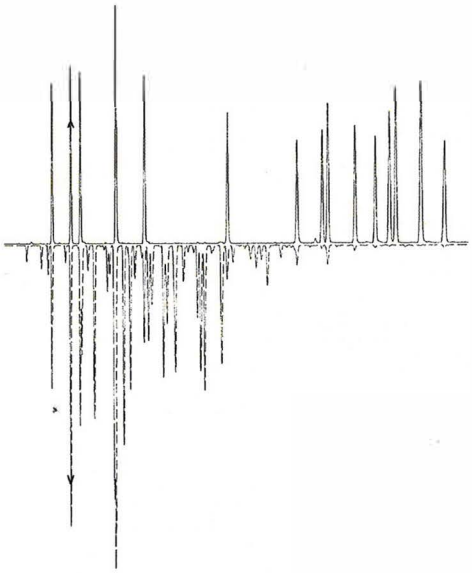
Department of Chemistry, University of Jyväskylä

PCBs IN PROCESSES, PRODUCTS AND ENVIRONMENT OF PAPER MILLS USING WASTEPAPER AS THEIR RAW MATERIAL

KEIJO MÄNTYKOSKI

Academic Dissertation
for the Degree of
Doctor of Philosophy



Jyväskylä, Finland 2006

Research Report No. 119

DEPARTMENT OF CHEMISTRY, UNIVERSITY OF JYVÄSKYLÄ

RESEARCH REPORT No. 119

PCBs IN PROCESSES, PRODUCTS AND ENVIRONMENT OF PAPER MILLS USING WASTEPAPER AS THEIR RAW MATERIAL

By

KEIJO MÄNTYKOSKI

Academic Dissertation for the Degree of

Doctor of Philosophy

To be presented, by the permission of the Faculty of Mathematics and Science of the University of Jyväskylä. for public examination in Auditorium KEM 4, on December 1st, 2006, at 12 noon

URN: ISBN: 978-951-39-8848-7
ISBN 978-951-39-8848-7 (PDF)
ISSN 0357-346X

ISBN 951-39-2676-1
ISSN 0357-346X

To Tallfors foundation

PREFACE

This research was carried out at the Department of Chemistry, University of Jyväskylä and at the Institute for Environmental Research, University of Jyväskylä during the years 2000-2006.

My warmest thanks go to my supervisors Professor Kari Rissanen and Research Professor Jarmo J. Meriläinen. Their excellent guidance and tireless support and encouragement have been of great importance throughout these years.

I am also indebted to thank emeritus Professor Jaakko Paasivirta for his support, co-operation and valuable advice and for familiarizing me with the secrets of environmental chemistry in the early 1980s. Many shared journeys, congresses and symposia have also been unforgettable. The old sea shanties from Oulu, that Jaakko sometimes sang as we returned to Jyväskylä at night are also stuck forever in my mind.

I also thank the whole staff at the Institute for Environmental Research, but especially my own laboratory group (Anki, Hanna, Leena, Leena, Lyyti, Pirjo and Tony) for creating an agreeable working environment.

Special thanks go to the personel of the forestry companies and environmental authorities involved this study for their helpful co-operation. I would especially like to acknowledge Jukka Karppinen, Saara Ranta-aho and Anja Niinisalo, Metsä Tissue Corporation, Mänttä, Kirsti Krogerus, Pirkanmaa Regional Environment Centre and Sirpa Herve, Central Finland Regional Environment Centre.

I am thankful for the reviewers of my thesis Tiina Rantio, Ph.D. and Docent Leif Kronberg, for their constructive criticism and valuable comments that distinctly improved the content of this study. I also express my warmest thanks to lecturer Michael Freeman, for helping with my English in this thesis.

Finally I would like to thank my family for optimism and encouragement throughout this research effort.

Financial support from Metsä Tissue Corporation, Finnish Forest Industries Federation, Paperinkeräys Oy and Pirkanmaa Regional Environment Centre for my experimental work and from University of Jyväskylä to finish this thesis, are gratefully acknowledged.

Jyväskylä, November 2006

Keijo Mäntykoski

ABSTRACT

The occurrence of PCBs in raw materials, processes, products and environmental samples were analysed with the aim of resolving the sources and pathways of PCBs in the processes and environment of paper mills producing recycled paper products. In the wastepaper grades examined, PCBs were observed only in archival paper (0.47-1.0 mg/kg). In the deinking process, PCBs were observed in deinking sludge, but it was not observed in pulper stock, recycled fibre pulp, tissue paper reject or process waters. In deinking sludge, PCBs were mainly observed in samples from a pulper that used wastepaper from offices as its raw material. Between 1993 and 2002 PCB concentrations in the latter decreased from 1.3 mg/kg to 0.14 mg/kg. PCBs were also observed in the wastewater treatment plant in sludge, but not in wastewater. Between 1993 and 2004 concentrations in biosludge decreased from 0.56 mg/kg to 0.13 mg/kg. The PCB fingerprint in raw material and process samples corresponded to the fingerprint from Aroclor 1242. The greater proportion of recycled paper products did not contain PCBs. Low concentrations of PCB were however observed in hand towel sheet (0.02-0.07 mg/kg) and toilet tissue (0.02-0.14). The PCB fingerprint in the recycled paper products corresponded to the fingerprint from Aroclor 1242.

The PCB concentrations in pike (*Esox lucius*) caught in Lake Melasjärvi, a small lake basin downstream from the Mänttä mill and from lakes from the region of Tampere and Nokia were low (0.02-0.07 mg/kg). The PCB concentrations in sediment from lakes upstream and downstream from the Mänttä mill were below 0.05-0.15 mg/kg, except in samples from Mäntänlahti (0.12-0.23 mg/kg) just below the paper mill. PCBs were also observed in soil and sediment at the former industrial site of Mänttä mill (0.05-0.08 mg/kg). In the case of the Mänttä mill it was notable that the fingerprint of PCB in fish, soil and sediment did not correspond to the fingerprint from Aroclor 1242, which was observed in the paper mill processes, but corresponded to the fingerprint from Aroclor 1260, which has been used, for example, as a dielectric fluid in transformers. For the purpose of comparison PCB concentrations in sediment were also determined in lake basins downstream from the Nokia and Kaipola mills. PCBs were observed (0.05 mg/kg) only in sediment downstream from the Kaipola mill. In the latter mill it was notable that the PCB fingerprint in sediment corresponded to the fingerprint from Aroclor 1242, which is typically observed in paper mills using wastepaper as a raw material. On the basis of these results it could be concluded that the production of recycled fibre pulps and recycled paper products were not the main source of increasing PCB concentrations in mussels incubated in the vicinity of Mänttä mill. The most probable source was Aroclor 1260, which was found in sediment just downstream from the Mänttä mill.

CONTENTS

ABBREVIATIONS

ASE	accelerated solvent extraction
mg/kg dw	mg/kg dry weight
mg/kg fw	mg/kg fresh weight
LLE	liquid-liquid extraction
LOQ	limit of quantification
MAE	microwave-assisted extraction
PCBs	polychlorinated biphenyls
PCB 8	2,4'-dichlorobiphenyl
PCB 18	2,2',5-trichlorobiphenyl
PCB 28	2,4,4'-trichlorobiphenyl
PCB 30	2,4,6-trichlorobiphenyl
PCB 52	2,2',5,5'-tetrachlorobiphenyl
PCB 101	2,2',4,5,5'-pentachlorobiphenyl
PCB 105	2,3,3'4,4'-pentachlorobiphenyl
PCB 118	2,3',4,4',5-pentachlorobiphenyl
PCB 128	2,2',3,3',4,4'-hexachlorobiphenyl
PCB 138	2,2',3,4,4'5'-hexachlorobiphenyl
PCB 153	2,2',4,4',5,5'-hexachlorobiphenyl
PCB 156	2,3,3',4,4'.5-hexachlorobiphenyl
PCB 180	2,2',3,4,4',5,5'-heptachlorobiphenyl
PCB 187	2,2',3,4',5,5',6-heptachlorobiphenyl
PFE	pressurized fluid extraction
PLE	pressurized liquid extraction
POPs	persistent organic pollutants

SFE	supercritical fluid extraction
SPE	solid phase extraction
SPME	solid phase microextraction
TSS	total suspended solids
USE	ultrasonication extraction

1. REVIEW OF THE LITERATURE

1.1 Introduction

Polychlorinated biphenyls (PCBs) were first synthesized by Schmidt and Schulz in 1881 and their industrial use started in 1929.[1-3] Since then PCBs have been used worldwide in different industrial and domestic applications because of their unique physical and chemical properties (e.g., chemical and thermal stability, low or non-flammability, high permittivity, low vapor pressure at ambient temperature) and because of their low acute toxicity.[2-4] The historically largest use of PCBs was in closed systems as a dielectric fluid in transformers and capacitors.[5] One of the main applications of PCBs in open systems was in carbonless copy paper as an ink carrier.[3, 6-7] They were also used in cutting oils, hydraulic oils, heat transfer fluids, paints, pesticides and sealants.[3-4, 6, 8-9] In the period between 1957 and 1971 more than 20 000 tons of a technical PCB mixture were used in the United States in the production of carbonless copy paper.[7] This paper usually contained between 2 and 6 % PCBs by weight.[7] The technical mixture of PCBs used in the manufacture of carbonless copy paper was a type containing 42-43 % chlorine by weight (Aroclor 1242, in Europe also Clophen A 30 and Fenclor 42, and in Japan Kanechlor-300).[6-7] The use of PCBs in carbonless copy paper in the USA and most other OECD countries practically ceased during the seventies, but due to their persistence, traces of PCBs in wastepaper can be detected even today.[10]

PCBs have been among the most studied environmental contaminants for more than three decades because of the large quantitities (leakage, disposal, evaporation, etc.) released into the environment, their persistence, and their potential toxicity to a broad spectrum of organisms.[1-4] PCBs were identified as pollutants initially in 1966 and since then intensive

efforts have been made to locate the major sources and pathways of PCBs in the environment.[11] One of the possible routes by which PCBs are introduced into the environment is the recycling of paper and paper waste.[5, 7, 12] Although at present no PCBs are found in carbonless copy paper, recycled paper from discarded archives can be contaminated with PCBs originating from that use in carbonless copy paper.[7, 12] In the aquatic environment PCBs tend to accumulate in sediments and biota because of their hydrophobic character and consequent low solubility in water.[4, 13-14] Sediments act as a sink for PCBs and are therefore important in pollution studies and monitoring.[4, 13] The amounts of PCBs in sediments also reflect regional or global discharge of PCBs.[15]

1.2 Determination of PCBs

1.2.1 Methods

In the literature on PCBs there are hundreds of methods for the determination of these compounds in solid and liquid samples. Since the aim of this study was not to develop and validate new methods for the determination of PCBs in paper, pulp, sludge, fish, sediment, soil and water samples, only a brief overview of the methods currently in use is presented.

The methods typically used for the extraction of PCBs in solid samples are Soxhlet extraction, Soxtec extraction, ultrasonication extraction (USE), supercritical fluid extraction (SFE), microwave-assisted extraction (MAE) and accelerated solvent extraction (ASE).[16-27] Impurities interfering with the quantitative analysis of PCBs have been removed from samples, for example by shaking with concentrated sulfuric acid or by column chromatography (e.g., alumina, Florisil or Silica gel).[2, 14, 17, 28-29] Elementary sulfur

has been removed from samples by activated copper, or mercury.[2, 14, 28, 30] Quantitave determination has been carried out by a gas chromatograph equipped with two electron capture detectors (ECDs) or a gas chromatograph coupled with a mass spectrometer (GC/MS).[2, 14, 17, 29, 31-32]

Soxhlet extraction, originally used for the determination of fat content in milk has been the traditional method used in the extraction of PCBs from solid samples (e.g., paper, fish and sediment) and it has been the main reference against which the performance of other leaching methods has been compared.[12, 16-17, 29, 33-35] An improved extraction technique, based on the Soxhlet system, is Soxtec. The technique was invented in the early 1970s and commercialized in 1982.[16, 36]

A common conventional alternative to Soxhlet extraction is ultrasonication extraction, USE (also known as ultrasound-assisted extraction, ultrasonic extraction and sonication), which has been applied for the extraction of PCBs from sludge samples and various solid environmental samples (e.g., sediment and soil).[14, 17, 29-30, 37-40]

Analytical-scale supercritical fluid extraction (SFE) was first introduced by Stahl and Schiltz in 1976, but it was not until 1986 that it was applied to the extraction of persistent organic pollutants (POPs) in environmental samples.[41-42] Consequently, SFE has been applied in several investigations for the extraction of PCBs from sewage sludge and environmental samples (e.g., biota, sediment and soil).[17, 43-52]

The first attempts at analytical-scale microwave-assisted extraction (MAE) were performed by Ganzler *et al.*[53] using a domestic microwave oven with solvents normally used in Soxhlet. Since, several applications utilizing MAE for the extraction of PCBs from

solid samples (e.g., sewage sludge, biota, sediment and soil) have been published during the last few years.[8, 13, 17, 29, 54-57]

One of the latest contributions to the increasing number of extraction techniques for solid samples is accelerated solvent extraction, ASE (also known as pressurized liquid extraction, PLE, and pressurized fluid extraction, PFE). The first publications refering to the method appeared in 1995, but it was only in 1996 that the details of ASE as a technique were reported by Richter *et al.*[17, 58] Consequently, several studies on the methods for the extraction of PCBs in solid matrices (e.g., sludge, biota, sediment, and soil) have been published during the last 10 years.[17, 25, 29, 33, 59-67] Accelerated solvent extraction is also a proposed method in the United States (U.S EPA Method 3545).[68-69]

Liquid-liquid extraction (LLE), solid phase extraction (SPE) and solid phase microextraction (SPME) have been the methods of sample pretreatment most frequently used for the determination of PCBs in water.[2, 20, 70-78] The methods typically used for sample clean-up are shaking with concentrated sulfuric acid, and column chromatography by alumina, Florisil or Silica gel.[2, 70] Elementary sulfur has been removed from wastewater samples by activated copper, or mercury.[70] Quantitative determination has been carried out by a gas chromatograph equipped with two electron capture detectors (ECDs) or a gas chromatograph coupled with a mass spectrometer (GC/MS).[31-32, 70]

1.2.2 Earlier results

PCB concentrations in carbonless copy paper were determined for the first time in the early 1970s in Japan. Masuda *et al.*[6] analysed PCBs in different layers of carbonless copy

paper. The highest PCB concentrations were observed in the surface layer of the paper (64.7 mg/g, 30.7 mg/g and 31.6 mg/g, respectively) and the lowest concentrations in the lowest layer of the paper (0.24 mg/g, 0.28 mg/g and 0.20 mg/g, respectively). In the middle layer of the paper the PCB concentrations were 63.8 mg/g, 26.0 mg/g and 22.2 mg/g, respectively. The PCB fingerprint in carbonless copy paper corresponded to the fingerprint from Kanechlor-300.

Shahied *et al.*[79] determined PCB residues in 1971 in, among others, three samples of newsprint manufactured from recycled fibre pulp. PCBs were observed in only one sample (1.38 mg/kg). The PCB fingerprint in newsprint corresponded to the fingerprint from Aroclor 1242.

Welling,[80] in her study in 1991 observed, that the PCB concentrations in the magazine and newspaper shavings used in the manufacturing of recycled fibre pulps were 0.01 mg/kg fw and 0.02 mg/kg fw, respectively. The PCB fingerprint was not reported.

Neukum *et al.*[81] reported in 2001 that in Germany the average PCB concentrations in recovered paper fractions were clearly lower in 1999 than in 1993. The average PCB concentrations in 1993 and 1999 in brown recovered paper fractions were almost 0.6 mg/kg and 0.027 mg/kg, respectively, and in graphic recovered paper fractions over 0.3 mg/kg and 0.005 mg/kg, respectively. The PCB fingerprint was not reported.

In 1990 Welling[82] observed PCBs in two pulper stock samples (pulper 060 and pulper 080) and in two deinking sludge samples (deinking 060 and deinking 080) from a paper mill in Mänttä. The first pulper used wastepaper from households and the second one wastepaper from offices as their raw materials. The PCB concentrations measured in the

pulper stocks were 0.31 mg/kg dw and 0.23 mg/kg dw, respectively, and in the deinking sludges 0.20 mg/kg dw and 0.80 mg/kg dw, respectively. The PCB fingerprint in pulper stock and deinking sludge corresponded to the fingerprint from Aroclor 1242.

In 1990 Ettala[83] measured the quality of deinking sludge in five European paper mills. The average PCB concentration in deinking sludge (n=17) was 2.1 mg/kg dw and 80 % of the PCB concentrations were between 0.45 mg/kg dw and 7.3 mg/kg dw. Ettala also determined PCB concentrations in three wastewater and five wastewater sludge samples and in the leachate downstream from a deinking sludge landfill. The PCB concentrations in the wastewater samples and in the leachate downstream from the deinking sludge landfill were low (<0.01 µg/l) due to effective sorption to solids. The average PCB concentration in wastewater sludge was 0.46 mg/kg dw. Ettala also reported that the percentage partition of PCBs in the deinking process between deinking sludge, wastewater sludge and wastewater were 68 %, 30 % and 2 %, respectively. Ettala pointed out however, that the results gave only a tentative view of partition due to the limited amount of data.

PCB concentrations in deinking sludge were also determined in 1990 in one English, one Finnish and one Swedish sample, and in 1991 in two Swedish samples (Katrinefors, Nyholm).[82, 84] The PCB concentrations in the English, Finnish and Swedish samples were 1.3 mg/kg dw, 1.9 mg/kg dw and 4.7 mg/kg dw, respectively, and in the samples from Katrinefors and Nyholm 8.8 mg/kg dw and 0.34 mg/kg dw, respectively. The PCB fingerprint in the first three samples corresponded to the fingerprint from Aroclor 1242. The PCB fingerprint in samples from Katrinefors and Nyholm was not reported.

Raitio[85-86] reported PCB concentrations in deinking sludge from three Finnish paper mills (United Paper Mills Ltd. in Kaipola, Nokian Paperi Oy in Nokia and Keräyskuitu Oy in Sunila) in 1992. PCBs were observed in all samples and the concentrations ranged between 1.1 and 1.4 mg/kg dw. The PCB fingerprint in deinking sludge corresponded to the fingerprint from a mixture of Aroclor 1242 and Aroclor 1254.

In 1981 Walter and Zambrano[5] published the results of an investigation in which PCB concentrations were determined in wastewater from paper mills producing board, tissue or fine paper. A summary of the results from the fine tissue mills is presented in Table 1.1. The PCB fingerprint in wastewaters commonly corresponded to the fingerprint from Aroclor 1242 and Aroclor 1254.

Table 1.1. PCB concentrations in wastewater from paper mills manufacturing tissue papers between 1976 and 1978.[5]

Mill	Number of analyses	Number of positive analyses	Range µg/l
B*	13	2	< 0.5-3.0
F	14	6	< 0.06-12.0
G	5	1	< 1.0-13.0
L	11	3	< 0.01-18.0
N	11	6	< 0.1-4.5
P	13	4	< 1.0-1.5
Q*	4	2	< 1.0-2.7
Total	71	24	

*Untreated wastewater.

Miner and Berger[87] reported PCB levels in effluents from eleven deinking mills producing mainly fine paper or tissue paper. PCB concentrations were determined in 612 samples in

1990-1994. Only approximately one percent (9 samples) contained measurable levels of PCBs (Aroclors). None of the measured values exceeded 1 µg/l, and all but one were below 0.5 µg/l.

In 1990 Welling reported PCBs in biosludge (0.78 mg/kg dw) from a Finnish paper mill (Mänttä) and in 1991 PCBs in sludge from sedimentation (0.66 mg/kg dw) from a Swedish paper mill (Katrinefors).[82, 84] Both paper mills used wastepaper as their raw material. The PCB fingerprint in biosludge corresponded to the fingerprint from Aroclor 1242, but the PCB fingerprint in sludge from sedimentation was not reported.

Sullivan *et al.*[88] reported PCB concentrations in fish and sediment in the vicinity of recycling paper mills at Lower Fox River, Wisconsin between 1976 and 1981. Over 200 fish samples, representing 15 different species were analysed. The PCB concentrations in fish ranged from < 0.2 to 90 mg/kg. The average PCB concentrations in carp decreased during this period from 40 mg/kg to 5 mg/kg. The PCB fingerprint was not reported. The concentrations of PCB in sediment downstream from paper mill A ranged from 0.2 to 68 mg/kg and downstream from paper mill B from 56 to 100 mg/kg. The PCB fingerprint in these sediments corresponded to the fingerprint from commercial Aroclor 1242.

Larsson *et al.*[89] reported concentrations of PCBs in pike (*Esox lucius)* and sediment from the River Em (catchment area 4 460 km^2, mean discharge 30 m^3/s at river mouth, maximum estimated 270 m^3/s) in Southern Sweden in 1990. Sediment and fish from a small lake (26 ha, maximum depth 2.5 m, average depth 0.7 m, water residence time about 4 h) situated about 60 km from the river mouth showed the highest levels. In the lake the PCB concentrations in sediment were 14-100 mg/kg dw and in fish 0.85-2.2 mg/kg fw. A paper mill situated just above the lake was assumed the source of the PCBs. The paper

mill used recycled paper as raw material, and it was suspected that PCBs in self-copying paper from old archives were the sources of the contaminants. The PCB fingerprint in fish and sediment corresponded to the fingerprint from commercial Aroclor 1242.

In their study Herve *et al.*[90-91] observed increasing PCB concentrations in incubated mussels in the watercourse downstream from a paper mill in Mänttä. The PCB fingerprint was not reported.

Piiroinen[92] reported PCB concentrations in pike (*Esox lucius*) from Lake Kernaalanjärvi, Finland in 2001. Samples were caught in Tervajokisuu downsteam from the paper mill operated by Tervakoski Oy. PCB concentrations varied between 0.20 and 1.1 mg/kg fw. The PCB fingerprint in the fish corresponded to the fingerprint from Aroclor 1254.

Hurme and Puhakka[93] determined the content and distribution of individual PCB congeners in sediment from Lake Kernaalanjärvi. Total PCB concentrations ranged from 0.5 to 10.7 mg/kg dw. Comparison of PCB discharge documentation with congener distribution patterns in sediment suggested selective removal of lower chlorinated PCBs by physical processes. There was no evidence of *in situ* biotransformation of PCBs by indigenous sediment micro-organisms. The PCB fingerprint was not reported.

In 2002 a preliminary investigation was conducted on the former site of the paper mill in Mänttä.[94] In soil sample (1.0-2.0 m) from in front of a former acid plant a PCB concentration of 0.74 mg/kg was observed. The PCB fingerprint in the soil corresponded to the fingerprint from Aroclor 1260.

PCB concentrations in toilet tissue samples, representing 11 different brands were determined in Canada at the end of the 1970s.[95] Nine brands were positive for PCBs and contained levels of PCBs ranging from trace amounts (0.03 mg/kg) to amounts as high as 21 mg/kg.

de Voogt *et al.*[7] determined PCB concentrations in magazine and various commercially available tissue paper products in the Netherlands in the early 1980s. PCB concentrations of 2.85 mg/kg in paper towel and of 3.95 and 12.40 mg/kg, respectively, in light and dark toilet tissue were observed. PCBs were not observed in magazines. The PCB fingerprint in tissue papers corresponded to the fingerprint from Aroclor 1242.

PCB contents in paper towels and toilet papers manufactured from recycled and virgin fibre pulps were determined in Denmark in the 1980s.[12] PCBs were found in all samples manufactured from recycled fibre pulp, but not in the sample manufactured from virgin fibre pulp (a Danish toilet paper). PCB concentrations in paper towels from West Germany and Sweden were 0.11 and 0.05 mg/kg, respectively, and in toilet paper from Denmark, The Netherlands, Finland and Yugoslavia 0.09, 0.21, 0.08 and 0.26 mg/kg respectively. The PCB fingerprint in the samples corresponded to the fingerprint from commercial Aroclor 1242.

Welling *et al.*[96] determined the levels of PCBs in two Finnish hand towel samples in the early 1990s. PCBs were observed in both samples and the concentrations were 0.33 and 0.02 mg/kg fw. The PCB fingerprint in hand towels corresponded to the fingerprint from Aroclor 1242. PCB levels were also determined in three German (0.005-0.47 mg/kg fw), one Austrian (0.13 mg/kg fw) and four Finnish (0.02-0.07 mg/kg fw) toilet tissue samples.

The PCB levels were most often higher in the Central European, than Finnish samples.

The PCB fingerprint in the samples corresponded to the fingerprint from Aroclor 1242.

2. EXPERIMENTAL

2.1 Background

The occurrence of PCBs in the production of recycled paper products in Finland has arisen as a topic of public debate on two occasions. The first was when Welling *et al.*[96] observed PCBs in recycled paper products in the early 1990s and the second was when Herve *et al.*[90-91] observed increasing PCB concentrations in incubated mussels in the watercourse downstream from the paper mill in Mänttä. The present study started immediately after Herve *et al.* published their results in 2000.

2.2 Aims of the study

The aims of the study were

(i) to analyse the occurrence of PCBs in the paper mill at different stages of the manufacture of recycled paper and recycled paper products

(ii) to analyse the occurrence of PCBs at different stages of the wastewater treatment in a paper mill manufacturing recycled paper and recycled paper products

(iii) to analyse the occurrence of PCBs in the environment of a paper mill manufacturing recycled paper and recycled paper products

(iv) to analyse the occurrence of PCBs in recycled paper products sold to the general public.

2.3 Paper mills

The paper mill operated by Metsä Tissue Corporation in Mänttä (Figure 1) produces deinked waste paper pulp, woodsfree paper, recycled paper and converted products.[97-108] Earlier the mill also produced sulfite pulp, but ceased to do so in February 1991.[109] The capacity of the paper mill in 2004 was 125 000 t paper.[110] The detailed production data for the years 1993-2004 are presented in Appendix 1.

The paper mill operated by Georgia-Pacific Finland Ltd. in Nokia (Figure 1) produces deinked waste paper pulp, recycled paper and woodsfree paper.[97-108] In 2001 and 2003 the mill also produced undeinked waste paper pulp and in 2001 mechanical paper.[105, 107] The capacity of the paper mill in 2004 was 100 000 t paper.[110] The detailed production data for the years 1993-2004 are presented in Appendix 2.

