.520	0.291	0.061	0.031	0.046	0.031	0.031	0.031	0.000	0.031	1.610
	6.510	0.323	0.184	0.031	0.046	0.031	0.031	0.031	0.000	0.031	1.782
$\bar{x}$	6.046	0.285	0.086	0.036	0.050	0.044	0.044	0.040	0.000	0.040	1.757

OXY, ALPHA, TRANS and DDT were analysed but not detected.

Incubation station period	Chlorophenolics (µg/g fat) 24DCP	26DCP	246TCP	245TCP	TeCP	PeCP	45DCG	345TCG	456TCG	TeCG	DMP	S1PCP	S2PCP
MAT 4.8.-1.9.1987	0.000	0.000	0.000	0.045	0.392	0.166	0.000	0.226	0.045	0.196	0.361	0.557	1.039
	0.000	0.000	0.016	0.000	0.192	0.288	0.000	0.032	0.128	0.048	0.032	0.496	0.240
	0.000	0.000	0.000	0.085	0.137	0.000	0.000	0.000	0.000	0.000	0.051	0.137	0.137
	0.000	0.000	0.049	0.049	0.697	0.065	0.000	0.162	0.000	0.162	0.194	0.810	0.632
	0.000	0.000	0.099	0.028	0.366	0.141	0.000	0.127	0.000	0.155	0.183	0.606	0.493
$\bar{x}$	0.000	0.000	0.033	0.041	0.357	0.132	0.000	0.109	0.035	0.112	0.164	0.521	0.508
HÄR 5.8.-2.9.1987	0.118	0.000	0.074	0.059	0.089	0.000	0.000	0.000	0.000	0.000	0.030	0.163	0.207
	0.259	0.000	0.068	0.041	0.354	0.068	0.000	0.000	0.000	0.014	0.041	0.490	0.341
	0.156	0.000	0.099	0.014	0.212	0.000	0.000	0.000	0.000	0.014	0.141	0.311	0.325
	0.219	0.000	0.152	0.051	0.135	0.000	0.000	0.000	0.000	0.000	0.084	0.287	0.354
	0.180	0.000	0.049	0.049	0.196	0.082	0.000	0.000	0.000	0.016	0.033	0.327	0.278
$\bar{x}$	0.186	0.000	0.088	0.043	0.197	0.030	0.000	0.000	0.000	0.009	0.066	0.316	0.301
HTM 5.8.-2.9.1987	0.000	0.000	0.000	0.000	0.082	0.115	0.000	0.000	0.000	0.033	0.278	0.196	0.311
	0.000	0.000	0.000	0.000	0.129	0.277	0.000	0.000	0.000	0.000	0.203	0.407	0.203
	0.000	0.000	0.000	0.000	0.182	0.152	0.000	0.000	0.000	0.000	0.213	0.334	0.213
	0.000	0.000	0.000	0.000	0.179	0.375	0.000	0.000	0.000	0.000	0.261	0.554	0.261
	0.000	0.000	0.000	0.000	0.161	0.306	0.000	0.000	0.000	0.000	0.177	0.467	0.177
$\bar{x}$	0.000	0.000	0.000	0.000	0.147	0.245	0.000	0.000	0.000	0.007	0.226	0.392	0.233

Incubation		Chlorophenolics (µg/g fat)												
station	period	24DCP	26DCP	246TCP	245TCP	TeCP	PeCP	45DCG	345TCG	456TCG	TeCG	DMP	S1PCP	S2PCP
KUH 1	5.8.-2.9.1987	0.000	0.000	0.057	0.000	0.034	0.126	0.000	0.000	0.000	0.000	0.126	0.217	0.126
		0.000	0.000	0.298	0.000	1.190	0.675	0.000	0.000	0.000	0.000	0.198	2.163	0.198
		0.000	0.000	0.681	0.000	5.976	1.059	0.000	0.000	0.000	0.000	0.091	7.716	0.091
		0.000	0.000	0.082	0.000	0.493	0.757	0.000	0.000	0.000	0.000	0.099	1.332	0.099
		0.000	0.000	0.031	0.000	0.216	0.062	0.000	0.000	0.000	0.000	0.093	0.309	0.093
	$\bar{x}$	0.000	0.000	0.230	0.000	1.582	0.536	0.000	0.000	0.000	0.000	0.121	2.347	0.121
KUH 2	5.8.-2.9.1987	0.000	0.000	0.897	0.000	0.473	0.114	0.000	1.941	0.000	1.077	0.065	1.485	3.083
		0.000	0.000	0.672	0.000	0.336	0.336	0.000	1.440	0.144	0.544	0.032	1.344	2.160
		0.000	0.000	0.722	0.000	0.259	0.093	0.000	1.500	0.185	0.537	0.019	1.074	2.241
		0.000	0.000	0.827	0.000	0.376	0.038	0.000	1.654	0.188	0.583	0.019	1.241	2.444
		0.000	0.000	0.672	0.000	0.234	0.088	0.000	1.036	0.117	0.423	0.000	0.993	1.577
	$\bar{x}$	0.000	0.000	0.758	0.000	0.336	0.134	0.000	1.514	0.127	0.633	0.027	1.227	2.301
KUH 3	5.8.-2.9.1987	0.435	0.000	5.100	0.000	1.773	0.134	0.000	16.973	2.408	5.344	0.167	7.007	25.318
		0.569	0.000	3.557	0.000	1.589	0.000	0.000	12.259	2.201	5.335	0.044	5.146	20.408
		0.719	0.000	4.816	0.000	1.639	0.000	0.000	15.100	2.191	3.746	0.100	6.455	21.856
		0.548	0.000	5.066	0.000	1.711	0.000	0.000	13.158	1.952	3.158	0.066	6.776	18.882
		0.717	0.000	4.878	0.000	1.748	0.000	0.000	13.339	1.888	4.371	0.105	6.626	20.420
	$\bar{x}$	0.597	0.000	4.683	0.000	1.692	0.027	0.000	14.166	2.128	4.389	0.096	6.402	21.377
KUH 4	5.8.-2.9.1987	0.000	0.000	0.000	0.000	0.387	0.295	0.000	0.000	0.000	0.018	0.055	0.683	0.074
		0.000	0.000	0.000	0.000	0.156	0.078	0.000	0.020	0.000	0.020	0.078	0.234	0.098
		0.000	0.000	0.000	0.000	0.214	0.036	0.000	0.000	0.000	0.000	0.036	0.250	0.036
		0.000	0.000	0.000	0.000	0.328	0.000	0.000	0.000	0.000	0.017	0.035	0.328	0.052
		0.000	0.000	0.000	0.000	0.303	0.089	0.000	0.000	0.000	0.018	0.036	0.392	0.053
	$\bar{x}$	0.000	0.000	0.000	0.000	0.278	0.100	0.000	0.004	0.000	0.015	0.048	0.377	0.062
KUH 5	5.8.-2.9.1987	0.000	0.000	0.000	0.000	0.000	0.177	0.000	0.000	0.000	0.000	0.159	0.177	0.159
		0.000	0.000	0.000	0.000	0.000	0.122	0.000	0.000	0.000	0.027	0.095	0.122	0.122
		0.000	0.000	0.000	0.000	0.000	0.066	0.000	0.000	0.000	0.000	0.099	0.066	0.099
		0.000	0.000	0.000	0.000	0.000	0.266	0.000	0.000	0.000	0.000	0.142	0.266	0.142
		0.000	0.000	0.000	0.000	0.000	0.241	0.000	0.000	0.000	0.000	0.138	0.241	0.138
	$\bar{x}$	0.000	0.000	0.000	0.000	0.000	0.174	0.000	0.000	0.000	0.005	0.126	0.174	0.132
KUU	5.8.-2.9.1987	0.000	0.000	0.525	0.000	0.290	0.152	0.000	1.133	0.152	0.235	0.069	0.967	1.588
		0.000	0.000	0.493	0.000	0.116	0.073	0.000	1.074	0.131	0.261	0.116	0.682	1.582
		0.000	0.000	0.853	0.000	2.969	0.529	0.000	1.348	0.205	0.341	0.119	4.352	2.014
		0.000	0.000	0.419	0.000	0.070	0.042	0.000	1.061	0.154	0.321	0.056	0.531	1.592
		0.000	0.000	0.572	0.000	0.179	0.107	0.000	1.342	0.179	0.447	0.125	0.859	2.093
	$\bar{x}$	0.000	0.000	0.573	0.000	0.725	0.181	0.000	1.192	0.164	0.321	0.097	1.478	1.774
TOR	5.8.-2.9.1987	0.000	0.000	0.531	0.000	0.359	0.000	0.000	1.391	0.000	0.500	0.078	0.891	1.969
		0.000	0.000	0.577	0.000	0.162	0.000	0.000	1.441	0.000	0.721	0.054	0.739	2.216
		0.000	0.000	0.590	0.000	0.648	0.838	0.000	1.371	0.000	0.362	0.114	2.076	1.848
		0.000	0.000	0.475	0.000	0.215	0.000	0.000	1.227	0.000	0.414	0.031	0.690	1.672
		0.000	0.000	0.430	0.000	0.292	0.000	0.000	1.336	0.077	0.507	0.061	0.722	1.982
	$\bar{x}$	0.000	0.000	0.521	0.000	0.335	0.168	0.000	1.353	0.015	0.501	0.068	1.024	1.937

34DCC, 345TCC and TeCC were analysed but not detected.

Incubation station	period		Chlorinated anisoles and veratroles (µg/g fat) 246TCA	TeCA	345TCV	PeCA	TeCV	SANIS
MAT	4.8.-1.9.1987		0.000	0.000	0.000	0.000	0.000	0.000
			0.000	0.000	0.000	0.000	0.000	0.000
			0.000	0.000	0.000	0.068	0.000	0.068
			0.000	0.097	0.000	0.049	0.000	0.146
			0.000	0.028	0.000	0.000	0.000	0.028
		$\bar{x}$	0.000	0.025	0.000	0.023	0.000	0.048
HÄR	5.8.-2.9.1987		0.000	0.000	0.000	0.000	0.000	0.000
			0.000	0.000	0.000	0.000	0.000	0.000
			0.000	0.000	0.000	0.000	0.000	0.000
			0.000	0.000	0.000	0.000	0.000	0.000
			0.000	0.000	0.000	0.000	0.000	0.000
		$\bar{x}$	0.000	0.000	0.000	0.000	0.000	0.000
HTM	5.8.-2.9.1987		0.000	0.000	0.000	0.000	0.000	0.000
			0.000	0.000	0.000	0.000	0.000	0.000
			0.000	0.015	0.000	0.000	0.000	0.015
			0.000	0.016	0.000	0.000	0.000	0.016
			0.000	0.000	0.000	0.000	0.000	0.000
		$\bar{x}$	0.000	0.006	0.000	0.000	0.000	0.006
KUH 1	5.8.-2.9.1987		0.000	0.000	0.000	0.057	0.000	0.057
			0.000	0.000	0.000	0.020	0.000	0.020
			0.000	0.000	0.000	0.015	0.000	0.015
			0.000	0.000	0.000	0.000	0.000	0.000
			0.000	0.000	0.000	0.031	0.000	0.031
		$\bar{x}$	0.000	0.000	0.000	0.025	0.000	0.025
KUH 2	5.8.-2.9.1987		0.000	0.016	0.261	0.000	0.163	0.440
			0.000	0.032	0.224	0.000	0.256	0.512
			0.000	0.019	0.241	0.000	0.333	0.593
			0.000	0.056	0.338	0.000	0.282	0.677
			0.000	0.058	0.190	0.000	0.000	0.248
		$\bar{x}$	0.000	0.036	0.251	0.000	0.207	0.494
KUH 3	5.8.-2.9.1987		0.050	0.134	2.425	0.167	1.672	4.448
			0.058	0.131	2.172	0.190	1.691	4.242
			0.067	0.217	2.826	0.217	1.923	5.251
			0.088	0.263	2.697	0.482	2.083	5.614
			0.105	0.245	2.430	0.315	2.010	5.105
		$\bar{x}$	0.074	0.198	2.510	0.274	1.876	4.932
KUH 4	5.8.-2.9.1987		0.000	0.000	0.000	0.018	0.000	0.018
			0.000	0.000	0.000	0.020	0.000	0.020
			0.000	0.000	0.000	0.036	0.000	0.036
			0.000	0.000	0.000	0.035	0.000	0.035
			0.000	0.000	0.000	0.036	0.000	0.036
		$\bar{x}$	0.000	0.000	0.000	0.029	0.000	0.029
KUH 5	5.8.-2.9.1987		0.000	0.000	0.000	0.018	0.000	0.018
			0.000	0.000	0.000	0.041	0.000	0.041
			0.000	0.000	0.000	0.017	0.000	0.017
			0.000	0.000	0.000	0.018	0.000	0.018
			0.000	0.000	0.000	0.017	0.000	0.017
		$\bar{x}$	0.000	0.000	0.000	0.022	0.000	0.022

Incubation station	period		Chlorinated anisoles and veratroles (µg/g fat) 246TCA	TeCA	345TCV	PeCA	TeCV	SANIS
KUU	5.8.-2.9.1987		0.000	0.041	0.290	0.069	0.428	0.829
			0.000	0.029	0.203	0.044	0.450	0.726
			0.000	0.017	0.239	0.068	0.563	0.887
			0.000	0.028	0.237	0.084	0.601	0.950
			0.000	0.054	0.233	0.089	0.751	1.127
		$\bar{x}$	0.000	0.034	0.240	0.071	0.559	0.904
TOR	5.8.-2.9.1987		0.000	0.063	0.141	0.031	0.406	0.641
			0.000	0.036	0.090	0.018	0.306	0.450
			0.000	0.019	0.095	0.038	0.286	0.438
			0.000	0.031	0.061	0.000	0.368	0.460
			0.000	0.046	0.077	0.031	0.353	0.507
		$\bar{x}$	0.000	0.039	0.093	0.024	0.344	0.499

245TCA, 345TCA, 34DCV and 45DCV were analysed but not detected.

Appendix 6

The chemical results of mussels incubated in the monitoring programme in 1988.

