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Screening studies of POP levels in fish from selected lakes in the Paz watercourse

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Screening studies of POP levels in fish from selected lakes in the Paz watercourse

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Sammendrag / Summary

This screening study of POPs in fish (whitefish and pike) from selected lakes in the Paz watercourse reveals that the highest levels of almost all of the analysed contaminants were found in fish from Kuetsjarvi. The levels of POPs decreased with increasing distance from the smelters. Increased cytochrome P450 activity was found in fish from the Lake Kuetsjarvi compared to those in fish from less contaminated areas. PAH were the major contaminants in fish analysed. The levels of POPs in fish tissue did not exceed known Russian and International food quality criteria.

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1. Introduction

This report presents the results of an assessment of chemical pollutants in fish. The fish were collected throughout the Paz watercourse and at a reference site in Lake Stuorajavri (Alta-Kautokeino watercourse) (Figure 1) in 2004 - 2005. This study one part of the INTERREG project "Development and implementation of an environmental monitoring and assessment system in the joint Finnish, Norwegian and Russian border area". The project has been divided into the three subject areas: air; terrestrial and water. The studies in the "watergroup" have been conducted in cooperation between the following partners from the three countries:

Russia: Murmansk Department for Hydrometeorology and Environmental Monitoring (HYDROMET); Institute of North Industrial Ecology Problems, Kola Science Centre, RAS; Institute of Biology, Karelian Research Centre, RAS; SPA "Typhoon", Obninsk.
Finland: Lapland Regional Environment Centre; Finnish Environment Institute, Finnish Game and Fisheries Research Institute
Norway: Norwegian College of Fishery Science (NCFS), University of Tromsø; Akvaplan-niva, Norwegian Institute for Nature Research (NINA); Geological Survey of Norway (NGU).

Smelting of copper-nickel ore at the Kola Peninsula has significant pollution effects on the environment in the border areas. The main contaminant source to aquatic and terrestrial environments is the Kola Mining Company (former Pechenganikel). Investigations carried out in the early 1990s revealed numerous acidified and heavy metal polluted lakes in the border areas (Traaen *et al., 1991; 1992;* Moiseenko*, 1994;* Dauvalter and Rognerud*, 2001*). Water quality monitoring in eastern Finnmark (Norway) has shown that the heavy metal concentrations in the lakes in this area has remained high during the 1990s (SFT, 2001; 2002). Heavy metal levels in fish are well studied by Russian and Norwegian scientists (Amundsen *et al.*, 1993; 1997; Arnesen *et al*., 1996; Kashulina & Kashulin, 1997; Moiseenko *et al.,* 1995; Lukin *et al*., 2003). However, smelting process is the potential source of many other different contaminants, including persistent organochlorine pollutants (POPs) and polycyclic aromatic hydrocarbons (PAHs). Elevated PAH levels have been detected in soil in the area around smelters (Reimann *et al*., 1998), but only limited information exists on POP levels in fish from the border area.

Fish from the Paz watercourse is an important food source for the people in the area. There are more than 15 species of freshwater fishes in the Lake Inari – Paz watercourse. The fish community is a mixture of eastern, western and man introduced species. The most important fish species for food consumption are whitefish (*Coregonus lavaretus*), trout (*Salmo trutta*), perch (*Perca fluviatilis*) and pike (*Esox lucius*). The fish resources are utilised commercially, in household and for recreational purposes, but the utilisation varies between the three countries (Aspholm, 2004).

The Nordic Investment Bank and the Norwegian Government are now supporting the modernisation of the Pechenganikel smelter; and the goal is to reduce the emissions by 90%. In order to be able to document and evaluate the effects of possible reductions in emission levels there is a need for establishing new reference values of the environmental status prior to modernisation of the smelters. The area has been identified by the Arctic Monitoring and Assessment Programme (AMAP) as a "Key monitoring area," in which pollution emissions and their effects are to be monitored.

The aims of this study were to document levels of a wide range of environmental contaminants in fish and to assess their effects on fish through analyses of biochemical biomarkers. Many hydrophobic organic compounds are potential treats to organisms due to their high affinity to lipids in combination with their persistent nature. In addition, the data gathered through the

project can be used to evaluate if it is safe for the local population to continue to consume fish caught in the Paz watercourse.