The paper mill operated by UPM-Kymmene Corporation in Kaipola (Figure 1) produces refined mechnical pulp, deinked waste paper pulp, mechanical paper and recycled paper.[97-108] The capacity of the paper mill in 2004 was 400 000 t newsprint.[110] The detailed production data for the years 1993-2004 are presented in Appendix 3.

The wastewaters from the Mänttä mill are treated in mechanical and biological treatment plants (activated sludge plant).[111-112] The wastewaters from the town of Mänttä have also been treated in the mill since 1996.[100] The values of total suspended solids from the paper mill during the years 1993-2004 are presented in Appendix 4.[97-108] Part of the deinking sludge and wastewater sludge from the paper mill has been landfilled (for detailed numerical data see Appendix 5 and Appendix 6).[97-105]

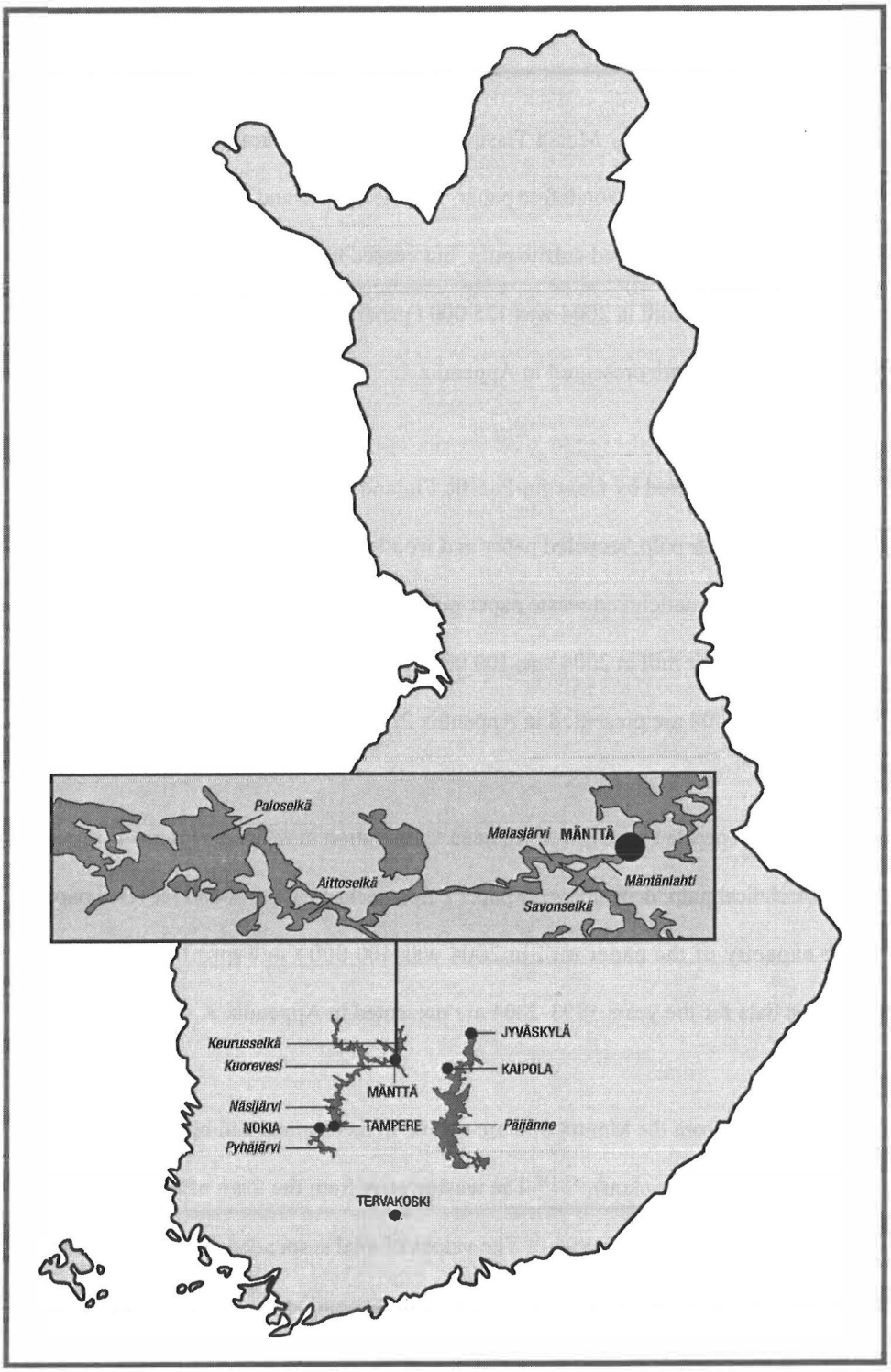


Figure 1. Location of the paper and pulp mills and watercourses.

The wastewaters from the Nokia mill are treated in a biological treatment plant (activated sludge plant).[111-112] The values of total suspended solids from the the paper mill during the years 1993-2004 are presented in Appendix 4.[97-108] Part of the deinking sludge and wastewater sludge from the paper mill has been landfilled (for detailed numerical data see Appendix 5 and Appendix 6).[97-105]

The wastewaters from the Kaipola mill are treated in biological treatment plant (activated sludge plant).[111] The wastewaters from the settlement of Kaipola have also been treated occasionally in the mill.[97-99, 112] The values of total suspended solids from the paper mill during the years 1993-2004 are presented in Appendix 4.[97-108] Part of the deinking sludge from the paper mill has been landfilled (for detailed numerical data see Appendix 5).[97-105]

2.4 Sampling

Samples for the analysis of PCBs in Mänttä mill were taken from incoming wastepaper and raw water used in the pulping and deinking processes (Appendix 7), from pulper stock, recycled fibre pulp and tissue paper reject used in the production of recycled fibre pulp (Appendix 8, table 1 and table 2), from deinking sludge (Appendix 8, table 3), from process water (Appendix 8, table 4) and from the area immediately adjacent to the mill's electrical equipment (Appendix 8, table 5). Samples in the wastewater treatment plant were taken from wastewater and wastewater sludge (Appendix 9). The flow chart of the wastewater treatment plant and the municipal and industrial wastewater and treated water sampling points are presented in Figure 2. The flow chart of the wastewater treatment plant and the sludge sampling points are presented in Figure 3. Deinking sludge and biosludge samples from the 1990s from the archives of the Mänttä mill were also utilized

during this study. All the samples were taken by Metsä Tissue Corporation, excluding those from the areas immediately adjacent to the mill's electrical equipment, which were taken by the Institute for Environmental Research, University of Jyväskylä. Wastepaper and deinking sludge samples were also taken from other sources. The wastepaper sample (shavings) was a quality control sample taken by Paperinkeräys Oy. (Appendix 7, table 1). The deinking sludge samples were from the paper mill operated by Georgia-Pacific Finland Ltd. in Nokia (Appendix 8, table 3) and were taken by Pirkanmaa Regional Environment Centre.

Fish samples (Appendix 10, table 1) for the analysis of PCBs were taken from Lake Melasjärvi, which is a small lake basin downstream from the paper mill in Mänttä (Figure 1). Samples were collected by the Institute for Environmental Research, University of Jyväskylä. For the purpose of comparison fish samples (Appendix 10, table 2) were also collected from other watercourses, polluted or possibly polluted by PCBs. Samples were taken in the region of Tampere and Nokia (Figure 1) from Lake Näsijärvi (downstream from M-real pulp mill in Tampere), from Lake Pyhäjärvi (downstream from a former capacitor factory and a current sewage treatment plant operated by the city of Tampere), from Lake Kulovesi (downstream from Lake Pyhäjärvi and from the region of Nokia) and from Lake Iidesjärvi (downstream from a former landfill). Samples were collected by Pirkanmaa Regional Environment Centre.

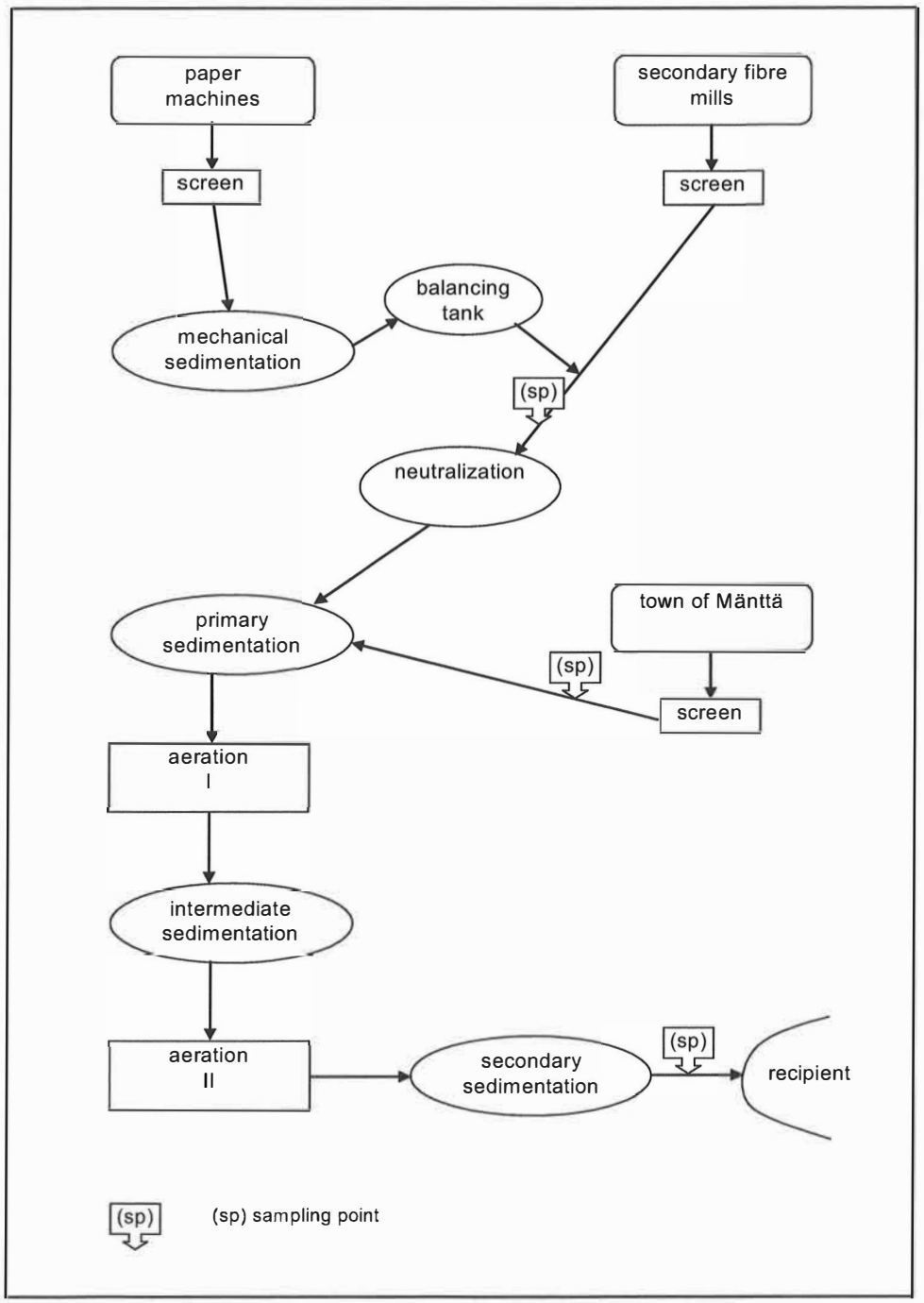


Figure 2. Flow chart of the wastewater treatment plant and water sampling points (sp).

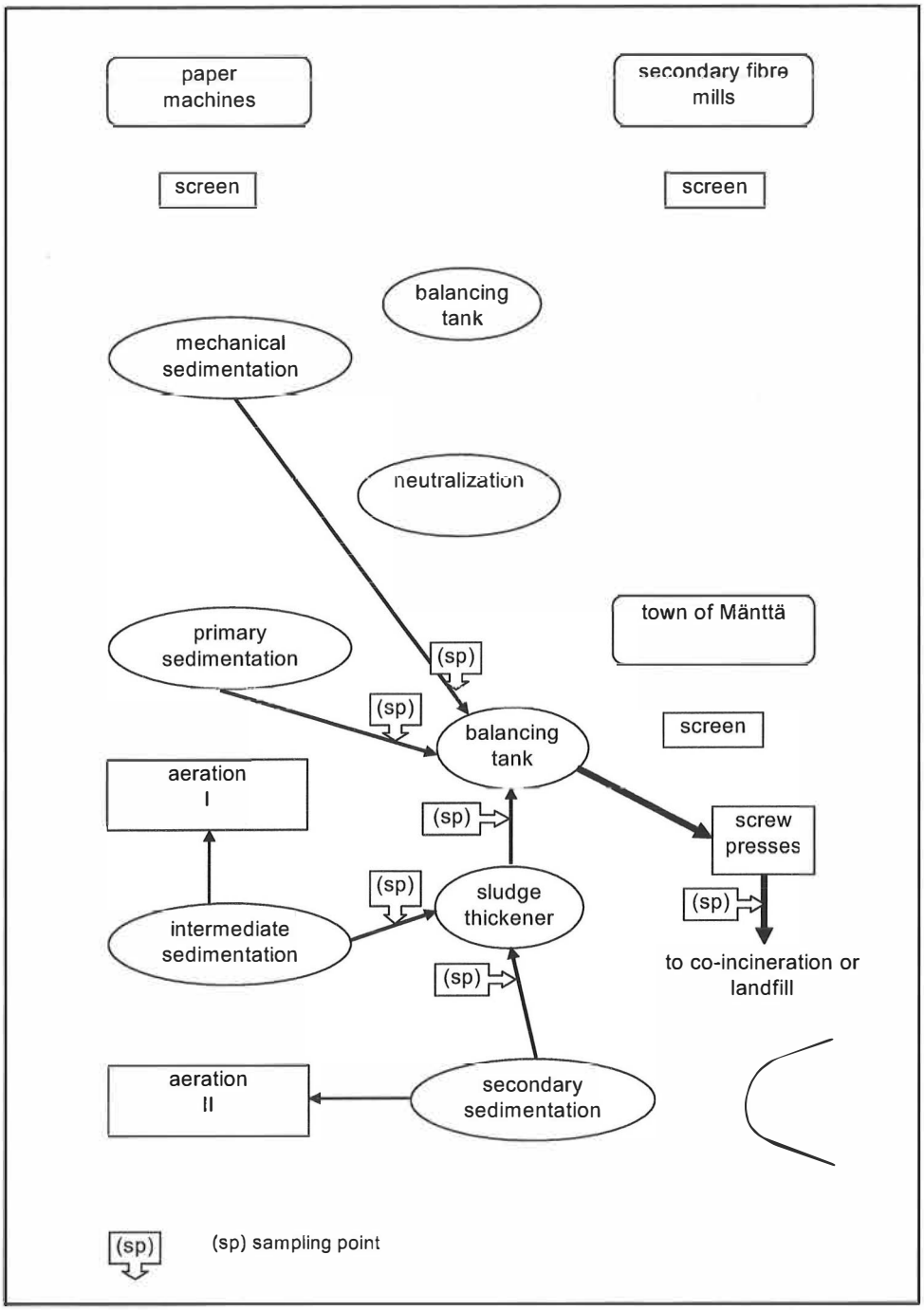


Figure 3. Flow chart of the wastewater treatment plant and the sludge sampling points (sp).

Sediment samples were taken from lake basins (Appendix 11, table 1) upstream and downstream from the paper mill in Mänttä (Figure 1) and from lakes (Appendix 11, table 2) downstream from the Mänttä mill (Figure 1). Samples were also taken from the industrial site of the Mänttä mill and from sites downstrean from municipal and industrial landfills (Appendix 11, table 3). Samples from the lake basins were taken by the Institute for Environmental Research, University of Jyväskylä, from lakes by the Water Protection Association of the River Kokemäenjoki and from the industrial site of the paper mill and from sites downstream landfills by Pirkanmaa Regional Environment Centre. For the purpose of comparison sediment samples were also collected from other watercourses, polluted or possibly polluted by PCBs. Samples (Figure 1) were taken from lakes in the region of Tampere and Nokia (Appendix 11, table 5, table 7 and table 8) by Pirkanmaa Regional Environment Centre and from Lake Päijänne (Appendix 11, table 6) by the Institute for Environmental Research, University of Jyväskylä. Soil and sediment samples (Figure 4) for the analysis of PCBs were taken from a former industrial site of the paper mill in Mänttä (Appendix 11, table 4). Samples were taken by IP-Engineering Finland Ltd. A river water sample (Appendix 12) was taken from a site downstream from a former municipal landfill. The sample was taken by Metsä Tissue Corporation.

Various commercially available tissue paper products were collected during the years 2000-2004. Samples for the analysis of PCBs were taken from hand towel (Appendix 13), kitchen towel (Appendix 14), handkerchief (Appendix 15) and toilet tissue (Appendix 16). Random samples from superstores (Lidl Seppälä and Prisma Seppälä) in Jyväskylä, from the University of Jyväskylä and from the Central Finland Regional Environment Centre were taken by the Institute for Environmental Research, University of Jyväskylä. Samples from paper mills from different parts of Europe were their own quality control samples.

Wastepaper samples were collected in 2-3 litre plastic bags. Samples were stored in the dark at room temperature before analysis. Raw water, process water and wastewater samples were taken in one-litre glass flasks according to the guidelines by Mäkelä *et al.*[113] Samples were stored in a refrigerator in the dark before analysis. Pulper stock, pulp and sludge samples were taken in one-litre glass jars. Samples were stored in a refrigerator in the dark before drying. Samples were freeze-dried in the laboratory as soon as possible after which they were stored prior to analysis in tightly closed glass jars in the dark at room temperature. Fish samples were packed[113] in aluminium foil and plastic bags after the measurement of weight. Samples were stored frozen in the dark before analysis. Sediment sampling from lake basins was based on the guidelines issued by the Institute for Environmental Research, University of Jyväskylä[114] and on the guidelines by Mäkelä *et al.*[113] The samples were taken in plastic tubes suitable for sediment sampling. The tubes were stored in a refrigerator in the dark before cutting into sub-samples. This has been an accredited sampling method (FINAS accreditation) since 1998.[115] Other sediment samples were taken in-one litre glass jars according to the guidelines by Mäkelä *et al.*[113] Samples were stored in a refrigerator in the dark before analysis. Soil samples were taken by a heavy pneumatically operated earth auger. Samples were packed in 0.5-litre glass jars and stored in a refrigerator in the dark before analysis. The river water sample was taken and handled in the same way as the above raw water, process water and wastewater samples. Recycled paper products were stored in their originally package in the dark at room termperature before analysis.

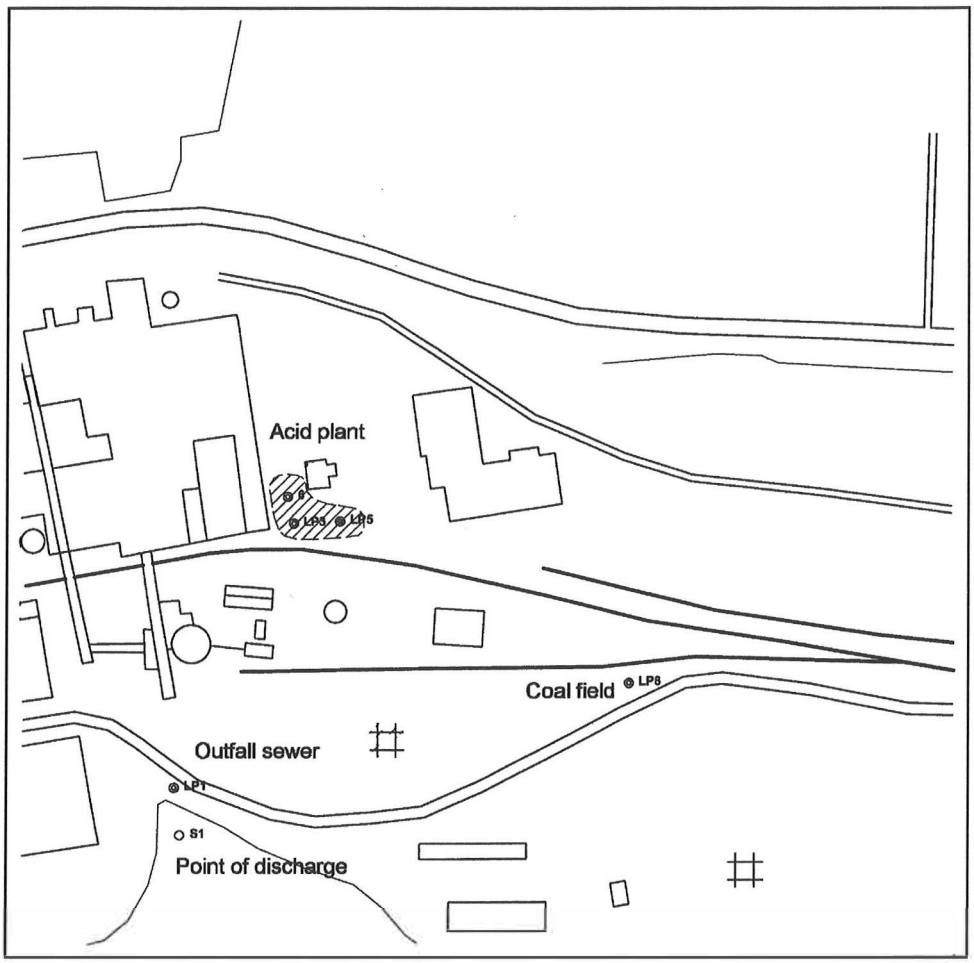


Figure 4. Soil sampling points (6, LP1, LP3, LP5 and LP8) and sediment sampling point (S1) on the former site of the paper mill in Mänttä

2.5 Apparatus, reagents and gases

Accelerated solvent extractor. Solid samples (except paper and fish samples) were extracted with accelerated solvent extractor (Dionex ASE 200). A dried sub-sample was placed in a stainless steel extraction vessel. An internal standard (PCB 30) was added to the sample and the vessel was closed tightly. The extraction was performed with a mixture of petroleum spirit, acetone, hexane and diethyl ether (9:5.5:2.5:1 v/v/v/v) at 1500 psi and

a temperature of 80 °C. The heating phase was 5 min and static extraction time 20 min (two static cycles). Eluation was performed with 100 % of the total cell volume (11 ml).

Gas chromatographs. PCB concentrations were determined with gas chromatographs equipped with two electron capture detectors (ECD).

A Micromat HRGC 412 equipped with two ^{63}Ni electron capture detectors (ECD) and a split/splitless injector. GC column A: a fused silica capillary column (NB-54, HNU-Nordion), length 25 m, inside diameter 0.32 mm, film thickness 0.25 µm. GC column B: a fused silica capillary column (NB-1701, HNU-Nordion), length 25 m, inside diameter 0.32 mm, film thickness 0.25 µm. Operating conditions: injector 250 °C, detector 350 °C; injection volume 1 µl, splitless time 0.50 min; column initial temperature 150 °C, increase at rate of 5 °C/min to 260 °C, isothermal run for 10 min at 260 °C; carrier gas: helium (2 ml/min); detector make-up gas: argon/methane (30 ml/min).

An Agilent 6890N equipped with two ^{63}Ni electron capture detectors (ECD) and a split/splitless injector. GC column A: a fused silica capillary column (HP-5, Agilent), length 30 m, inside diameter 0.32 mm, film thickness 0.25 µm. GC column B: a fused silica capillary column (HP-50+, Agilent), length 30 m, inside diameter 0.32 mm, film thickness 0.25 µm. Operating conditions: injector 250 °C, detector 300 °C; injection volume 1 µl, splitless time 0.75 min; column initial temperature 80 °C, increase at a rate of 20 °C/min to 200 °C, followed by an increase to 250 °C at a rate of 5 °C/min, isothermal run for 20 min at 250 °C; carrier gas: helium (2.3 ml/min, 39 cm/sec); detector make-up gas: argon/methane (40 ml/min).

The quantitation of total PCBs was done by comparing the intensities of the main peaks to the corresponding peaks of weighed standards of Aroclor 1242, Aroclor 1254, Aroclor 1260 and Clophen A 60.[96]

Standard mixtures. The following commercial and certified standard solutions were used during this investigation:

(1) PCB 8 (Dr. Ehrenstorfer GmBH, L 20000800),

(2) PCB 18 (Dr. Ehrenstorfer GmBH, L 20001800),

(3) PCB 28 (Dr. Ehrenstorfer GmBH, L 20002800),

(4) PCB 52 (Dr. Ehrenstorfer GmBH, L 20005200),

(5) PCB 101 (Dr. Ehrenstorfer GmBH, L 20010100),

(6) PCB 105 (Dr. Ehrenstorfer GmBH, L 20010500),

(7) PCB 118 (Dr. Ehrenstorfer GmBH, L 20011800),

(8) PCB 128 (Dr. Ehrenstorfer GmBH, L 20012800),

(9) PCB 138 (Dr. Ehrenstorfer GmBH, L 20013800),

(10) PCB 153 (Dr. Ehrenstorfer GmBH, L 20015300),

(11) PCB 156 (Dr. Ehrenstorfer GmBH, L 20015600),

(12) PCB 180 (Dr. Ehrenstorfer GmBH, L 20018000),

(13) PCB 187 (Dr. Ehrenstorfer GmBH, L 20018700),

(14) Aroclor 1242 (Dr. Ehrenstorfer GmBH, X 20124200),

(15) Aroclor 1254 (Dr. Ehrenstorfer GmBH, X 20125400),

(16) Aroclor 1260 (Dr. Ehrenstorfer GmBH, X 20126000),

(17) Clophen A 60 (Dr. Ehrenstorfer GmBH, X 20306000),

(18) PCB 30, internal standard (Dr. Ehrenstorfer GmBH, L 20003000 and X 20003000).

Reagents and gases. The following reagents and gases were used during this investigation:

(1) Acetone (Rathburn Chemicals Ltd, RG 2001).