Incubation station period	fat %	Chlorohydrocarbons (ng/g fat) CYMS	CYMD	HCBz	α-HCH	LIND	OXY	GAMMA	ALPHA	HEPTA	SCHL	DDE	DDD	DDT	SDDT	PCB
LOH	5.57	0	0	0	0	9	0	0	0	0	0	9	0	0	9	90
10.8.-7.9.	5.58	0	0	0	9	9	0	0	0	0	0	9	0	0	9	54
	6.13	8	0	8	8	8	0	0	0	0	0	8	0	0	8	82
$\bar{x}$	5.76	3	0	3	6	9	0	0	0	0	0	9	0	0	9	75
KER	5.70	70	0	0	0	53	0	158	0	0	158	544	0	0	544	40596
10.8.-7.9.	6.03	50	0	0	0	33	0	166	0	0	166	630	0	0	630	45738
	5.81	86	0	0	0	17	0	172	0	0	172	465	0	0	465	31394
$\bar{x}$	5.85	69	0	0	0	34	0	165	0	0	165	546	0	0	546	39243
MIE	6.62	136	0	0	0	8	30	0	257	0	287	91	30	45	166	8142
10.8.-7.9.	5.28	152	0	9	9	9	9	0	227	0	237	76	38	38	152	7462
	4.96	141	0	10	10	10	10	0	161	0	171	60	20	40	121	5302
$\bar{x}$	5.62	143	0	7	7	9	17	0	215	0	232	76	29	41	146	6969
VAN	6.79	59	0	7	44	44	74	0	133	0	206	118	0	0	118	5493
10.8.-7.9.	6.29	127	0	0	0	8	8	0	143	0	151	159	0	0	159	5262
	5.15	10	0	10	10	10	58	0	155	0	214	58	10	39	107	5961
$\bar{x}$	6.08	65	0	6	18	21	47	0	144	0	190	112	3	13	128	5572
HÄM	6.81	250	0	0	7	29	7	0	29	0	37	29	0	7	37	8047
10.8.-7.9.	6.25	224	8	0	8	64	8	0	32	0	40	32	0	8	40	11024
	5.69	158	0	9	9	53	9	0	53	9	70	9	9	9	26	6907
$\bar{x}$	6.25	211	3	3	8	49	8	0	38	3	49	23	3	8	34	8659
HAT	6.90	594	0	0	0	43	0	14	14	0	29	29	0	0	29	928
10.8.-7.9.	6.27	399	0	8	8	8	0	8	8	0	16	16	8	0	24	829
	5.98	502	0	8	8	17	0	8	8	0	17	17	8	0	25	803
$\bar{x}$	6.38	498	0	5	5	23	0	10	10	0	21	21	5	0	26	853
MEL	6.30	540	0	8	0	8	0	0	0	0	0	8	0	0	8	381
9.8.-6.9.	6.84	380	0	7	0	7	0	0	0	0	0	7	0	0	7	365
	7.79	1155	6	6	0	6	0	0	0	0	0	6	0	0	6	244
$\bar{x}$	6.98	692	2	7	0	7	0	0	0	0	0	7	0	0	7	330
MAJ	5.96	419	0	8	0	8	0	0	0	34	34	34	67	0	101	285
9.8.-6.9.	6.72	342	0	7	7	7	0	0	0	15	15	45	60	0	104	357
	6.72	372	0	7	7	7	0	0	0	7	7	15	30	0	45	268
$\bar{x}$	6.47	378	0	8	5	8	0	0	0	19	19	31	52	0	83	303
PÖY	6.33	79	0	0	8	8	0	0	0	0	0	32	0	0	32	190
9.8.-6.9.	6.02	100	0	8	8	8	0	0	0	0	0	8	17	0	25	116
	6.69	90	0	7	7	7	0	0	0	7	7	7	7	0	15	90
$\bar{x}$	6.35	89	0	5	8	8	0	0	0	2	2	16	8	0	24	132
NÄS	5.87	17	0	9	9	34	0	0	0	9	9	17	0	0	17	170
9.8.-6.9.	6.28	16	0	8	8	16	0	0	0	8	8	16	0	0	16	191
	5.15	19	0	10	10	10	0	0	0	10	10	39	0	0	39	39
$\bar{x}$	5.77	17	0	9	9	20	0	0	0	9	9	24	0	0	24	133

Incubation station period	fat %	Chlorohydrocarbons (ng/g fat) CYMS	CYMD	HCBz	α-HCH	LIND	OXY	GAMMA	ALPHA	HEPTA	SCHL	DDE	DDD	DDT	SDDT	PCB
PYH	5.86	34	0	9	9	9	34	0	0	0	34	34	0	0	34	495
9.8.-6.9.	6.85	7	0	7	7	7	15	0	7	7	29	29	7	0	36	394
	6.01	50	0	8	8	8	8	0	8	0	17	8	8	0	17	349
$\bar{x}$	6.24	30	0	8	8	8	19	0	5	2	27	24	5	0	29	413
KUL	4.75	126	0	11	0	42	0	0	0	42	42	21	0	0	21	526
9.8.-6.9.	5.86	34	0	9	9	17	0	0	0	0	0	34	0	0	34	648
	5.01	40	0	10	10	20	0	0	0	10	10	20	0	0	20	439
$\bar{x}$	5.21	67	0	10	6	26	0	0	0	17	17	25	0	0	25	538
LIE	6.47	0	0	8	0	8	0	0	0	0	0	31	0	0	31	433
9.8.-6.9.	6.18	0	0	8	8	49	0	0	0	8	8	16	0	0	16	388
	6.86	0	0	7	7	15	0	0	0	7	7	15	0	0	15	204
$\bar{x}$	6.50	0	0	8	5	24	0	0	0	5	5	21	0	0	21	342
MAT	8.16	0	0	0	0	6	0	0	0	0	0	0	0	0	0	0
9.8.-6.9.	8.33	0	0	0	6	12	0	0	0	0	0	6	0	0	6	36
	8.32	0	0	6	6	6	0	0	0	0	0	12	0	0	12	6
$\bar{x}$	8.27	0	0	2	4	8	0	0	0	0	0	6	0	0	6	14
KUU	6.20	177	8	16	0	16	0	0	0	16	16	0	0	0	0	1742
9.8.-6.9.	5.66	177	18	18	9	9	0	0	0	9	9	0	0	9	9	1360
	5.79	173	9	0	9	9	0	0	0	17	17	0	0	0	0	708
$\bar{x}$	5.88	176	11	11	6	11	0	0	0	14	14	0	0	3	3	1270
TOR	6.40	47	141	0	0	8	0	0	0	8	8	0	0	0	0	891
9.8.-6.9.	6.39	8	31	8	8	8	0	0	0	0	0	8	0	0	8	1111
	5.56	9	9	18	9	9	0	0	0	0	0	18	0	0	18	827
$\bar{x}$	6.12	21	60	9	6	8	0	0	0	3	3	9	0	0	9	943
KÄR	5.06	0	0	10	0	20	0	0	0	10	10	0	0	0	0	119
10.8.-7.9.	5.89	0	0	0	8	8	0	0	0	0	0	8	0	0	8	170
	5.74	0	0	9	9	9	0	0	0	9	9	9	0	0	9	122
$\bar{x}$	5.56	0	0	6	6	12	0	0	0	6	6	6	0	0	6	137
LEH	5.10	39	0	0	0	10	0	0	0	0	0	0	0	0	0	78
10.8.-7.9.	5.76	52	0	9	9	9	0	0	0	0	0	0	0	0	0	69
	4.86	10	0	10	10	10	0	0	0	0	0	10	0	0	10	82
$\bar{x}$	5.24	34	0	6	6	10	0	0	0	0	0	3	0	0	3	77
TEH	4.63	0	0	0	0	11	0	0	0	11	11	0	0	0	0	0
9.8.-6.9.	5.16	0	0	0	0	10	0	0	0	0	0	0	0	0	0	0
	4.45	45	0	11	11	11	0	0	0	11	11	11	0	0	11	45
$\bar{x}$	4.75	15	0	4	4	11	0	0	0	7	7	4	0	0	4	15
ASI	5.08	20	0	0	10	10	0	0	0	10	10	20	0	0	20	79
9.8.-6.9.	5.76	35	0	9	9	9	0	0	0	9	9	17	0	0	17	52
	6.47	8	77	8	8	15	8	0	0	0	8	15	0	0	15	62
$\bar{x}$	5.77	21	26	5	9	11	3	0	0	6	9	18	0	0	18	64
KEL	6.69	194	60	30	0	0	0	209	0	0	209	0	0	0	0	553
9.8.-6.9.	6.41	374	140	62	0	8	0	234	31	16	281	31	0	0	31	1030
	6.11	98	33	33	0	0	0	65	0	8	74	8	0	0	8	180
$\bar{x}$	6.40	222	78	42	0	3	0	170	10	8	188	13	0	0	13	588

Incubation station period	fat %	Chlorohydrocarbons (ng/g fat) CYMS	CYMD	HCBz	α-HCH	LIND	OXY	GAMMA	ALPHA	HEPTA	SCHL	DDE	DDD	DDT	SDDT	PCB
SUS	6.69	149	45	105	0	15	0	105	0	30	135	0	0	0	0	254
9.8.-6.9.	5.30	132	38	57	9	9	0	57	0	9	66	0	0	0	0	283
	6.63	90	45	15	0	8	0	30	0	8	38	8	0	0	8	181
$\bar{x}$	6.21	124	43	59	3	11	0	64	0	16	79	3	0	0	3	239
HIR	6.20	290	81	81	0	0	0	194	0	32	226	8	0	8	16	1097
9.8.-6.9.	5.36	112	37	37	0	0	0	93	0	9	103	0	0	0	0	485
	5.40	56	37	9	0	0	0	56	0	9	65	0	0	0	0	204
$\bar{x}$	5.65	153	52	42	0	0	0	114	0	17	131	3	0	3	5	595
MAR	5.37	19	0	9	0	0	0	0	0	0	0	0	0	0	0	0
10.8.-7.9.	5.44	0	0	0	9	0	0	0	0	0	0	0	0	0	0	0
	7.11	42	14	7	0	0	0	0	0	7	7	7	0	0	7	98
$\bar{x}$	5.97	20	5	5	3	0	0	0	0	2	2	2	0	0	2	33
MAL	6.59	8	0	8	0	15	0	0	0	0	0	0	0	0	0	46
10.8.-7.9.	6.19	48	0	8	8	8	0	0	0	16	16	8	0	0	8	65
	5.89	51	0	8	8	8	0	0	0	34	34	8	0	0	8	51
$\bar{x}$	6.22	36	0	8	6	11	0	0	0	17	17	6	0	0	6	54
HIE	6.85	0	0	0	0	7	0	44	0	0	44	7	0	0	7	73
9.8.-6.9.	5.90	0	0	0	8	8	0	85	8	0	93	8	0	0	8	119
	5.23	0	0	0	0	10	0	96	10	0	105	0	0	0	0	57
$\bar{x}$	5.99	0	0	0	3	8	0	75	6	0	81	5	0	0	5	83
ITK	5.79	0	0	9	0	104	0	121	0	35	155	17	0	0	17	0
9.8.-6.9.	6.96	0	0	0	0	7	0	144	0	0	144	0	0	0	0	0
	5.99	0	0	8	8	8	0	100	8	8	117	8	0	0	8	100
$\bar{x}$	6.25	0	0	6	3	40	0	122	3	14	139	9	0	0	9	33
SII	6.59	637	30	15	8	8	0	0	8	8	15	8	0	0	8	182
9.8.-6.9.	6.72	595	30	15	15	7	7	0	0	7	15	7	7	0	15	0
	7.06	439	28	14	7	7	7	0	0	7	14	7	0	0	7	57
$\bar{x}$	6.79	557	29	15	10	7	5	0	3	7	15	7	2	0	10	80
HEP	4.66	236	0	11	11	11	0	64	0	11	75	0	0	0	0	0
9.8.-6.9.	7.07	99	0	7	7	7	0	42	0	7	50	7	0	0	7	71
	4.48	156	0	11	11	11	0	45	0	11	56	11	0	0	11	67
$\bar{x}$	5.40	164	0	10	10	10	0	50	0	10	60	6	0	0	6	46
HAA	7.31	82	0	0	14	0	0	0	0	14	14	14	0	0	14	0
9.8.-6.9.	7.59	79	0	7	7	7	0	7	0	7	13	7	0	0	7	40
	7.59	66	0	7	7	7	0	7	0	7	13	13	0	0	13	66
$\bar{x}$	7.50	76	0	4	9	4	0	4	0	9	13	11	0	0	11	35
SIK	6.11	8	33	8	0	8	0	115	0	33	147	0	0	0	0	0
10.8.-7.9.	5.60	643	9	9	0	9	0	0	0	36	36	0	0	0	0	0
	6.26	575	8	8	0	8	0	32	0	16	48	0	0	0	0	0
$\bar{x}$	5.99	409	17	8	0	8	0	49	0	28	77	0	0	0	0	0
SOT	6.66	420	0	15	0	8	0	0	0	0	0	0	0	0	0	0
10.8.-7.9.	5.45	936	0	9	9	9	0	0	0	37	37	0	0	0	0	0
	5.86	375	0	9	9	9	0	0	0	0	0	0	0	0	0	0
$\bar{x}$	5.99	577	0	11	6	8	0	0	0	12	12	0	0	0	0	0

Incubation station period	fat %	Chlorohydrocarbons (ng/g fat) CYMS	CYMD	HCBz	α-HCH	LIND	OXY	GAMMA	ALPHA	HEPTA	SCHL	DDE	DDD	DDT	SDDT	PCB
TIU	5.89	153	0	0	0	0	0	0	0	0	0	34	0	0	34	0
10.8.-7.9.	6.71	164	0	7	0	7	0	15	0	0	15	7	0	0	7	164
	7.00	129	0	7	7	7	0	29	0	7	36	14	0	0	14	157
$\bar{x}$	6.53	148	0	5	2	5	0	14	0	2	17	19	0	0	19	107
VUO	6.33	126	0	32	8	8	0	0	0	32	32	16	0	0	16	648
10.8.-7.9.	6.73	119	0	15	7	7	0	7	0	7	15	7	0	0	7	461
	5.77	121	9	9	9	9	0	9	0	9	17	9	0	0	9	260
$\bar{x}$	6.28	122	3	18	8	8	0	5	0	16	21	11	0	0	11	456
PAJ	5.77	0	0	0	0	0	0	0	0	0	0	0	0	0	0	87
10.8.-7.9.	6.76	44	0	7	7	0	0	0	0	7	7	7	0	0	7	59
	6.06	8	0	8	8	8	0	0	0	8	8	8	0	0	8	66
$\bar{x}$	6.20	18	0	5	5	3	0	0	0	5	5	5	0	0	5	71
PAS	7.25	0	0	7	7	28	0	0	0	0	0	7	0	0	7	83
10.8.-7.9.	5.15	0	0	10	10	19	0	0	0	10	10	10	0	0	10	117
	4.67	0	0	11	11	43	0	0	0	0	0	0	0	0	0	0
$\bar{x}$	5.69	0	0	9	9	30	0	0	0	3	3	6	0	0	6	66
ÄRJ	6.68	0	0	0	0	7	0	0	0	0	0	7	0	0	7	0
10.8.-7.9.	6.18	0	0	0	0	8	0	0	0	0	0	0	0	0	0	0
	5.78	17	0	9	9	9	0	0	0	0	0	9	0	0	9	52
$\bar{x}$	6.21	6	0	3	3	8	0	0	0	0	0	5	0	0	5	17
TER	5.99	17	0	17	17	0	0	8	0	8	17	8	0	0	8	50
9.8.-6.9.	7.99	25	0	25	6	0	0	0	0	6	6	6	0	0	6	225
	6.65	30	0	8	8	0	8	0	0	8	15	8	0	0	8	316
$\bar{x}$	6.88	24	0	16	10	0	3	3	0	7	13	7	0	0	7	197
AIL	5.49	91	0	0	0	0	0	0	0	36	36	0	0	0	0	0
10.8.-7.9.	5.51	109	0	9	0	9	0	0	0	9	9	0	0	0	0	0
	5.29	57	0	9	0	9	0	0	0	9	9	9	0	0	9	76
$\bar{x}$	5.43	86	0	6	0	6	0	0	0	18	18	3	0	0	3	25
KEM	5.27	95	0	9	0	0	0	0	0	9	9	0	0	0	0	0
10.8.-7.9.	5.36	112	0	9	0	0	75	0	0	9	84	0	0	0	0	75
	5.89	68	0	17	0	0	68	0	0	0	68	0	0	0	0	68
$\bar{x}$	5.51	92	0	12	0	0	48	0	0	6	54	0	0	0	0	48