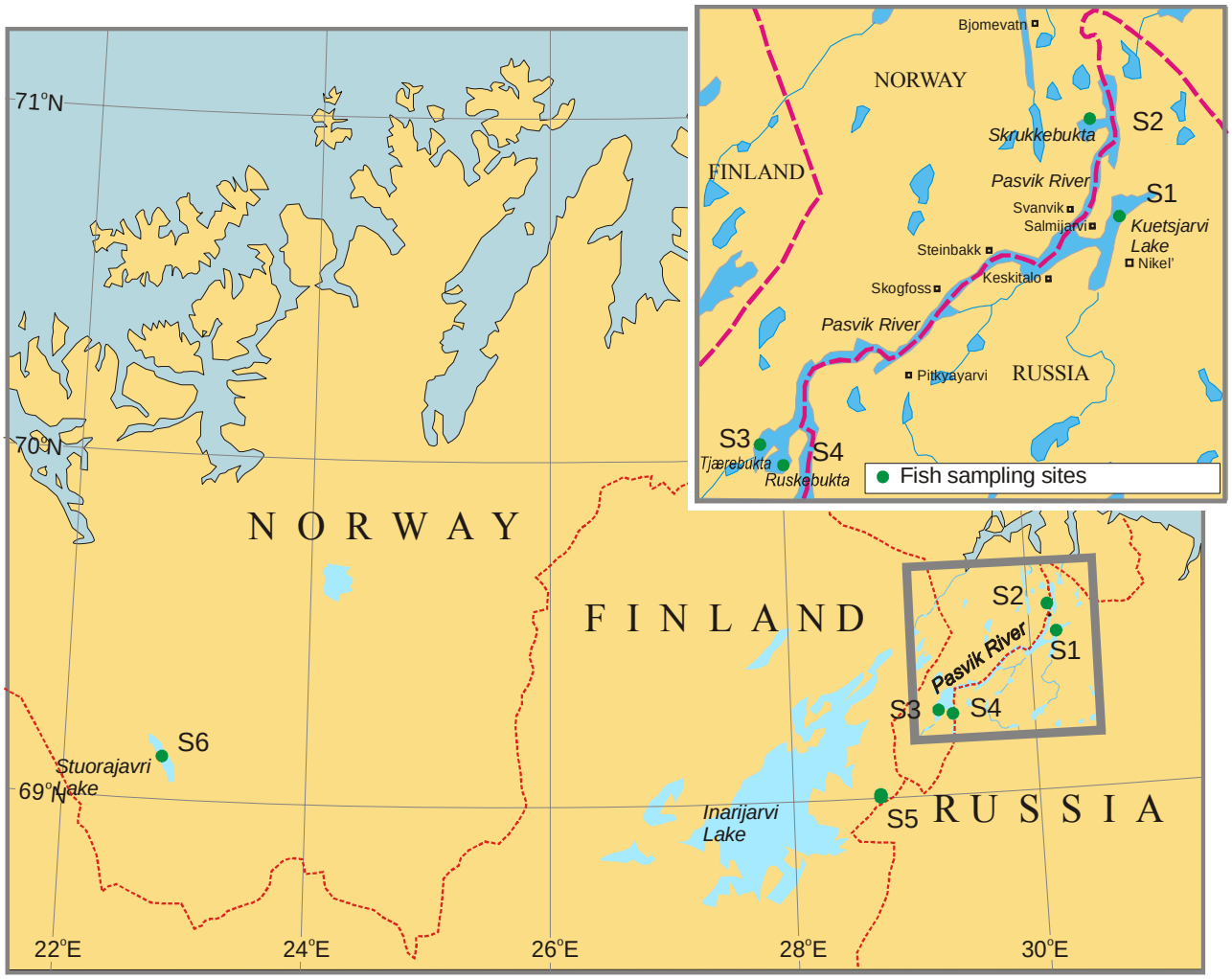

Figure 1. Fish sampling sites in the Paz watercourse Lake Kuetsjarvi (station), Skrukkebukta (station 2), Vaggetem (Ruskebukta and Tjærebukta = station 3 and 4), Rajakoski (station 5) and the reference lake; Lake Stuorajavri (station 6).

2 Study area and sampling locations

The Inari-Pasvik watershed is the main freshwater system in the region, covering an area of approximately 1250 km^2 It has a catchment area of 18 404 km^2, of which approximately 70 % belongs to Finland, 25 % to Russia and 5 % to Norway. The watercourse has important environmental qualities and rich natural resources, constituting a subarctic system with high biodiversity and production of fish and other aquatic organisms. Detailed descriptions of the study area are given in numerous report and publications (e.g. Arnesen *et al.*, 1996; Moiseenko *et al.*, 1995; Amundsen *et al*., 1993; 1997; Lukin *et al*., 2003).

Sampling of fish was carried out in several periods from 2004 to 2005. The following lakes in the Paz watercourse were sampled: Lake Kuetsjarvi (station 1), Skrukkebukta (station 2), Tjærebukta (station 3), Ruskebukta (station 4) and Rajakoski (station 5). In addition fish samples were collected from the reference Lake Stuorajavri, Kautokeino (station 6) (Table 1).

Table 1. Study localities in the Paz watercourse. Lake Stuorajavri is not part of the Paz watercourse, but it was included in the study as a reference lake. R = Russia, N = Norway.

Locality	Station number	Country	Approx. distance from smelters	2004		2005	
				Aug.	Sept.	June	Sept.
Kuetsjarvi	1	R	5 km	X			
Skrukkebukta	2	N	16 km		X		X
Tjærebukta (Vaggatem)	3	N	40 km		X		X
Ruskebukta (Vaggatem)	4	N	40 km		X		X
Rajakoski	5	R	65 km	X			
Stuorajavri[1)]	6	N	290 km			X	

[1)] Reference lake located in the Kautokeino-Alta watercourse, Norway.

3 Sampling procedure

The fieldwork was carried out as in cooperation between the Norwegian College of Fishery Science (NFH), Institute of North Industrial Ecology Problems (INEP), Kola Scientific Centre, Russian Academy of Sciences, Institute of Biology (IB), Karelian Research Centre, Russian Academy of Sciences, and Akvaplan-niva.

Fish sampling was performed in the littoral (< 8 m), profundal (> 10 m) and pelagic habitats (0 - 6 m), using gillnets. The gillnets were 40 m long and contained eight sections with different mesh sizes. Each section was 5 meter long. In the pelagic zone, 6 m deep floating nets were used, whereas 1.5 m deep bottom nets were employed in the littoral and profundal zones. The mesh sizes used were 10, 12.5, 15, 18.5, 22, 26, 35 and 45 mm (knot to knot). Additional samples of perch, pike and brown trout were collected using large-sized gillnets ($\geq$35 mm mesh size). In all studied lakes, the whitefish is represented by two different morphs, differentiated by their number and morphology of gill rakers and referred to as sparsely rakered (SR) and densely rakered (DR) whitefish (Amundsen *et al.*, 2004). The two whitefish morphs exhibit distinct genetic and ecological differences (Amundsen 1988; Amundsen *et al.*, 2004), and are treated as functional species in the analysis and presentation of the results. After retrieval from sampling devices, each fish was identified to the species level by personnel that are familiar with the taxonomy of the fish in the Pasvik River Basin.

The following fish species were collected for contaminant analyses during 2004-2005: whitefish (*Coregonus lavaretus*), pike (*Esox lucius*), perch (*Perca fluviatilis*) and vendace (*Coregonus albula*).