(2) Alumina, neutral, 70-230 mesh (Merck, 1077), heated to 750 °C for 16 h, deactivated with 5 % water.

(3) Copper, powder (Merck, 2703), activated with 2 M HCl, rinsed first with water (pH 7) and then with methanol and finally dried by a centrifuge equipped with refrigerated solvent trap.

(4) Diethyl ether (Rathburn Chemicals Ltd, RG 2013).

(5) Hexane (Rathburn Chemicals Ltd, RH 1002).

(6) Hydrochloric acid, 37 % (Merck 317).

(7) Kieselgel 60, 70-230 mesh, 0.063-0.200 mm (Merck 7754), heated to 150 °C for 16 h, deactivated with 5.6 % water.

(8) Kieselgel 60, 230-400 mesh, 0.040-0.063 mm (Merck 9385), heated to 150 °C for 16 h, deactivated with 6.3 % water.

(9) Methanol (Rathburn Chemicals Ltd, RH 1019).

(10) Petroleum spirit, 40-60° (Rathburn Chemicals Ltd, RG 2031).

(11) Concentrated sulfuric acid, 95-97 % (Merck, 731).

(12) Nitrogen, 99.9 % (AGA).

(13) Argon 95 % + methane 5 % (Agamix P-5, AGA).

(14) Helium, with a purity of at least 99.99 % (AGA).

2.6 Column chromatography

Alumina. One gram of neutral alumina (heated to 750 °C for 16 h, deactivated with 5 % water) was placed into a Pasteur pipette (length 230 mm, closed with a hexane-washed cotton wool plug). The sample was added to the column and the column was eluated with 10 ml hexane.

Kieselgel. Kieselgel 60 (70-230 mesh, heated to 150 °C for 16 h, deactivated with 5.6 % water) was placed into a Pasteur pipette (length 230 mm, closed with a hexane-washed cotton wool plug) to a height of 70 mm followed by Kieselgel 60 (230-400 mesh, heated to 150 °C for 16 h, deactivated with 6.3 % water) to a height of 7 mm and closed with a plug of hexane-washed cotton wool.[116] The column was washed with 5 ml hexane. After that the sample was added to the column and the column was eluated with hexane to a volume of 5.5 ml.

2.7 Determination of PCBs

The quality system of the laboratory during this study was based on standard SFS-EN 45001.[117-118] The laboratory also had previously validated methods for the determination of PCBs in solid and water samples. The laboratory also participates regularly in interlaboratory test comparisons for PCBs in conjunction with the methods quality assurance procedure and the results of such tests have been approved.[40, 85, 123] Because new methods were not developed during this study the methods used were not compared with those presented in the literature. The methods used in this study for the determination of

PCB congeners and total PCB in sediment and soil were accredited (FINAS accreditation) in 2004 and 2005, respectively.[115]

In solid samples concentrations both of PCB congeners (PCB 8, PCB 18, PCB 28, PCB 52, PCB 101, PCB 105, PCB 118, PCB 128, PCB 138, PCB 153, PCB 156, PCB 180 and PCB 187) and of total PCB as Aroclor 1242, Aroclor 1254, Aroclor 1260 and Clophen A 60 were determined. In the case of PCB congeners both the observed concentrations and the limits of quantification (LOQ) are reported in the appendixes. In the case of total PCBs only the observed concentrations as Aroclor 1242, Aroclor 1254 and Aroclor 1260 are reported in the appendixes. The absence of a numerical value in the table means that Aroclor 1242, Aroclor 1254 or Aroclor 1260 was not observed in the sample. In water samples only concentrations of total PCBs as Aroclor 1242, Aroclor 1254 and Aroclor 1260 were determined. Because PCBs were not observed in the samples only LOQs are reported in the appendixes.

Wastepaper and recycled paper products. A twenty gram sub-sample of paper was cut into small pieces. An internal standard (PCB 30, 0.15 µg) was added to the paper sample and the sample was Soxhlet-extracted for 6 hours with a solvent mixed from petroleum spirit, acetone, hexane and diethyl ether (9:5.5:2.5:1 v/v/v/v). The extract was concentrated to approximately 2 ml using a rotary evaporator (bath temperature 35-40 °C) and stream of nitrogen, and then carefully shaken three times with 2 ml of concentrated sulfuric acid. When needed, the extract (some wastepaper samples) was further cleaned by a column of neutral alumina. Before the quantitative analysis by a gas chromatograph equipped with two electron capture detectors the extract was concentrated to 0.5 ml using stream of nitrogen. The LOQs for PCB congeners and total PCBs were 0.001-0.003 mg/kg fw and 0.02 mg/kg fw, respectively.

Wastepaper samples 010, 050, 070, 080 and 060 (Appendix 7, table 2) were analysed in duplicate. In samples 070 and 060 the applicability of the alumina column for sample cleaning was also confirmed. The results proved that alumina column was suitable for the removal of impurities in wastepaper samples. In tissue paper products containing PCBs, the results were confirmed by reanalysis. Soxhlet extraction with an organic solvent mixture was also compared with the EN ISO 15318 method (reflux with ethanolic potassium hydroxide solution).[120] The results did not differ markedly from each other. The EN ISO method, however, was more effective in extracting the impurities from the samples than did the Soxhlet method; this was shown in the chromatograms as tailing peaks. For this reason the need for column chromatography was higher in the case of samples extracted with the EN ISO method.

Pulper stock, recycled fibre pulp and tissue paper reject. An internal standard (PCB 30, 0.3 μg) was added to a seven gram sub-sample of freeze-dried pulper stock, recycled fibre pulp or tissue paper reject and the sample was extracted with an accelerated solvent extractor. The extract was concentrated to approximately 2 ml using a rotary evaporator (bath temperature 35-40 °C) and stream of nitrogen, and then carefully shaken three times with 2 ml of concentrated sulfuric acid. Before the quantitative analysis by a gas chromatograph equipped with two electron capture detectors the extract was concentrated to 0.5 ml using stream of nitrogen. The LOQs for PCB congeners and total PCBs were 0.002-0.007 mg/kg dw and 0.04 mg/kg dw, respectively.

Deinking sludge and wastewater sludge. An internal standard (PCB 30, 0.15-0.3 μg) was added to a sub-sample (2-7 g) of freeze-dried deinking sludge or wastewater sludge and the sample was extracted with an accelerated solvent extractor. The extract was concentrated to approximately 2 ml using a rotary evaporator (bath temperature 35-40 °C)

and stream of nitrogen, and then carefully shaken three times with 2 ml of concentrated sulfuric acid. Before the quantitative analysis by a gas chromatograph equipped with two electron capture detectors the extract was concentrated to 0.5 ml using stream of nitrogen. The LOQs for PCB congeners and total PCBs were 0.002-0.007 mg/kg dw and 0.04 mg/kg dw, respectively.

In some deinking sludge (DI-70 in 1996, DI-80 in 1993 and DI-80 in 1996) and wastewater sludge (biosludge in 1999) samples containing PCBs, accelerated solvent exraction was compared with Soxhlet extraction. The results did not differ from each other.

Samples of material originating from cable channels. An internal standard (PCB 30, 0.2 µg) was added to a sub-sample (5-20 g) of air-dried sample and the sample was extracted with an accelerated solvent extractor. The extract was concentrated to approximately 2 ml using a rotary evaporator (bath temperature 35-40 °C) and stream of nitrogen, and then carefully shaken three times with 2 ml of concentrated sulfuric acid. After that the extract was further cleaned by a column of Kieselgel. Before the quantitative analysis by a gas chromatograph equipped with two electron capture detectors the extract was concentrated to 0.5 ml using stream of nitrogen. The LOQs for PCB congeners and total PCBs were 0.002-0.007 mg/kg dw and 0.05 mg/kg dw, respectively.

Fish. An internal standard (PCB 30, 0.1-0.3 µg) was added to one gram of freeze-dried fish sample (sample from fish dorsal area) and the sample was Soxhlet-extracted for 6 hours with a mixture of petroleum spirit, acetone, hexane and diethyl ether (9:5.5:2.5:1). The extract was concentrated to dryness using a rotary evaporator (bath temperature 35-40 °C) and stream of nitrogen for the gravimetric analysis of fat content. The residue was

dissolved in hexane and then carefully shaken three times with 2 ml of concentrated sulfuric acid. Before the quantitative analysis by a gas chromatograph equipped with two electron capture detectors the extract was concentrated to 0.5 ml using stream of nitrogen. The LOQs for PCB congeners and total PCBs were 0.001-0.003 mg/kg fw and 0.02 mg/kg fw, respectively.

Sediment and soil. An internal standard (PCB 30, 0.2-0.3 μg) was added to a sub-sample (2-10 g) of freeze-dried sediment or air-dried soil and the sample was extracted with ASE. The extract was concentrated to approximately 2 ml using a rotary evaporator (bath temperature 35-40 °C) and stream of nitrogen, and then carefully shaken three times with 2 ml of concentrated sulfuric acid. The elementary sulfur was removed using activated copper. When needed, the extract was further cleaned by a column of Kieselgel (sediment samples) or neutral alumina (soil samples). Before the quantitative analysis by a gas chromatograph equipped with two electron capture detectors the extract was concentrated to 0.5 ml using stream of nitrogen. The LOQs for PCB congeners and total PCBs were 0.002-0.007 mg/kg dw and 0.05 mg/kg dw, respectively. The dry matter content was determined according to standard method SFS 3008 of the Finnish Standards Association.[121]

Sediment samples from the reservoir and point of discharge (Appendix 11, table 3) were reanalysed using larger sample amounts to confirm that Aroclor 1242 was not present in low concentrations in sediment.

Water. An internal standard (PCB 30, 0.1 μg) was added to the water sample (150-500 ml) in a separatory funnel and the sample was extracted 5 minutes with 5 ml of hexane. After that the extract was carefully shaken three times with 2 ml of concentrated sulfuric

acid. Before the quantitative analysis by a gas chromatograph equipped with two electron capture detectors the extract was concentrated to 0.5 ml using stream of nitrogen. LOQ for total PCBs was 0.1 µg/l.

3. RESULTS

3.1 Raw materials

The PCB concentrations in the different wastepaper grades (Appendix 17, table 1 and table 2) exceeded the quantification limit only in archival paper samples (total PCB in lots I and II 1.0 and 0.47 mg/kg, respectively), while the total PCB concentrations in new carbonless copy paper, magazine and newspapers were below 0.02 mg/kg and in shavings below 0.05 mg/kg. Similar results were obtained for wastepaper from households, printing works and offices (Appendix 17, table 3). The very low total PCB concentration was observed in one office sample (total PCB 0.02 mg/kg). The PCB fingerprint in the samples corresponded to the fingerprint from Aroclor 1242. In the raw water (Appendix 17, table 4) used in the Mänttä paper mill PCBs were not observed.

3.2 Paper mill processes

Low concentrations of PCB 118 and PCB 138 (0.002-0.003 mg/kg), but not Aroclors were observed in pulper stocks (Appendix 18) from pulpers using wastepaper from households and printing works as their raw materials. PCBs were not, however, observed in the samples of recycled fibre pulps (Appendix 19, table 1) and in tissue paper reject (Appendix 19, table 2) used in the manufacture of recycled fibre pulps.

PCBs have occasionally observed in sludge samples (total PCB 0.09-1.9 mg/kg) from the deinking of wastepaper from households (Appendix 20, table 1) and wastepaper from printing works (Appendix 20, table 2). The highest concentrations were observed in 1996 and the lowest concentrations in 2002. In the samples from a deinking using wastepaper from offices (Appendix 20, table 3), PCBs were observed in all samples excluding that from the year 2000. The total PCB concentrations in the samples, however, fell from 1.3 mg/kg to 0.14 mg/kg between 1993 and 2002. The PCB fingerprint in deinking sludge corresponded to the fingerprint from Aroclor 1242.

For comparison the total PCB concentration in deinking sludges from the Nokia paper mill (Appendix 20, table 4) was below 0.08 mg/kg in 2001 and 3.4 mg/kg in 2002. The PCB fingerprint in the comparison sample corresponded to the fingerprint from Aroclor 1242.

PCB concentrations in process waters (incoming water, cleaned water and reject) from deinking departments (Appendix 21) in the Mänttä paper mill were below 0.2-0.3 µg/l.

PCB concentrations in samples which were taken in the close proximity to electrical equipment (Appendix 22) in the Mänttä paper mill were determined in 2003. In the surface material sample from the cable channel below the transformer the total PCB content was 2.2 mg/kg and in the sand sample from the cable channel 0.34 mg/kg. The observed PCB content in the first sample was a mixture of Aroclor 1242 and Aroclor 1260 (2.1 and 0.09 mg/kg, respectively) and in the second sample a mixture of Aroclor 1242 and Aroclor 1260 (0.21 and 0.13 mg/kg, respectively).

3.3 Wastewater treatment plant

PCB concentrations in municipal and industrial wastewater (Appendix 23, table 1 and table 2) and in treated water (Appendix 23, table 3) in the treatment plant of the Mänttä paper mill were below 0.3 µg/l in 2000 and below 0.2 µg/l in 2002. PCBs were not observed in wastewater (Appendix 23, table 4) from mechanical sedimentation, primary sedimentation, sludge thickener, intermediate sedimentation or aeration (stage II). LOQs varied between 0.2-0.3 µg/l.

PCBs were present in every biosludge sample from a sludge thickener of a wastewater treatment plant (Appendix 24, table 1 and table 2). The total PCB concentrations in those samples, however, fell from 0.56 mg/kg to 0.13 mg/kg between 1993 and 2004. PCBs were also observed (Appendix 24, table 3 and table 4) in all the samples taken from various parts of the same wastewater treatment plant (total PCB 0.08-1.7 mg/kg), excluding the sample from secondary sedimentation in 2002. The amount of the sludge from secondary sedimentation was too low for the determination of PCBs. The PCB fingerprint in wastewater sludges corresponded to the fingerprint from Aroclor 1242 (Figure 5). The sludge sample from primary sedimentation in 2004 (Appendix 24, table 4) also contained the higher chlorinated PCB congeners typical of Aroclor 1254 and Aroclor 1260. The fingerprints of those Aroclors were not however observed in the sample. Municipal wastewater from Mänttä enters the mill's primary sedimentation tank, (Figure 2) so it is in theory possible that the higher chlorinated congeners originate in the municipal wastewater.

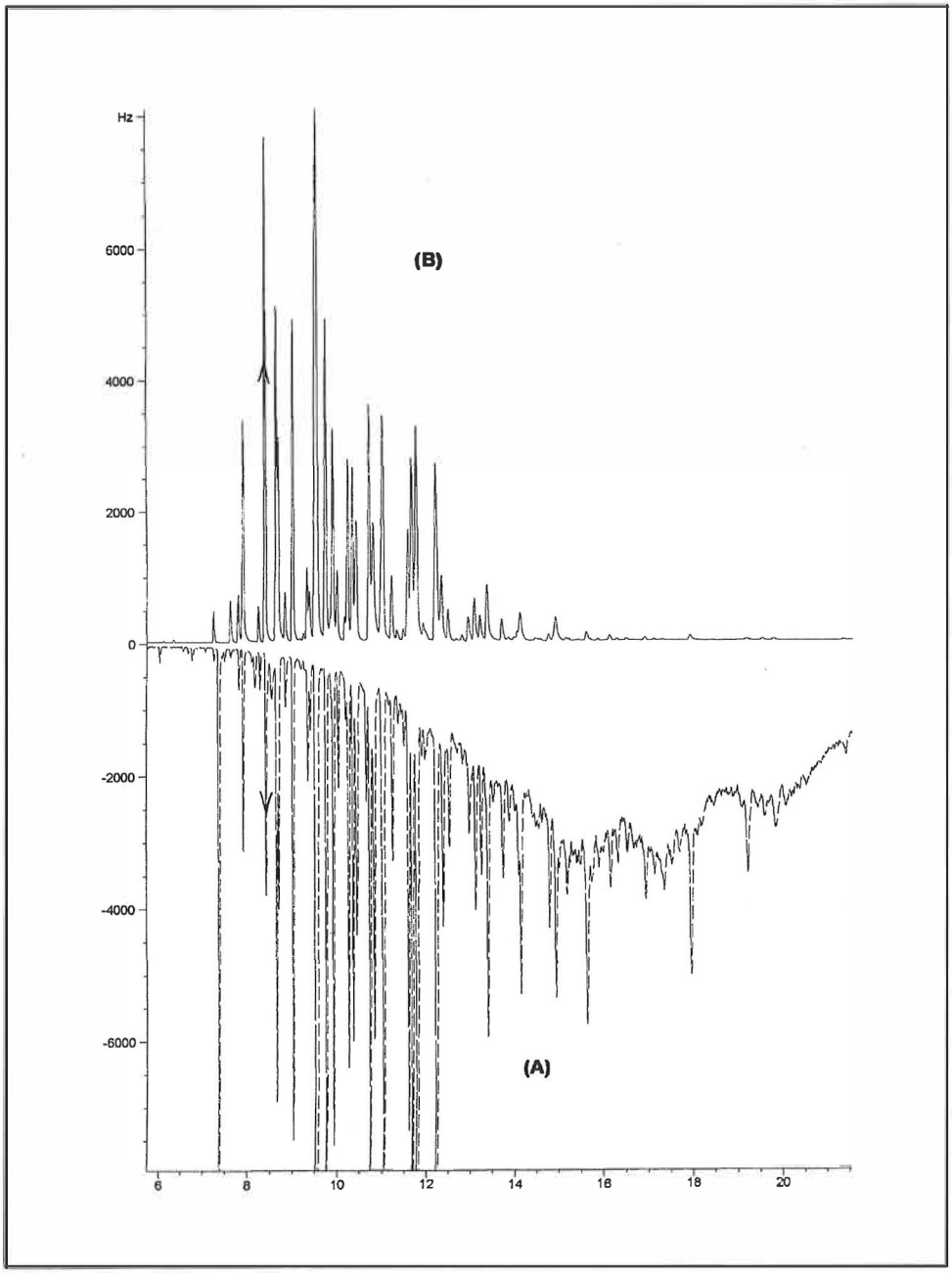


Figure 5. GC/ECD chromatogram of a wastewater sludge extract containing PCB after accelerated solvent extraction (A) and an Aroclor 1242 reference mixture solution (B). Time scale in min.

3.4 Area around the paper mill

Total PCB concentrations (Appendix 25) in pike (*Esox lucius*) caught in Lake Melasjärvi, a small lake basin downstream from Mänttä mill were 0.02-0.05 mg/kg in four samples and < 0.02 mg/kg in one sample. It was notable that the PCB fingerprint in the pike corresponded to the fingerprint from Aroclor 1260 and Clophen A 60. The quantitative part of the analytical method used for the determination of PCBs in fish was validated using Clophen A 60. For this reason the total PCB concentrations were calculated as Clophen A 60. Since the industrial use, composition and fingerprints of Clophen A 60 and Aroclor 1260 do not differ from each other, the use of Clophen A 60 and Aroclor 1260 in fingerprint considerations yield the same final result.

Total PCB concentrations (Appendix 26) remained low (< 0.02 mg/kg) in fish caught in Lake Näsijärvi, Lake Pyhäjärvi, Lake Kulovesi and Lake Iidesjärvi except, in one pike sample (0.07 mg/kg) from Lake Kulovesi. The PCB fingerprint in the sample corresponded to the fingerprint from commercial Clophen A 60 and Aroclor 1260.

Total PCB concentrations in sediment profiles (Appendix 27, tables 1-12) from lake basins upstream and downstream (Figure 1) from the Mänttä mill were below 0.10-0.15 mg/kg, except in two samples (Appendix 27, table 4 and table 10) one from Mäntänlahti (total PCB 0.18-0.22 mg/kg) just below the paper mill and the other from Lake Melasjärvi (total PCB 0.23 mg/kg). According to the dating results the discharge in Lake Melasjärvi happened in the early 1950s.[122] It was notable that the PCB fingerprint in the sediments did not correspond to the fingerprint from Aroclor 1242, which was observed in the processes of the paper mill, but corresponded to the fingerprint from Aroclor 1260, which has been used for, example, as a dielectric fluid in transformers.[3]

The observations of the foregoing pilot study were confirmed by taking surface sediment samples (Appendix 28, tables 1-4) from four sampling points downstream from the Mänttä mill. Total PCB concentrations exceeded the quantification limit only in samples from Mäntänlahti (total PCB 0.12-0.23 mg/kg). Traces of PCB 138 and PCB 180 were also observed in samples from Savonselkä, Aittoselkä and Paloselkä. The PCB fingerprint in the surface sediments corresponded to that of Aroclor 1260, as in the pilot study.

PCBs were also observed at the industrial site of Mänttä mill in sediment samples (Appendix 29, table 1) from the reservoir and point of discharge (total PCB 0.28 and 0.24 mg/kg, respectively), but not in the sample from Koskelanlampi. The PCB fingerprint in the samples corresponded to the fingerprint from Aroclor 1260, as in the case of Mäntänlahti. Sediment samples (Appendix 29, table 2) from sites downstream from landfills and from Lake Kuorevesi (reference sample) and the water sample (Appendix 29, table 3) from Vuohijoki downstream from a former municipal landfill did not contain PCBs.

In the soil sample (Figure 4) from immediately in front of a former acid plant of Mänttä mill were observed PCB concentrations of 0.74 mg/kg.[94] After this observation, PCBs were determined in another sample, which was taken from a greater depth at the same sampling point (Appendix 30). PCBs were also observed in this sample (total PCB 0.08 mg/kg). The PCB fingerprint from the samples corresponded to Aroclor 1260. Since PCBs were found in the soil samples around the mill, further studies were conducted in March 2003. PCBs were observed in the soil samples (Appendix 30) from the former acid plant (total PCB 0.05 mg/kg) and from the side of a former outfall sewer (total PCB 0.06 mg/kg), and in a sediment sample from the former point of discharge (total PCB 0.06 mg/kg). In the soil sample from the coalfield PCBs were not observed. The PCB

fingerprint in the soil (Figure 6) and sediment (Figure 7) corresponded to the fingerprint from Aroclor 1260. Kolehmainen[94] estimated that the size of the area highly polluted by PCBs and heavy metals was about 700 m^2. The total volume of polluted soil was estimated to be between 1000-1500 m^3. The source of the release of Aroclor 1260, which has been used, for example, as a dielectric fluid in transformers[3] is at present, however, unknown.

Total PCB concentrations in sediment (Appendix 31, table 1) from Lukkilanlahti downstream from the paper mill operated by Georgia-Pacific Finland Ltd in Nokia and from Lake Pyhäjärvi (Eden) downstream from the region of Tampere were below 0.05 mg/kg. PCBs were found (total PCB 0.05 mg/kg) in sediment at the depth of 25-30 cm (Appendix 31, table 3) from a lake basin in Lake Päijänne just downstream from the paper mill operated by UPM-Kymmene Corporation in Kaipola. Traces of PCBs were also detected in sediment at depths of 15-20 cm and 20-25 cm, but the total PCB concentrations were below 0.05 mg/kg. In sediment at depths of 0-5 cm, 5-10 cm and 10-15 cm (Appendix 31, table 2) PCBs were not observed. It was notable that the PCB fingerprint in these sediments corresponded to the fingerprint from Aroclor 1242, which is typically observed in paper mills using wastepaper as their raw material.[89]

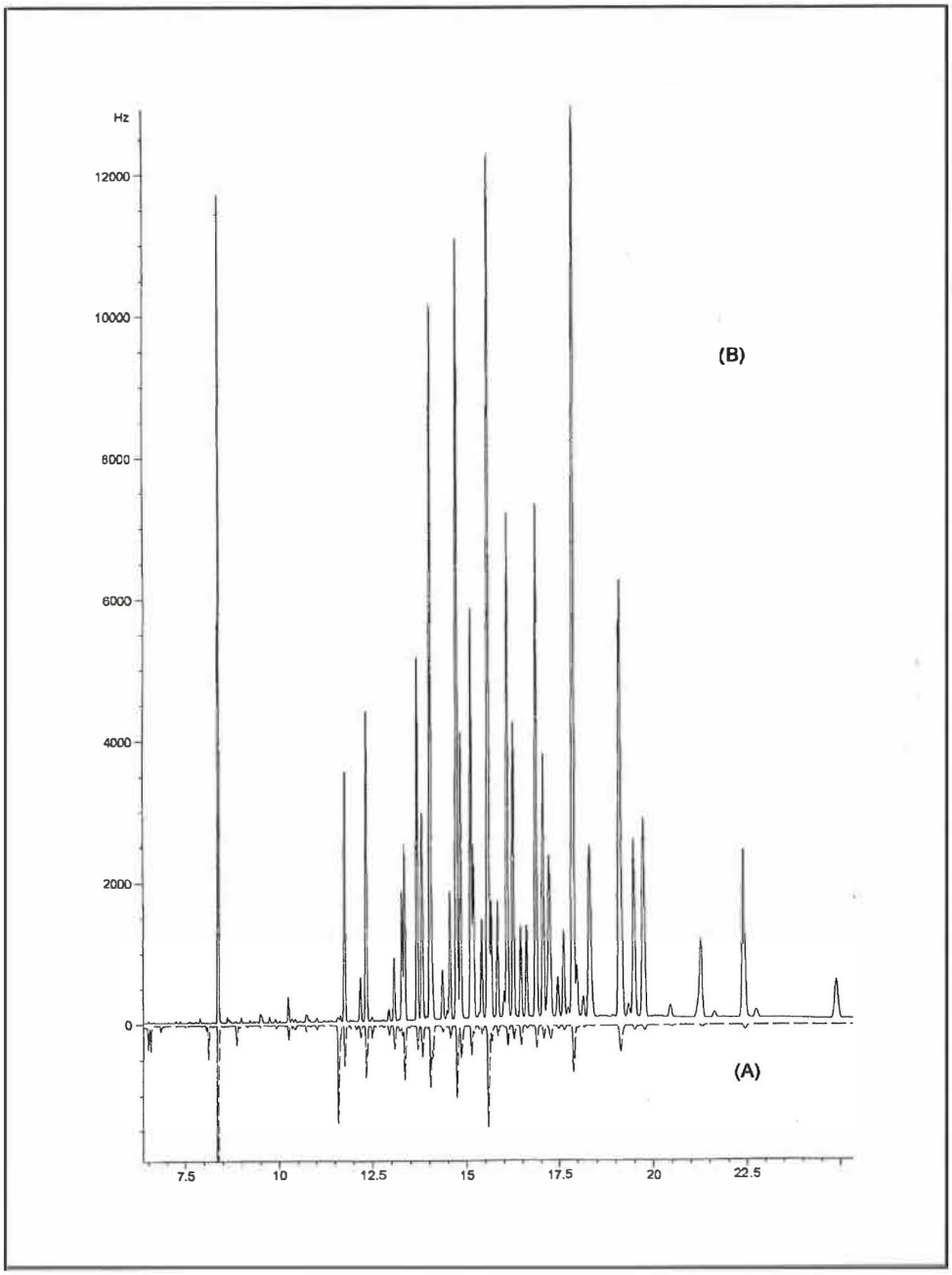


Figure 6. GC/ECD chromatogram of a soil extract containing PCB after accelerated solvent extraction (A) and an Aroclor 1260 reference mixture solution (B). Time scale in min.