Incubation station period	Chlorophenolics (ng/g fat) 24DCP	26DCP	246TCP	245TCP	TeCP	PeCP	TeCC	45DCG	345TCG	456TCG	TeCG	DMP	S1PCP	S2PCP
LOH	0	0	305	0	305	718	0	0	0	0	0	0	1329	0
10.8.-7.9.	0	0	18	0	90	18	0	0	0	0	0	0	125	0
	0	0	33	0	49	16	0	0	0	0	0	0	98	0
$\bar{x}$	0	0	119	0	148	251	0	0	0	0	0	0	517	0

Incubation station period		Chlorophenolics (ng/g fat)												
		24DCP	26DCP	246TCP	245TCP	TeCP	PeCP	TeCC	45DCG	345TCG	456TCG	TeCG	DMP	S1PCP	S2PCP
KER		0	667	439	0	667	421	0	0	0	0	0	0	1526	667
10.8.-7.9.		0	763	398	0	614	133	0	0	0	0	0	0	1144	763
		0	413	34	0	344	482	0	0	0	0	0	0	861	413
	$\bar{x}$	0	614	290	0	541	345	0	0	0	0	0	0	1177	614
MIE		0	0	0	0	0	0	0	0	0	634	0	725	0	1360
10.8.-7.9.		0	0	0	0	76	0	0	0	0	133	0	511	76	644
		0	0	0	0	20	0	0	0	0	403	0	343	20	746
	$\bar{x}$	0	0	0	0	32	0	0	0	0	390	0	526	32	916
VAN		0	781	15	0	604	44	0	0	0	0	0	0	663	781
10.8.-7.9.		0	32	16	0	334	16	0	0	0	0	0	0	366	32
		0	155	58	0	311	19	0	0	0	0	0	0	388	155
	$\bar{x}$	0	323	30	0	416	26	0	0	0	0	0	0	472	323
HÄM		0	0	382	0	8209	954	0	0	0	0	0	0	9545	0
10.8.-7.9.		0	0	304	0	9328	1280	0	0	0	0	0	0	10912	0
		0	0	299	0	7768	791	0	0	0	0	0	0	8858	0
	$\bar{x}$	0	0	328	0	8435	1008	0	0	0	0	0	0	9771	0
HAT		0	275	188	0	2783	667	58	0	0	0	0	0	3638	333
10.8.-7.9.		0	0	175	0	2233	48	0	0	0	0	0	0	2456	0
		0	268	184	0	2492	268	0	0	0	0	0	0	2943	268
	$\bar{x}$	0	181	183	0	2502	327	19	0	0	0	0	0	3012	200
MEL		0	0	1524	0	460	190	0	0	1254	95	127	0	2175	1476
9.8.-6.9.		88	0	2237	0	614	29	0	0	1623	292	190	0	2880	2193
		103	0	1592	0	1900	372	0	0	1065	231	231	0	3864	1630
	$\bar{x}$	63	0	1784	0	991	197	0	0	1314	206	183	0	2973	1766
MAJ		0	0	705	0	789	84	0	0	1091	0	252	0	1577	1342
9.8.-6.9.		0	0	357	0	491	15	0	0	685	0	164	0	863	848
		0	0	313	0	238	15	0	0	655	30	179	0	565	863
	$\bar{x}$	0	0	458	0	506	38	0	0	810	10	198	0	1002	1018
PÖY		0	221	63	0	553	126	0	0	284	0	126	0	742	632
9.8.-6.9.		0	17	83	0	199	17	0	0	216	0	50	0	299	233
		0	75	60	0	359	15	0	0	239	30	60	0	433	404
	$\bar{x}$	0	104	69	0	370	53	0	0	246	10	79	0	492	423
NÄS		0	0	17	0	2027	2896	0	0	290	0	0	0	4940	290
9.8.-6.9.		0	80	510	0	143	366	0	0	366	0	64	0	1019	510
		0	19	97	0	835	39	0	0	388	0	78	0	971	485
	$\bar{x}$	0	33	208	0	1002	1100	0	0	348	0	47	0	2310	428
PYH		0	563	188	0	290	375	0	0	256	0	34	0	853	853
9.8.-6.9.		0	599	117	0	686	292	0	0	277	0	29	0	1095	905
		0	433	100	0	632	715	0	0	316	0	50	0	1448	799
	$\bar{x}$	0	531	135	0	536	461	0	0	283	0	38	0	1132	852
KUL		105	0	337	0	274	147	0	0	189	0	63	0	758	358
9.8.-6.9.		34	0	51	0	256	137	0	0	171	0	34	0	444	239
		0	0	200	0	220	160	0	0	200	0	40	0	579	240
	$\bar{x}$	46	0	196	0	250	148	0	0	187	0	46	0	593	279

Incubation station period		Chlorophenolics (ng/g fat)												
		24DCP	26DCP	246TCP	245TCP	TeCP	PeCP	TeCC	45DCG	345TCG	456TCG	TeCG	DMP	S1PCP	S2PCP
LIE		0	0	31	0	201	495	0	0	185	0	46	0	726	232
9.8.-6.9.		0	0	32	0	162	259	0	0	194	0	49	0	453	243
		0	0	29	0	102	204	0	0	58	0	29	0	335	87
	x̄	0	0	31	0	155	319	0	0	146	0	41	0	505	187
MAT		0	0	0	0	98	12	0	0	0	0	0	0	110	0
9.8.-6.9.		0	12	240	0	228	120	12	0	0	0	12	60	588	96
		0	0	276	0	589	168	180	0	0	0	12	36	1034	228
	x̄	0	4	172	0	305	100	64	0	0	0	8	32	577	108
KUU		0	0	113	0	613	0	0	0	1161	97	532	0	726	1790
9.8.-6.9.		0	0	88	0	707	265	0	0	1095	124	548	0	1060	1767
		0	0	86	0	311	0	0	155	1105	138	553	0	397	1952
	x̄	0	0	96	0	543	88	0	52	1121	120	544	0	728	1836
TOR		-1	-1	422	0	313	63	-1	-1	-1	-1	-1	-1	797	-1
9.8.-6.9.		16	16	219	0	250	16	329	16	1502	125	908	16	485	2926
		54	36	252	0	342	90	108	18	1547	108	827	18	683	2716
	x̄	35	26	298	0	302	56	218	17	1525	117	868	17	655	2821
KÄR		0	0	99	0	494	178	0	0	356	0	79	0	771	435
10.8.-7.9.		0	0	34	0	323	85	0	0	340	0	85	0	441	424
		0	0	70	0	192	35	0	0	314	0	70	0	296	383
	x̄	0	0	67	0	336	99	0	0	336	0	78	0	503	414
LEH		0	0	39	0	78	20	98	0	196	0	78	0	137	373
10.8.-7.9.		0	0	52	0	191	35	17	0	226	0	35	0	278	278
		0	103	41	0	370	185	0	0	185	0	41	0	597	329
	x̄	0	34	44	0	213	80	38	0	202	0	51	0	337	327
TEH		0	0	0	0	0	0	0	367	324	0	22	0	0	713
9.8.-6.9.		0	0	19	0	116	0	0	19	233	0	19	0	136	271
		0	0	22	0	157	45	0	270	202	22	22	22	225	539
	x̄	0	0	14	0	91	15	0	219	253	7	21	7	120	508
ASI		0	0	20	0	118	256	0	0	315	0	0	0	394	315
9.8.-6.9.		0	0	35	0	365	52	0	0	156	0	35	0	451	191
		0	0	31	0	93	15	0	0	185	0	15	0	139	201
	x̄	0	0	28	0	192	108	0	0	219	0	17	0	328	236
KEL		0	0	404	0	538	135	0	179	2422	135	703	299	1076	3737
9.8.-6.9.		0	0	406	0	468	109	0	16	2278	109	390	156	983	2949
		0	0	393	0	458	82	0	115	2373	131	344	180	933	3142
	x̄	0	0	401	0	488	109	0	103	2357	125	479	212	997	3276
SUS		0	0	643	0	1300	389	0	0	3543	194	1241	299	2332	5277
9.8.-6.9.		0	0	642	0	830	189	0	0	3321	189	1245	283	1660	5038
		0	0	543	0	739	106	0	0	3122	181	1629	347	1388	5279
	x̄	0	0	609	0	957	228	0	0	3329	188	1372	310	1793	5198
HIR		0	0	565	0	613	0	0	16	3500	129	1597	387	1177	5629
9.8.-6.9.		0	0	504	0	616	75	0	19	3470	149	1418	392	1194	5448
		0	0	463	0	556	19	0	19	3611	167	1444	352	1037	5593
	x̄	0	0	510	0	595	31	0	18	3527	148	1486	377	1136	5556

Incubation station period		Chlorophenolics (ng/g fat)												
		24DCP	26DCP	246TCP	245TCP	TeCP	PeCP	TeCC	45DCG	345TCG	456TCG	TeCG	DMP	S1PCP	S2PCP
MAR		0	19	391	0	2644	652	0	0	149	0	112	223	3687	503
10.8.-7.9.		0	184	368	0	1342	18	0	0	147	18	110	257	1728	717
		0	98	323	14	14	647	0	56	127	14	84	141	985	534
	$\bar{x}$	0	100	361	5	1333	439	0	19	141	11	102	207	2133	585
MAL		0	0	137	0	895	152	0	0	76	0	15	30	1184	121
10.8.-7.9.		0	0	65	0	2649	355	0	0	32	0	16	32	3069	81
		0	0	85	0	747	85	0	0	68	0	34	51	917	153
	$\bar{x}$	0	0	95	0	1431	197	0	0	59	0	22	38	1723	118
HIE		0	44	0	0	88	0	0	0	0	0	0	0	88	44
9.8.-6.9.		0	0	0	0	68	0	0	0	0	0	0	0	68	0
		0	0	0	0	115	0	0	0	0	0	0	0	115	0
	$\bar{x}$	0	15	0	0	90	0	0	0	0	0	0	0	90	15
ITK		0	984	725	0	604	121	0	0	0	0	0	0	1451	984
9.8.-6.9.		0	690	474	0	359	14	0	0	0	0	0	0	848	690
		0	301	301	0	12187	2037	0	0	0	0	0	0	14524	301
	$\bar{x}$	0	658	500	0	4384	724	0	0	0	0	0	0	5608	658
SII		0	0	303	0	653	1047	152	0	288	0	319	46	2003	804
9.8.-6.9.		0	0	119	0	432	104	119	0	238	0	223	30	655	610
		0	0	113	0	184	57	0	0	212	0	199	28	354	439
	$\bar{x}$	0	0	179	0	423	403	90	0	246	0	247	35	1004	618
HEP		0	0	279	0	494	150	0	0	172	0	86	0	923	258
9.8.-6.9.		0	0	297	0	184	71	0	0	156	0	85	0	552	240
		0	0	290	0	179	45	0	0	201	0	89	0	513	290
	$\bar{x}$	0	0	289	0	285	89	0	0	176	0	87	0	663	263
HAA		0	0	0	0	1710	2927	0	0	96	0	27	0	4637	123
9.8.-6.9.		0	0	66	0	303	105	0	0	105	0	40	26	474	171
		0	0	53	0	448	303	0	0	79	0	26	26	804	132
	$\bar{x}$	0	0	40	0	820	1112	0	0	93	0	31	18	1972	142
SIK		0	0	245	0	442	164	0	0	1489	49	638	0	851	2013
10.8.-7.9.		0	0	411	0	679	89	0	0	2518	125	1054	0	1179	3696
		48	0	319	0	463	32	0	0	2013	96	767	32	815	2955
	$\bar{x}$	16	0	325	0	528	95	0	0	2007	90	820	11	948	2888
SOT		0	0	661	0	586	75	0	0	1126	45	556	0	1321	1727
10.8.-7.9.		92	0	550	0	349	18	0	0	936	0	422	0	917	1450
		85	0	495	0	392	34	0	0	904	51	427	0	922	1382
	$\bar{x}$	59	0	569	0	442	43	0	0	989	32	468	0	1053	1520
TIU		0	221	153	0	730	306	0	0	374	0	187	0	1188	781
10.8.-7.9.		0	164	104	0	373	75	0	0	328	0	134	30	551	656
		0	100	100	0	300	71	0	0	243	0	86	0	471	429
	$\bar{x}$	0	162	119	0	468	151	0	0	315	0	136	10	737	622
VUO		0	0	363	0	411	0	0	0	1706	0	1011	0	774	2717
10.8.-7.9.		0	0	253	0	446	223	0	0	1590	89	832	0	921	2511
		0	0	260	0	329	0	0	0	1213	52	537	0	589	1802
	$\bar{x}$	0	0	292	0	395	74	0	0	1503	47	793	0	762	2344