Each fish was measured for fork length and weight, sex and stage of maturation were recorded, and stomachs samples were collected and preserved in 96 % ethanol for diet analyses. Otoliths were sampled from whitefish and vendace and opercula from perch for age determinations. Dissection of fish and sampling of tissues were carried out with knife, scissors and scalpel made of stainless steel. The tissue samples (muscle and liver, weight 3-10 g) were put into plastic sachets for mercury analysis and in aluminium foil for POP analyses. Samples were stored frozen in the field and transported frozen to the laboratory for analyses.

For biochemical (biomarker) analyses, liver and fish bile were collected at two locations (Kuetsjarvi and Rajakoski). To quantify bile acids in fish bile, gallbladders were dissected out and bile was extracted into glass flasks and fixed by 96% ethanol (volume per cent). Samples were stored at 4°C until analysis**.** To assess of aniline hydroxylase activity in fish liver microsomes, hepatic tissues from each fish were removed in package and frozen on liquid nitrogen. Samples were stored at liquid nitrogen until analysis**.**

Liver and muscle samples from fish of the same age and sex were pooled and analysed for a wide range of POPs and mercury. We expect that there is limited variance between the fish in the pooled samples.

4 Analyses

4.1. Analysed material

Due to limited funding for analyses, two species, whitefish and pike from selected localities (Kuestjarvi, Ruskebukta, Skrukkebukta, Tjærebukta and Stuorajavri), were selected for contaminant analyses. Other fish species are stored in a freezer and will be available for future analyses. The analysed material and the main parameters are given in *Table 2*. The complete results are given in *Appendix 3*.

Table2. Concentrations of ΣDDT, Hexachlorobenzene (HCB), Chlordanes (ΣCHL), Hexachlorcyclohexane (ΣHCH), ΣPCB, Toxaphene, ΣPCDD/F, ΣPBDE and ΣPAH in samples from fish from Tjærebukta, Skrukkebukta, Ruskebukta, Kuetsjarvi and Lake Stuorajavri (lower table). All concentrations are given in ng/g ww except for ΣPBDE (pg/g ww).

Component	White fish								Pike	
	Tjærebukta		Skrukkebukta		Ruskebukta		Kuetsjarvi		Kuetsjarvi	
	4-5 years, Wt 100-500 g		3-5 years, Wt 100-300 g		4-6 years, Wt 300-500 g		3-5 years, Wt 50-140 g			
	Muscle	Liver	Muscle	Liver	Muscle	Liver	Muscle	Liver	Muscle	Liver
	N=10	N=10	N=5	N=5	N=5	N=5	N=10	N=15	N=10	N=10
Lipids, %	0.66	14.1	0.88	5.25	0.54	7.94	1.86	6.99	0.41	25.9
[1]ΣDDT	3.59	1.96	0.32	3.47	n.d.	1.66	17.5	88.1	3.59	109
Hexachlorobenzene (HCB)	n.d.	1.23	0.28	0.69	0.15	0.97	0.58	2.81	0.20	3.71
[2]Chlordanes (ΣCHL)	0.17	0.30	n.d.	n.d.	n.d.	n.d.	0.18	0.46	0.05	3.00
[3]Hexachlorcyclohexane (ΣHCH)	n.d.	n.d.	0.07	n.d.	n.d.	n.d.	0.29	1.51	n.d.	5.50
[4]ΣPCB	4.94	5.1	0.94	8.32	0.93	3.79	21	150	5.84	283
[5]Toxaphene	3.24	30.7	n.d.	n.d.	n.d.	5.73	6.27	n.d.	3.24	138.9
ΣPCDD/F	n.d.	2.52	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	7.39
[6]ΣPBDE	1.72	39.4	11.9	75.5	0.50	30.3	137	758	29.4	2968
[7]ΣPAH	n.d.	34.1	7.86	101.8	6.26	73.6	2.48	286	n.d.	155.5

Tabel 2 continues.

OCs	Whitefish, female						Whitefish, male				Pike, M&F	
	N=13		N=6		N=9		N=10		N=6		N=5	
	Wt=100-200g		Wt=300-400 g		Wt=400-500g		Wt=100-200g		Wt=200-300g			
	Muscle	Liver	Muscle	Liver	Muscle	Liver	Muscle	Liver	Muscle	Liver	Muscle	Liver
Lipid, %	0.71	3.05	0.50	3.60	0.76	8.40	0.44	3.06	0.55	3.17	0.32	6.86
[1]ΣDDT	0.35	1.87	0.2	1.1	n.d.	0.60	0.41	3.87	0.55	2.08	0.24	5.87
Hexachlorobenzene	0.27	1.39	0.2	1.3	0.16	0.2	0.28	2.19	0.22	1.11	0.18	2.07
[2]Chlordanes (ΣCHL)	0.10	2.71	n.d.	4.90	0	0.11	0.23	6.88	0.82	3.95	0.60	3.94
[3]ΣHCH	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
[4]ΣPCB	2.58	23.2	2.82	8.13	1.53	7.33	2.45	32.3	7.88	33.8	5.61	25.3
[5]Toxaphene	6.37	10.2	1.1	3.8	1.22	4.3	7.97	22.9	5.16	1.04	5.26	2.06
ΣPCDD/F	1.26	n.d	1.49	n.d	n.d	n.d	n.d	n.d	n.d	n.d	1.33	n.d
[7]ΣPAH	14.6	50.9	n.d	n.d	n.d	n.d	0.25	46.2	n.d	69.9	22.0	50.3

[1]ΣDDT is sum of *o,p*`-DDE, *p,p*`-DDE, *o,p*`-DDD, *p,p*`-DDD, *o,p*`-DDT and *p,p*`-DDT;
[2] ΣCHL is sum of heptachlor, heptachlor epoxide, oxychlordane, *trans*-chlordane, *cis*-chlordane, *trans*-nonachlor and *cis*-nonachlor;
[3]ΣHCH is sum of α-HCH, β-HCH, and γ-HCH
[4]ΣPCB is sum of 53 PCB congeners
[5]Toxaphene compounds Parlar-26, Parlar-50, Parlar-62
[6]ΣPBDE is sum of congener; 28, 47, 99, 100. 153. 154 and 183
[7]ΣPAH is sum of 40 individual polycyclic aromatic hydrocarbons
n.d.=not detected

4.2. Contaminant analyses

Analyses were carried out at Typhoon analytical laboratory (Obninsk, Russia). Detailed descriptions of analytical methods used for determination of environmental contaminants, along with information on QC/QA, are given in *Appendix 1*.