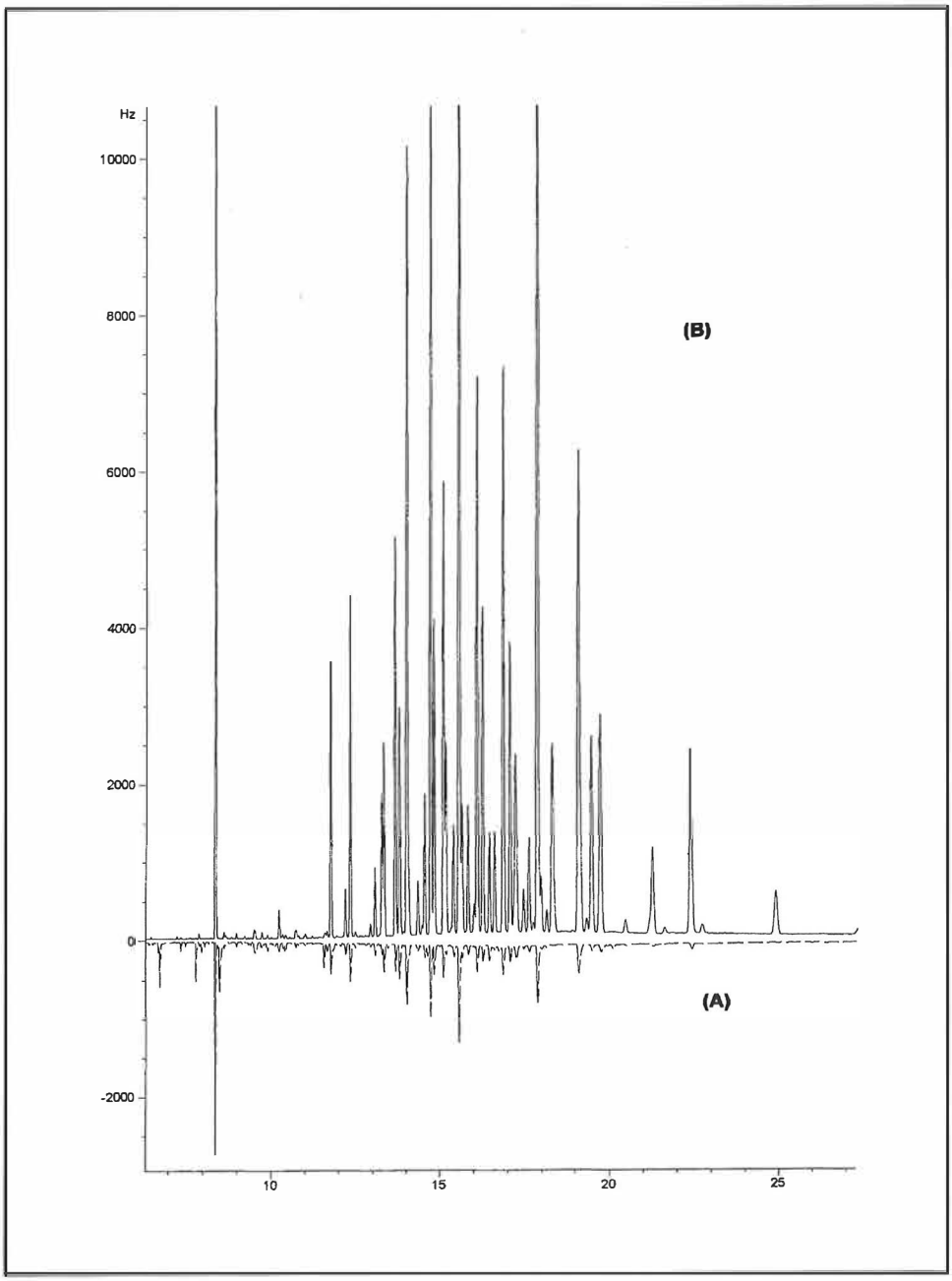


Figure 7. GC/ECD chromatogram of a sediment extract containing PCB after accelerated solvent extraction (A) and an Aroclor 1260 reference mixture solution (B). Time scale in min.

In the other lakes studied (Appendix 32 tablel and table 2), PCBs were found only in the the bay of Viinikanlahti in Pyhäjärvi at a concentration of 6.9 mg/kg; elsewhere the concentrations were below 0.10 mg/kg. The result for Lake Pyhäjärvi was confirmed in 2001 by taking a sediment sample (Appendix 32, table 3) in the bay of Viinikanlahti from immediately in front of a sewer of a former capacitor factory. High concentrations of PCBs (total PCB 86 mg/kg) were observed in the sample. The PCB fingerprint in the samples corresponded to the fingerprint from Aroclor 1242, which was earlier used in the manufacture of capacitors.[123-124]

3.5 Recycled paper products

Low concentrations of PCBs were observed (Appendix 33, table 1) in German and Swedish hand towel sheets (0.07 and 0.02 mg/kg, respectively), but no PCBs were found in the Finnish sheet sample. No PCBs were found in hand towel rolls (Appendix 33, table 2), kitchen towels (Appendix 33, table 3 and table 4) and handkerchiefs (Appendix 33 table 5). The PCB fingerprint in the hand towel sheets corresponded to the fingerprint from Aroclor 1242.

The majority of the toilet tissue samples (Appendix 34, tables 1-3) did not contain PCBs. Aroclor 1242 was, however, found in low concentration (0.02 mg/kg) in one Finnish product (Appendix 34, table 2) and slightly higher concentrations (0.07-0.14 mg/kg) in one product whose country of manufacture was unknown (Appendix 34, table 1). Product A (country of manufacture unknown) and product C (a Polish product) also contained the higher chlorinated PCB congeners typical of Aroclor 1254 used earlier in inks.[3, 125] The fingerprint of Aroclor 1254 was, however, not observed in the samples. PCBs have also

been produced in Eastern Europe, but their composition is quite different from that of Aroclors.[126] The use of such PCBs may also be the reason for the different PCB fingerprint in the Polish sample.

4. DISCUSSION

Rather high concentrations of Aroclor 1242 (1.0 and 0.47 mg/kg) continued to be observed in 2000 in the Mänttä mill in wastepaper (Table 4.1) from archives used as raw material in the production of recycled fibre pulp. The archival paper lots in question contained large amounts of old carbonless copy paper to which Aroclor 1242 had been added in connection with the manufacturing process. The concentrations of PCBs were however notably lower than the highest PCB concentrations in carbonless copy paper (Table 4.1) observed in the early 1970s in Japan.[6] Wastepaper from households, printing works and offices only occasionally contained Aroclor 1242 and the observed concentrations of PCBs were very low (0.02 mg/kg). In magazins, newspapers and new carbonless copy paper lots Aroclor 1242 was not observed. The PCB concentrations in magazins and newspapers (Table 4.1) in this study did not essentially differ from the observations (0.01-0.02 mg/kg) of Welling,[80] but differed from those (1.38 mg/kg) of Shahied *et al.*[79] in newsprint.

The analytical data from the deinking departments of the Mänttä mill proved that the deinking process (Table 4.1) was an effective sink for Aroclor 1242 and the resulting pulper stock, recycled fibre pulp and tissue paper reject did not contain PCBs. The change in the PCB concentrations in pulper stocks is noticeable as the concentrations of Aroclor 1242 in these stocks ranged between 0.23 and 0.31 mg/kg yet in 1990.[82] The concentrations of Aroclor 1242 in deinking sludge from pulper DI-60 between 1993 and 2002 were low and the results did not differ from the observations (0.20 mg/kg) of Welling.[82] In deinking sludges from pulpers DI-70 and DI-80, Aroclor 1242 concentrations decreased over the same period. The Aroclor 1242 concentrations in sludge from pulper DI-80 (0.14 mg/kg) in 2002 were about 11 % of the highest PCB

concentrations (1.3 mg/kg) observed in the 1990s. The PCB concentrations in deinking sludge in the Mänttä mill in the early 1990s did not differ from those reported by Raitio[85-86] and Ettala[83] (1.1-1.4 and 2.1 mg/kg, respectively), but were lower than the highest PCB concentrations (8.8 mg/kg) which were observed in Katrinefors in 1991.[84]

Because the deinking sludge containing Aroclor 1242 had been landfilled, leaching of PCBs into the environment from the landfills is a possibility. However analytical data from sediment and water samples downstream from such landfills did not show leaching of PCBs from landfills. On the basis of the Aroclor 1242 concentrations in deinking sludge from pulper DI-80 in the years 1993, 1996, 1999 and 2002 (1.3, 1.1, 1.3 and 0.14 mg/kg, respectively) and the sludge amounts to landfilled in the same years (15600, 22200, 23500 and 26800 t/a, respectively) it can be estimated the amounts of PCBs landfilled in 1993, 1996, 1999 and 2002 were 20, 24, 31 and 3.8 kg/a, respectively. In these calculations the amount of landfilled deinking sludge in 2001 was used instead of the value in 2002 as the Finnish Forest Industries Federation stopped compiling statistics on the amounts of landfilled deinking sludge in 2001. Should be noted that due to the limited data, the calculations give only approximate values for PCB contents in landfills near the Mänttä paper mill.

The analytical data from the wastewater treatment plant showed that Aroclor 1242 appeared in sludge from various components of the plant. The concentrations of Aroclor 1242 in biosludge in the thickener (Table 4.1) decreased between 1990 and 2004. The Aroclor 1242 concentration of biosludge (0.13 mg/kg) in 2004 was about 17 % of the PCB concentration (0.78 mg/kg) observed in the earlier study in 1990.[82] The possibility of recycling the wastewater sludge in the plant enabled the effective recovery of sludge containing Aroclor 1242 under normal operating conditions. In exceptional cases it is

possible that Aroclor 1242 passed through the treatment plant to the recipient, but the data from the sediment samples showed that the Aroclor 1242 concentration was very low. The highest PCB concentration measured in wastewater sludge from the secondary sedimentation stage of the treatment plant was 0.20 mg/kg. The average discharge of total suspended solids from the treatment plant in 1993-2004 was about 87 t/a. The maximum amount of PCBs discharged into recipient is thus 0.017 kg/a. The major fraction of the recovered sludge in Mänttä mill has been utilized in energy for the paper mill's power plant since 1992. A small fraction of the waste has also been utilized in the closing of landfill sites.

Since PCBs bind effectively to solid particles, the municipal and industrial wastewaters, the final effluent and wastewaters from various components of the wastewater treatment plant did not contain PCBs. Similar results for PCB levels in effluents from eleven deinking mills producing mainly fine paper or tissue paper were reported by Miner and Berger.[87] PCB concentrations were determined from 612 samples in 1990-1994. Approximately only one percent (9 samples) contained measurable levels of PCBs (Aroclors). None of the measured values exceeded 1 µg/l, and all but one were below 0.5 µg/l.

PCB concentrations in pike (Table 4.1) from Lake Melasjärvi downstream from the Mänttä mill were extremely low (0.02-0.05 mg/kg) and the concentrations did not differ from those found in the Tampere and Nokia regions. The PCB fingerprint in pike corresponded to the fingerprint from commercial Clophen A 60/Aroclor 1260, which has been used, for example, as a dielectric fluid in transformers, and not to that from Aroclor 1242, which was observed in the Mänttä mill. The PCB concentrations in fish from Lake Melasjärvi ranged between 1-2.5 % of the acceptable maximum (2.0 mg/kg) laid down by

the Ministry of Trade and Industy in 1996.[127] Larsson *et al.*[89] determined also concentrations of PCB in pike downstream from a paper mill using wastepaper as its raw material. The concentrations (0.85-2.2 mg/kg) were about 98 % higher than in the case of Melasjärvi. The most interesting result, however, was that the PCB fingerprint in pike corresponded to the fingerprint from commercial Aroclor 1242, which was also observed in the paper mill. Welling[129] and Kärki[130] observed both Aroclor 1242 (0.48-0.75 mg/kg fat) and Aroclor 1260 (0.52-0.55 mg/kg fat) in incubated mussels downstream from a former capacitor factory in Tampere. This was apparently the first time Aroclor 1242 in mussels has been reported.

Aroclor 1260 was observed in sediments (0.12-0.23 mg/kg) just downstream from the paper mill in Mänttä (Table 4.1) and in soil at several sampling points on the former industrial site of Mänttä mill. Aroclor 1260 was not observed in sediments upstream from the paper mill or further downstream from the paper mill except at one depth (24-26 cm) in Lake Melasjärvi (0.23 mg/kg). The source of release of Aroclor 1260, which has been used for example as a dielectric fluid in transformers[3] is, however, currently unknown. Larsson *et al.*[89] also determined the concentrations of PCBs in sediment (14-100 mg/kg) downstream from a paper mill using wastepaper as its raw material. The PCB fingerprint (Aroclor 1242), however, differed from that (Aroclor 1260) observed in Mäntänlahti. The concentrations in sediment (14-100 mg/kg) were about 99 % higher than in Mäntänlahti. The most interesting of the sediment results obtained by Larsson *et al.*, however, was that sediment contaminated with PCBs can also be a significant source of PCBs in river systems.

The highest PCB concentration (Table 4.1) measured in the Tiirinselkä basin in Lake Päijänne downstream from the paper mill in Kaipola (0.05 mg/kg) was about 0.05 % of

the highest concentration reported by Larsson *et al.*[89] In both cases the PCB fingerprint corresponded to Aroclor 1242. PCBs were also determined from lake sites downstream from a former capacitor factory (6.9 86 mg/kg) in Tampere. The fingerprint of the samples was also Aroclor 1242.

The results of this study proved that Aroclor 1242 was observed in the manufacturing processes of Mänttä mill, but not in the environs of Mänttä mill. In the case of Mänttä mill the PCB fingerprint observed in fish and sediment was Aroclor 1260. Aroclor 1242 was, however, observed in sediment downstream from the Kaipola mill and downstream from a former capacitor factory in Tampere. The fingerprint of Aroclor 1242, observed in those sediments, was as stable and characteristic as the fingerprint of Aroclor 1260 observed in the sediments in Mäntänlahti. For this reason it was possible to use the fingerprints of different Aroclors to trace the possible sources of PCBs. The results by Larsson *et al.*,[89] Welling[129] and Kärki[130] demonstrated that it is possible to observe the fingerprint of Aroclor 1242 in fish and mussels if Aroclor 1242 is the source of PCBs in the watercourse. Larsson *et al.*[89] also showed that sediment contaminated with PCBs can act as a significant source of PCBs in river systems. On the basis of these results it can be concluded that the production of recycled fibre pulps and recycled paper products are not the main source of increasing PCB concentrations in mussels incubated in the vicinity of Mänttä mill. The most probable source is Aroclor 1260, which was found in sediment just downstream from the Mänttä mill.

Low concentrations of Aroclor 1242 was still occasionally observed in recycled paper products. The highest concentrations (Table 4.1) in toilet tissue and paper towel were notably lower than in the earlier studies by Williams and Benoit[95] and de Voogt *et al.*[7] The concentrations of Aroclor 1242 in toilet tissue and paper towel were also lower than the

concentrations measured in the earlier studies by Storr-Hansen and Rastogi[12] and Welling *et al.*[96] The levels of PCBs in toilet tissue samples from Central Europe and Finland did not differ from each other unlike either, in the earlier study by Welling *et al.*[96] All the Aroclor 1242 concentrations in recycled paper products were also clearly under the acceptable maximum (2 mg/kg) laid down by the EU Commission in 2001.[128]

Table 4.1 PCB concentrations in manufacturing processes and environs of paper mills, and in recycled paper products.[6, 7, 12, 79-80, 82-86, 89, 92, 93, 95-96]

Sample matrix	Earlier results mg/kg	Results of this study mg/kg
Old Carbonless copy paper	200-65 000	0.47-1.0
New Carbonless copy paper		< 0.02
Magazine	0.01	< 0.02
Newspaper	0.02-1.38	< 0.02
Pulper stock, Mänttä	0.23-0.31	< 0.04
Deinking sludge	1.1-8.8	
Deinking sludge, Mänttä	0.20-0.80	< 0.04-1.9
Deinking sludge, Nokia		< 0.04-3.4
Biosludge, Mänttä	0.78	0.13-0.56
Fish, Järnsjö	0.85-2.2	
Fish, Kernaalanjärvi	0.20-1.1	
Fish, Melasjärvi, Mänttä		0.02-0.05
Sediment, Järnsjö	14-100	
Sediment, Kernaalanjärvi	0.5-11	
Sediment, Mäntänlahti		0.12-0.23
Sediment, Kaipola		< 0.05-0.05
Paper towel	0.02-2.9	< 0.02-0.07
Toilet tissue	0.02-21	< 0.02-0.14

5. SUMMARY AND CONCLUSIONS

The aim of the present study was to analyse the occurrence of PCBs in papermaking processes, in recycled paper products and in the close vicinity of paper mills using wastepaper as their raw material. Over 200 samples were analysed to resolve the sources and pathways of PCBs in the processes and environs of paper mills. The majority of the samples were from the Mänttä mill, but samples were also taken from Nokia and Kaipola mills. Recycled paper product samples were also taken from paper mills in Germany, Poland and Sweden. Accelerated solvent extraction and Soxhlet extraction were used to extract PCBs from solid samples and liquid-liquid extraction to extract PCBs from water samples. Concentrations of PCB congeners and concentrations of total PCBs as Aroclor 1242, Aroclor 1254, Aroclor 1260 and Clophen A 60 were determined by a gas chromatograph equipped with two electron capture detectors. PCBs were observed in the paper mills (Aroclor 1242), in recycled paper products (Aroclor 1242) and in the vicinity of the paper mills (Aroclor 1242 and Aroclor 1260).

The present study showed that

(i) Aroclor 1242 originating in old carbonless copy paper were occasionally found in the raw materials, processes and wastewater treatment plant of the paper mills. The concentrations were clearly lower than those measured in the earlier studies conducted in the 1980s and 1990s. New waste treatment techniques will probably be needed in the near future, especially in the case of deinking sludge, owing to the new environmental legislation with lower threshold values for PCBs

(ii) PCB concentrations in fish downstream from the recycled paper mills were so low that on PCB grounds it was not necessary limit the human consumption of

fish. In the case of Mänttä new studies on the concentrations of PCBs in fish are not required.

(iii) PCBs were observed in sediments, but the discharges were local and were situated just downstream from the paper mills. In the case of the Mänttä mill, it was notable that the PCB fingerprint from the sediment and soil samples did not correspond to the fingerprint from Aroclor 1242, which was observed in the paper mill, but in fact corresponded to the fingerprint from Aroclor 1260, which has been used, for example, as a dielectric fluid in transformers. Further research on the former site of Mänttä mill is probably needed because the source of Aroclor 1260 has not yet been determined.

(iv) The recycled paper products were usually clean, and did not contain PCBs. The concentrations of Aroclor 1242 occasionally found were so low that restrictions on the use of these products are not required. All the concentrations in recycled paper products also were clearly under the acceptable maximum (2 mg/kg) laid down by the E U Commission in 2001. Thus further research on this topic is not needed.

(v) Aroclor 1242 originating in recycled paper production was not the source of the increasing PCB concentrations found in incubated mussels downstream from the Mänttä mill. The most probable source was Aroclor 1260, which was found in sediment just downstream from the Mänttä mill.

(vi) The fingerprints of Aroclor 1242 and Aroclor 1260 are stable in sediments in Finland and hence they can be used to trace the possible sources of PCBs.

6. REFERENCES

1. S. Tanabe, PCB problems in the future: Foresight from current knowledge, *Environ. Pollut.* **1988**, *50*, 5-28.
2. V. Lang, Polychlorinated biphenyls in the environment, *J. Chromatogr.* **1992**, *595*, 1-43.
3. O. Hutzinger, S. Safe and V. Zitko, *The Chemistry of PCB's*, CRC Press, Cleveland, Ohio, USA, 1974.
4. J. Borja, D.M. Taleon, J. Auresenia and S. Gallardo, Polychlorinated biphenyls and their biodegradation, *Process Biochem.* **2005**, *40*, 1999-2013.
5. K.J. Walter and J.J. Zambrano, PCBs and wastepaper, *Industrial Wastes* **1981**, *27*, 12-15.
6. Y. Masuda, R. Kagawa and M. Kuratsune, Polychlorinated biphenyls in carbonless copying paper, *Nature (London)* **1972**, *237*, 41-42.
7. P. de Voogt, J.C. Klamer and U.A. Th. Brinkman, Identification and quantification of polychlorinated biphenyls in paper and paper board using fused silica capillary gas chromatography, *Bull. Environ. Contam. Toxicol.* **1984**, *32*, 45-52.
8. G. Dupont, C. Delteil, V. Camel and A. Bermond, The determination of polychlorinated biphenyls in municipal sewage sludges using microwave-assisted ectraction and gas chromatography-mass spectrometry, *Analyst* **1999**, *124*, 453-458.
9. E. Priha, S. Hellman and J. Sorvari, PCB contamination from polysulphide sealants in residential areas - exposure and risk assesment, *Chemosphere* **2005**, *59*, 537-543.
10. U. Hamm, B. Bobek and L. Göttsching, Material balancing of undesirable organic substances in recovered paper processing, *ATIP* **2002**, *56*, 18, 24-26, 28-30.
11. S. Jensen, Report of a new chemical hazard, *New Sci.* **1966**, *32*, 612.

12. E. Storr-Hansen and S.C. Rastogi, Polychlorinated biphenyls and heavy metal levels in recycled paper for household use, *Bull. Environ. Contam. Toxicol.* **1988**, *40*, 451-456.

13. O. Zuloaga, N. Etxebarria, L. A. Fernandez and J.M. Madariaga, Optimisation and comparison of microwave-assisted extraction and Soxhlet extraction for the determination of polychlorinated biphenyls in soil samples using an experimental design approach, *Talanta* **1999**, *50*, 345-357.

14. I. Moret, R. Piazza, M. Benedetti, A. Gambano, C. Barbante and P. Cescon, Determination of polychlorobiphenyls in Venice Lagoon sediments, *Chemosphere* **2001**, *43*, 559-565.

15. M. Numata, T. Yarita, Y. Aoyagi, M. Yamazaki and A. Takatsu, Investigation of saponification for determination of polychlorinated biphenyls in marine sediments, *Chemosphere* **2005**, *58*, 865-875.

16. M.D. Luque de Castro and L.E. Garcia-Ayuso, Soxhlet extraction of solid materials: an outdated technique with a promising innovative future, *Anal. Chim. Acta* **1998**, *369*, 1-10.

17. S. Sporring, S. Bøwadt, B. Svensmark and E. Björklund, Comprehensive comparison of classic Soxhlet extraction with Soxtec extraction, ultrasonication extraction, supercritical fluid extraction, microwave assisted extraction and accelerated solvent extraction for the determination of polychlorinated biphenyls in soil, *J. Chromatogr. A* **2005**, *1090*, 1-9.

18. J.L. Luque-Garcia and M.D. Luque de Castro, Ultrasound: a powerfull tool for leaching, *TrAC, Trends Anal. Chem.* **2003**, *22*, 41-47.

19. S. Bøwadt and S.B. Hawthorne, Supercritical fluid extraction in environmental analysis, *J. Chromatogr. A* **1995**, *703*, 549-571.

20. V. Lopez-Avila, Sample preparation for environmental analysis, *Crit. Rev. Anal. Chem.* **1999**, *29*, 195-230.

21. J.R. Dean and G. Xiong, Extraction of organic pollutants from environmental matrices: selection of extraction technique, *TrAC, Trends Anal. Chem.* **2000**, *19*, 553-564.

22. C. Turner, C.S. Eskilsson and E. Björklund, Collection in analytical-scale supercritical fluid extractrion, *J. Chromatogr. A* **2002**, *947*, 1-22.

23. C.S. Eskilsson and E. Björklund, Analytical-scale microwave-assisted ectraction, *J. Chromatogr. A* **2000**, *902*, 227-250.

24. E. Björklund, T. Nilsson and S. Bøwadt, Pressurised liquid extraction of persistent organic pollutants in environmental analysis, *TrAC, Trends Anal. Chem.* **2000**, *19*, 434-445.

25. A. Hubert, K.-D. Wenzel, W. Engelwald and G. Schüürmann, Accelerated solvent extraction - more efficient extraction of POPs and PAHs from real contaminated plant and soil samples, *Rev. Anal. Chem.* **2001**, *20*, 101-144.

26. L. Ramos, E.M. Kristenson and U.A.Th. Brinkman, Current use of pressurised liquid extraction and subcritical water extraction in environmental analysis, *J. Chromatogr. A* **2002**, *975*, 3-29.

27. R. Carabias-Martinez, E. Rodriguez-Gonzalo, P. Revilla-Ruiz and J. Hernandez-Mendez, Pressurized liquid extraction in the analysis of food and biological samples, *J. Chromatogr. A* **2005**, *1089*, 1-17.

28. J. Paasivirta, K. Mäntykoski, R. Paukku, T. Piilola, H. Vihonen, J. Särkkä and K. Granberg, PCB in the sediments of the Lake Jyväsjärvi, *Aqua Fennica* **1986**, *16*, 17-23.