Incubation station period		Chlorophenolics (ng/g fat) 24DCP	26DCP	246TCP	245TCP	TeCP	PeCP	TeCC	45DCG	345TCG	456TCG	TeCG	DMP	S1PCP	S2PCP
PAJ		0	0	381	0	6118	52	0	0	0	0	0	0	6551	0
10.8.-7.9.		0	0	163	0	976	2130	0	0	0	0	0	0	3269	0
		0	0	248	0	1155	413	0	0	0	0	0	0	1815	0
	$\bar{x}$	0	0	264	0	2750	865	0	0	0	0	0	0	3879	0
PAS		0	234	28	0	524	138	0	0	0	0	0	0	690	234
10.8.-7.9.		0	58	58	0	388	97	0	0	0	0	0	0	544	58
		0	150	107	0	364	107	0	0	0	0	0	0	578	150
	$\bar{x}$	0	148	64	0	426	114	0	0	0	0	0	0	604	148
ÄRJ		0	0	0	0	150	105	0	0	0	0	0	0	254	0
10.8.-7.9.		0	631	340	0	307	210	0	0	0	0	0	0	858	631
		0	17	208	0	260	87	0	0	0	0	0	0	554	17
	$\bar{x}$	0	216	182	0	239	134	0	0	0	0	0	0	555	216
TER		0	1336	735	0	785	33	0	17	4791	434	1636	33	1553	8247
9.8.-6.9.		0	63	413	0	363	50	0	88	3367	300	1151	38	826	5006
		0	466	496	0	466	30	0	75	3789	316	1293	30	992	5970
	$\bar{x}$	0	621	548	0	538	38	0	60	3983	350	1360	34	1124	6408
AIL		0	0	346	0	510	91	0	0	2368	164	1093	55	947	3679
10.8.-7.9.		0	0	309	0	1543	672	0	0	1742	145	726	36	2523	2650
		0	38	321	0	359	57	0	0	2193	170	870	38	737	3308
	$\bar{x}$	0	13	325	0	804	273	0	0	2101	160	896	43	1402	3212
KEM		0	0	114	0	816	190	0	0	1195	0	398	0	1120	1594
10.8.-7.9.		0	0	56	0	392	75	0	0	1343	37	429	37	522	1847
		0	0	68	0	289	68	0	0	900	17	424	51	424	1392
	$\bar{x}$	0	0	79	0	499	111	0	0	1146	18	417	29	689	1611

-1 = no results

Incubation station	period		Chlorinated anisoles and veratroles (ng/g fat) 246TCA	245TCA	345TCA	TeCA	345TCV	PeCA	TeCV	SANIS
LOH	10.8.-7.9.1988		9	126	305	0	898	197	305	1840
			9	90	341	0	860	72	806	2177
			8	33	212	0	946	114	506	1819
		$\bar{x}$	9	83	286	0	901	128	539	1946
KER	10.8.-7.9.1988		0	0	0	842	0	0	0	842
			0	0	0	746	0	0	0	746
			0	0	0	155	0	0	0	155
		$\bar{x}$	0	0	0	581	0	0	0	581

Incubation station	period	Chlorinated anisoles and veratroles (ng/g fat) 246TCA	245TCA	345TCA	TeCA	345TCV	PeCA	TeCV	SANIS
MIE	10.8.-7.9.1988	0	0	151	76	0	8	8	242
		0	0	208	473	0	19	9	710
		0	0	81	141	0	40	10	272
	x̄	0	0	147	230	0	22	9	408
VAN	10.8.-7.9.1988	7	0	295	44	0	7	7	361
		8	0	48	48	0	8	8	119
		39	0	233	78	0	39	10	398
	x̄	18	0	192	57	0	18	8	293
HÄM	10.8.-7.9.1988	0	0	132	837	0	44	7	1021
		0	0	224	720	96	48	8	1096
		0	0	193	1054	0	35	9	1292
	x̄	0	0	183	870	32	42	8	1136
HAT	10.8.-7.9.1988	43	217	130	232	0	116	29	768
		0	0	128	144	0	96	48	415
		50	67	67	268	0	100	8	560
	x̄	31	95	108	214	0	104	28	581
MEL	9.8.-6.9.1988	0	8	1492	8	111	0	175	1794
		0	0	819	132	205	58	58	1272
		6	6	668	218	167	0	51	1117
	x̄	2	5	993	119	161	19	95	1394
MAJ	9.8.-6.9.1988	8	8	252	671	688	67	1577	3272
		7	7	149	357	372	45	714	1652
		7	7	670	521	1324	342	491	3363
	x̄	8	8	357	516	795	151	928	2762
PÖY	9.8.-6.9.1988	0	0	632	8	363	8	553	1564
		0	0	698	66	432	8	598	1802
		7	7	299	269	374	7	703	1667
	x̄	2	2	543	114	390	8	618	1678
NÄS	9.8.-6.9.1988	0	0	375	494	0	0	9	877
		0	0	143	159	0	0	8	311
		0	0	680	544	0	0	10	1233
	x̄	0	0	399	399	0	0	9	807
PYH	9.8.-6.9.1988	0	0	85	0	0	34	9	128
		29	0	88	102	0	29	7	255
		0	0	67	50	0	17	8	141
	x̄	10	0	80	51	0	27	8	175
KUL	9.8.-6.9.1988	0	0	274	11	0	11	11	305
		0	0	205	17	0	9	17	247
		0	0	220	10	0	10	10	250
	x̄	0	0	233	13	0	10	13	267
LIE	9.8.-6.9.1988	0	0	402	46	340	8	8	804
		0	0	113	65	583	32	16	809
		0	0	175	44	0	44	7	270
	x̄	0	0	230	52	308	28	10	627

Incubation station	period	Chlorinated anisoles and veratroles (ng/g fat) 246TCA	245TCA	345TCA	TeCA	345TCV	PeCA	TeCV	SANIS
MAT	9.8.-6.9.1988	0	0	0	184	0	0	0	184
		0	0	0	192	0	0	0	192
		0	0	0	276	0	0	0	276
	$\bar{x}$	0	0	0	217	0	0	0	217
KUU	9.8.-6.9.1988	0	0	0	8	0	16	113	137
		0	0	0	9	9	18	124	159
		9	0	0	9	9	17	86	130
	$\bar{x}$	3	0	0	9	6	17	108	142
TOR	9.8.-6.9.1988	0	0	0	594	0	8	47	648
		0	0	0	548	8	31	47	634
		0	0	0	216	9	36	54	315
	$\bar{x}$	0	0	0	452	6	25	49	532
KÄR	10.8.-7.9.1988	0	0	0	10	0	0	10	20
		0	0	0	119	8	8	8	144
		0	0	0	105	9	9	17	139
	$\bar{x}$	0	0	0	78	6	6	12	101
LEH	10.8.-7.9.1988	0	0	0	863	686	39	0	1588
		0	0	0	278	538	226	0	1042
		0	0	0	206	0	21	0	226
	$\bar{x}$	0	0	0	449	408	95	0	952
TEH	9.8.-6.9.1988	0	0	0	0	756	497	0	1253
		0	0	0	0	756	194	0	950
		0	0	0	0	629	225	11	865
	$\bar{x}$	0	0	0	0	714	305	4	1022
ASI	9.8.-6.9.1988	0	0	0	669	0	10	10	689
		0	0	0	434	0	9	9	451
		0	0	0	216	0	8	8	232
	$\bar{x}$	0	0	0	440	0	9	9	457
KEL	9.8.-6.9.1988	7	60	0	359	7	30	7	471
		31	62	78	328	8	16	31	554
		8	16	0	409	16	33	49	532
	$\bar{x}$	16	46	26	365	11	26	29	519
SUS	9.8.-6.9.1988	0	0	75	404	7	7	90	583
		0	113	151	547	9	9	75	906
		0	8	30	106	15	8	45	211
	$\bar{x}$	0	40	85	352	11	8	70	567
HIR	9.8.-6.9.1988	0	194	0	1161	1210	8	65	2637
		0	56	0	1287	1418	19	93	2873
		0	0	0	981	1074	19	56	2130
	$\bar{x}$	0	83	0	1143	1234	15	71	2547
MAR	10.8.-7.9.1988	9	0	149	559	9	9	9	745
		9	9	331	588	9	9	9	965
		7	7	56	98	7	7	7	190
	$\bar{x}$	9	5	179	415	9	9	9	633

Incubation		Chlorinated anisoles and veratroles (ng/g fat)							
station	period	246TCA	245TCA	345TCA	TeCA	345TCV	PeCA	TeCV	SANIS
MAL	10.8.-7.9.1988	0	0	455	8	0	8	8	478
		0	0	307	8	0	8	8	331
		0	0	238	8	0	8	8	263
	$\bar{x}$	0	0	333	8	0	8	8	357
HIE	9.8.-6.9.1988	0	0	569	438	1051	88	248	2394
		0	0	1356	678	475	8	424	2941
		0	0	1166	669	478	38	287	2639
	$\bar{x}$	0	0	1031	595	668	45	320	2658
ITK	9.8.-6.9.1988	0	0	173	0	0	9	9	190
		0	0	72	445	0	7	7	532
		0	0	134	401	0	8	8	551
	$\bar{x}$	0	0	126	282	0	8	8	424
SII	9.8.-6.9.1988	0	46	0	8	0	15	30	99
		0	30	0	7	0	15	30	82
		0	28	0	7	0	7	7	50
	$\bar{x}$	0	35	0	7	0	12	22	77
HEP	9.8.-6.9.1988	0	0	0	21	0	21	21	64
		0	0	0	14	0	14	42	71
		0	0	0	22	0	11	45	78
	$\bar{x}$	0	0	0	19	0	16	36	71
HAA	9.8.-6.9.1988	0	0	0	27	0	27	27	82
		0	0	0	26	0	13	13	53
		0	0	0	13	0	0	13	26
	$\bar{x}$	0	0	0	22	0	14	18	54
SIK	10.8.-7.9.1988	8	8	1277	311	573	33	65	2275
		9	0	1357	696	446	18	107	2634
		8	8	974	80	0	8	48	1126
	$\bar{x}$	8	5	1203	362	340	20	74	2012
SOT	10.8.-7.9.1988	0	45	1306	225	661	8	8	2252
		92	9	1284	147	752	9	9	2303
		0	0	3823	324	205	9	9	4369
	$\bar{x}$	31	18	2138	232	539	8	8	2975
TIU	10.8.-7.9.1988	0	0	0	0	0	0	0	0
		0	0	0	75	447	7	7	537
		7	0	0	71	214	7	7	307
	$\bar{x}$	2	0	0	49	220	5	5	281
VUO	10.8.-7.9.1988	0	0	0	0	1058	0	221	1280
		0	0	0	45	1174	0	624	1842
		0	0	0	104	919	0	381	1404
	$\bar{x}$	0	0	0	50	1050	0	409	1509
PAJ	10.8.-7.9.1988	0	0	173	35	884	9	9	1109
		0	0	89	15	562	7	7	680
		0	0	165	116	1287	8	8	1584
	$\bar{x}$	0	0	142	55	911	8	8	1125

Incubation		Chlorinated anisoles and veratroles (ng/g fat)							
station	period	246TCA	245TCA	345TCA	TeCA	345TCV	PeCA	TeCV	SANIS
PAS	10.8.-7.9.1988	0	0	110	55	0	7	7	179
		0	0	117	58	0	10	10	194
		0	0	150	86	0	11	11	257
	$\bar{x}$	0	0	126	66	0	9	9	210
ÄRJ	10.8.-7.9.1988	0	0	0	0	853	0	0	853
		0	0	0	0	841	0	0	841
		9	0	0	17	865	0	0	891
	$\bar{x}$	3	0	0	6	853	0	0	862
TER	9.8.-6.9.1988	0	0	0	50	1419	0	50	1519
		0	0	0	0	1189	0	50	1239
		0	0	0	60	722	0	60	842
	$\bar{x}$	0	0	0	37	1110	0	53	1200
AIL	10.8.-7.9.1988	55	0	291	1111	0	0	36	1494
		73	0	200	1016	0	9	36	1334
		38	0	284	510	0	9	57	898
	$\bar{x}$	55	0	258	879	0	6	43	1242
KEM	10.8.-7.9.1988	0	0	398	133	949	114	266	1860
		0	0	1437	373	1828	112	336	4086
		0	0	2886	645	2767	187	255	6740
	$\bar{x}$	0	0	1574	384	1948	138	285	4229

Incubation		Chlorinated dibenzo-p-dioxins and dibenzofurans (pg/g fat)					
station	period	123678 -HxCDD	1234678 -HpCDD	2378 -TeCDF	1234678 -HpCDF	OCDF	TCDD -eq
KER	10.8.-7.9.1988	0	0	444	0	0	44
HÄM	10.8.-7.9.1988	0	0	272	0	0	27
KEL	9.8.-6.9.1988	266	109	4484	3234	1781	510
SUS	9.8.-6.9.1988	97	81	950	10080	11224	218
HIR	9.8.-6.9.1988	0	0	1027	8248	3735	189
MAR	10.8.-7.9.1988	0	0	117	318	0	15
VUO	10.8.-7.9.1988	143	0	318	223	0	48
ÄRJ	10.8.-7.9.1988	0	0	0	0	0	0
PAJ	10.8.-7.9.1988	0	0	0	0	0	0
TER	9.8.-7.9.1988	0	0	276	0	0	28

The chemical results of mussels incubated in winter 1989 (16.2. - 30.3.) in Kuusaankoski station (KUU).

Chlorohydrocarbons (ng/g fat) mean values (n = 17)

fat %	CYMS	α-HCH	LIND	HCBz	GAMMA	ALPHA	HEPTA	SCHL	DDE	DDT	SDDT	PCB
6.53	31	3	9	0	1	0	1	2	18	5	22	62

Chlorophenols (ng/g fat) mean values (n = 17)

24DCP	246TCP	TeCP	PeCP	345TCC	TeCC	45DCG	345TCG	456TCG	TeCG	DMP	S1PCP	S2PCP
130	986	1851	599	65	11	57	2673	267	509	56	3437	3767

Chlorinated anisoles and veratroles (ng/g fat) mean values (n = 17)

246TCA	245TCA	TeCA	345TCV	PeCA	TeCV	SANIS
14	7	23	74	83	137	338

Appendix 8

The chemical results of mussels incubated in the monitoring programme in 1989.