The following persistent pollutants were determined in the biological samples:

- chlorinated pesticides and industrial organochlorines: DDT-group (*o,p*`- and *p,p'*-DDE, *o,p*`- and *p,p'*-DDD, *o,p*`- and *p,p'*-DDT), HCH (α-, β- and γ- isomers of HCH), Hexachlorobenzene (HCB), chlordanes (Heptachlor, Heptachlor epoxide, Oxychlordane, *trans*- and *cis*-Nonachlors, , *trans*- and *cis*-Chlordanes), mirex, endrin and dieldrin;
- *ortho*-substituted congeners of polychlorinated biphenyls;
- planar and *non-ortho*-substituted congeners of PCBs (IUPAC): # 77, 81, 105, 114, 118, 123, 126, 156, 157, 167, 169, 189, as well as PCB congeners # 170 and 180;
- toxaphene compounds Parlar-26, Parlar-50, Parlar-62;
- brominated flame-retardants 2,4,4`–TrBDE (#28); 2,2`,4,4`-TeBDE (#47); 2,2`,4,4`,5-PBDE (#99); 2,2`,4,4`,6-PBDE (#100); 2,2',4,4',5,5'- HeBDE (#153); 2,2',4,4',5,6-HeBDE (#154); 2,2',3,4,4',5,6-HpBDE (#183);
- polychlorinated dibenzo-*p*-dioxines and dibenzofurans (PCDD/PCDF);
- 40 individual polycyclic aromatic hydrocarbons (PAHs), included alkyl-homologues and 16 PAHs recommended by EPA

Samples were analyzed in two analytical batches, which included laboratory procedural blank, spiked blank sample for biological samples. To control recovery of analytes, surrogate isotope-labelled substances were used. They were introduced into the samples before extraction. Extracts were analyzed using GC/MS. The Typhoon laboratory has national accreditation

within the framework of Russian Analytical Laboratories Accreditation System (ALAS) for POPs and mercury in abiotic and biotic environmental media (fresh- and seawater, air, soil, bottom sediments, biological tissues). The laboratory has recently and successfully participated in the QUASIMEME International interlaboratory study on POPs and heavy metals in biological samples (exercise number: 20, 22, 24 and 28).

4.3. Biochemical biomarker analyses

Pike and whitefish collected in Rajakoski and Kuetsjarvi were selected for biochemical biomarker analyses. Bile acids were quantified using the method described by Ripatti *et al.* (1969). Aniline hydroxylase activity was measured using the method described by Mazel (1972). Detailed method descriptions are given in the *Appendix 2.*

5 Results and discussion

5.1 Legacy POP levels

5.1.1. Organochlorines

Of all legacy organochlorine compounds that were analyzed the most frequently observed compounds were chlordane and related compounds, HCB and the DDT series of structural analogs (DDT, DDE, DDD). Analytical data are presented in *Table 3.1. (*Pasvik area*)* and *Table 3.2.* (Stuorajavri) in *Appendix 3*.

DDT

DDT was, from 1946, widely used as a pesticide and insecticide, but DDT has since the early 1970's been banned in North America, Europe and the former USSR. In Norway, DDT use was restricted in 1969 and banned in 1988. However, it continues to be used in Asia, Africa, Central and South America (Voldner and Li, 1995), resulting in a continued global source.

Total DDT is the sum of the DDT structural analogs and breakdown products: *p,p'* - and *o,p'* -DDT, *p,p-'* and *o,p'* -DDD, and *p,p'*- and *o,p'* -DDE. DDT found in the environment gradually degrades to DDE. The highest concentrations of *p,p'*-DDE was measured in liver from whitefish (75.3 ng/g ww) and pike (55.4 ng/g ww) from Kuetsjarvi. Concentrations of *p,p'*-DDE comprised approximately 80% and 50% of the total DDT concentrations in liver of whitefish and pike from Kuetsjarvi, respectively. In whitefish liver from Ruskebukta, Skrukkebukta and Tjærebukta, contribution of *p,p'*-DDE to the total DDT was 65%, 75% and 85%, respectively. In liver of male whitefish the contribution of *p,p'*-DDE to the total DDT was higher compared to those in female whitefish of the same size group – 88% vs 72% (*Table 3.2, Appendix 3*). p,p'-DDT was not detected in whitefish from Finnmark and Stuorajavri. However, it was detected in whitefish from Kuetsjarvi at low level in muscle (0.95 ng/g) and liver (1.73 ng/g). Geographical distribution of total DDT in fish liver is shown in *Figure 2*.

In a study carried out in selected Finnmark lakes in the 1990s (Skotvold *et al.*, 1997), all DDT concentrations in whitefish (muscle) were below 1 ng/g ww, with average concentrations between 0.17 and 0.6 ng/g ww. Of the DDT components and their metabolites, the largest proportion (about 80%) was made up of *p,p*'-DDE.