29. D. Martens, M, Gfrerer, T. Wenzl, A. Zhang, B.M. Gawlik, K.-W. Schramm, E. Lankmayr and A. Kettrup, Comparison of different extraction techniques for the determination of polychlorinated organic compounds in sediment, *Anal. Bioanal. Chem.* **2002**, *372*, 562-568.

30. E.M. Kristenson, H.C. Neidig, R.J.J. Vreuls and U.A.TH. Brinkman, Fast miniaturised sample preparation for the screening and comprehensive two-dimensional gas chromatographic determination of polychlorinated biphenyls in sludge, *J. Sep. Sci.* **2005**, *28*, 1121-1128.

31. J.W. Cochran and G.M. Frame, Recent developments in the high-resolution gas chromatography of polychlorinated biphenyls, *J. Chromatogr. A* **1999**, *843*, 323-368.

32. G. Castello, Retention index systems: alternatives to the *n*-alkanes as calibration standards, *J. Chromatogr. A* **1999**, *842*, 51-64.

33. C. Bandh, E. Björklund, L. Mathiasson, C. Näf and Y. Zebühr, Comparison of accelerated solvent extraction and Soxhlet extraction for the determination of PCBs in Baltic sea sediments, *Environ. Sci. Technol.* **2000**, *34*, 4995-5000.

34. M.L. Hattula, Some aspects of the recovery of chlorinated residues (DDT-type compounds and PCB) from fish tissue by using different extraction methods, *Bull. Environ. Contam. Toxicol.* **1974**, *12*, 301-307.

35. J. Axelman and D. Broman, Inventories and fluxes of polychlorinated biphenyls from a contaminated industrial site, *Environ. Toxicol. Chem.* **1999**, *18*, 1871-1881.

36. E.L. Randall, Extractor assembly, *US Pat.*, 3,798,133, 1974. *Chem. Abstr.* 80:135281.

37. M.S. Rahman, M. Parreno, R. Bossi, A.B. Paya-Perez and B. Larsen, Chlorobiphenyls in sewage sludge; comparison of extraction methods, *Fresenius J. Anal. Chem.* **1998**, *360*, 556-563.

38. F.M. Dunnivant and A.W. Elzerman, Determination of polychlorinated biphenyls in sediments, using sonication extraction and capillary column gas chromatography-electron capture detection with internal standard calibration, *J. Assoc. Off. Anal. Chem.*, **1988**, *71*, 551-556.

39. K.H. Karstensen, Nordic guidelines for chemical analysis of contaminated soil samples, NT Technical Report 329, Nordtest, 1996, 159 pp.

40. K.H. Karstensen, O. Ringstad, I. Rustad, K. Kalevi, K Jørgensen, K. Nylund, T. Alsberg, K, Olafsdottir, O. Heidenstam and H. Solberg, Methods for chemical analysis of contaminated soil samples - tests of their reproducibilility between Nordic laboratories, *Talanta* **1998**, *46*, 423-437.

41. E. Stahl and W. Schilz, Extraction with supercritical gases in coupling with thin-layer chromatography, *Fresenius' Z. Anal. Chem.* **1976**, *280*, 99-104.

42. S.B. Hawthorne and D.J. Miller, Extraction and recovery of organic pollutants from environmental solids and Tenax-GC using supercritical CO_2, *J. Chromatogr. Sci.*, **1986**, *24*, 258-264.

43. J.D. Berset and R. Holzer, Quantitative determination of polycyclic aromatic hydrocarbons, polychlorinated biphenyls and organochlorine pesticides in sewage sludges using supercritical fluid extraction and mass spectrometric detection, *J. Chromatogr. A* **1999**, *852*, 545-558.

44. R.C. Hale and M.O. Gaylor, Determination of PCBs in fish tissues using supercritical fluid extraction, *Environ. Sci. Technol.* **1995**, *29*, 1043-1047.

45. M.M. Schantz, S. Bøwadt, B.A. Benner Jr., S.A. Wise and S.B. Hawthorne, Comparison of supercritical fluid extraction and Soxhlet extraction for the determination of polychlorinated biphenyls in environmental matrix standard reference materials, *J. Chromatogr. A* **1998**, *816*, 213-220.

46. P. Antunes, O. Gil and M.G. Bernardo-Gil, Supercritical fluid extraction of organochlorines from fish muscle with different sample preparation, *J. Supercrit. Fluids* **2003**, *25*, 135-142.

47. J.J. Langenfeld, S.B. Hawthorne, D.J. Miller and J. Pawliszyn, Effects of temperature and pressure on supercritical fluid extration efficiencies of polycyclic aromatic hydrocarbons and polychlorinated biphenyls, *Anal. Chem.* **1993**, *65*, 338-344.

48. K. Hartonen, S. Bøwadt, S.B. Hawthorne and M.-L. Riekkola, Supercritical fluid extraction with solid-phase trapping of chlorinated and brominated pollutants from sediment samples, *J. Chromatogr. A* **1997**, *774*, 229-242.

49. T. Nilsson, E. Björklund and S. Bøwadt, Comparison of two extraction methods independently developed on two conceptually different automated supercritical fluid extraction systems for the determination of polychlorinated biphenyls in sediments, *J. Chromatogr. A* **2000**, *891*, 195-199.

50. T. Nilsson, S. Bøwadt and E. Björklund, Development of a simple selective SFE method for the determination of desorption behaviour of PCBs in two Swedish sediments, *Chemosphere* **2002**, *46*, 469-476.

51. S. Bøwadt, B. Johansson, S. Wunderli, M. Zennegg, L.F. de Alencastro and D. Grandjean, Independent comparison of Soxhlet and supercritical fluid extraction for the determination of PCBs in an industrial soil, *Anal. Chem.* **1995**, *67*, 2424-2430.

52. K. Hartonen, S. Bøwadt, H.P. Dybdahl, K. Nylund, S. Sporring, H, Lund and F. Oreld, Nordic laboratory intercomparison of supercritical fluid extraction for the determination of total petroleum hydrocarbon, polychlorinated biphenyls and polycyclic aromatic hydrocarbons in soil, *J. Chromatogr. A* **2002**, *958*, 239-248.

53. K. Ganzler, A. Salgo and K. Valko, Microwave extraction. A novel sample preparation method for chromatography, *J. Chromatogr.* **1986**, *371*, 299-306.

54. R.-A. Düring and St. Gäth, Microwave assisted methodology for the determination of organic pollutants in organic municipal wastes and soils: extraction of polychlorinated biphenyls using heat transformer disks, *Fresenius J. Anal. Chem.* **2000**, *368*, 684-688.

55. S. Jayaraman, R.J. Pruell and R. McKinney, Extraction of organic contaminants from marine sediments and tissues using microwave energy, *Chemosphere* **2001**, *44*, 181-191.

56. N. Carro, Y. Saavedra, I. Garcia and M. Llompart, Optimization of microwave assisted solvent extraction of polychlorinated biphenyls from marine sediments, *J. Microcolumn Sep.* **1999**, *11*, 544-549.

57. M. Numata, T. Yarita, Y. Aoyagi and A. Takatsu, Evaluation of microwave-assisted extraction technique for the determination of polychlorinated biphenyls and organochlorine pesticides in sediments, *Anal. Sci.* **2004**, *20*, 793-798.

58. B.E. Richter, B.A. Jones, J. L. Ezzell, N.L. Porter, N. Avdalovic and C. Pohl, Accelerated solvent extraction: A technique for sample preparation, *Anal. Chem.* **1996**, *68*, 1033-1039.

59. E. Björklund, S. Bøwadt, T. Nilsson and L. Mathiasson, Pressurized fluid extraction of polychlorinated biphenyls in solid environmental samples, *J. Chromatogr. A* **1999**, *836*, 285-293.

60. M.M Schantz, J.J. Nichols and S.A. Wise, Evaluation of pressurized fluid extraction for the extraction of environmental matrix reference materials, *Anal. Chem.* **1997**, *69*, 4210-4219.

61. J.L. Gomez-Ariza, M. Bujalance, I. Giraldez, A. Velasco and E. Morales, Determination of polychlorinated biphenyls in biota samples using simultaneous pressurized liquid extraction and purification, *J. Chromatogr. A* **2002**, *946*, 209-219.

62. P. Suchan, J. Pulkrabova, J. Hajslova and V. Kocourek, Pressurized liquid extraction in determination of polychlorinated biphenyls and organochlorine pesticides in fish samples, *Anal. Chim. Acta* **2004**, *520*, 193-200.

63. L. Dabrowski, H. Giergielewicz-Mozajska, M. Biziuk, J. Gaca and J. Namiesnik, Some aspects of the analysis of environmental pollutants in sediments using pressurized liquid extraction and gas chromatography-mass spectrometry, *J. Chromatogr. A* **2002**, *957*, 59-67.

64. S. Josefsson, R. Westbom, L. Mathiasson and E. Björklund, Evaluation of PLE exhaustiveness for the extraction of PCBs from sediments and the influence of sediment characteristics, *Anal. Chim. Acta* **2006**, *560*, 94-102.

65. O. Zuloaga, N. Etxebarria, L.A. Fernandez and J.M. Madariaga, Comparison of accelerated solvent extraction with microwave-assisted extraction and Soxhlet for the extraction of chlorinated biphenyls in soil samples, *TrAC, Trends Anal. Chem.* **1998**, 17, 642-647.

66. A. Hubert, K.-D. Wenzel, M. Manz, L. Weissflog, W. Engewald and G. Schüürmann, High extraction efficiency for POPs in real contaminated soil samples using accelerated solvent extraction, *Anal. Chem.* **2000**, *72*, 1294-1300.

67. Y. Abrha and D. Raghavan, Polychlorinated biphenyl (PCB) recovery from spiked organic matrix using accelerated solvent extraction (ASE) and Soxhlet extraction, *J. Hazard. Mater.* **2000**, *B80*, 147-157.

68. U.S. EPA Method 3545, Pressurized fluid extraction (PFE), revision 0, December 1996, http://www.epa.gov/SW-846/pdfs/3545.pdf, U.S. Environmental Protection Agency (7.3.2006).

69. U.S. EPA Method 3545A, Pressurized fluid extraction (PFE), revision 1, January 1998, http://www.epa.gov/SW-846/up4b.htm, U.S. Environmental Protection Agency (7.3.2006).

70. G. Font, J. Manes , J.C. Molto and Y. Pico, Current developments in the analysis of water pollution by polychlorinated biphenyls, *J. Chromatogr. A* **1996**, *733*, 449-471.

71. I. Liska, Fifty years of solid-phase extraction in water analysis - historical development and overview, *J. Chromatogr. A* **2000**, *885*, 3-16.

72. R. Westbom, L. Thörneby, S. Zorita, L. Mathiasson and E. Björklund, Development of a solid-phase extraction method for the determination of polychlorinated biphenyls in water, *J. Chromatogr. A* **2004**, *1033*, 1-8.

73. M. Llompart, K. Li and M. Fingas, Solid-phase microextraction and headspace solid-phase microextraction for the determination of polychlorinated biphenyls in water samples, *Anal. Chem.* **1998**, *70*, 2510-2515.

74. Y. Yang, D.J. Miller and S.B. Hawthorne, Solid-phase microextraction of polychlorinated biphenyls, *J. Chromatogr. A* **1998**, *800*, 257-266.

75. E. Cortazar, O. Zuloaga, J. Sanz, J.C. Raposo, N. Etxebarria and L.A. Fernandez, MultiSimplex optimisation of the solid-phase microextraction-gas chromatographic-mass spectrometric determination of polycyclic aromatic hydrocarbons, polychlorinated biphenyls and phthalates from water samples, *J. Chromatogr. A* **2002**, *978*, 165-175.

76. Y.Y Shu, S.S. Wang, M. Tardif and Y. Huang, Analysis of polychlorinated biphenyls in aqueous samples by microwave-assisted headspace solid-phase microextraction, *J. Chromatogr. A* **2003**, *1008*, 1-12.

77. D.B. Eeasty and B.A. Wabers, Determination of polychlorinated biphenyls in paper mill effluents and process streams, *Analytical Letters* **1977**, *10*, 857-867.

78. J.J.Delfino and D.B.Easty, Interlaboratory study of the determination of polychlorinated biphenyls in a paper mill effluent, *Anal. Chem.* **1979**, *51*, 2235-2239.

79. S.I. Shahied, R.P. Stanovick, D.E. McInturff and E. Missaghi, Determination of polychlorinated biphenyl (PCB's) residues in grades of pulp, paper and paperboard, *Bull. Environ. Contam. Toxicol.* **1973**, *10*, 80-87.

80. L. Welling, Tutkimustodistus, 10.1.1991, Jyväskylän yliopiston ympäristön-tutkimuskeskus, Jyväskylä, 1991, 2 pp.

81. P. Neukum, H.-J. Putz and L. Göttsching, Zusammensetzung und Qualitätseigenschaften verschiedener Altpapiersorten, *Wochenbl. Papierfabr.* **2001**, *129*, 335-338, 340, 342-343.

82. L. Welling, Tutkimustodistus, 14.11.1990, Jyväskylän yliopiston ympäristön-tutkimuskeskus, Jyväskylä, 1990, 1 p.

83. M. Ettala, Quality of deinking sludge, *J. Environ. Sci. Health* **1993**, *A28*, 923-932.

84. L. Welling, Tutkimustodistus, 29.4.1991, Jyväskylän yliopiston ympäristön-tutkimuskeskus, Jyväskylä, 1991, 2 pp.

85. L. Raitio, *The environmental load of deinked pulp production*, Thesis for the degree of Licenciate of Technology, Helsinki University of Technology, Department of Forest Products Technology, Espoo, 1992.

86. L. Raitio, The properties of deinking sludge, *Pap. Puu*, **1992**, *74*, 132-138.

87. R. Miner and H. Berger, PCB and TCDD/F levels in effluents from deinking mills producing fine paper or tissue and towelling, Technical Bulletin No. 671, NCASI, New York, NY, USA, 1994, 15pp.

88. J.R. Sullivan, J.J. Delfino, C.R. Buelow and T.B. Sheffy, Polychlorinated biphenyls in the fish and sediment of the Lower Fox River, Wisconsin, *Bull. Environ. Contam. Toxicol.* **1983**, *30*, 58-64.

89. P. Larsson, L. Okla, S.-O. Ryding and B. Westöö, Contaminated sediment as a source of PCBs in a river system, *Can. J. Fish. Aquat. Sci.* **1990**, 47, 746-754.

90. S. Herve, J. Paasivirta and P. Heinonen, Orgaanisten klooriyhdisteiden trendit 1984-1998 Suomen sisävesissä: Simpukkaseurannan tulokset, Keski-Suomen ympäristökeskuksen monistesarja 38, Keski-Suomen ympäristökeskus, 2000, 140 pp.

91. S. Herve, J. Paasivirta and P. Heinonen, Trends of organochlorine compounds in Finnish inland waters, *Environ. Sci. & Pollut. Res.* **2001**, *8*, 19-26.

92. O. Piiroinen, Vanajaveden reitin yläosan kalojen PCB-pitoisuuden tarkkailu vuonna 2000, Raportti no. 616/OP, Kokemäenjoen vesistön vesiensuojeluyhdistys r.y., Tampere, 2001, 14 pp.

93. T.S. Hurme and J.A. Puhakka, Characterization and fate of polychlorinated biphenyl contaminants in Kernaalanjärvi sediments, *Boreal Env. Res.*, **1999**, *4*, 331-342.

94. A. Kolehmainen, Metsä Tissue Oyj, Mäntän tehtaat: Maaperän ja pohjaveden pilaantuneisuustutkimus, Raportti 18277, Suomen IP-Tekniikka Oy, Kuopio, 2003, 10 pp.

95. D.T. Williams and F.M. Benoit, The determination of polychlorinated biphenyls in selected household products, *Bull. Environ. Contam. Toxicol.* **1979**, *21*, 179-184.

96. L. Welling, R. Paukku and K. Mäntykoski, PCB in recycled paper products, *Chemosphere* **1992**, *25*, 293-295.

97. A. Karessuo, Ympäristönsuojelun vuosikirja 1994, Metsäteollisuus ry, 1994, ISSN 0789-9858, 134 pp.

98. A. Karessuo, Ympäristönsuojelun vuosikirja 1995, Metsäteollisuus ry, 1995, ISSN 0789-9858, 142 pp.

99. A. Karessuo, Ympäristönsuojelun vuosikirja 1996, Metsäteollisuus ry, 1996, ISSN 0789-9858, 139 pp.

100. M. Vainio-Mattila, Ympäristönsuojelun vuosikirja, vuoden 1996 tilastot, Metsäteollisuus ry, 1997, ISSN 0789-9858, 145 pp.

101. S. Niskanen, Ympäristönsuojelun vuosikirja, vuoden 1997 tilastot, Metsäteollisuus ry, 1998, ISSN 0789-9858, 156 pp.

102. S. Sieppi, Ympäristönsuojelun vuosikirja, massa- ja paperiteollisuus, vuoden 1998 tilastot, Metsäteollisuus ry, 1999, ISSN 1456-6931, 118 pp.

103. S. Sieppi, Ympäristönsuojelun vuosikirja, massa- ja paperiteollisuus, vuoden 1999 tilastot, Metsäteollisuus ry, 2000, ISSN 1456-6931, 126 pp.

104. T. Harjanne, Ympäristönsuojelun vuosikirja, massa- ja paperiteollisuus, vuoden 2000 tilastot, Metsäteollisuus ry, 2001, ISSN 1456-6931, 118 pp.

105. S. Sieppi, Ympäristönsuojelun vuosikirja, massa- ja paperiteollisuus, vuoden 2001 tilastot, Metsäteollisuus ry, 2002, ISSN 1456-6931, 122 pp.

106. S. Sieppi, Ympäristönsuojelun vuosikirja, massa- ja paperiteollisuus, vuoden 2002 tilastot, Metsäteollisuus ry, 2003, ISSN 1456-6931, 24 pp.

107. O. Laatikainen, Ympäristönsuojelun vuosikirja, massa- ja paperiteollisuus, vuoden 2003 tilastot, Metsäteollisuus ry, 2004, 18 pp.

108. Ympäristönsuojelun vuosikirja 2005, massa- ja paperiteollisuus, puuteollisuus, tilastot vuodelta 2004, Metsäteollisuus ry, 2005, 28 pp.

109. A. Karessuo, Ympäristönsuojelun vuosikirja 1992, Suomen metsäteollisuuden keskusliitto, 1992, ISSN 0789-9858, 104 pp.

110. Environmental report 2005, pulp and paper industry, wood products industry, statistics for 2004, Finnish Forest Industries Federation, 2005, 26 pp.

111. Ympäristönsuojelun vuosikirja 1991, Suomen metsäteollisuuden keskusliitto, 1991, ISBN 952-9506-03-1, 88 pp.

112. A. Karessuo, Ympäristönsuojelun vuosikirja 1993, Metsäteollisuus ry, 1993, ISSN 0789-9858, 122 pp.

113. A.Mäkelä, S. Antikainen, I. Mäkinen, J. Kivinen and T. Leppänen, Vesitutkimusten näytteenottomenetelmät, Vesi- ja ympäristöhallinnon julkaisuja, Sarja B 10 , Vesi- ja ympäristöhallitus, 1992, 87 pp.

114. J. Meriläinen and H. Veijola, Vesistötutkimukset ja pohjasedimenttinäytteet, Näytteenoton työohje NTO-10, Jyväskylän yliopiston ympäristöntutkimuskeskus, versio nro 1, 20.5.1998, 2 pp.

115. Scope of accreditation by the laboratory of Institute for Environmental Research, University of Jyväskylä, http://www.finas.fi/Scopes/T142_M09_2005.htm, FINAS (26.5.2006).

116. O. Roerden, K. Reisinger, W. Leymann and C.B.G. Frischkorn, A simple clean-up procedure for the quantitative determination of PCBs in complex materials, *Fresenius' Z. Anal. Chem.* **1989**, *334*, 413-417.

117. Laboratorion laatukäsikirja, Jyväskylän yliopiston ympäristöntutkimuskeskus, versio nro 3.0, 3.5.1999, 75 pp.

118. SFS-EN 45001 -standardi, Testauslaboratorioiden toiminta. Yleiset vaatimukset, 2. painos, 19.3.1990, Suomen standardisoimisliitto.

119. B. Eijgenraam, International sediment exchange for tests on organic contaminants, Annual report 2004, Wageningen university, 2005, 122 pp.

120. EN ISO 15318 Method, Pulp, paper and board - Determination of 7 specified polychlorinated biphenyls (PCB), October 1999, European committee for standardization.

121. SFS 3008 -standardi, Veden, lietteen ja sedimentin kuiva-aineen ja hehkutusjäännöksen määritys, 2. painos, 3.12.1990, Suomen standardisoimisliitto.

122. H. Salo, Metsä-Tissue Oyj: PCB-tutkimusraportti, tutkimusraportti 143/2000, Jyväskylän yliopiston ympäristöntutkimuskeskus, Jyväskylä, 2000, 31 pp.

123. D.L. Phillips, A.B. Smith, V.B. Burse, G.K. Steele, L.L. Needham and W.H. Hannon, Half-life of polychlorinated biphenyls in occupationally exposed workers, *Arch. Environ. Health* **1989**, *44*, 351-354.

124. M. Luotamo, Polyklooratut bifenyylit (PCB), Altisteet työssä 17, Työterveyslaitos, 1991, 40 pp.

125. A. Someshwar, P. Wiegand, D. Borton, R. Miner, R. Fisher, J. Unwin and H. Berger, Characterization of wastes and emissions from mills using recycled fiber, Technical Bulletin No. 613, NCASI, New York, NY, USA, 1991, 44 pp.

126. T. Takasuga, K. Senthilkumar, T. Matsumura, K. Shiozaki and S. Sakai, Isotope dilution analysis of polychlorinated biphenyls (PCBs) in transformer oil and global commercial PCB formulations by high resolution gas chromatography-high resolution mass spectrometry, *Chemosphere* **2006**, *62*, 469-484.

127. Kauppa- ja teollisuusministeriön päätös (134/96) eräiden tavallisimpien kontaminanttien enimmäismääristä elintarvikkeissa, *Suomen säädöskokoelma*, 1.3.1996.

128. Commission decision of 4 May 2001 (2001/405/EC) establishing the ecological criteria for the award of the Community eco-label to tissue-paper products, *Off. J. Eur. Communities L*, **2001**, *44* (29 May 2001), L142/10-L142/17.

129. L. Welling, Tutkimustodistus 2005-4140, 8.11.2005, Jyväskylän yliopiston ympäristöntutkimuskeskus, Jyväskylä, 2006, 4 pp.

130. S. Kärki, unpublished results.

Appendix 1

Table 1. Production of paper mill operated by Metsä Tissue Corporation in Mänttä during 1993 and 2004.[97-108]

Year	Deinked waste paper pulp t/a	Woodsfree paper t/a	Recycled paper t/a	Converted products t/a
1993	37 000	16 000	80 000	-
1994	48 000	17 000	86 000	-
1995	51 000	17 000	89 000	-
1996	53 000	16 000	88 000	-
1997	50 000	19 700	95 700	67 900
1998	51 000	22 200	94 800	63 400
1999	47 000	23 000	95 300	66 700
2000	48 300	22 800	92 600	76 700
2001	54 500	23 100	92 000	69 800
2002	49 500	24 000	95 000	70 000
2003	51 600	27 200	98 400	72 700
2004	50 512	27 889	101 378	74 023

Appendix 2

Table 1. Production of paper mill operated by Georgia-Pacific Finland Ltd. in Nokia during 1993-2004.[97-108]

Year	Waste paper pulp		Paper	
	Deinked t/a	Undeinked t/a	Recycled t/a	Woodsfree t/a
1993	36 000	-	76 500	-
1994	41 000	-	86 000	-
1995	40 000	-	80 000	-
1996	40 000	-	83 000	-
1997	35 000	-	85 000	-
1998	35 000	-	85 000	-
1999	41 000	-	90 000	-
2000	40 000	-	-	90 000
2001	40 000	72 000	42 000	25 000
2002	40 000	-	65 000	25 000
2003	-	40 000	65 000	25 000
2004	40 000	-	65 000	25 000

Appendix 3

Table 1. Production of paper mill operated by UPM-Kymmene Corporation in Kaipola during 1993 and 2004.[97-108]

Year	Refined mechanical pulp t/a	Deinked waste paper pulp t/a	Mechanical paper t/a	Recycled paper t/a
1993	307 000	123 000	255 000	296 000
1994	317 000	116 000	568 000	320 000
1995	340 000	107 000	603 000	337 000
1996	282 000	94 100	513 000	308 000
1997	318 000	119 000	217 000	357 000
1998	327 000	132 000	237 000	387 000
1999	304000	151 000	228 000	383 000
2000	315000	146 000	269 000	366 000
2001	301 000	151 000	251 000	367 000
2002	282 000	154 000	239 000	353 000
2003	269 500	142 950	251 405	368 231
2004	280 225	135 057	274 418	366 135

Appendix 4

Table 1. Discharges of suspended solids (total suspended solids, TSS) from paper mills during 1993 and 2004.[97-108]

Year	Mänttä t/a	Nokia t/a	Kaipola t/a
1993	65	132	214
1994	70	110	204
1995	48	79	168
1996	112	112	113
1997	77	76	197
1998	78	111	188
1999	77	116	164
2000	131	47	256
2001	110	150	233
2002	86	74	187
2003	105	141	246
2004	89	165	259

Appendix 5

Table 1. Amounts of landfilled deinking sludge (t/a dry weight) from paper mills during 1993-2001.[97-105]

Year	Mänttä t/a	Nokia t/a	Kaipola t/a
1993	15 600	16 850	1 860
1994	20 754	18 400	1 500
1995	23 386	22 000	859
1996	22 172	20 700	978
1997	22 558	22 000	1 064
1998	23 177	14 000	1 241
1999	23 471	7 480	835
2000	22 355	4 645	1 060
2001	26 811	10 000	590

Appendix 6

Table 1. Amounts of landfilled wastewater sludge (t/a dry weight) from paper mills during 1993-2001.[97-105]

Year	Mänttä t/a	Nokia t/a
1993	401	4 100
1994	1 525	4 300
1995	1 130	5 100
1996	13	4 860
1997	294	4 600
1998	5	4 500
1999	212	4 114
2000	525	4 024
2001	-	10 000

Appendix 7

Table 1. Samples from different wastepaper grades.