Incubation station period	fat %	Chlorohydrocarbons (ng/g fat) CYMS	HCBz	α-HCH	LIND	OXY	GAMMA	ALPHA	TRANS	SCHL	DDE	DDD	DDT	SDDT	PCB
KER	7.36	24	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	61028
9.8.-6.9.1989	6.11	28	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	97773
	6.88	13	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	69104
$\bar{x}$	6.78	22	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	75968
HÄM	6.27	147	18	8	12	0	0	0	0	0	56	48	0	104	4892
9.8.-6.9.1989	7.47	7	7	7	16	0	0	0	0	0	96	44	0	140	4665
	7.18	93	7	7	7	0	0	0	0	0	75	7	0	82	3946
$\bar{x}$	6.97	82	11	7	12	0	0	0	0	0	76	33	0	109	4501
MEL	7.30	180	22	8	0	0	11	29	3	43	24	0	0	24	558
8.8.-5.9.1989	8.04	491	42	14	0	0	35	62	9	106	32	0	0	32	1073
$\bar{x}$	7.67	336	32	11	0	0	23	46	6	75	28	0	0	28	816
PYH	6.57	14	9	8	11	0	0	0	0	0	36	8	0	44	865
8.8.-5.9.1989	6.76	13	12	7	16	0	0	0	0	0	39	31	0	70	1067
	7.63	19	12	7	11	0	0	0	0	0	32	20	0	52	983
$\bar{x}$	6.99	15	11	7	13	0	0	0	0	0	36	20	0	55	972
MAT	5.99	0	8	8	21	0	0	0	0	0	12	0	0	12	71
8.8.-5.9.1989	5.92	0	8	8	0	0	0	0	0	0	12	0	0	12	96
	8.04	0	6	6	16	0	0	0	0	0	12	0	0	12	98
$\bar{x}$	6.65	0	7	7	12	0	0	0	0	0	12	0	0	12	88
KUU	6.17	187	14	8	14	0	0	0	0	0	0	0	0	0	2581
8.8.-5.9.1989	5.82	160	20	9	29	0	0	0	0	0	0	0	0	0	1878
	6.75	199	20	7	22	0	0	0	0	0	0	0	0	0	2620
$\bar{x}$	6.25	182	18	8	22	0	0	0	0	0	0	0	0	0	2360
TOR	6.51	129	10	8	8	0	0	0	0	0	0	0	0	0	1517
8.8.-5.9.1989	6.11	167	8	8	8	0	0	0	0	0	0	0	0	0	1469
	7.04	43	9	7	8	0	0	0	0	0	0	0	0	0	1232
$\bar{x}$	6.55	113	9	8	8	0	0	0	0	0	0	0	0	0	1406
KÄR	6.87	23	7	7	0	0	0	0	0	0	23	7	0	30	183
8.8.-5.9.1989	7.38	15	7	7	0	0	0	0	0	0	17	0	0	17	193
	6.94	31	13	7	0	0	0	0	0	0	19	10	7	36	268
$\bar{x}$	7.06	23	9	7	0	0	0	0	0	0	20	6	2	28	215
KEL	5.85	141	0	0	0	0	341	36	0	377	0	0	0	0	768
8.8.-5.9.1989	8.14	226	0	0	0	0	364	52	0	416	0	0	0	0	807
	7.48	163	0	0	0	0	274	35	0	309	0	0	0	0	1082
$\bar{x}$	7.16	177	0	0	0	0	326	41	0	367	0	0	0	0	886
SUS	5.95	162	10	8	34	0	239	40	0	279	18	0	0	18	696
8.8.-5.9.1989	6.55	261	20	9	9	0	253	44	0	297	21	0	0	21	1412
	7.73	176	12	0	0	0	161	39	0	200	30	14	0	44	906
$\bar{x}$	6.74	200	14	6	14	0	218	41	0	259	23	5	0	28	1005

Incubation station period	fat %	Chlorohydrocarbons (ng/g fat) CYMS	HCBz	α-HCH	LIND	OXY	GAMMA	ALPHA	TRANS	SCHL	DDE	DDD	DDT	SDDT	PCB
HIR	7.02	151	55	12	61	0	198	30	0	228	20	9	0	29	1189
8.8.-5.9.1989	6.12	168	44	8	10	0	144	42	0	186	8	33	0	41	1154
	6.66	261	50	11	15	0	188	35	0	223	16	33	0	49	879
$\bar{x}$	6.60	193	50	10	29	0	177	36	0	212	15	25	0	40	1074
MAR	5.15	10	10	10	0	0	0	0	0	0	10	0	0	10	331
8.8.-5.9.1989	5.36	9	9	9	0	0	0	0	0	0	9	0	0	9	307
	6.13	8	8	8	0	0	0	0	0	0	7	8	0	15	407
$\bar{x}$	5.55	9	9	9	0	0	0	0	0	0	9	3	0	11	348
ITK	7.06	0	7	7	13	0	114	31	13	158	7	11	0	18	198
8.8.-5.9.1989	7.13	0	7	7	9	0	97	24	10	131	7	10	0	17	130
	7.99	0	6	6	10	0	85	24	10	119	7	6	0	13	116
$\bar{x}$	7.39	0	7	7	11	0	99	26	11	136	7	9	0	16	148
SII	8.08	331	45	14	14	0	92	126	15	233	7	12	0	19	344
9.8.-6.9.1989	7.06	280	35	11	11	0	74	76	8	158	8	8	0	16	369
	5.91	163	67	21	21	0	104	80	18	202	8	8	0	16	319
$\bar{x}$	7.02	258	49	15	15	0	90	94	14	198	8	9	0	17	344
HAA	8.41	32	7	6	9	0	7	20	7	34	12	8	9	29	113
9.8.-6.9.1989	7.08	20	7	7	16	0	7	14	7	28	15	8	7	30	149
	7.89	31	6	6	8	0	19	6	0	25	10	6	6	22	93
$\bar{x}$	7.79	28	7	6	11	0	11	13	5	29	12	7	7	27	118
TIU	6.87	87	11	6	21	0	26	6	0	32	13	14	0	27	342
8.8.-5.9.1989	6.34	139	17	8	38	0	36	8	0	44	49	11	0	60	408
	8.60	114	7	7	18	0	42	7	0	49	28	10	0	38	191
$\bar{x}$	7.27	113	12	7	26	0	35	7	0	42	30	12	0	42	314
VUO	8.54	132	8	8	0	0	16	8	8	32	14	0	0	14	463
8.8.-5.9.1989	7.26	91	7	7	0	0	10	0	0	10	13	0	0	13	419
	7.63	93	7	7	0	0	15	0	0	15	9	0	0	9	390
$\bar{x}$	7.81	105	7	7	0	0	14	3	3	19	12	0	0	12	424
PAJ	7.51	34	13	7	0	0	0	23	0	23	19	0	0	19	294
8.8.-5.9.1989	7.62	27	10	0	0	0	0	16	0	16	7	0	0	7	230
	7.78	71	8	7	0	0	0	19	0	19	19	0	0	19	260
$\bar{x}$	7.64	44	10	5	0	0	0	19	0	19	15	0	0	15	261
KEM	6.28	55	21	11	9	0	0	14	0	14	15	0	0	15	280
9.8.-6.9.1989	6.92	47	24	12	7	0	0	0	0	0	0	0	0	0	409
	8.99	0	17	0	19	0	0	17	0	17	0	0	0	0	264
$\bar{x}$	7.40	34	21	8	12	0	0	10	0	10	5	0	0	5	318
TER	7.26	0	59	13	78	0	0	45	0	45	0	0	0	0	1068
9.8.-6.9.1989	7.31	0	59	15	60	0	0	27	0	27	0	0	0	0	584
	8.80	0	56	0	23	0	0	40	0	40	0	0	0	0	632
$\bar{x}$	7.79	0	58	9	54	0	0	37	0	37	0	0	0	0	761

HEPTA was analysed but not detected.

-1 = no results

Incubation station period	Chlorophenolics (ng/g fat)									
	246TCP	TeCP	PeCP	45DCG	345TCG	456TCG	TeCG	DMP	S1PCP	S2PCP
KER	573	178	183	0	17	0	30	0	934	47
9.8.-6.9.1989	27	159	29	0	0	0	0	0	215	0
	111	94	59	0	36	54	66	0	264	156
$\bar{x}$	237	144	90	0	18	18	32	0	471	68
HÄM	293	8767	1078	0	0	0	0	0	10138	0
9.8.-6.9.1989	249	9639	1294	0	0	0	0	0	11182	0
	203	7509	1263	0	0	0	0	0	8975	0
$\bar{x}$	248	8638	1212	0	0	0	0	0	10098	0
MEL	1134	126	0	0	3287	562	599	49	1260	4497
8.8.-5.9.1989	534	331	0	0	3760	350	526	32	865	4668
$\bar{x}$	834	229	0	0	3524	456	563	41	1063	4583
PYH	0	65	241	0	186	0	0	0	306	186
8.8.-5.9.1989	0	0	0	0	120	0	0	0	0	120
	0	61	0	0	164	0	0	0	61	164
$\bar{x}$	0	42	80	0	157	0	0	0	122	157
MAT	0	0	125	0	0	0	0	0	125	0
8.8.-5.9.1989	0	0	129	0	0	0	0	0	129	0
	0	151	542	0	0	0	0	0	693	0
$\bar{x}$	0	50	265	0	0	0	0	0	316	0
KUU	84	446	202	0	3251	106	296	0	732	3653
8.8.-5.9.1989	106	126	100	0	2910	72	237	0	332	3219
	52	230	146	0	3530	63	324	0	428	3917
$\bar{x}$	81	267	149	0	3230	80	286	0	497	3596
TOR	190	322	140	0	2822	79	333	0	652	3234
8.8.-5.9.1989	95	222	134	0	2329	82	370	0	451	2781
	241	653	2930	0	2939	41	404	0	3824	3384
$\bar{x}$	175	399	1068	0	2697	67	369	0	1642	3133
KÄR	529	345	1978	0	472	0	94	0	2852	566
8.8.-5.9.1989	268	265	468	0	330	0	30	0	1001	360
	148	0	157	0	333	0	0	0	305	333
$\bar{x}$	315	203	868	0	378	0	41	0	1386	420
KEL	137	247	38	0	504	0	131	0	422	635
8.8.-5.9.1989	26	217	46	0	602	0	143	0	289	745
	44	213	57	0	510	0	134	0	314	644
$\bar{x}$	69	226	47	0	539	0	136	0	342	675
SUS	0	237	90	0	762	0	206	0	327	968
8.8.-5.9.1989	0	355	210	0	786	0	200	0	565	986
	38	405	169	0	966	0	301	0	612	1267
$\bar{x}$	13	332	156	0	838	0	236	0	501	1074
HIR	0	249	208	0	1039	19	334	0	457	1392
8.8.-5.9.1989	58	199	54	0	858	19	262	0	311	1139
	0	279	74	0	846	36	279	0	353	1161
$\bar{x}$	19	242	112	0	914	25	292	0	374	1231

Incubation station period	Chlorophenolics (ng/g fat)									
	246TCP	TeCP	PeCP	45DCG	345TCG	456TCG	TeCG	DMP	S1PCP	S2PCP
MAR	155	0	131	0	65	0	36	0	286	101
8.8.-5.9.1989	268	1212	303	0	100	0	25	312	1783	156
	0	0	120	0	85	0	23	0	120	108
$\bar{x}$	141	404	185	0	83	0	28	104	730	122
ITK	199	131	386	0	38	0	15	0	716	53
8.8.-5.9.1989	180	296	495	0	39	0	85	0	971	124
	81	295	160	0	19	0	25	0	536	44
$\bar{x}$	153	241	347	0	32	0	42	0	741	74
SII	424	212	52	0	447	0	262	0	688	709
9.8.-6.9.1989	530	194	126	0	407	0	345	0	850	752
	554	625	174	0	421	0	221	0	1353	642
$\bar{x}$	503	344	117	0	425	0	276	0	964	701
HAA	0	72	0	0	68	0	37	0	72	105
9.8.-6.9.1989	31	0	0	0	95	0	70	0	31	165
	0	0	0	0	31	0	22	0	0	53
$\bar{x}$	10	24	0	0	65	0	43	0	34	108
TIU	66	0	0	0	298	0	133	0	66	431
8.8.-5.9.1989	107	0	362	0	365	0	126	0	469	491
	188	0	119	0	316	0	231	0	307	547
$\bar{x}$	120	0	160	0	326	0	163	0	281	490
VUO	348	118	56	0	2163	212	424	22	522	2821
8.8.-5.9.1989	448	201	88	0	2637	245	576	24	737	3482
	244	281	1155	0	1973	196	518	21	1680	2708
$\bar{x}$	347	200	433	0	2258	218	506	22	980	3004
PAJ	0	800	280	0	0	0	24	0	1080	24
8.8.-5.9.1989	0	626	160	0	0	0	16	0	786	16
	0	808	349	0	0	0	0	0	1157	0
$\bar{x}$	0	745	263	0	0	0	13	0	1008	13
KEM	223	96	41	0	996	23	252	46	360	1317
9.8.-6.9.1989	209	229	165	0	1040	12	224	36	603	1312
	210	414	321	0	1063	22	274	12	945	1371
$\bar{x}$	214	246	176	0	1033	19	250	31	636	1333
TER	328	296	64	439	5623	337	1360	146	688	7905
9.8.-6.9.1989	484	214	40	309	5401	180	1152	92	738	7134
	542	403	156	206	5386	193	917	80	1101	6782
$\bar{x}$	451	304	87	318	5470	237	1143	106	842	7274

24DCP, 26DCP, 245TCP, 34DCC, 345TCC and TeCC were analysed but not detected.

Incubation		Chlorinated dibenzo-p-dioxins and dibenzofurans (pg/g fat)			
station	period	2378TeCDF	1234678HpCDF	OCDF	TCDDeq
KER	9.8.-6.9.1989	973	0	0	97,3
MEL	8.8.-5.9.1989	0	0	0	0
KUU	8.8.-5.9.1989	0	0	0	0
KEL	8.8.-5.9.1989	0	5615	3408	59,6
MAR	8.8.-5.9.1989	0	0	0	0
VUO	8.8.-5.9.1989	0	948	0	9,5

Following compounds were analysed but not detected:
2378TCDD, 12378PeCDD, 123478HxCDD, 123678HxCDD, 123789HxCDD, 1234678HpCDD, OCDD, 12378PeCDF, 23478PeCDF, 123478HxCDF, 123678HxCDF, 234678HxCDF and 1234789HpCDF.