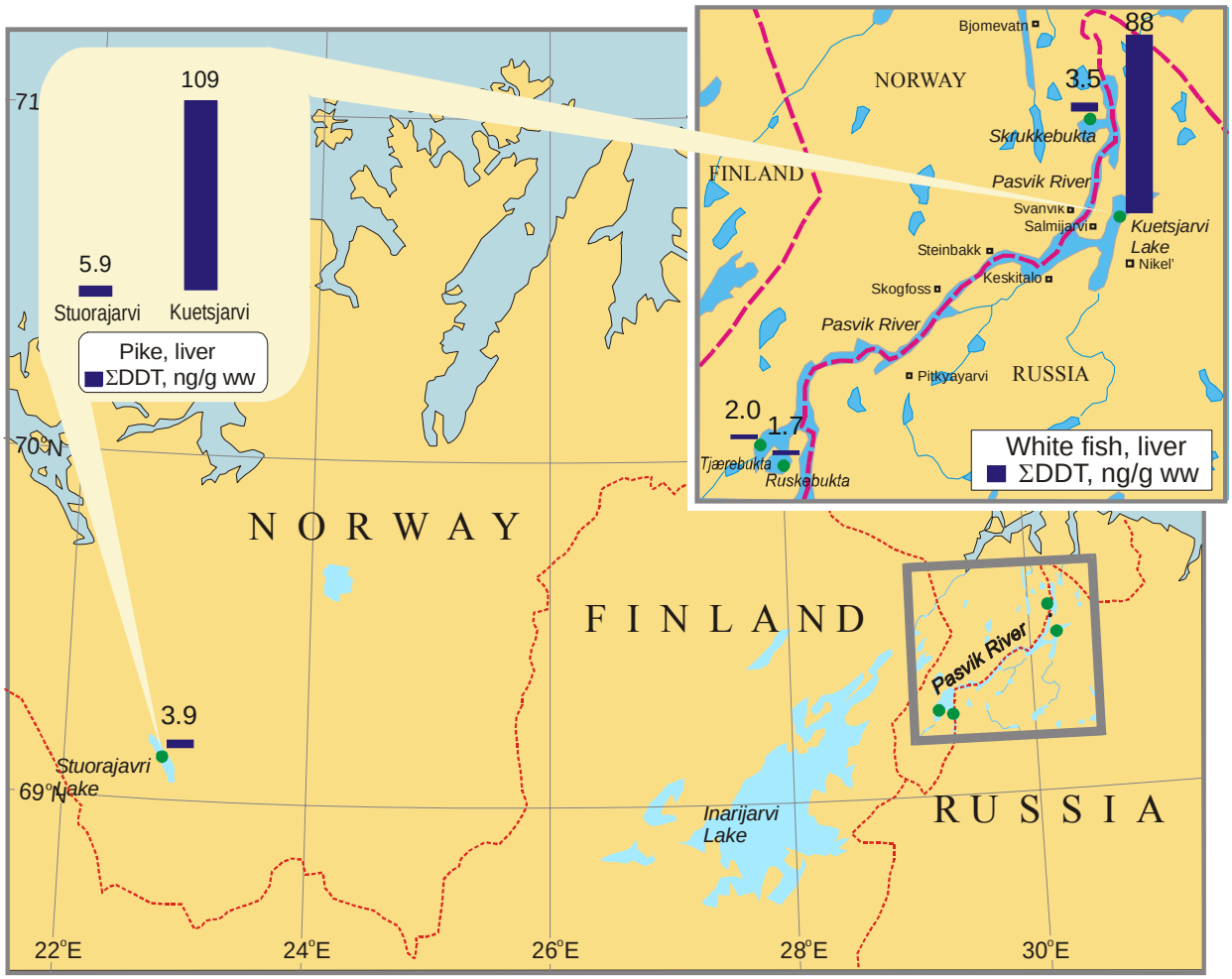

Figure 2. Distribution of DDT hepatic levels in fish from the study area

Exposure and effects: DDT has been shown to be a hormone-disrupting chemical that can affect the reproductive and nervous systems. Although there is insufficient evidence for humans, animal experiments have shown the carcinogenicity of DDT (Group 2B), which caused liver tumours in rats and mice (IARC, 1987).

Based on NOAELs (No Observed Adverse Effect Level) of 6.25 mg/kg of body weight per day in rats, 10 mg/kg of body weight per day in monkeys, and 0.25 mg/kg of body weight per day in humans, Joint FAO/WHO Meetings on Pesticide Residues (JMPR) recommended an average daily intake (ADI) for humans of 0.02 mg/kg of body weight (WHO, 2002). In Russia currently accepted DDT ADI for adults and children are 0.005 and 0.0025 mg/kg of body weight, respectively. Maximum permissible concentration (MPC) of DDT in freshwater fish is 0.3 mg/kg (Hygienic norms, 2003). Thus, even the highest detected levels of total DDT in liver of pike from the Kuetsjarvi did not exceed this MPC.

More information about external exposure and health effects is available from the U.S. EPA's IRIS Web site at http://www.epa.gov/iris and from ATSDR's Toxicological Profiles at http://www.atsdr.cdc.gov/toxprofiles.

Hexachlorobenzene (HCB)

HCB has been widely used as a fungicide to protect the seeds of onions, wheat, and sorghum. It has also been used as a solvent and as a manufacturing intermediate or additive in the production of synthetic rubber, plastic, pyrotechnics, ammunition, wood preservatives and

dyes. Production and use has ceased in many countries. HCB continues to be created as a by-product in the manufacture of many chlorinated solvents and pesticides and in other chlorinated processes. It is also released in the burning of municipal waste, during incomplete combustion. HCB has also limited use as a pesticide. In Russia, HCB was used until 1990, and was banned in 1997.

The highest levels of HCB were detected in pike and whitefish from Lake Kuetsjarvi (*Table 3.1., Appendix 3*). Geographical distribution of HCB levels in fish liver from the study area is shown in *Figure 3*.