Wastepaper grade	Additional information and source
Archival paper I	Lot I in October 2000 (Mänttä mill)
Archival paper II	Lot II in October 2000 (Mänttä mill)
Carbonless copy paper	October 2000 (Mänttä mill)
Magazine	Anna 36/2000, Kotiliesi 16/2000, Seura 28/2000, Apu 37/2000, Me Naiset 36/2000 (Mänttä mill)
Newspaper I	Papers (Aamulehti) from September 2000 to October 2000 (Mänttä mill)
Newspaper II	Papers (Helsingin Sanomat) from September 2000 to October 2000 (Mänttä mill)
Shavings	August 2001 (Paperinkeräys Ltd.)

Table 2. Wastepaper samples from different sources in 2002.

Sample	Additional information and source
010	Wastepaper from households (Mänttä mill)
050	Wastepaper from printing works (Mänttä mill)
070	Wastepaper from printing works (Mänttä mill)
080	Wastepaper from offices (Mänttä mill)
060	Wastepaper from offices (Mänttä mill)

Table 3. Sample from raw water.

Sample	Additional information and source
Raw water	November 2002 (Mänttä mill)

Appendix 8 1(2)

Table 1. Samples from pulper stock in 2002.

Pulper	Additional information and source
DI-60	Raw material: wastepaper from households (Mänttä mill)
DI-70	Raw material: wastepaper from printing works (Mänttä mill)
DI-80	Raw material: wastepaper from offices (Mänttä mill)

Table 2. Samples from recycled fibre pulp and tissue paper reject.

Sample	Additional information and source
Recycled fibre pulp	DI-60 in 2002 (Mänttä mill)
	DI-70 in 2000 (Mänttä mill)
	DI-70 in 2002 (Mänttä mill)
	DI-80 in 2000 (Mänttä mill)
	DI-80 in 2002 (Mänttä mill)
Tissue paper reject	Tissue paper reject used in DI-60 and DI-70 in 2002 (Mänttä mill)

Table 3. Samples from deinking sludge in the paper mills of Mänttä and Nokia.

Samples	Additional information
Deinking sludge, Mänttä	DI-60 in 1993, 1996, 1999, 2000 and 2002
	DI-70 in 1996, 1999, 2000 and 2002
	DI-80 in 1993, 1996, 1999, 2000 and 2002
Deinking sludge, Nokia	In 2001 and 2002

Appendix 8 2(2)

Table 4. Process water samples from deinking departments.

Sample	Pulper
Incomig water	DI-60 in 2002 (Mänttä mill)
	DI-70 in 2002 (Mänttä mill)
	DI-80 in 2002 (Mänttä mill)
Cleaned water	DI-60 in 2002 (Mänttä mill)
	DI-70 in 2002 (Mänttä mill)
	DI-80 in 2002 (Mänttä mill)
Reject	DI-60 in 2002 (Mänttä mill)
	DI-70 in 2002 (Mänttä mill)
	DI-80 in 2002 (Mänttä mill)

Table 5. Surface material and sand samples in close proximity to electrical equipment in paper mill.

Sample	Additional information and source
Surface material sample	Sample from cable channel below transformer (Mänttä mill)
Sand sample	Sample from cable channel 4,5 kV (Mänttä mill)

Appendix 9 1(2)

Table 1. Samples from incoming wastewaters and treated water from the wastewater treatment plant.

Sample	Additional information and source
Municipal wastewater	Wastewater from Mänttä in 2000 (Mänttä mill)
	Wastewater from Mänttä in 2002 (Mänttä mill)
Industrial wastewater	Wastewater from paper mill in 2000 (Mänttä mill)
	Wastewater from paper mill in 2002 (Mänttä mill)
Treated water	Treated water to recipient in 2000 (Mänttä mill)
	Treated water to recipient in 2002 (Mänttä mill)

Table 2. Wastewater samples from various parts of wastewater treatment plant.

Sample	Additional information and source
MS	Mechanical sedimentation in 2002 (Mänttä mill)
PS	Primary sedimentation in 2002 (Mänttä mill)
ST	Sludge thickener in 2002 (Mänttä mill)
IS	Intermediate sedimentation in 2002 (Mänttä mill)
AE	Aeration (stage II) in 2002 (Mänttä mill)

Appendix 9 2(2)

Table 3. Biosludge samples from a sludge thickener of a wastewater treatment plant.

Sample	Additional information and source
BS 93	Biosludge from a sludge thickener in 1993 (Mänttä mill)
BS 96	Biosludge from a sludge thickener in 1996 (Mänttä mill)
BS 99	Biosludge from a sludge thickener in 1999 (Mänttä mill)
BS 01	Biosludge from a sludge thickener in 2001 (Mänttä mill)
BS 02	Biosludge from a sludge thickener in 2002 (Mänttä mill)
BS 04	Biosludge from a sludge thickener in 2004 (Mänttä mill)

Table 4. Samples of wastewater sludge from various parts of a wastewater treatment plant.

Sample	Additional information and source
MX 02	Mixed sludge to co-incineration in 2002 (Mänttä mill)
MX 04	Mixed sludge to co-incineration in 2004 (Mänttä mill)
MS 02	Mechanical sedimentation in 2002 (Mänttä mill)
MS 04	Mechanical sedimentation in 2004 (Mänttä mill)
PS 02	Primary sedimentation in 2002 (Mänttä mill)
PS 04	Primary sedimentation in 2004 (Mänttä mill)
IS 02	Intermediate sedimentation in 2002 (Mänttä mill)
IS 04	Intermediate sedimentation in 2004 (Mänttä mill)
SS 02	Secondary sedimentation in 2002 (Mänttä mill)
SS 04	Secondary sedimentation in 2004 (Mänttä mill)

Appendix 10

Table 1. Fish samples from Lake Melasjärvi downstream from Mänttä mill in 2000.

Sample	Additional information
Pike 1	weight 690 g
Pike 2	weight 665 g
Pike 3	weight 880 g
Pike 4	weight 1005 g
Pike 5	weight 1245 g

Table 2. Samples of pike from lakes in the region of Tampere and Nokia in 2000.

Lake	Additional information
Näsijärvi	Sampling point downstream from M-real pulp mill in Tampere. Composite sample from five fish.
Pyhäjärvi	Sampling point downstream from a former capacitor factory and a Tampere municipal sewage treatment plant. Composite sample from five fish.
Kulovesi 1	Sampling point downstream from Lake Pyhäjärvi and from region of Nokia and Nokia mill. Composite sample from two fish.
Kulovesi 2	Composite sample from two fish.
Iidesjärvi	Sampling point downstream from a former landfill. Composite sample from five fish.

Appendix 11 1(4)

Table 1. Sediment samples from lake basins upstream and downstream from Mänttä mill in 2000.

Sampling site	Additional information
Keurusselkä	Sampling point K2 upstream from paper mill. Sediment profile 0-24 cm. Sub-samples at intervals of 2 cm were analysed.
Mäntänlahti	Sampling point downstream from paper mill. Sediment profile 0-10 cm. Sub-samples at intervals of 5 cm were analysed.
Kuorevesi	Sampling point in Kotkanselkä downstream from paper mill. Sediment profile 0-28 cm. Sub-samples at intervals of 2 cm were analysed.
Melasjärvi	Sampling point downstream from paper mill. Sediment profile 0-30 cm. Sub-samples at intervals of 2 cm were analysed.
Aittoselkä	Sampling point A2 downstream from Mänttä mill. Sediment profile 0-20 cm. Sub-samples at intervals of 2 cm were analysed.

Table 2. Sediment samples from lakes downstream from Mänttä mill in 2001.

Sampling site	Additional information
Mäntänlahti	Sampling point downstream from paper mill. Sediment layers 0-2 cm, 2-3 cm and 3-4 cm.
Savonselkä	Sampling point downstream from paper mill. Sediment layers 0-2 cm, 2-3 cm and 3-4 cm.
Aittoselkä	Sampling point downstream from paper mill. Sediment layers 0-2 cm, 2-3 cm and 3-4 cm.
Paloselkä	Sampling point downstream from paper mill. Sediment layers 0-2 cm, 2-3 cm and 3-4 cm.

Appendix 11 2(4)

Table 3. Sediment samples from the industrial site of Mänttä mill and from sites downstream from industrial and municipal landfills in 2001.

Sampling point	Additional information
Reservoir	Sample from reservoir in the vicinity of paper mill
Point of discharge	Sample from the existing final effluent discharge point of paper mill
Koskelanlampi	Sample from a pond just upstream from paper mill
Riuttaoja	Sample from mouth of Riuttaoja downstream from the industrial waste landfill of paper mill
Vuohijoki	Sample from mouth of Vuohijoki downstream from a former municipal waste landfill in Mänttä
Kuorevesi	A reference sample from an area (Lake Kuorevesi, Salmion salmi) relatively free of industrial influence

Table 4. Soil and sediment samples from the former industrial site of Mänttä mill.

Sampling point	Additional information
6	Soil sample (2.0-2.9 m) from area of acid tower in 2002
LP3+LP5	Soil samples (LP3/1.5-2 m) and (LP5/0-1 m) from area of acid tower in 2003. Composite sample.
LP8	Soil sample (2-3 m) from coalfield in 2003
LP1	Soil sample (4-5 m) from side of a former outfall sewer in 2003
S1	Sediment sample (0-0.5) from the former point of discharge in 2003

Appendix 11 3(4)

Table 5. Sediment samples from sites downstream from Nokia mill and region of Nokia and Tampere in 2001.

Sample	Sampling site
Lukkilanlahti I	Lukkilanlahti, Nokia (load from region of Nokia and Tampere and from a paper mill operated by Georgia-Pacific Finland Ltd. in Nokia).
Lukkilanlahti II	Lukkilanlahti, Nokia (load from region of Nokia and Tampere and from a paper mill operated by Georgia-Pacific Finland Ltd. in Nokia).
Eden	Eden, Pyhäjärvi (load from region of Tampere)

Table 6. Sediment sample from lake basin downstream from Kaipola mill in 2002.

Sampling site	Additional information
Päijänne	Sampling point Kaipola 654 downstream from the paper mill operated by UPM-Kymmene Corporation in Kaipola. Sediment profile 0-30 cm. Sub-samples at intervals of 5 cm were analysed.

Appendix 11 4(4)

Table 7. Sediment samples from Lake Näsijärvi, Lake Iidesjärvi, Lake Kulovesi and Lake Pyhäjärvi in 2000.

Sample	Sampling site
Näsijärvi I	Lielahti (load from a pulp mill operated by M-real in Tampere)
Näsijärvi II	Sokeritoppa (load from a pulp mill of M-real in Tampere)
Iidesjärvi	Western part of Lake Iidesjärvi (load from a former landfill)
Kulovesi	121 Kalmetsaari (load from Lake Pyhäjärvi and from region of Nokia)
Pyhäjärvi I	South side of Isle of Saunasaari (load from a former capacitor factory and a Tampere municipal sewage treatment plant)
Pyhäjärvi II	Viinikanlahti (load from a former capacitor factory and a Tampere municipal sewage treatment plant)

Table 8. Sediment sample from in front of a sewer of a former capacitor factory

Sampling site	Additional information
Pyhäjärvi	In front of a sewer in 2001

Appendix 12

Table 1. River water sample from Vuohijoki.

Sampling site	Additional information
Vuohijoki	River water downstream from a former municipal landfill in Mänttä in October 2000

Appendix 13

Table 1. Hand towel sheet and roll samples.

Product/lot	Additional information and source
Sheet A/I	A German product manufactured from recycled fibre (a random sample from the University of Jyväskylä in 2003).
Sheet A/II	A German product manufactured from recycled fibre (a random sample from the University of Jyväskylä in 2003).
Sheet B	A Swedish product manufactured from recycled fibre (a quality control sample from a paper mill in 2003).
Sheet C	A Finnish product manufactured from recycled fibre (a quality control sample from a paper mill in 2003).
Roll D	A Finnish product manufactured from recycled fibre (a random sample from the University of Jyväskylä in 2003).
Roll E	A Swedish product manufactured from recycled fibre (a random sample from the University of Jyväskylä in 2003).

Appendix 14

Table 1. Kitchen towel samples.

Product/lot	Additional information and source
A/I	A Finnish product manufactured from recycled fibre (a quality control sample from a paper mill in 2001).
A/II	A Finnish product manufactured from recycled fibre (a random sample from a superstore (Prisma Seppälä) in 2003).
B	A product manufactured from recycled fibre (a random sample from a superstore (Lidl Seppälä) in 2003).
C	A Finnish product manufactured from recycled fibre (a random sample from a superstore (Prisma Seppälä) in 2003).
D	A Finnish product manufactured from recycled fibre and cellulose (a random sample from a superstore (Prisma Seppälä) in 2003).
E/I	A Finnish product manufactured from recycled fibre (a random sample from the Central Finland Regional Environment Centre in 2003).
E/II	A Finnish product manufactured from recycled fibre (a random sample from a superstore (Prisma Seppälä) in 2003).
F	A Finnish product manufactured from recycled fibre (a quality control sample from a paper mill in 2000).

Appendix 15

Table 1. Handkerchief samples.

Product	Additional information and source
A	A Finnish product manufactured from recycled fibre and cellulose (a random sample from a superstore (Lidl Seppälä) in 2003).
B	A Finnish product manufactured from recycled fibre (a random sample from a superstore (Prisma Seppälä) in 2003).
C	A Finnish product manufactured from recycled fibre and cellulose (a random sample from a superstore (Prisma Seppälä) in 2003).

Appendix 16

Table 1. Toilet tissue samples.

Product/lot	Additional information and source
A/I	A product manufactured from recycled fibre (a random sample from a superstore (Lidl Seppälä) in March 2003).
A/II	A product manufactured from recycled fibre (a random sample from a superstore (Lidl Seppälä) in November 2003).
B	A German product manufactured from recycled fibre (a quality control sample from a paper mill in 2003).
C	A Polish product manufactured from recycled fibre (a quality control sample from a paper mill in 2003).
D	A Finnish product manufactured from recycled fibre (a random sample from a superstore (Prisma Seppälä) in 2003).
E	A Finnish product manufactured from recycled fibre (a random sample from a superstore (Prisma Seppälä) in 2003).
F/I	A Finnish product manufactured from recycled fibre and cellulose (a random sample from a superstore (Prisma Seppälä) in 2003).
F/II	A Finnish product manufactured from recycled fibre and cellulose (a random sample from a superstore (Prisma Seppälä) in 2004).
G	A Finnish product manufactured from recycled fibre (a random sample from a superstore (Prisma Seppälä) in 2003).
H	A Finnish product manufactured from recycled fibre (a random sample from the University of Jyväskylä in 2003).
I	A Finnish product manufactured from recycled fibre (a random sample from a superstore (Prisma Seppälä) in 2003).
J	A Finnish product manufactured from recycled fibre (a quality control sample from a paper mill in 2000).

Appendix 17 1(4)

Table 1. PCB concentrations in different wastepaper grades.

PCB	Archival paper I mg/kg fw	Archival paper II mg/kg fw	Carbonless copy paper mg/kg fw
PCB congeners			
PCB 8	0.008	0.015	< 0.003
PCB 18	0.053	0.025	< 0.003
PCB 28	0.068	0.038	< 0.002
PCB 52	0.044	0.010	< 0.001
PCB 101	< 0.001	< 0.001	< 0.001
PCB 118	< 0.001	< 0.001	< 0.001
PCB 153	< 0.001	< 0.001	< 0.001
PCB 105	< 0.001	< 0.001	< 0.001
PCB 138	< 0.001	< 0.001	< 0.001
PCB 187	< 0.001	< 0.001	< 0.001
PCB 128	< 0.001	< 0.001	< 0.001
PCB 156	< 0.001	< 0.001	< 0.001
PCB 180	< 0.001	< 0.001	< 0.001
Total PCB as			
Aroclor 1242	1.0	0.47	

Appendix 17 2(4)

Table 2. PCB concentrations in different wastepaper grades.

PCB	Magazine mg/kg fw	Newspaper I mg/kg fw	Newspaper II mg/kg fw	Shavings mg/kg fw
PCB congeners				
PCB 8	< 0.003	< 0.003	< 0.003	< 0.007
PCB 18	< 0.003	< 0.003	< 0.003	< 0.006
PCB 28	< 0.002	< 0.002	< 0.002	< 0.005
PCB 52	< 0.001	< 0.001	< 0.001	< 0.003
PCB 101	< 0.001	< 0.001	< 0.001	< 0.003
PCB 118	< 0.001	< 0.001	< 0.001	< 0.002
PCB 153	< 0.001	< 0.001	< 0.001	< 0.002
PCB 105	< 0.001	< 0.001	< 0.001	< 0.002
PCB 138	< 0.001	< 0.001	< 0.001	< 0.002
PCB 187	< 0.001	< 0.001	< 0.001	< 0.002
PCB 128	< 0.001	< 0.001	< 0.001	< 0.002
PCB 156	< 0.001	< 0.001	< 0.001	< 0.002
PCB 180	< 0.001	< 0.001	< 0.001	< 0.002
*Total PCB**				

*Aroclor 1242, Aroclor 1254 and Aroclor 1260 were not observed in the samples.

Appendix 17 3(4)

Table 3. PCB concentrations in wastepaper from different sources.

PCB	Household	Printing works		Office	
	010	050	070	080	060
	mg/kg fw	mg/kg fw	mg/kg fw	mg/kg fw	mg/kg fw
PCB congeners					
PCB 8	< 0.003	< 0.003	< 0.003	< 0.003	< 0.003
PCB 18	< 0.003	< 0.003	< 0.003	< 0.003	< 0.003
PCB 28	< 0.002	< 0.002	< 0.002	< 0.002	0.002
PCB 52	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
PCB 101	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
PCB 118	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
PCB 153	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
PCB 105	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
PCB 138	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
PCB 187	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
PCB 128	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
PCB 156	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
PCB 180	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Total PCB as					
Aroclor 1242					0.02

Appendix 17 4(4)

Table 4. PCB concentrations in raw water.

PCB	Raw water µg/l
Total PCB as	
Aroclor 1242	< 0.1
Aroclor 1254	< 0.1
Aroclor 1260	< 0.1

Appendix 18

Table 1. PCB concentrations in pulper stock.

PCB	DI-60 mg/kg dw	DI-70 mg/kg dw	DI-80 mg/kg dw
PCB congeners			
PCB 8	< 0.007	< 0.007	< 0.007
PCB 18	< 0.006	< 0.006	< 0.006
PCB 28	< 0.005	< 0.005	< 0.005
PCB 52	< 0.003	< 0.003	< 0.003
PCB 101	< 0.003	< 0.003	< 0.003
PCB 118	0.002	0.002	< 0.002
PCB 153	< 0.002	< 0.002	< 0.002
PCB 105	< 0.002	< 0.002	< 0.002
PCB 138	< 0.002	0.003	< 0.002
PCB 187	< 0.002	< 0.002	< 0.002
PCB 128	< 0.002	< 0.002	< 0.002
PCB 156	< 0.002	< 0.002	< 0.002
PCB 180	< 0.002	< 0.002	< 0.002
*Total PCB**			

*Aroclor 1242, Aroclor 1254 and Aroclor 1260 were not observed in the samples.

Appendix 19 1(2)

Table 1. PCB concentrations in recycled fibre pulp.

PCB	DI-60 2002 mg/kg dw	DI-70 2000 mg/kg dw	DI-70 2002 mg/kg dw	DI-80 2000 mg/kg dw	DI-80 2002 mg/kg dw
PCB congeners					
PCB 8	< 0.007	< 0.021	< 0.007	< 0.021	< 0.007
PCB 18	< 0.006	< 0.018	< 0.006	< 0.018	< 0.006
PCB 28	< 0.005	< 0.015	< 0.005	< 0.015	< 0.005
PCB 52	< 0.003	< 0.009	< 0.003	< 0.009	< 0.003
PCB 101	< 0.003	< 0.009	< 0.003	< 0.009	< 0.003
PCB 118	< 0.002	< 0.006	< 0.002	< 0.006	< 0.002
PCB 153	< 0.002	< 0.006	< 0.002	< 0.006	< 0.002
PCB 105	< 0.002	< 0.006	< 0.002	< 0.006	< 0.002
PCB 138	< 0.002	< 0.006	< 0.002	< 0.006	< 0.002
PCB 187	< 0.002	< 0.006	< 0.002	< 0.006	< 0.002
PCB 128	< 0.002	< 0.006	< 0.002	< 0.006	< 0.002
PCB 156	< 0.002	< 0.006	< 0.002	< 0.006	< 0.002
PCB 180	< 0.002	< 0.006	< 0.002	< 0.006	< 0.002
*Total PCB**					

*Aroclor 1242, Aroclor 1254 and Aroclor 1260 were not observed in the samples.

Appendix 19 2(2)

Table 2. PCB concentrations in tissue paper reject.

PCB	Tissue paper reject mg/kg dw
PCB congeners	
PCB 8	< 0.007
PCB 18	< 0.006
PCB 28	< 0.005
PCB 52	< 0.003
PCB 101	< 0.003
PCB 118	< 0.002
PCB 153	< 0.002
PCB 105	< 0.002
PCB 138	< 0.002
PCB 187	< 0.002
PCB 128	< 0.002
PCB 156	< 0.002
PCB 180	< 0.002
*Total PCB**	

*Aroclor 1242, Aroclor 1254 and Aroclor 1260 were not observed in the samples.

Appendix 20 1(4)

Table 1. PCB concentrations in deinking sludge from Mänttä mill.

PCB	DI-60 1993 mg/kg dw	DI-60 1996 mg/kg dw	DI-60 1999 mg/kg dw	DI-60 2000 mg/kg dw	DI-60 2002 mg/kg dw
PCB congeners					
PCB 8	< 0.021	< 0.021	< 0.014	< 0.021	0.007
PCB 18	< 0.018	< 0.018	< 0.012	< 0.018	0.014
PCB 28	0.028	0.027	< 0.010	< 0.015	0.005
PCB 52	< 0.009	< 0.009	< 0.006	< 0.009	< 0.003
PCB 101	< 0.009	< 0.009	< 0.006	< 0.009	< 0.003
PCB 118	< 0.006	< 0.006	< 0.004	< 0.006	< 0.002
PCB 153	< 0.006	< 0.006	< 0.004	< 0.006	< 0.002
PCB 105	< 0.006	< 0.006	< 0.004	< 0.006	< 0.002
PCB 138	< 0.006	< 0.006	< 0.004	< 0.006	< 0.002
PCB 187	< 0.006	< 0.006	< 0.004	< 0.006	< 0.002
PCB 128	< 0.006	< 0.006	< 0.004	< 0.006	< 0.002
PCB 156	< 0.006	< 0.006	< 0.004	< 0.006	< 0.002
PCB 180	< 0.006	< 0.006	< 0.004	< 0.006	< 0.002
Total PCB as					
Aroclor 1242					0.09

Appendix 20 2(4)

Table 2. PCB concentrations in deinking sludge from Mänttä mill.

PCB	DI-70 1996 mg/kg dw	DI-70 1999 mg/kg dw	DI-70 2000 mg/kg dw	DI-70 2002 mg/kg dw
PCB congeners				
PCB 8	0.070	< 0.014	< 0.014	< 0.007
PCB 18	0.10	< 0.012	< 0.012	0.006
PCB 28	0.21	< 0.010	< 0.010	< 0.005
PCB 52	0.043	< 0.006	< 0.006	< 0.003
PCB 101	0.007	< 0.006	< 0.006	< 0.003
PCB 118	< 0.004	< 0.004	< 0.004	< 0.002
PCB 153	< 0.004	< 0.004	< 0.004	< 0.002
PCB 105	< 0.004	< 0.004	< 0.004	< 0.002
PCB 138	< 0.004	< 0.004	< 0.004	< 0.002
PCB 187	< 0.004	< 0.004	< 0.004	< 0.002
PCB 128	< 0.004	< 0.004	< 0.004	< 0.002
PCB 156	< 0.004	< 0.004	< 0.004	< 0.002
PCB 180	< 0.004	< 0.004	< 0.004	< 0.002
Total PCB as				
Aroclor 1242	1.9			

Appendix 20 3(4)

Table 3. PCB concentrations in deinking sludge from Mänttä mill.

PCB	DI-80 1993 mg/kg dw	DI-80 1996 mg/kg dw	DI-80 1999 mg/kg dw	DI-80 2000 mg/kg dw	DI-80 2002 mg/kg dw
PCB congeners					
PCB 8	0.055	0.050	0.047	< 0.014	0.008
PCB 18	0.082	0.079	0.069	< 0.012	0.011
PCB 28	0.15	0.13	0.073	0.011	0.035
PCB 52	0.030	0.020	0.053	< 0.006	< 0.003
PCB 101	< 0.006	< 0.006	< 0.006	< 0.006	< 0.003
PCB 118	< 0.004	< 0.004	< 0.004	< 0.004	< 0.002
PCB 153	< 0.004	< 0.004	< 0.004	< 0.004	< 0.002
PCB 105	< 0.004	< 0.004	< 0.004	< 0.004	< 0.002
PCB 138	< 0.004	< 0.004	< 0.004	< 0.004	< 0.002
PCB 187	< 0.004	< 0.004	< 0.004	< 0.004	< 0.002
PCB 128	< 0.004	< 0.004	< 0.004	< 0.004	< 0.002
PCB 156	< 0.004	< 0.004	< 0.004	< 0.004	< 0.002
PCB 180	< 0.004	< 0.004	< 0.004	< 0.004	< 0.002
Total PCB as					
Aroclor 1242	1.3	1.1	1.3		0.14

Appendix 20 4(4)

Table 4. PCB concentrations in deinking sludge from Nokia mill.