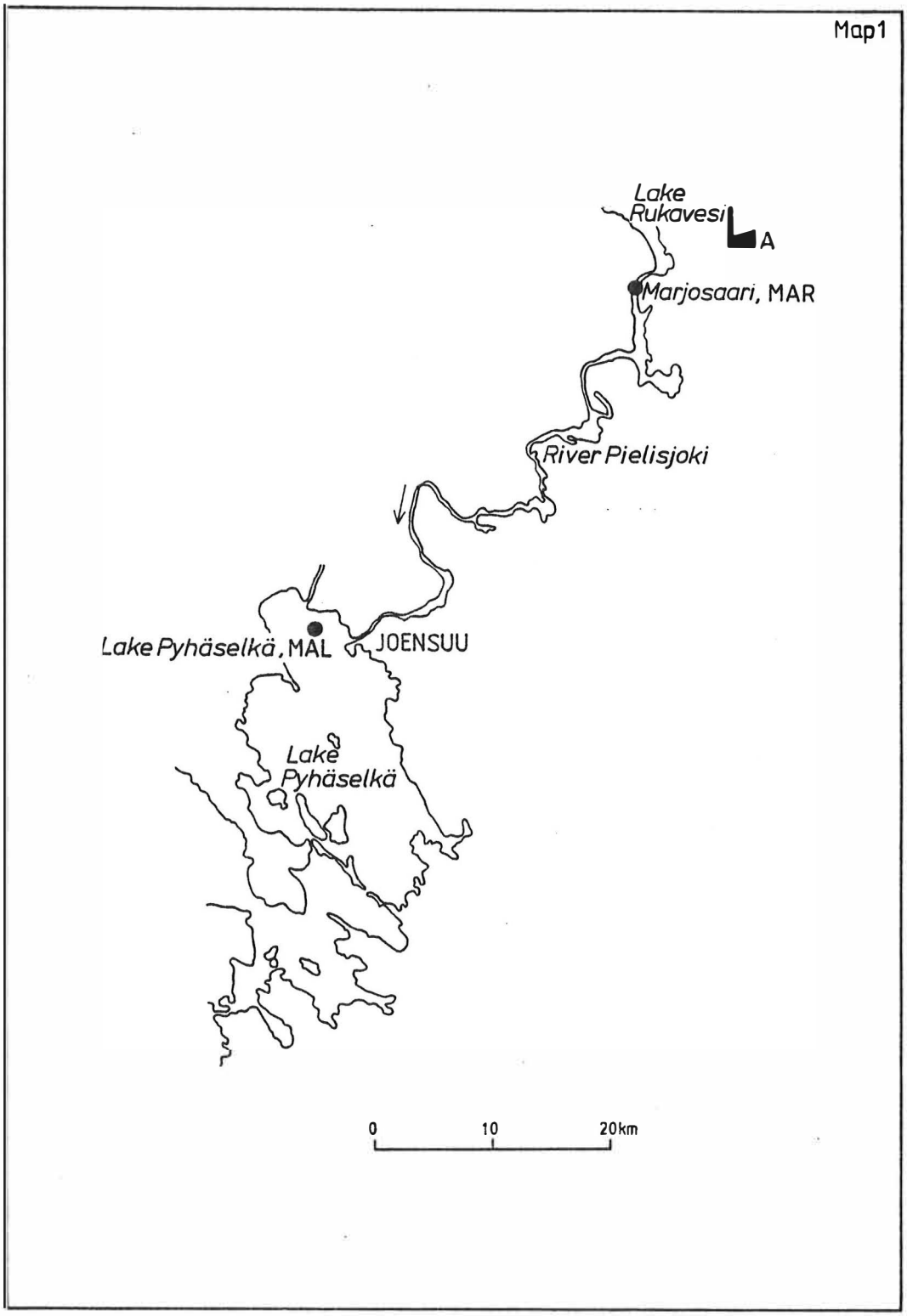
Appendix 9

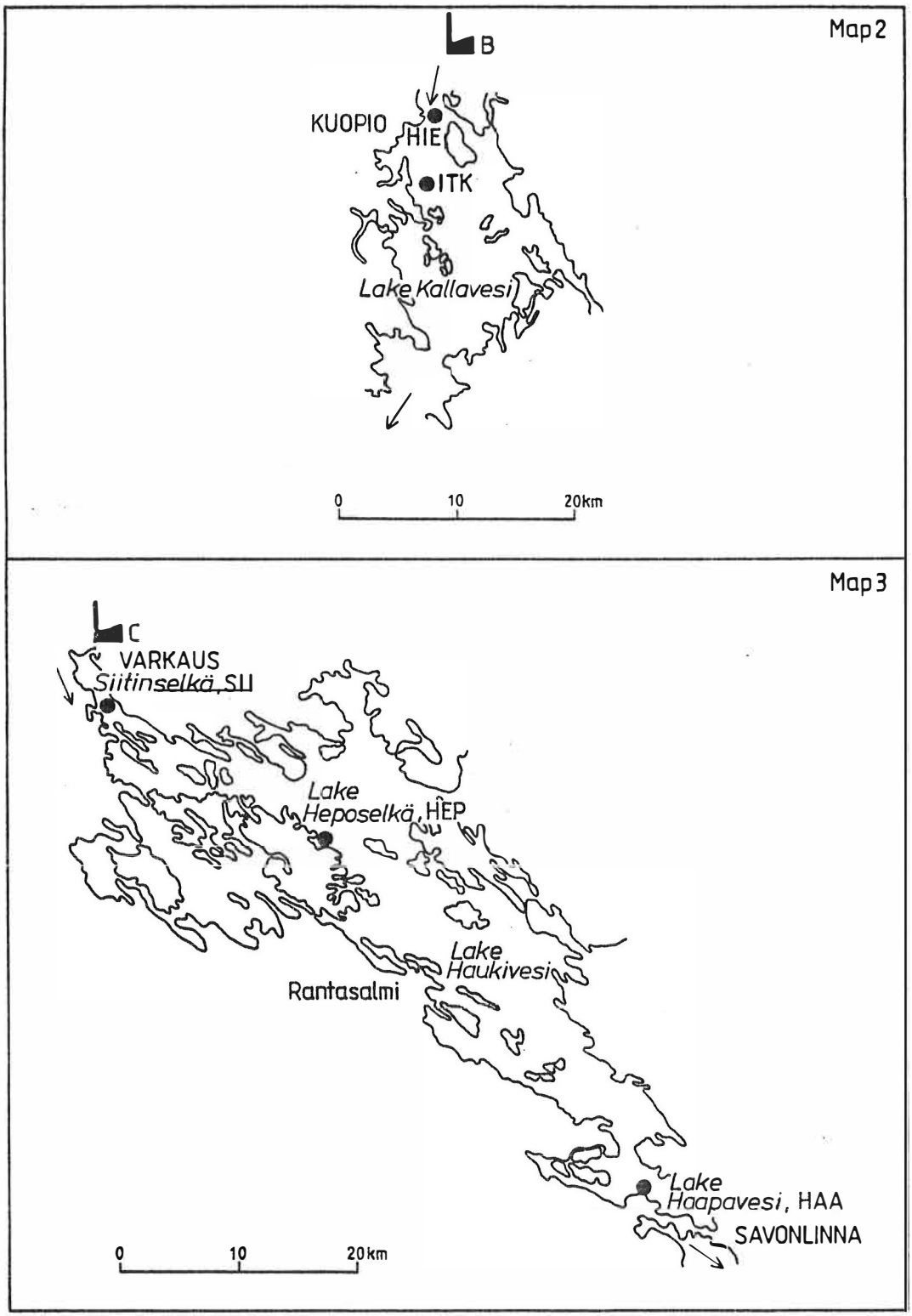
The locations of the incubation stations

Maps 1 - 12

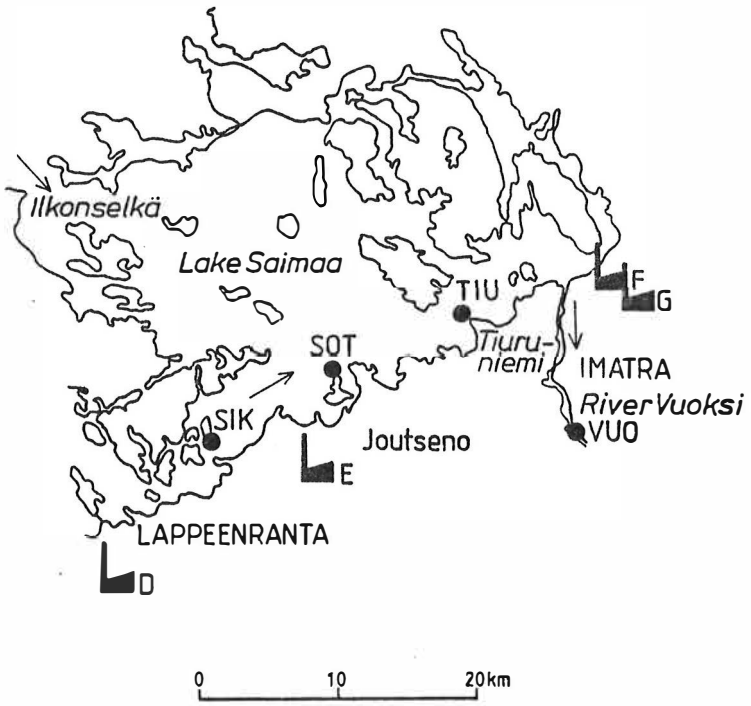
● incubation station (abbreviations see Appendix 11)

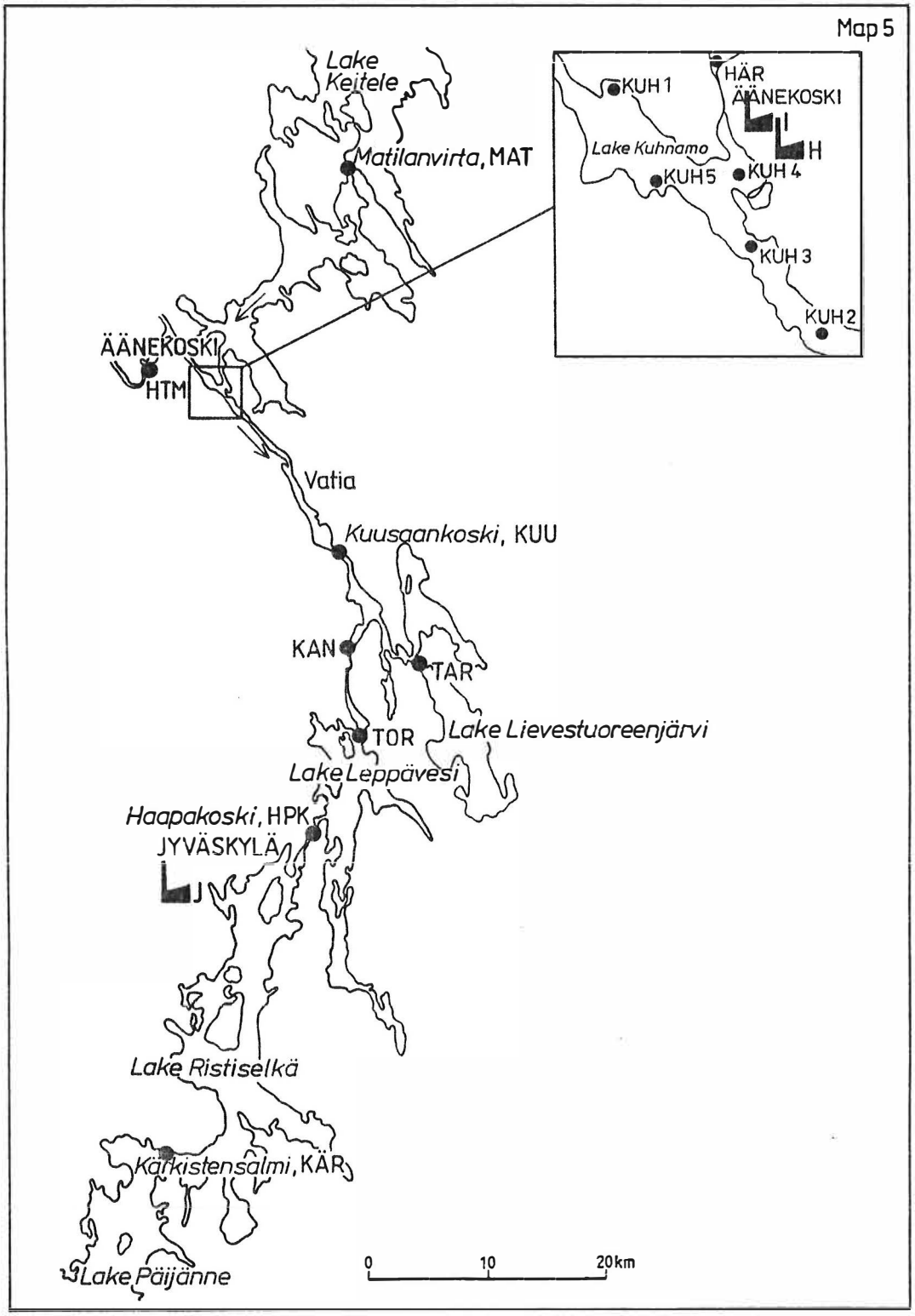
 pulp and/or paper mill (symbols see Appendix 10)


Map1
Lake
Rukavesi
A
Marjosaari, MAR
River Pielisjoki
Lake Pyhäselkä, MAL
JOENSUU
Lake
Pyhäselkä
0
10
20km

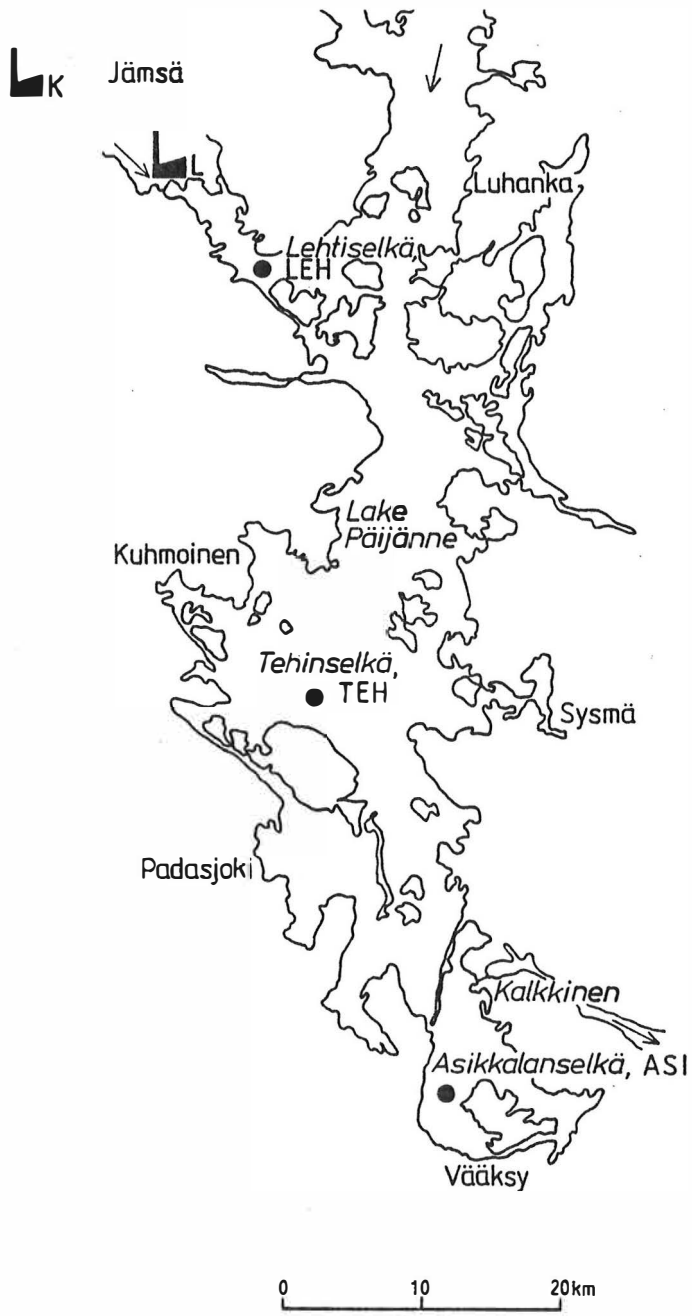

Map 2
B
KUOPIO
HIE
ITK
Lake Kallavesi
0
10
20km
Map 3
C
VARKAUS
Siitinselkä, SII
Lake
Heposelkä, HEP
Lake
Haukivesi
Rantasalmi
Lake
Haapavesi, HAA
SAVONLINNA
0
10
20km