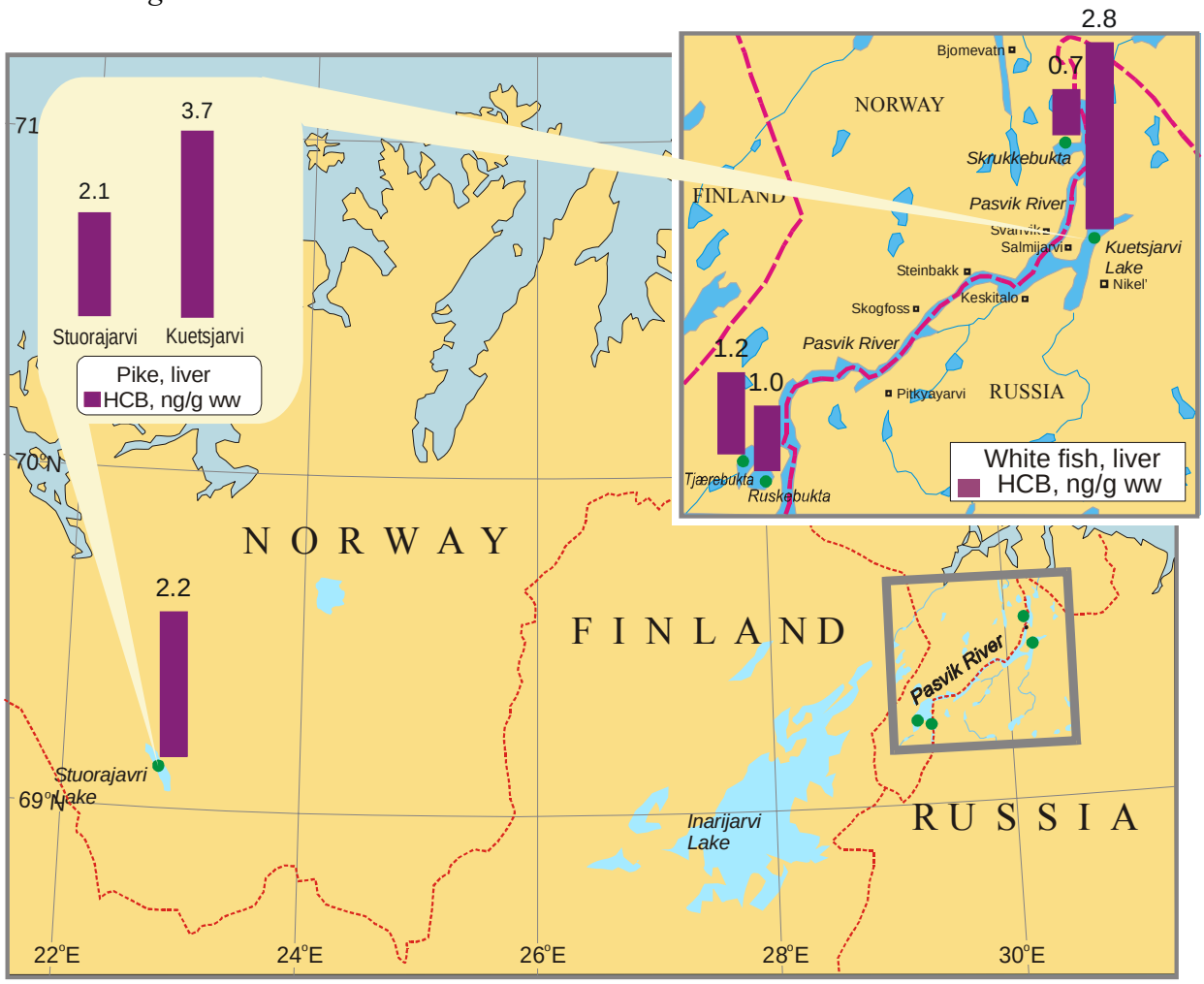

Figure 3. Distribution of HCB hepatic levels in fish from the study area

Exposure and effects: Contaminated food is probably the major route of exposure for most organisms. HCB is toxic by all routes of exposure and can damage the liver, thyroid, kidney, as well as the endocrine, immune, reproductive, and nervous systems. The evidence for carcinogenicity of HCB in humans is considered inadequate, because no documentation of a direct association between HCB and human cancer exists (IARC, 2001).

In Russia currently accepted HCB ADI is 0.0006 mg/kg of body weight (Hygienic norms, 2003). Maximum permissible concentration of HCB in freshwater fish is not established in Russia.

Chlordanes

Chlordane is a versatile, broad-spectrum contact insecticide used mainly for non-agricultural purposes (primarily for the protection of structures, but also on lawn and turf, ornamental trees, and drainage ditches). It is also used on corn, potatoes, and livestock. When used for termite control, it is applied to the soil by subsurface injection. Recently, the use of chlordane has been restricted in many countries, due to its toxic effects and capacity to persist and bioaccumulate in the environment. Chlordane is banned in Russia (de March *et al*., 1989).

Chlordane levels in fish from the study area are presented in *Tables 3.1 and 3.2*., *Appendix 3*. The distribution of Chlordanes in hepatic tissues is also is shown in *Figure 4*. Chlordane levels were higher in fish from Lake Stuorajavri than in fish from the Pasvik area. The individual compounds which contributed most to the concentrations of ΣChlordanes in whitefish and pike from the Pasvik area were *trans*- and *cis*-nonachlor, followed by *cis*-chlordane. Oxychlordane was not detected in whitefish from this area - only in pike liver at low level (0.4 ng/g ww). However, in fish from Stuorajavri the oxychlordane was the dominant chlordane compound.

In an earlier study carried out in the 1990s (Skotvold *et al.*, 1997) in selected Finnmark lakes, all ΣCHL concentrations in whitefish were below 0.5 ng/g ww.