PCB	2001 mg/kg dw	2002 mg/kg dw
PCB congeners		
PCB 8	< 0.014	0.16
PCB 18	< 0.012	0.19
PCB 28	< 0.010	0.46
PCB 52	< 0.006	0.10
PCB 101	< 0.006	0.026
PCB 118	< 0.004	< 0.004
PCB 153	< 0.004	< 0.004
PCB 105	< 0.004	< 0.004
PCB 138	< 0.004	< 0.004
PCB 187	< 0.004	< 0.004
PCB 128	< 0.004	< 0.004
PCB 156	< 0.004	< 0.004
PCB 180	< 0.004	< 0.004
Total PCB as		
Aroclor 1242		3.4

Appendix 21 1(2)

Table 1. PCB concentrations in process water (pulper DI-60) from deinking department.

PCB	Incoming water µg/l	Cleaned water µg/l	Reject µg/l
Total PCB as			
Aroclor 1242	< 0.3	< 0.2	< 0.2
Aroclor 1254	< 0.3	< 0.2	< 0.2
Aroclor 1260	< 0.3	< 0.2	< 0.2

Table 2. PCB concentrations in process water (pulper DI-70) from deinking department.

PCB	Incoming water µg/l	Cleaned water µg/l	Reject µg/l
Total PCB as			
Aroclor 1242	< 0.2	< 0.2	< 0.2
Aroclor 1254	< 0.2	< 0.2	< 0.2
Aroclor 1260	< 0.2	< 0.2	< 0.2

Appendix 21 2(2)

Table 3. PCB concentrations in process water (pulper DI-80) from deinking department.

PCB	Incoming water µg/l	Cleaned water µg/l	Reject µg/l
Total PCB as			
Aroclor 1242	< 0.2	< 0.2	< 0.2
Aroclor 1254	< 0.2	< 0.2	< 0.2
Aroclor 1260	< 0.2	< 0.2	< 0.2

Appendix 22

Table 1. PCB concentrations in samples in close proximity to electrical equipment in paper mill.

PCB	Surface material sample mg/kg dw	Sand sample mg/kg dw
PCB congeners		
PCB 8	0.059	< 0.007
PCB 18	0.14	0.011
PCB 28	0.26	0.031
PCB 52	0.011	0.012
PCB 101	< 0.003	0.011
PCB 118	0.020	0.004
PCB 153	< 0.002	0.020
PCB 105	0.011	0.005
PCB 138	< 0.002	0.021
PCB 187	< 0.002	0.008
PCB 128	< 0.002	0.002
PCB 156	0.002	0.003
PCB 180	0.007	0.017
Total PCB as		
Aroclor 1242	2.1	0.21
Aroclor 1260	0.09	0.13

Appendix 23 1(2)

Table 1. PCB concentrations in municipal wastewater from town of Mänttä.

PCB	Year 2000 µg/l	Year 2002 µg/l
Total PCB as		
Aroclor 1242	< 0.3	< 0.2
Aroclor 1254	< 0.3	< 0.2
Aroclor 1260	< 0.3	< 0.2

Table 2. PCB concentrations in industrial wastewater from Mänttä mill.

PCB	Year 2000 µg/l	Year 2002 µg/l
Total PCB as		
Aroclor 1242	< 0.3	< 0.2
Aroclor 1254	< 0.3	< 0.2
Aroclor 1260	< 0.3	< 0.2

Appendix 23 2(2)

Table 3. PCB concentrations in treated wastewater from treatment plant of Mänttä mill.

PCB	Year 2000 µg/l	Year 2002 µg/l
Total PCB as		
Aroclor 1242	< 0.3	< 0.2
Aroclor 1254	< 0.3	< 0.2
Aroclor 1260	< 0.3	< 0.2

Table 4. PCB concentrations in wastewater from various parts of treatment plant of Mänttä mill.

PCB	MS µg/l	PS µg/l	ST µg/l	IS µg/l	AE µg/l
Total PCB as					
Aroclor 1242	< 0.3	< 0.3	< 0.3	< 0.2	< 0.2
Aroclor 1254	< 0.3	< 0.3	< 0.3	< 0.2	< 0.2
Aroclor 1260	< 0.3	< 0.3	< 0.3	< 0.2	< 0.2

MS=mechanical sedimentation, PS=primary sedimentation, ST=sludge thickener, IS=intermediate sedimentation, AE=aeration, stage II.

Appendix 24 1(4)

Table 1. PCB concentrations in biosludge from a wastewater treatment plant.

PCB	BS 93 mg/kg dw	BS 96 mg/kg dw	BS 99 mg/kg dw
PCB congeners			
PCB 8	0.034	0.023	< 0.021
PCB 18	0.020	0.022	0.020
PCB 28	0.059	0.043	0.034
PCB 52	< 0.009	< 0.009	< 0.009
PCB 101	< 0.009	< 0.009	< 0.009
PCB 118	< 0.006	< 0.006	< 0.006
PCB 153	< 0.006	< 0.006	< 0.006
PCB 105	< 0.006	< 0.006	< 0.006
PCB 138	< 0.006	< 0.006	< 0.006
PCB 187	< 0.006	< 0.006	< 0.006
PCB 128	< 0.006	< 0.006	< 0.006
PCB 156	< 0.006	< 0.006	< 0.006
PCB 180	< 0.006	< 0.006	< 0.006
Total PCB as			
Aroclor 1242	0.56	0.39	0.30

Appendix 24 2(4)

Table 2. PCB concentrations in biosludge from a wastewater treatment plant.

PCB	BS 01 mg/kg dw	BS 02 mg/kg dw	BS 04 mg/kg dw
PCB congeners			
PCB 8	< 0.014	0.008	< 0.007
PCB 18	0.017	0.015	0.017
PCB 28	0.029	0.011	0.015
PCB 52	< 0.006	0.059	0.011
PCB 101	< 0.006	0.005	< 0.003
PCB 118	< 0.004	< 0.002	< 0.002
PCB 153	< 0.004	< 0.002	0.003
PCB 105	< 0.004	< 0.002	< 0.002
PCB 138	< 0.004	< 0.002	0.002
PCB 187	< 0.004	< 0.002	< 0.002
PCB 128	< 0.004	< 0.002	< 0.002
PCB 156	< 0.004	< 0.002	< 0.002
PCB 180	< 0.004	< 0.002	< 0.002
Total PCB as			
Aroclor 1242	0.39	0.11	0.13

Appendix 24 3(4)

Table 3. PCB concentrations in wastewater sludge from various parts of treatment plant in 2002.

PCB	MX 02 mg/kg dw	MS 02 mg/kg dw	PS 02 mg/kg dw	IS 02 mg/kg dw	*SS 02 mg/kg dw
PCB congeners					
PCB 8	< 0.007	< 0.007	< 0.007	0.012	-
PCB 18	< 0.006	< 0.006	0.047	0.010	-
PCB 28	0.008	< 0.005	0.006	0.030	-
PCB 52	0.015	0.003	0.021	0.017	-
PCB 101	< 0.003	< 0.003	< 0.003	< 0.003	-
PCB 118	< 0.002	0.003	0.003	< 0.002	-
PCB 153	< 0.002	< 0.002	< 0.002	< 0.002	-
PCB 105	< 0.002	< 0.002	< 0.002	< 0.002	-
PCB 138	< 0.002	< 0.002	< 0.002	< 0.002	-
PCB 187	< 0.002	< 0.002	< 0.002	< 0.002	-
PCB 128	< 0.002	< 0.002	< 0.002	< 0.002	-
PCB 156	< 0.002	< 0.002	< 0.002	< 0.002	-
PCB 180	< 0.002	< 0.002	< 0.002	< 0.002	-
Total PCB as					
Aroclor 1242	0.08		0.12	0.18	

MX=mixed sludge, MS=mechanical sedimentation, PS=primary sedimentation, IS=intermediate sedimentation, SS=secondary sedimentation. *The amount of the sludge from secondary sedimentation was too low for the determination of PCBs.

Appendix 24 4(4)

Table 4. PCB concentrations in wastewater sludge from various parts of a treatment plant in 2004.

PCB	MX 04 mg/kg dw	MS 04 mg/kg dw	PS 04 mg/kg dw	IS 04 mg/kg dw	SS 04 mg/kg dw
PCB congeners					
PCB 8	0.038	< 0.007	0.078	0.020	< 0.014
PCB 18	0.042	0.010	0.15	0.054	0.028
PCB 28	0.067	0.008	0.18	0.032	0.021
PCB 52	0.022	0.004	0.11	0.026	0.016
PCB 101	0.007	< 0.003	0.044	< 0.006	< 0.006
PCB 118	0.008	< 0.002	0.056	0.004	< 0.004
PCB 153	< 0.002	< 0.002	0.024	< 0.004	< 0.004
PCB 105	< 0.002	< 0.002	0.027	< 0.004	< 0.004
PCB 138	< 0.002	< 0.002	0.038	< 0.004	< 0.004
PCB 187	< 0.002	< 0.002	< 0.002	< 0.004	< 0.004
PCB 128	< 0.002	< 0.002	< 0.002	< 0.004	< 0.004
PCB 156	< 0.002	< 0.002	< 0.002	< 0.004	< 0.004
PCB 180	< 0.002	< 0.002	0.031	< 0.004	< 0.004
Total PCB as					
Aroclor 1242	0.54	0.09	1.7	0.39	0.20

MX=mixed sludge, MS=mechanical sedimentation, PS=primary sedimentation, IS=intermediate sedimentation, SS=secondary sedimentation.

Appendix 25

Table 1. PCB concentrations in pike from Lake Melasjärvi downstream from Mänttä mill.

PCB	Pike 1 mg/kg fw	Pike 2 mg/kg fw	Pike 3 mg/kg fw	Pike 4 mg/kg fw	Pike 5 mg/kg fw
PCB congeners					
PCB 8	< 0.003	< 0.003	< 0.003	< 0.003	< 0.003
PCB 18	< 0.003	< 0.003	< 0.003	< 0.003	< 0.003
PCB 28	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002
PCB 52	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
PCB 101	0.003	0.002	0.003	0.004	< 0.001
PCB 118	0.002	0.001	0.003	0.002	< 0.001
PCB 153	0.005	0.004	0.008	0.007	0.003
PCB 105	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
PCB 138	0.006	0.004	0.008	0.007	0.003
PCB 187	< 0.001	< 0.001	0.002	0.001	< 0.001
PCB 128	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
PCB 156	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
PCB 180	0.002	0.002	0.003	0.003	0.002
Total PCB as Clophen A 60/ Aroclor 1260*	0.04	0.02	0.05	0.05	

*The total PCB concentrations were calculated as Clophen A 60. Since the industrial use, composition and fingerprints of Clophen A 60 and Aroclor 1260 do not differ from each other, the use of Clophen A 60 and Aroclor 1260 in fingerprint considerations yield the same final result.

Appendix 26

Table 1. PCB concentrations in pike from lakes in the region of Tampere and Nokia.

PCB	Näsijärvi mg/kg fw	Pyhäjärvi mg/kg fw	Kulovesi I mg/kg fw	Kulovesi II mg/kg fw	Iidesjärvi mg/kg fw
PCB congeners					
PCB 8	< 0.003	< 0.003	< 0.003	< 0.003	< 0.003
PCB 18	< 0.003	< 0.003	< 0.003	< 0.003	< 0.003
PCB 28	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002
PCB 52	< 0.001	< 0.001	0.003	< 0.001	< 0.001
PCB 101	< 0.001	< 0.001	0.006	< 0.001	< 0.001
PCB 118	< 0.001	< 0.001	0.003	< 0.001	< 0.001
PCB 153	< 0.001	< 0.001	0.012	< 0.001	< 0.001
PCB 105	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
PCB 138	< 0.001	< 0.001	0.010	< 0.001	< 0.001
PCB 187	< 0.001	< 0.001	0.002	< 0.001	< 0.001
PCB 128	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
PCB 156	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
PCB 180	< 0.001	< 0.001	0.004	< 0.001	< 0.001
Total PCB as Clophen A 60/ Aroclor 1260*			0.07		

*The total PCB concentrations were calculated as Clophen A 60. Since the industrial use, composition and fingerprints of Clophen A 60 and Aroclor 1260 do not differ from each other, the use of Clophen A 60 and Aroclor 1260 in fingerprint considerations yield the same final result.

Appendix 27 1(12)

Table 1. PCB concentrations in sediment from lake basin (Keurusselkä) upstream from Mänttä mill in 2000.

PCB	0-2 cm mg/kg dw	2-4 cm mg/kg dw	4-6 cm mg/kg dw	6-8 cm mg/kg dw
PCB congeners				
PCB 8	< 0.014	< 0.014	< 0.014	< 0.014
PCB 18	< 0.012	< 0.012	< 0.012	< 0.012
PCB 28	< 0.010	< 0.010	< 0.010	< 0.010
PCB 52	< 0.006	< 0.006	< 0.006	< 0.006
PCB 101	< 0.006	< 0.006	< 0.006	< 0.006
PCB 118	< 0.004	< 0.004	< 0.004	< 0.004
PCB 153	< 0.004	< 0.004	< 0.004	< 0.004
PCB 105	< 0.004	< 0.004	< 0.004	< 0.004
PCB 138	< 0.004	< 0.004	< 0.004	< 0.004
PCB 187	< 0.004	< 0.004	< 0.004	< 0.004
PCB 128	< 0.004	< 0.004	< 0.004	< 0.004
PCB 156	< 0.004	< 0.004	< 0.004	< 0.004
PCB 180	< 0.004	< 0.004	< 0.004	< 0.004
*Total PCB**				

*Aroclor 1242, Aroclor 1254 and Aroclor 1260 were not observed in the samples.

Appendix 27 2(12)

Table 2. PCB concentrations in sediment from lake basin (Keurusselkä) upstream from Mänttä mill in 2000.

PCB	8-10 cm mg/kg dw	10-12 cm mg/kg dw	12-14 cm mg/kg dw	14-16 cm mg/kg dw
PCB congeners				
PCB 8	< 0.014	< 0.014	< 0.014	< 0.014
PCB 18	< 0.012	< 0.012	< 0.012	< 0.012
PCB 28	< 0.010	< 0.010	< 0.010	< 0.010
PCB 52	< 0.006	< 0.006	< 0.006	< 0.006
PCB 101	< 0.006	< 0.006	< 0.006	< 0.006
PCB 118	< 0.004	< 0.004	< 0.004	< 0.004
PCB 153	< 0.004	< 0.004	< 0.004	< 0.004
PCB 105	< 0.004	< 0.004	< 0.004	< 0.004
PCB 138	< 0.004	< 0.004	< 0.004	< 0.004
PCB 187	< 0.004	< 0.004	< 0.004	< 0.004
PCB 128	< 0.004	< 0.004	< 0.004	< 0.004
PCB 156	< 0.004	< 0.004	< 0.004	< 0.004
PCB 180	< 0.004	< 0.004	< 0.004	< 0.004
*Total PCB**				

*Aroclor 1242, Aroclor 1254 and Aroclor 1260 were not observed in the samples.

Appendix 27 3(12)

Table 3. PCB concentrations in sediment from lake basin (Keurusselkä) upstream from Mänttä mill in 2000.

PCB	16-18 cm mg/kg dw	18-20 cm mg/kg dw	20-22 cm mg/kg dw	22-24 cm mg/kg dw
PCB congeners				
PCB 8	< 0.014	< 0.014	< 0.014	< 0.014
PCB 18	< 0.012	< 0.012	< 0.012	< 0.012
PCB 28	< 0.010	< 0.010	< 0.010	< 0.010
PCB 52	< 0.006	< 0.006	< 0.006	< 0.006
PCB 101	< 0.006	< 0.006	< 0.006	< 0.006
PCB 118	< 0.004	< 0.004	< 0.004	< 0.004
PCB 153	< 0.004	< 0.004	< 0.004	< 0.004
PCB 105	< 0.004	< 0.004	< 0.004	< 0.004
PCB 138	< 0.004	< 0.004	< 0.004	< 0.004
PCB 187	< 0.004	< 0.004	< 0.004	< 0.004
PCB 128	< 0.004	< 0.004	< 0.004	< 0.004
PCB 156	< 0.004	< 0.004	< 0.004	< 0.004
PCB 180	< 0.004	< 0.004	< 0.004	< 0.004
*Total PCB**				

*Aroclor 1242, Aroclor 1254 and Aroclor 1260 were not observed in the samples.

Appendix 27 4(12)

Table 4. PCB concentrations in sediment from lake basin (Mäntänlahti) downstream from Mänttä mill in 2000.

PCB	0-5 cm mg/kg dw	5-10 cm mg/kg dw
PCB congeners		
PCB 8	< 0.021	< 0.021
PCB 18	< 0.018	< 0.018
PCB 28	< 0.015	< 0.015
PCB 52	< 0.009	< 0.009
PCB 101	< 0.009	0.016
PCB 118	0.014	0.016
PCB 153	0.022	0.026
PCB 105	< 0.006	< 0.006
PCB 138	0.037	0.046
PCB 187	0.010	< 0.006
PCB 128	< 0.006	< 0.006
PCB 156	< 0.006	< 0.006
PCB 180	0.015	0.017
Total PCB as		
Aroclor 1260	0.18	0.22

Appendix 27 5(12)

Table 5. PCB concentrations in sediment from lake basin (Kuorevesi) downstream from Mänttä mill in 2000.

PCB	0-2 cm mg/kg dw	2-4 cm mg/kg dw	4-6 cm mg/kg dw	6-8 cm mg/kg dw	8-10 cm mg/kg dw
PCB congeners					
PCB 8	< 0.014	< 0.014	< 0.014	< 0.014	< 0.014
PCB 18	< 0.012	< 0.012	< 0.012	< 0.012	< 0.012
PCB 28	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010
PCB 52	< 0.006	< 0.006	< 0.006	< 0.006	< 0.006
PCB 101	< 0.006	< 0.006	< 0.006	< 0.006	< 0.006
PCB 118	< 0.004	< 0.004	< 0.004	< 0.004	< 0.004
PCB 153	< 0.004	< 0.004	< 0.004	< 0.004	< 0.004
PCB 105	< 0.004	< 0.004	< 0.004	< 0.004	< 0.004
PCB 138	< 0.004	< 0.004	< 0.004	< 0.004	< 0.004
PCB 187	< 0.004	< 0.004	< 0.004	< 0.004	< 0.004
PCB 128	< 0.004	< 0.004	< 0.004	< 0.004	< 0.004
PCB 156	< 0.004	< 0.004	< 0.004	< 0.004	< 0.004
PCB 180	< 0.004	< 0.004	< 0.004	< 0.004	< 0.004
*Total PCB**					

*Aroclor 1242, Aroclor 1254 and Aroclor 1260 were not observed in the samples.

Appendix 27 6(12)

Table 6. PCB concentrations in sediment from lake basin (Kuorevesi) downstream from Mänttä mill in 2000.

PCB	10-12 cm mg/kg dw	12-14 cm mg/kg dw	14-16 cm mg/kg dw	16-18 cm mg/kg dw	18-20 cm mg/kg dw
PCB congeners					
PCB 8	< 0.014	< 0.014	< 0.014	< 0.014	< 0.014
PCB 18	< 0.012	< 0.012	< 0.012	< 0.012	< 0.012
PCB 28	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010
PCB 52	< 0.006	< 0.006	< 0.006	< 0.006	< 0.006
PCB 101	< 0.006	< 0.006	< 0.006	< 0.006	< 0.006
PCB 118	< 0.004	< 0.004	< 0.004	< 0.004	< 0.004
PCB 153	< 0.004	< 0.004	< 0.004	< 0.004	< 0.004
PCB 105	< 0.004	< 0.004	< 0.004	< 0.004	< 0.004
PCB 138	< 0.004	< 0.004	< 0.004	< 0.004	< 0.004
PCB 187	< 0.004	< 0.004	< 0.004	< 0.004	< 0.004
PCB 128	< 0.004	< 0.004	< 0.004	< 0.004	< 0.004
PCB 156	< 0.004	< 0.004	< 0.004	< 0.004	< 0.004
PCB 180	< 0.004	< 0.004	< 0.004	< 0.004	< 0.004
*Total PCB**					

*Aroclor 1242, Aroclor 1254 and Aroclor 1260 were not observed in the samples.

Appendix 27 7(12)

Table 7. PCB concentrations in sediment from lake basin (Kuorevesi) downstream from Mänttä mill in 2000.

PCB	20-22 cm mg/kg dw	22-24 cm mg/kg dw	24-26 cm mg/kg dw	26-28 cm mg/kg dw
PCB congeners				
PCB 8	< 0.014	< 0.014	< 0.014	< 0.014
PCB 18	< 0.012	< 0.012	< 0.012	< 0.012
PCB 28	< 0.010	< 0.010	< 0.010	< 0.010
PCB 52	< 0.006	< 0.006	< 0.006	< 0.006
PCB 101	< 0.006	< 0.006	< 0.006	< 0.006
PCB 118	< 0.004	< 0.004	< 0.004	< 0.004
PCB 153	< 0.004	< 0.004	< 0.004	< 0.004
PCB 105	< 0.004	< 0.004	< 0.004	< 0.004
PCB 138	< 0.004	< 0.004	< 0.004	< 0.004
PCB 187	< 0.004	< 0.004	< 0.004	< 0.004
PCB 128	< 0.004	< 0.004	< 0.004	< 0.004
PCB 156	< 0.004	< 0.004	< 0.004	< 0.004
PCB 180	< 0.004	< 0.004	< 0.004	< 0.004
*Total PCB**				

*Aroclor 1242, Aroclor 1254 and Aroclor 1260 were not observed in the samples.

Appendix 27 8(12)

Table 8. PCB concentrations in sediment from lake basin (Melasjärvi) downstream from Mänttä mill in 2000.

PCB	0-2 cm mg/kg dw	2-4 cm mg/kg dw	4-6 cm mg/kg dw	6-8 cm mg/kg dw	8-10 cm mg/kg dw
PCB congeners					
PCB 8	< 0.014	< 0.014	< 0.014	< 0.014	< 0.014
PCB 18	< 0.012	< 0.012	< 0.012	< 0.012	< 0.012
PCB 28	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010
PCB 52	< 0.006	< 0.006	< 0.006	< 0.006	< 0.006
PCB 101	< 0.006	< 0.006	< 0.006	< 0.006	< 0.006
PCB 118	< 0.004	< 0.004	< 0.004	< 0.004	< 0.004
PCB 153	< 0.004	< 0.004	< 0.004	< 0.004	< 0.004
PCB 105	< 0.004	< 0.004	< 0.004	< 0.004	< 0.004
PCB 138	< 0.004	< 0.004	< 0.004	< 0.004	< 0.004
PCB 187	< 0.004	< 0.004	< 0.004	< 0.004	< 0.004
PCB 128	< 0.004	< 0.004	< 0.004	< 0.004	< 0.004
PCB 156	< 0.004	< 0.004	< 0.004	< 0.004	< 0.004
PCB 180	< 0.004	< 0.004	< 0.004	< 0.004	< 0.004
*Total PCB**					

*Aroclor 1242, Aroclor 1254 and Aroclor 1260 were not observed in the samples.

Appendix 27 9(12)

Table 9. PCB concentrations in sediment from lake basin (Melasjärvi) downstream from Mänttä mill in 2000.

PCB	10-12 cm mg/kg dw	12-14 cm mg/kg dw	14-16 cm mg/kg dw	16-18 cm mg/kg dw	18-20 cm mg/kg dw
PCB congeners					
PCB 8	< 0.014	< 0.014	< 0.014	< 0.021	< 0.021
PCB 18	< 0.012	< 0.012	< 0.012	< 0.018	< 0.018
PCB 28	< 0.010	< 0.010	< 0.010	< 0.015	< 0.015
PCB 52	< 0.006	< 0.006	< 0.006	< 0.009	< 0.009
PCB 101	< 0.006	< 0.006	< 0.006	< 0.009	< 0.009
PCB 118	< 0.004	< 0.004	< 0.004	< 0.006	< 0.006
PCB 153	< 0.004	< 0.004	< 0.004	< 0.006	< 0.006
PCB 105	< 0.004	< 0.004	< 0.004	< 0.006	< 0.006
PCB 138	< 0.004	< 0.004	< 0.004	< 0.006	< 0.006
PCB 187	< 0.004	< 0.004	< 0.004	< 0.006	< 0.006
PCB 128	< 0.004	< 0.004	< 0.004	< 0.006	< 0.006
PCB 156	< 0.004	< 0.004	< 0.004	< 0.006	< 0.006
PCB 180	< 0.004	< 0.004	< 0.004	< 0.006	< 0.006
*Total PCB**					

*Aroclor 1242, Aroclor 1254 and Aroclor 1260 were not observed in the samples.

Appendix 27 10(12)

Table 10. PCB concentrations in sediment from lake basin (Melasjärvi) downstream from Mänttä mill in 2000.

PCB	20-22 cm mg/kg dw	22-24 cm mg/kg dw	24-26 cm mg/kg dw	26-28 cm mg/kg dw	28-30 cm mg/kg dw
PCB congeners					
PCB 8	< 0.021	< 0.021	< 0.014	< 0.014	< 0.014
PCB 18	< 0.018	< 0.018	< 0.012	< 0.012	< 0.012
PCB 28	< 0.015	< 0.015	< 0.010	< 0.010	< 0.010
PCB 52	< 0.009	< 0.009	< 0.006	< 0.006	< 0.006
PCB 101	< 0.009	< 0.009	< 0.006	< 0.006	< 0.006
PCB 118	< 0.006	< 0.006	0.019	< 0.004	< 0.004
PCB 153	< 0.006	< 0.006	0.030	< 0.004	< 0.004
PCB 105	< 0.006	< 0.006	< 0.004	< 0.004	< 0.004
PCB 138	< 0.006	< 0.006	0.049	< 0.004	< 0.004
PCB 187	< 0.006	< 0.006	< 0.004	< 0.004	< 0.004
PCB 128	< 0.006	< 0.006	< 0.004	< 0.004	< 0.004
PCB 156	< 0.006	< 0.006	< 0.004	< 0.004	< 0.004
PCB 180	< 0.006	< 0.006	0.018	< 0.004	< 0.004
Total PCB as Aroclor 1260			0.23		

Appendix 27 11(12)

Table 11. PCB concentrations in sediment from lake basin (Aittoselkä) downstream from Mänttä mill in 2000.