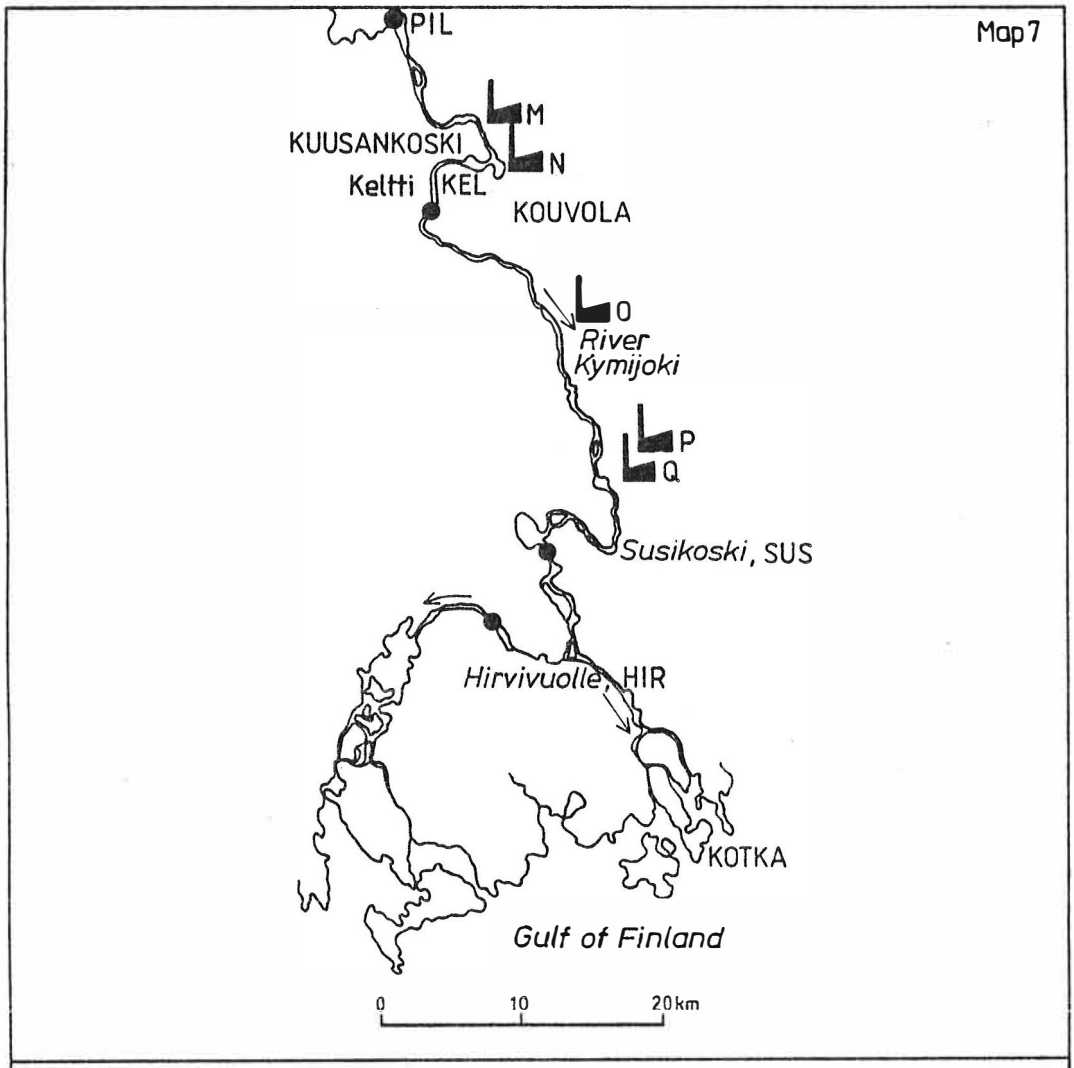
Map 4

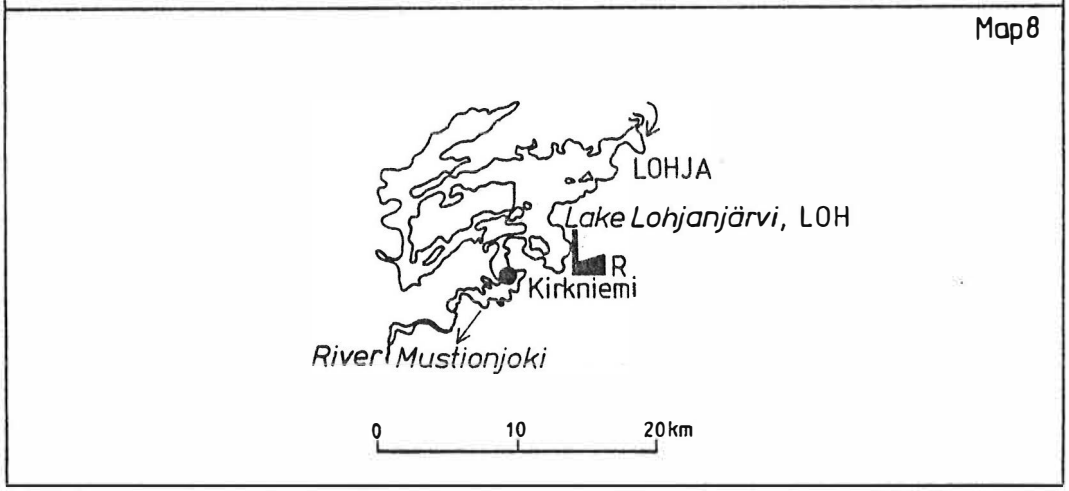

Ilkonselkä
Lake Saimaa
TIU
F
G
SOT
Tiuru-
niemi
IMATRA
River Vuoksi
SIK
VUO
Joutseno
E
LAPPEENRANTA
D
0
10
20km


Map 5
Lake
Keitele
Matilanvirta, MAT
ÄÄNEKOSKI
HTM
Vatia
Kuusaankoski, KUU
KAN
TAR
TOR
Lake Lievestuoreenjärvi
Lake Leppävesi
Haapakoski, HPK
JYVÄSKYLÄ
J
Lake Ristiselkä
Kärkistensalmi, KÄR
Lake Päijänne
KUH 1
HÄR
ÄÄNEKOSKI
I
H
Lake Kuhnamo
KUH 5
KUH 4
KUH 3
KUH 2
0
10
20km

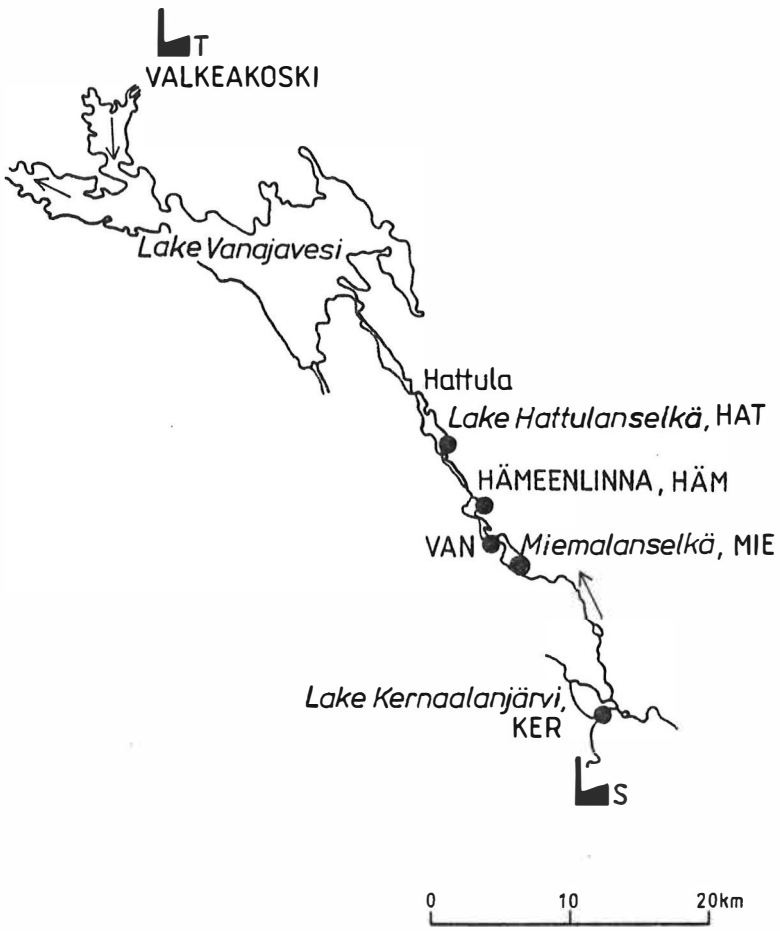
Map 6

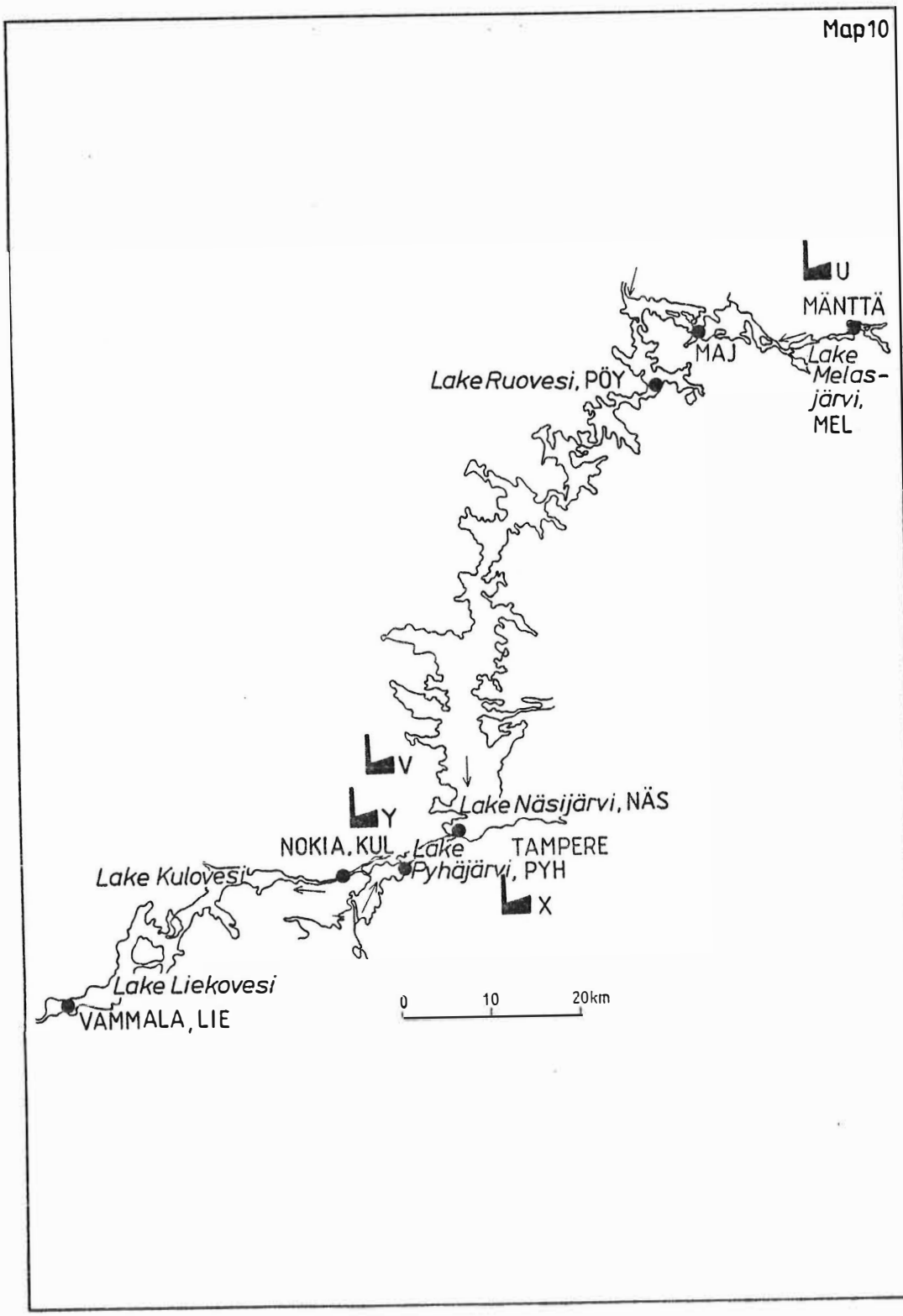

K
Jämsä
L
Luhanka
Lehtiselkä,
LEH
Lake
Päijänne
Kuhmoinen
Tehinselkä,
TEH
Sysmä
Padasjoki
Kalkkinen
Asikkalanselkä, ASI
Vääksy
0
10
20km