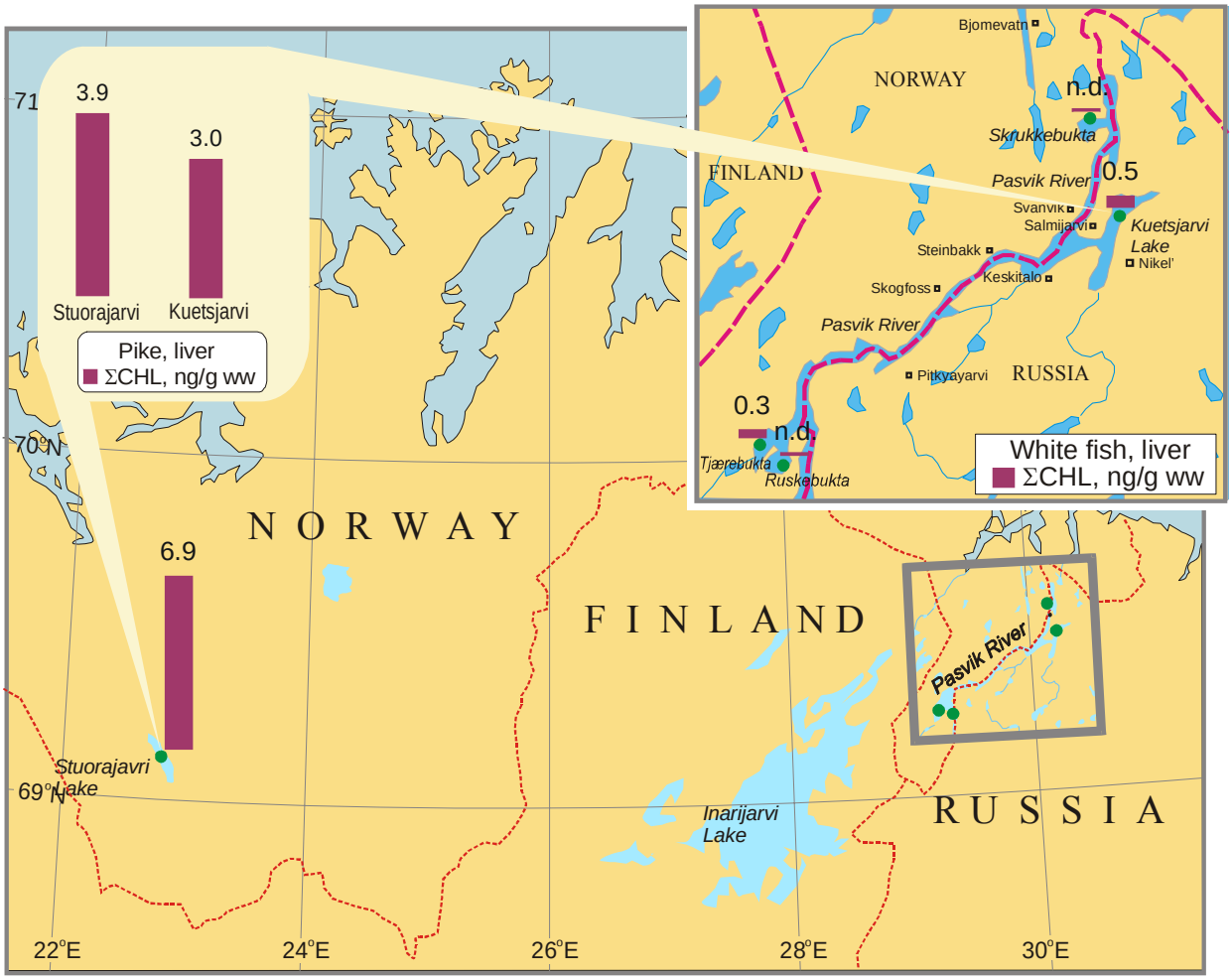

Figure 4. Distribution of ΣCHL hepatic levels in fish from the study area.

Exposure and effects: Chlordane exposure has been linked to liver and blood disorders, severe neurological effects and damage to the endocrine and reproductive systems. JMPR re-evaluated chlordane in 1986 and established an ADI of 0.5 µg/kg of body weight (IARC, 1979). A re-evaluation of chlordane was carried out in 1991 and it was concluded that although there is

inadequate evidence for its carcinogenicity in humans, the evidence from animals was sufficient to classify it in Group 2B (IARC, 1991). No MPC or ADI for chlordane exist in Russian legislative documents.

Hexachlorcyclohexane (HCH)

The γ-isomer, also known as lindane, has the highest pesticidal properties. However, technical mixtures of all isomers have been widely used as commercial pesticides. These mixtures typically contain 60-70% α-, 5-12% β-, 10-12% γ-, and 3-4% σ-HCH (Kutz *et al.*, 1991). Lindane was first registered in 1938 and is currently used in its pure form in North America and Europe, while technical HCH (a mixture of α-, β-, γ-, and δ-HCH) is still widely used in southern Asia and China (Voldner and Li, 1995; Li, 1999; Li *et al.*, 2003). In Russia, lindane use was banned in 1990, when emissions in Russia were 929 000 kg (Holoubek *et al*., 2001). Estimated on the basis of spatial emission distribution, γ-HCH emissions in the Russian Federation in 1970, 1990, and 1996 were 540 047; 13 652; and 5 941 kg, respectively (Holoubek *et al*., 2001).

HCH levels in fish from the study area are presented in *Tables 3.1 and 3.2*., *Appendix 3*. The distribution of ΣHCH in hepatic tissues also is shown in *Figure 5*.

HCH and its isomers were not detected in fish from Lake Stuorajavri, but low levels were measured in fish from the Pasvik area. The highest concentration of ΣHCH (5.5. ng/g ww) was found in liver of pike from Lake Kuetsjarvi. Lindane contribution to the total HCH was 56 %.

In and earlier study in Finnmark lakes, lindane levels in fish did not exceed 0.05 ng/g ww (Skotvold *et al.*, 1997).