PCB	0-2 cm mg/kg dw	2-4 cm mg/kg dw	4-6 cm mg/kg dw	6-8 cm mg/kg dw	8-10 cm mg/kg dw
PCB congeners					
PCB 8	< 0.014	< 0.014	< 0.014	< 0.014	< 0.014
PCB 18	< 0.012	< 0.012	< 0.012	< 0.012	< 0.012
PCB 28	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010
PCB 52	< 0.006	< 0.006	< 0.006	< 0.006	< 0.006
PCB 101	< 0.006	< 0.006	< 0.006	< 0.006	< 0.006
PCB 118	< 0.004	< 0.004	< 0.004	< 0.004	< 0.004
PCB 153	< 0.004	< 0.004	< 0.004	< 0.004	< 0.004
PCB 105	< 0.004	< 0.004	< 0.004	< 0.004	< 0.004
PCB 138	< 0.004	< 0.004	< 0.004	< 0.004	< 0.004
PCB 187	< 0.004	< 0.004	< 0.004	< 0.004	< 0.004
PCB 128	< 0.004	< 0.004	< 0.004	< 0.004	< 0.004
PCB 156	< 0.004	< 0.004	< 0.004	< 0.004	< 0.004
PCB 180	< 0.004	< 0.004	< 0.004	< 0.004	< 0.004
*Total PCB**					

*Aroclor 1242, Aroclor 1254 and Aroclor 1260 were not observed in the samples.

Appendix 27 12(12)

Table 12. PCB concentrations in sediment from lake basin (Aittoselkä) downstream from Mänttä mill in 2000.

PCB	10-12 cm mg/kg dw	12-14 cm mg/kg dw	14-16 cm mg/kg dw	16-18 cm mg/kg dw	18-20 cm mg/kg dw
PCB congeners					
PCB 8	< 0.014	< 0.014	< 0.014	< 0.014	< 0.014
PCB 18	< 0.012	< 0.012	< 0.012	< 0.012	< 0.012
PCB 28	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010
PCB 52	< 0.006	< 0.006	< 0.006	< 0.006	< 0.006
PCB 101	< 0.006	< 0.006	< 0.006	< 0.006	< 0.006
PCB 118	< 0.004	< 0.004	< 0.004	< 0.004	< 0.004
PCB 153	< 0.004	< 0.004	< 0.004	< 0.004	< 0.004
PCB 105	< 0.004	< 0.004	< 0.004	< 0.004	< 0.004
PCB 138	< 0.004	< 0.004	< 0.004	< 0.004	< 0.004
PCB 187	< 0.004	< 0.004	< 0.004	< 0.004	< 0.004
PCB 128	< 0.004	< 0.004	< 0.004	< 0.004	< 0.004
PCB 156	< 0.004	< 0.004	< 0.004	< 0.004	< 0.004
PCB 180	< 0.004	< 0.004	< 0.004	< 0.004	< 0.004
*Total PCB**					

*Aroclor 1242, Aroclor 1254 and Aroclor 1260 were not observed in the samples.

Appendix 28 1(4)

Table 1. PCB concentrations in surface sediment from Mäntänlahti downstream from Mänttä mill in 2001.

PCB	0-2 cm mg/kg dw	2-3 cm mg/kg dw	3-4 cm mg/kg dw
PCB congeners			
PCB 8	< 0.007	< 0.007	< 0.007
PCB 18	< 0.006	< 0.006	< 0.006
PCB 28	< 0.005	< 0.005	< 0.005
PCB 52	< 0.003	< 0.003	< 0.003
PCB 101	< 0.003	< 0.003	< 0.003
PCB 118	< 0.002	< 0.002	< 0.002
PCB 153	0.013	0.015	0.016
PCB 105	< 0.002	< 0.002	< 0.002
PCB 138	0.017	0.039	0.044
PCB 187	< 0.002	< 0.002	< 0.002
PCB 128	< 0.002	< 0.002	< 0.002
PCB 156	< 0.002	< 0.002	< 0.002
PCB 180	0.009	0.011	0.013
Total PCB as			
Aroclor 1260	0.12	0.20	0.23

Appendix 28 2(4)

Table 2. PCB concentrations in surface sediment from Savonselkä downstream from Mänttä mill in 2001.

PCB	0-2 cm mg/kg dw	2-3 cm mg/kg dw	3-4 cm mg/kg dw
PCB congeners			
PCB 8	< 0.007	< 0.007	< 0.007
PCB 18	< 0.006	< 0.006	< 0.006
PCB 28	< 0.005	< 0.005	< 0.005
PCB 52	< 0.003	< 0.003	< 0.003
PCB 101	< 0.003	< 0.003	< 0.003
PCB 118	< 0.002	< 0.002	< 0.002
PCB 153	< 0.002	< 0.002	< 0.002
PCB 105	< 0.002	< 0.002	< 0.002
PCB 138	0.005	< 0.002	< 0.002
PCB 187	< 0.002	< 0.002	< 0.002
PCB 128	< 0.002	< 0.002	< 0.002
PCB 156	< 0.002	< 0.002	< 0.002
PCB 180	0.002	< 0.002	< 0.002
*Total PCB**			

*Aroclor 1242, Aroclor 1254 and Aroclor 1260 were not observed in the samples.

Appendix 28 3(4)

Table 3. PCB concentrations in surface sediment from Aittoselkä downstream from Mänttä mill in 2001.

PCB	0-2 cm mg/kg dw	2-3 cm mg/kg dw	3-4 cm mg/kg dw
PCB congeners			
PCB 8	< 0.007	< 0.007	< 0.007
PCB 18	< 0.006	< 0.006	< 0.006
PCB 28	< 0.005	< 0.005	< 0.005
PCB 52	< 0.003	< 0.003	< 0.003
PCB 101	< 0.003	< 0.003	< 0.003
PCB 118	< 0.002	< 0.002	< 0.002
PCB 153	< 0.002	< 0.002	< 0.002
PCB 105	< 0.002	< 0.002	< 0.002
PCB 138	0.012	< 0.002	0.012
PCB 187	< 0.002	< 0.002	< 0.002
PCB 128	< 0.002	< 0.002	< 0.002
PCB 156	< 0.002	< 0.002	< 0.002
PCB 180	0.003	< 0.002	0.003
*Total PCB**			

*Aroclor 1242, Aroclor 1254 and Aroclor 1260 were not observed in the samples.

Appendix 28 4(4)

Table 4. PCB concentrations in surface sediment from Paloselkä downstream from Mänttä mill in 2001.

PCB	0-2 cm mg/kg dw	2-3 cm mg/kg dw	3-4 cm mg/kg dw
PCB congeners			
PCB 8	< 0.007	< 0.007	< 0.007
PCB 18	< 0.006	< 0.006	< 0.006
PCB 28	< 0.005	< 0.005	< 0.005
PCB 52	< 0.003	< 0.003	< 0.003
PCB 101	< 0.003	< 0.003	< 0.003
PCB 118	< 0.002	< 0.002	< 0.002
PCB 153	< 0.002	< 0.002	< 0.002
PCB 105	< 0.002	< 0.002	< 0.002
PCB 138	0.003	0.003	0.003
PCB 187	< 0.002	< 0.002	< 0.002
PCB 128	< 0.002	< 0.002	< 0.002
PCB 156	< 0.002	< 0.002	< 0.002
PCB 180	< 0.002	< 0.002	< 0.002
*Total PCB**			

*Aroclor 1242, Aroclor 1254 and Aroclor 1260 were not observed in the samples.

Appendix 29 1(3)

Table 1. PCB concentrations in sediment at industrial site of Mänttä mill.

PCB	Reservoir mg/kg dw	Point of discharge mg/kg dw	Koskelanlampi mg/kg dw
PCB congeners			
PCB 8	< 0.007	< 0.007	< 0.007
PCB 18	< 0.006	< 0.006	< 0.006
PCB 28	< 0.005	< 0.005	< 0.005
PCB 52	< 0.003	< 0.003	< 0.003
PCB 101	0.012	< 0.003	< 0.003
PCB 118	< 0.002	< 0.002	< 0.002
PCB 153	0.032	0.026	< 0.002
PCB 105	< 0.002	< 0.002	< 0.002
PCB 138	0.049	0.056	< 0.002
PCB 187	< 0.002	< 0.002	< 0.002
PCB 128	< 0.002	< 0.002	< 0.002
PCB 156	< 0.002	< 0.002	< 0.002
PCB 180	< 0.002	< 0.002	< 0.002
Total PCB as			
Aroclor 1260	0.28	0.24	

Appendix 29 2(3)

Table 2. PCB concentrations in sediment at sites downstream from landfills.

PCB	Riuttaoja mg/kg dw	Vuohijoki mg/kg dw	*Kuorevesi mg/kg dw
PCB congeners			
PCB 8	< 0.007	< 0.007	< 0.007
PCB 18	< 0.006	< 0.006	< 0.006
PCB 28	< 0.005	< 0.005	< 0.005
PCB 52	< 0.003	< 0.003	< 0.003
PCB 101	< 0.003	< 0.003	< 0.003
PCB 118	< 0.002	< 0.002	< 0.002
PCB 153	< 0.002	< 0.002	< 0.002
PCB 105	< 0.002	< 0.002	< 0.002
PCB 138	< 0.002	< 0.002	< 0.002
PCB 187	< 0.002	< 0.002	< 0.002
PCB 128	< 0.002	< 0.002	< 0.002
PCB 156	< 0.002	< 0.002	< 0.002
PCB 180	< 0.002	< 0.002	< 0.002
*Total PCB***			

* A reference sample. **Aroclor 1242, Aroclor 1254 and Aroclor 1260 were not observed in the samples.

Appendix 29 3(3)

Table 3. PCB concentrations in river water at site downstream from landfill.

PCB	Vuohijoki µg/l
Total PCB as	
Aroclor 1242	< 0.3
Aroclor 1254	< 0.3
Aroclor 1260	< 0.3

Appendix 30

Table 1. PCB concentrations in soil and sediment at the former site of Mänttä mill.

PCB	6	LP3+LP5	LP 8	LP 1	S 1
	mg/kg dw	mg/kg dw	mg/kg dw	mg/kg dw	mg/kg dw
PCB congeners					
PCB 8	< 0.007	< 0.007	< 0.007	< 0.007	< 0.007
PCB 18	< 0.006	< 0.006	< 0.006	< 0.006	< 0.006
PCB 28	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005
PCB 52	< 0.003	< 0.003	< 0.003	< 0.003	< 0.003
PCB 101	0.005	0.006	< 0.003	0.007	0.005
PCB 118	0.002	0.003	< 0.002	0.004	< 0.002
PCB 153	0.011	0.007	< 0.002	0.009	0.008
PCB 105	< 0.002	< 0.002	< 0.002	0.002	< 0.002
PCB 138	0.011	0.008	< 0.002	0.011	0.010
PCB 187	0.003	< 0.002	< 0.002	0.002	0.003
PCB 128	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002
PCB 156	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002
PCB 180	0.008	0.004	< 0.002	0.006	0.006
Total PCB as					
Aroclor 1260	0.08	0.05		0.06	0.06

Appendix 31 1(3)

Table 1. PCB concentrations in sediment at sites downstream from Nokia mill and region of Nokia and Tampere.

PCB	Lukkilanlahti I mg/kg dw	Lukkilanlahti II mg/kg dw	Eden mg/kg dw
PCB congeners			
PCB 8	< 0.007	< 0.007	< 0.007
PCB 18	< 0.006	< 0.006	< 0.006
PCB 28	< 0.005	< 0.005	< 0.005
PCB 52	< 0.003	< 0.003	< 0.003
PCB 101	< 0.003	< 0.003	< 0.003
PCB 118	< 0.002	< 0.002	< 0.002
PCB 153	< 0.002	< 0.002	< 0.002
PCB 105	< 0.002	< 0.002	< 0.002
PCB 138	< 0.002	< 0.002	< 0.002
PCB 187	< 0.002	< 0.002	< 0.002
PCB 128	< 0.002	< 0.002	< 0.002
PCB 156	< 0.002	< 0.002	< 0.002
PCB 180	< 0.002	< 0.002	< 0.002
*Total PCB**			

*Aroclor 1242, Aroclor 1254 and Aroclor 1260 were not observed in the samples.

Appendix 31 2(3)

Table 2. PCB concentrations in sediment from lake basin (Päijänne) downstream from Kaipola mill in 2002.

PCB	0-5 cm mg/kg dw	5-10 cm mg/kg dw	10-15 cm mg/kg dw
PCB congeners			
PCB 8	< 0.007	< 0.007	< 0.007
PCB 18	< 0.006	< 0.006	< 0.006
PCB 28	< 0.005	< 0.005	< 0.005
PCB 52	< 0.003	< 0.003	< 0.003
PCB 101	< 0.003	< 0.003	< 0.003
PCB 118	< 0.002	< 0.002	< 0.002
PCB 153	< 0.002	< 0.002	< 0.002
PCB 105	< 0.002	< 0.002	< 0.002
PCB 138	< 0.002	< 0.002	< 0.002
PCB 187	< 0.002	< 0.002	< 0.002
PCB 128	< 0.002	< 0.002	< 0.002
PCB 156	< 0.002	< 0.002	< 0.002
PCB 180	< 0.002	< 0.002	< 0.002
*Total PCB**			

*Aroclor 1242, Aroclor 1254 and Aroclor 1260 were not observed in the samples.

Appendix 31 3(3)

Table 3. PCB concentrations in sediment from lake basin (Päijänne) downstream from Kaipola mill in 2002.

PCB	15-20 cm mg/kg dw	20-25 cm mg/kg dw	25-30 cm mg/kg dw
PCB congeners			
PCB 8	< 0.007	< 0.007	< 0.007
PCB 18	< 0.006	0.007	0.008
PCB 28	< 0.005	< 0.005	0.005
PCB 52	< 0.003	< 0.003	0.003
PCB 101	< 0.003	< 0.003	0.003
PCB 118	< 0.002	< 0.002	< 0.002
PCB 153	< 0.002	< 0.002	< 0.002
PCB 105	< 0.002	< 0.002	< 0.002
PCB 138	< 0.002	< 0.002	0.002
PCB 187	< 0.002	< 0.002	< 0.002
PCB 128	< 0.002	< 0.002	< 0.002
PCB 156	< 0.002	< 0.002	< 0.002
PCB 180	< 0.002	< 0.002	< 0.002
Total PCB as			
Aroclor 1242			0.05

Appendix 32 1(3)

Table 1. PCB concentrations in sediment from lakes in the region of Tampere and Nokia.

PCB	Näsijärvi I mg/kg dw	Näsijärvi II mg/kg dw	Iidesjärvi mg/kg dw
PCB congeners			
PCB 8	< 0.014	< 0.014	< 0.014
PCB 18	< 0.012	< 0.012	< 0.012
PCB 28	< 0.010	< 0.010	< 0.010
PCB 52	< 0.006	< 0.006	< 0.006
PCB 101	< 0.006	< 0.006	< 0.006
PCB 118	< 0.004	< 0.004	< 0.004
PCB 153	< 0.004	< 0.004	< 0.004
PCB 105	< 0.004	< 0.004	< 0.004
PCB 138	< 0.004	< 0.004	< 0.004
PCB 187	< 0.004	< 0.004	< 0.004
PCB 128	< 0.004	< 0.004	< 0.004
PCB 156	< 0.004	< 0.004	< 0.004
PCB 180	< 0.004	< 0.004	< 0.004
*Total PCB**			

*Aroclor 1242, Aroclor 1254 and Aroclor 1260 were not observed in the samples.

Appendix 32 2(3)

Table 2. PCB concentrations in sediment from lakes in the region of Tampere and Nokia.

PCB	Kulovesi mg/kg dw	Pyhäjärvi I mg/kg dw	Pyhäjärvi II mg/kg dw
PCB congeners			
PCB 8	< 0.014	< 0.014	0.11
PCB 18	< 0.012	< 0.012	0.24
PCB 28	< 0.010	< 0.010	0.43
PCB 52	< 0.006	< 0.006	0.072
PCB 101	< 0.006	< 0.006	< 0.003
PCB 118	< 0.004	< 0.004	< 0.002
PCB 153	< 0.004	< 0.004	0.013
PCB 105	< 0.004	< 0.004	< 0.002
PCB 138	< 0.004	< 0.004	0.018
PCB 187	< 0.004	< 0.004	< 0.002
PCB 128	< 0.004	< 0.004	< 0.002
PCB 156	< 0.004	< 0.004	< 0.002
PCB 180	< 0.004	< 0.004	0.011
Total PCB as Aroclor 1242			6.9

Appendix 32 3(3)

Table 3. PCB concentrations in sediment (Pyhäjärvi) downstream from a former capacitor factory.

PCB	Viinikanlahti mg/kg dw
PCB congeners	
PCB 8	4.7
PCB 18	6.8
PCB 28	8.6
PCB 52	2.7
PCB 101	0.68
PCB 118	< 0.02
PCB 153	< 0.02
PCB 105	< 0.02
PCB 138	< 0.02
PCB 187	< 0.02
PCB 128	< 0.02
PCB 156	< 0.02
PCB 180	< 0.02
Total PCB as Aroclor 1242	86

Appendix 33 1(5)

Table 1. PCB concentrations in hand towel sheet.

PCB	A/I mg/kg fw	*A/II mg/kg fw	*B mg/kg fw	C mg/kg fw
PCB congeners				
PCB 8	< 0.003	0.004	< 0.003	< 0.003
PCB 18	< 0.003	0.009	0.003	< 0.003
PCB 28	< 0.002	0.007	0.004	< 0.002
PCB 52	< 0.001	0.002	0.002	< 0.001
PCB 101	< 0.001	< 0.001	0.001	< 0.001
PCB 118	< 0.001	< 0.001	< 0.001	< 0.001
PCB 153	< 0.001	0.002	0.001	< 0.001
PCB 105	< 0.001	< 0.001	< 0.001	< 0.001
PCB 138	< 0.001	< 0.001	0.002	< 0.001
PCB 187	< 0.001	< 0.001	< 0.001	< 0.001
PCB 128	< 0.001	< 0.001	< 0.001	< 0.001
PCB 156	< 0.001	< 0.001	< 0.001	< 0.001
PCB 180	< 0.001	< 0.001	< 0.001	< 0.001
Total PCB as Aroclor 1242		0.07	0.02	

*A is a German product and B is a Swedish product.

Appendix 33 2(5)

Table 2. PCB concentrations in hand towel roll.

PCB	D mg/kg fw	E mg/kg fw
PCB congeners		
PCB 8	< 0.003	< 0.003
PCB 18	< 0.003	< 0.003
PCB 28	< 0.002	< 0.002
PCB 52	< 0.001	< 0.001
PCB 101	< 0.001	< 0.001
PCB 118	< 0.001	< 0.001
PCB 153	< 0.001	< 0.001
PCB 105	< 0.001	< 0.001
PCB 138	< 0.001	< 0.001
PCB 187	< 0.001	< 0.001
PCB 128	< 0.001	< 0.001
PCB 156	< 0.001	< 0.001
PCB 180	< 0.001	< 0.001
*Total PCB**		

*Aroclor 1242, Aroclor 1254 and Aroclor 1260 were not observed in the samples.

Appendix 33 3(5)

Table 3. PCB concentrations in kitchen towel.

PCB	A/I mg/kg fw	A/II mg/kg fw	B mg/kg fw	C mg/kg fw
PCB congeners				
PCB 8	< 0.003	< 0.003	< 0.003	< 0.003
PCB 18	< 0.003	< 0.003	< 0.003	< 0.003
PCB 28	< 0.002	< 0.002	< 0.002	< 0.002
PCB 52	< 0.001	< 0.001	< 0.001	< 0.001
PCB 101	< 0.001	< 0.001	< 0.001	< 0.001
PCB 118	< 0.001	< 0.001	< 0.001	< 0.001
PCB 153	< 0.001	< 0.001	< 0.001	< 0.001
PCB 105	< 0.001	< 0.001	< 0.001	< 0.001
PCB 138	< 0.001	< 0.001	< 0.001	< 0.001
PCB 187	< 0.001	< 0.001	< 0.001	< 0.001
PCB 128	< 0.001	< 0.001	< 0.001	< 0.001
PCB 156	< 0.001	< 0.001	< 0.001	< 0.001
PCB 180	< 0.001	< 0.001	< 0.001	< 0.001
*Total PCB**				

*Aroclor 1242, Aroclor 1254 and Aroclor 1260 were not observed in the samples.

Appendix 33 4(5)

Table 4. PCB concentrations in kitchen towel.

PCB	D mg/kg fw	E/I mg/kg fw	E/II mg/kg fw	F mg/kg fw
PCB congeners				
PCB 8	< 0.003	< 0.003	< 0.003	< 0.003
PCB 18	< 0.003	< 0.003	< 0.003	< 0.003
PCB 28	< 0.002	< 0.002	< 0.002	< 0.002
PCB 52	< 0.001	< 0.001	< 0.001	< 0.001
PCB 101	< 0.001	< 0.001	< 0.001	< 0.001
PCB 118	< 0.001	< 0.001	< 0.001	< 0.001
PCB 153	< 0.001	< 0.001	< 0.001	< 0.001
PCB 105	< 0.001	< 0.001	< 0.001	< 0.001
PCB 138	< 0.001	< 0.001	< 0.001	< 0.001
PCB 187	< 0.001	< 0.001	< 0.001	< 0.001
PCB 128	< 0.001	< 0.001	< 0.001	< 0.001
PCB 156	< 0.001	< 0.001	< 0.001	< 0.001
PCB 180	< 0.001	< 0.001	< 0.001	< 0.001
*Total PCB**				

*Aroclor 1242, Aroclor 1254 and Aroclor 1260 were not observed in the samples.

Appendix 33 5(5)

Table 5. PCB concentrations in handkerchief tissue.

PCB	A mg/kg fw	B mg/kg fw	C mg/kg fw
PCB congeners			
PCB 8	< 0.003	< 0.003	< 0.003
PCB 18	< 0.003	< 0.003	< 0.003
PCB 28	< 0.002	< 0.002	< 0.002
PCB 52	< 0.001	< 0.001	< 0.001
PCB 101	< 0.001	< 0.001	< 0.001
PCB 118	< 0.001	< 0.001	< 0.001
PCB 153	< 0.001	< 0.001	< 0.001
PCB 105	< 0.001	< 0.001	< 0.001
PCB 138	< 0.001	< 0.001	< 0.001
PCB 187	< 0.001	< 0.001	< 0.001
PCB 128	< 0.001	< 0.001	< 0.001
PCB 156	< 0.001	< 0.001	< 0.001
PCB 180	< 0.001	< 0.001	< 0.001
*Total PCB**			

*Aroclor 1242, Aroclor 1254 and Aroclor 1260 were not observed in the samples.

Appendix 34 1(3)

Table 1. PCB concentrations in toilet tissue.

PCB	*A/I mg/kg fw	*A/II mg/kg fw	B mg/kg fw	C mg/kg fw
PCB congeners				
PCB 8	0.009	0.003	< 0.003	< 0.003
PCB 18	0.015	0.007	0.003	< 0.003
PCB 28	0.012	0.006	0.002	< 0.002
PCB 52	0.006	0.002	< 0.001	0.002
PCB 101	0.002	0.001	< 0.001	0.001
PCB 118	0.002	0.002	< 0.001	0.001
PCB 153	< 0.001	0.003	< 0.001	< 0.001
PCB 105	< 0.001	0.001	< 0.001	< 0.001
PCB 138	< 0.001	0.001	< 0.001	< 0.001
PCB 187	< 0.001	0.001	< 0.001	< 0.001
PCB 128	< 0.001	< 0.001	< 0.001	< 0.001
PCB 156	< 0.001	< 0.001	< 0.001	< 0.001
PCB 180	< 0.001	0.001	< 0.001	< 0.001
Total PCB as				
Aroclor 1242	0.14	0.07		

*A is an unknown product.

Appendix 34 2(3)

Table 2. PCB concentrations in toilet tissue.

PCB	D mg/kg fw	E mg/kg fw	F/I mg/kg fw	*F/II mg/kg fw
PCB congeners				
PCB 8	< 0.003	< 0.003	< 0.003	< 0.003
PCB 18	< 0.003	< 0.003	< 0.003	0.003
PCB 28	< 0.002	< 0.002	< 0.002	0.002
PCB 52	< 0.001	< 0.001	< 0.001	< 0.001
PCB 101	< 0.001	< 0.001	< 0.001	< 0.001
PCB 118	< 0.001	< 0.001	< 0.001	< 0.001
PCB 153	< 0.001	< 0.001	< 0.001	< 0.001
PCB 105	< 0.001	< 0.001	< 0.001	< 0.001
PCB 138	< 0.001	< 0.001	< 0.001	< 0.001
PCB 187	< 0.001	< 0.001	< 0.001	< 0.001
PCB 128	< 0.001	< 0.001	< 0.001	< 0.001
PCB 156	< 0.001	< 0.001	< 0.001	< 0.001
PCB 180	< 0.001	< 0.001	< 0.001	< 0.001
Total PCB as				
Aroclor 1242				0.02

*F is a Finnish product.

Appendix 34 3(3)

Table 3. PCB concentrations in toilet tissue.

PCB	G mg/kg fw	H mg/kg fw	I mg/kg fw	J mg/kg fw
PCB congeners				
PCB 8	< 0.003	< 0.003	< 0.003	< 0.003
PCB 18	< 0.003	< 0.003	< 0.003	< 0.003
PCB 28	< 0.002	< 0.002	< 0.002	< 0.002
PCB 52	< 0.001	< 0.001	< 0.001	< 0.001
PCB 101	< 0.001	< 0.001	< 0.001	< 0.001
PCB 118	< 0.001	< 0.001	< 0.001	< 0.001
PCB 153	< 0.001	< 0.001	< 0.001	< 0.001
PCB 105	< 0.001	< 0.001	< 0.001	< 0.001
PCB 138	< 0.001	< 0.001	< 0.001	< 0.001
PCB 187	< 0.001	< 0.001	< 0.001	< 0.001
PCB 128	< 0.001	< 0.001	< 0.001	< 0.001
PCB 156	< 0.001	< 0.001	< 0.001	< 0.001
PCB 180	< 0.001	< 0.001	< 0.001	< 0.001
*Total PCB**				

*Aroclor 1242, Aroclor 1254 and Aroclor 1260 were not observed in the samples.