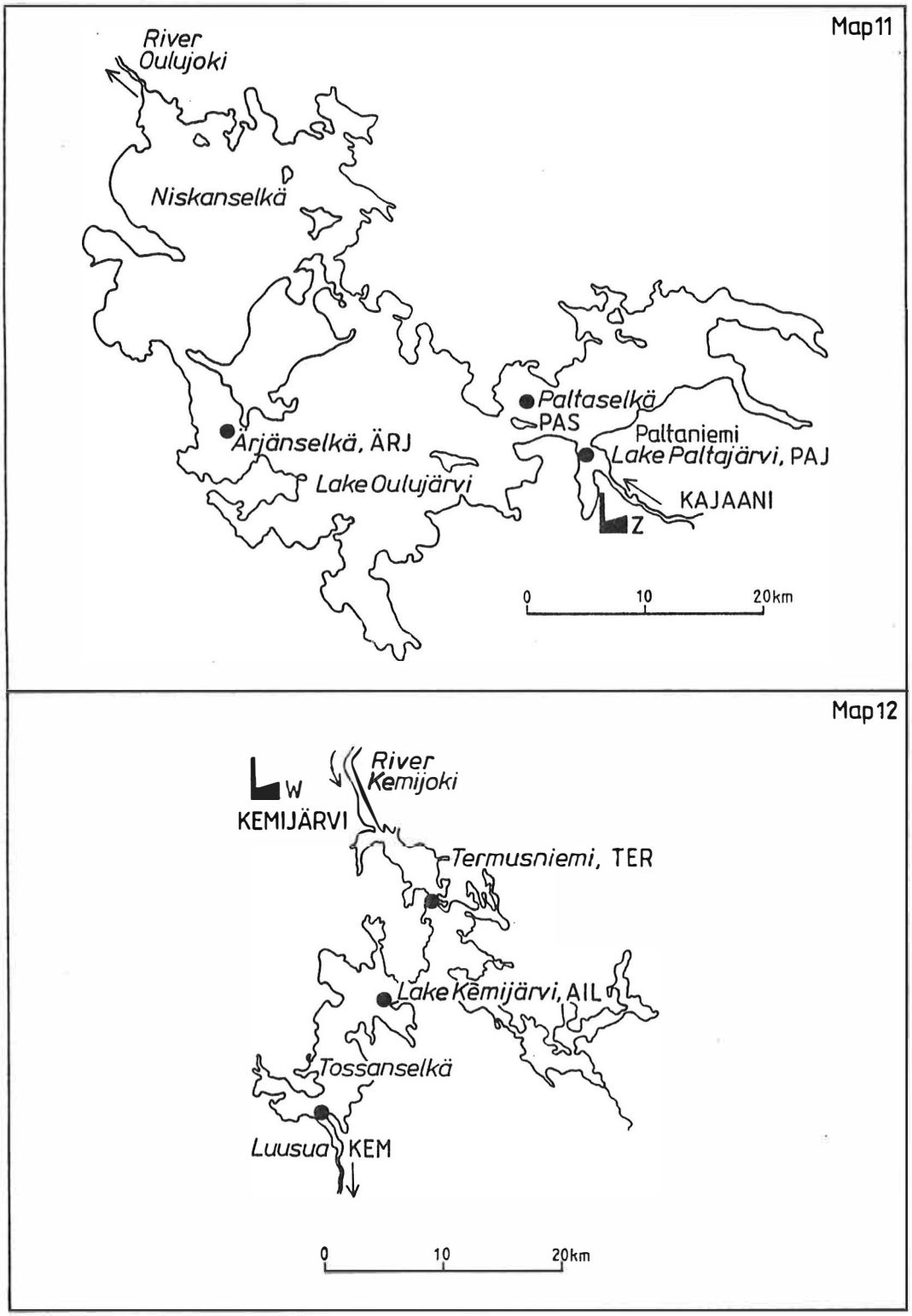

Map 7
PIL
M
KUUSANKOSKI
N
Keltti
KEL
KOUVOLA
O
River
Kymijoki
P
Q
Susikoski, SUS
Hirvivuolle, HIR
KOTKA
Gulf of Finland
0
10
20km


Map 8
LOHJA
Lake Lohjanjärvi, LOH
R
Kirkniemi
River Mustionjoki
0
10
20km

Map 9


T
VALKEAKOSKI
Lake Vanajavesi
Hattula
Lake Hattulanselkä, HAT
HÄMEENLINNA, HÄM
VAN
Miemalanselkä, MIE
Lake Kernaalanjärvi,
KER
S
0
10
20km


Map 10
U
MÄNTTÄ
MAJ
Lake Melas-järvi, MEL
Lake Ruovesi, PÖY
V
Y
Lake Näsijärvi, NÄS
NOKIA, KUL
Lake Pyhäjärvi, PYH
TAMPERE
X
Lake Kulovesi
Lake Liekovesi
VAMMALA, LIE
0
10
20km


Map 11
River
Oulujoki
Niskanselkä
Paltaselkä
PAS
Paltaniemi
Lake Paltajärvi, PAJ
Ärjänselkä, ÄRJ
Lake Oulujärvi
KAJAANI
Z
0
10
20km
Map 12
W
KEMIJÄRVI
River
Kemijoki
Termusniemi, TER
Lake Kemijärvi, AIL
Tossanselkä
Luusua
KEM
0
10
20km

Appendix 10

The waste water load of pulp and paper mills concerned, according to the data of the National Board of Waters and the Environment

Company	Year	Suspended solids t/a	BOD, t/a	Phosphorus kg/a
A. Enso-Gutzeit Co., Uimaharju				
	1988	1 400	4 795	37 835
	1989	1 241	4 161	32 120
B. Metsä-Serla Co., Savon Sellu				
	1988	1 085	1 190	14 805
	1989	445	736	9 358
C. Enso-Gutzeit Co., Varkaus				
	1988	875	3 290	41 160
	1989	550	3 177	37 807
D. Kaukas Co., Kaukas				
	1988	3 885	4 865	51 800
	1989	3 926	4 569	48 362
E. Joutseno-Pulp Co., Joutseno				
	1988	1 575	2 870	25 795
	1989	1 354	1 842	21 353
F. Enso-Gutzeit Co., Kaukopää				
	1988	5 495	16 380	52 150
	1989	4 918	14 644	51 591
G. Enso-Gutzeit Co., Tainionkoski				
	1988	1 435	5 985	18 375
	1989	1 443	5 296	20 699
H. Metsä-Sellu Co., Äänekoski				
	1988	2 555	1 120	23 975
	1989	2 324	590	26 176
I. Metsä-Serla Co., Äänekoski				
	1988	included in Metsä-Sellu Co.		
	1989	212	364	568
J. Metsä-Serla Co., Kangas				
	1988	105	175	280
	1989	143	227	671
K. Yhtyneet Paperitehtaat Co., Jämsänkoski				
	1988	980	3 360	7 630
	1989	1 101	3 243	5 360

Company	Year	Suspended solids t/a	BOD, t/a	Phosphorus kg/a
L. Yhtyneet Paperitehtaat Co., Kaipola				
	1988	1 750	2 135	31 640
	1989	794	808	11 560
M. Kymin Paperiteollisuus Co., Kuusankoski				
	1988	420	1 225	770
	1989	710	1 191	1 305
N. Kymin Paperiteollisuus Co., Kuusanniemi				
	1988	2 415	9 205	35 525
	1989	2 675	4 472	44 410
O. Myllykoski Co., Myllykoski				
	1988	1 225	1 750	15 155
	1989	911	1 918	23 224
P. Tampella Co., Anjala				
	1988	1 750	3 850	34 020
	1989	3 622	1 272	25 499
Q. Tampella Co., Inkeroinen				
	1988	315	665	945
	1989	338	480	1 006
R. Metsä-Serla Co., Kirkniemi				
	1988	700	490	6 405
	1989	309	185	4 508
S. Enso-Gutzeit Co., Tervakoski				
	1988	210	70	1 540
	1989	201	94	1 020
T. Yhtyneet Paperitehtaat Co., Tervasaari				
	1988	1 470	4 025	10 815
	1989	900	3 405	8 876
U. Metsä-Serla Co., Mänttä				
	1988	1 085	3 710	22 505
	1989	1 333	4 370	24 840
V. Metsä-Serla Co., Lielahti				
	1988	1 050	1 260	11 620
	1989	452	714	9 285
X. Metsä-Serla Co., Tako				
	1988	805	455	455
	1989	714	404	443

Company	Year	Suspended solids t/a	BOD$_7$ t/a	Phosphorus kg/a
Y. Nokian Paperi Co., Nokia				
	1988	770	525	3 045
	1989	686	455	5 617
Z. Yhtyneet Paperitehtaat Co., Kajaani				
	1988	1 540	2 030	14 315
	1989	771	1 250	7 174
W. Veitsiluoto Co., Kemijärvi				
	1988	770	3 885	25 760
	1989	763	3 210	27 448

Appendix 11

The abbreviations used

A. Chemical compounds

Chlorohydrocarbons

CYMS	2,3,6-Trichloro-p-cymene
CYMD	2,3,6-Trichloro-p-cymenene
HCBz	Hexachlorobenzene
LIND	Lindane, gamma-hexachlorocyclohexane
α-HCH	α-Hexachlorocyclohexane
OXY	Oxychlordane
GAMMA	Gamma-chlordane
ALPHA	Alpha-chlordane
TRANS	Trans-nonachlor
HEPTA	Heptachlor
DDE	p,p'-Dichloro-diphenyl-dichloroethylene
DDD	p,p'-Dichloro-diphenyl-dichloroethane
DDT	p,p'-Dichloro-diphenyl-trichloroethane
PCB	Polychlorinated biphenyls
SCHL	OXY + GAMMA + ALPHA + TRANS + HEPTA
SDDT	DDE + DDD + DDT

Chlorophenolics

24DCP	2,4-Dichlorophenol
26DCP	2,6-Dichlorophenol
245TCP	2,4,5-Trichlorophenol
246TCP	2,4,6-Trichlorophenol
TeCP	2,3,4,6-Tetrachlorophenol
PeCP	Pentachlorophenol
45DCG	4,5-Dichloroguaiacol
345TCG	3,4,5-Trichloroguaiacol
456TCG	4,5,6-Trichloroguaiacol
TeCG	Tetrachloroguaiacol
DMP	2,6-Dimethoxy-trichlorophenol
34DCC	3,4-Dichlorocatechol
345TCC	3,4,5-Trichlorocatechol
TeCC	Tetrachlorocatechol
S1PCP	246TCP + TeCP + PeCP
S2PCP	24DCP + 26DCP + 245TCP + 34DCC + 345TCC + TeCC+ 45DCG + 345TCG + 456TCG + TeCG + DMP

Chlorinated anisoles, veratroles and diphenyl ethers

245TCA	2,4,5-Trichloroanisole
246TCA	2,4,6-Trichloroanisole
345TCA	3,4,5-Trichloroanisole
TeCA	2,3,4,6-Tetrachloroanisole
PeCA	Pentachloroanisole
34DCV	3,4-Dichloroveratrole
45DCV	4,5-Dichloroveratrole

345TCV	3,4,5-Trichloroveratrole
TeCV	Tetrachloroveratrole
PCA	Polychlorinated anisoles
PCV	Polychlorinated veratroles
SANIS	The sum of chloroanisoles and chloroveratroles
PCDE	Polychlorinated diphenyl ethers

Polychlorinated dibenzo-p-dioxins and dibenzofurans

2378TeCDD	2,3,7,8-Tetrachlorodibenzo-p-dioxin
12378PeCDD	1,2,3,7,8-Pentachlorodibenzo-p-dioxin
123478HxCDD	1,2,3,4,7,8-Hexachlorodibenzo-p-dioxin
123678HxCDD	1,2,3,6,7,8-Hexachlorodibenzo-p-dioxin
123789HxCDD	1,2,3,7,8,9-Hexachlorodibenzo-p-dioxin
1234678HpCDD	1,2,3,4,6,7,8-Heptachlorodibenzo-p-dioxin
OCDD	Octachlorodibenzo-p-dioxin
2378TeCDF	2,3,7,8-Tetrachlorodibenzofuran
12378PeCDF	1,2,3,7,8-Pentachlorodibenzofuran
23478PeCDF	2,3,4,7,8-Pentachlorodibenzofuran
123678HxCDF	1,2,3,6,7,8-Hexachlorodibenzofuran
234678HxCDF	2,3,4,6,7,8-Hexachlorodibenzofuran
123478HxCDF	1,2,3,4,7,8-Hexachlorodibenzofuran
1234678HpCDF	1,2,3,4,6,7,8-Heptachlorodibenzofuran
1234789HpCDF	1,2,3,4,7,8,9-Heptachlorodibenzofuran
OCDF	Octachlorodibenzofuran
PCDD	Polychlorinated dibenzo-p-dioxin
PCDF	Polychlorinated dibenzofuran
TCDDeq	TCDD-equivalent estimated according to NORD 1988

Others

AOX	Adsorbable organic halogens
EOX	Extractable organic halogens
EOCl	Extractable organic chlorine
TOCl	Total organic chlorine
TOC	Total organic carbon
BOD	Biochemical oxygen demand
COD_{Cr}	Chemical oxygen demand, oxidation with dichromate
	Chemical oxygen demand, oxidation with permanganate

B. Incubation stations

AIL	Lake Kemijärvi, Ailanganniemi	map 12
ASI	Lake Päijänne, Asikkalanselkä	map 6
HAA	Lake Haapavesi	map 3
HAT	Lake Vanajavesi, Hattulanselkä	map 9
HEP	Lake Haukivesi, Heposelkä	map 3
HIE	Lake Kallavesi, Hietasalo	map 2
HIR	River Kymijoki, Hirvivuolle	map 7
HPK	Haapakoski	map 5
HTM	Hietama	map 5
HÄM	Lake Vanajavesi, Hämeenlinna	map 9

HÄR	Häränvirta	map 5
ITK	Lake Kallavesi, Itkonniemi	map 2
KAN	Kantolansalmi	map 5
KEL	River Kymijoki, Keltti	map 7
KEM	Lake Kemijärvi, Luusua	map 12
KER	Lake Kernaalanjärvi	map 9
KUH 1	Lake Kuhnamo 1	map 5
KUH 2	Lake Kuhnamo 2	map 5
KUH 3	Lake Kuhnamo 3	map 5
KUH 4	Lake Kuhnamo 4	map 5
KUH 5	Lake Kuhnamo 5	map 5
KUL	Lake Kulovesi	map 10
KUU	Kuusaankoski	map 5
KÄR	Lake Päijänne, Kärkistensalmi	map 5
LEH	Lake Päijänne, Lehtiselkä	map 6
LIE	Lake Liekovesi	map 10
LOH	Lake Lohjanjärvi	map 8
MAJ	Lake Ruovesi, Majaselkä	map 10
MAL	Lake Pyhäselkä, Maljakansaari	map 1
MAR	River Pielisjoki, Marjosaari	map 1
MAT	Lake Keitele, Matilanvirta	map 5
MEL	Lake Melasjärvi	map 10
MIE	Lake Vanajavesi, Miemalanselkä	map 9
NÄS	Lake Näsijärvi, Lielahti	map 10
PAJ	Lake Paltajärvi	map 11
PAS	Lake Oulujärvi, Paltaselkä	map 11
PIL	Lake Pyhäjärvi, Pilkanmaa	map 7
PYH	Lake Pyhäjärvi	map 10
PÖY	Lake Ruovesi, Pöytäselkä	map 10
SII	Lake Haukivesi, Siitinselkä	map 3
SIK	Lake Saimaa, Sikosalonselkä	map 4
SOT	Lake Saimaa, Sotsaaret	map 4
SUS	River Kymijoki, Susikoski	map 7
TAR	Tarvaalankoski	map 5
TEH	Lake Päijänne, Tehinselkä	map 6
TER	Lake Kemijärvi, Termusniemi	map 12
TIU	Lake Saimaa, Tiuruniemi	map 4
TOR	Lake Torronselkä	map 5
VAN	Lake Vanajavesi	map 9
VUO	River Vuoksi	map 4
ÄRJ	Lake Oulujärvi, Ärjänselkä	map 11