Exposure and effects: Because lindane has been extensively used for several decades, its long-term health effects have been well studied. Included among the reported effects of chronic exposure to lindane are nervous disorders and increased liver weight. It is concluded that lindane is a possible human carcinogen (class 2B, IARC,1979a). The Acceptable Daily Intake (ADI) for lindane, as determined by the international authority on food residues, Codex Alimentarius, is 0.001 mg/kg of body weight. For a 60 kg adult therefore the maximum daily dose should not exceed 0.06 mg in total. The ADI was changed in 1997 from a previously less stringent figure of 0.008 mg/kg (CAC, 1989). In Russia currently accepted HCH ADI for adults and children are 0.01 and 0.005 mg/kg of body weight, respectively. Maximum permissible concentration (MPC) of HCH for freshwater fish is 0.03 mg/kg in Russia (Hygienic norms, 2003).

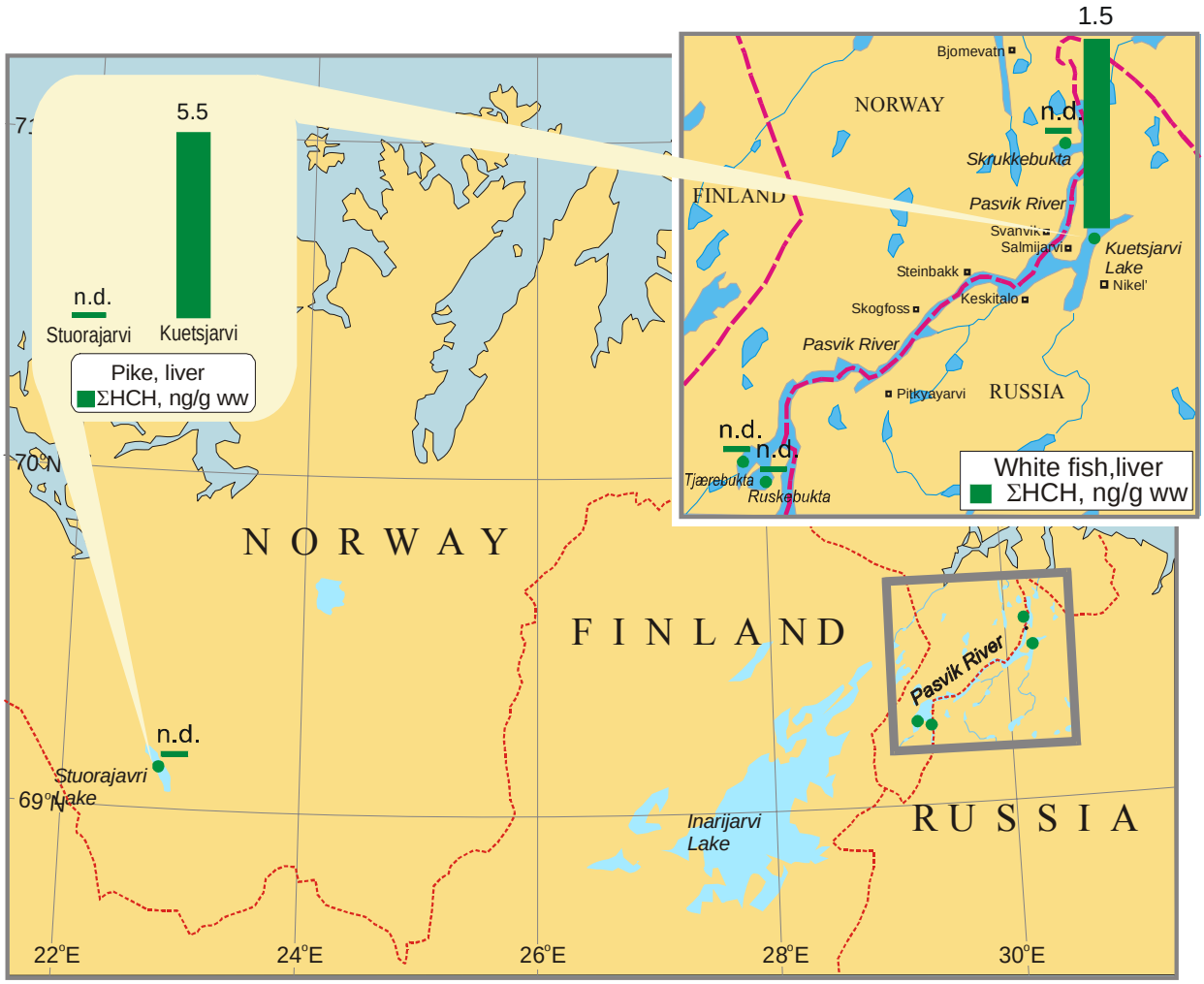

Figure 5. Distribution of ΣHCH hepatic levels in fish from the study area

5.1.2. Polychlorinated biphenyl (PCBs) levels

PCBs were first manufactured in 1929 and produced in many countries including the U.S., China, Slovakia, Germany, Japan, Russia and the United Kingdom. PCBs have been used extensively in a variety of industrial products, including transformer and capacitor oils, hydraulic and heat exchange fluids, and as plasticisers in paints, plastics and sealants, and even to control dust on roads. In Russia, production of PCBs was terminated between 1987 and 1993. Total production of PCBs in Russia by "Orgsteklo" Ltd. Production Amalgamation (Dzerzhinsk) and "Orgsintez" Ltd. Production Amalgamation (Novomoskovsk) has been estimated at 179 500 tonnes. After a PCB inventory in the Russian Federation (AMAP, 2000), the Murmansk region was highlighted as one of the priority areas for remedial actions. OSPAR and EU regulations aim at a complete phase-out of residual PCB-containing equipment and materials in the period between 1995 and 2010. However, not all PCBs in smaller applications, in particular in electrical equipment, may be removed within that period (OSPAR, 2000).

PCB levels in fish from the Pasvik area and Lake Stuorajavri are presented in *Tables 3.3.* and *3.4*, *Appendix 3. The d*istribution of PCBs in fish from the study area is shown in *Figure 6.* PCB concentrations were highest in liver of pike (283 ng/g ww) and whitefish (150 ng/g ww) from Lake Kuetsjarvi.

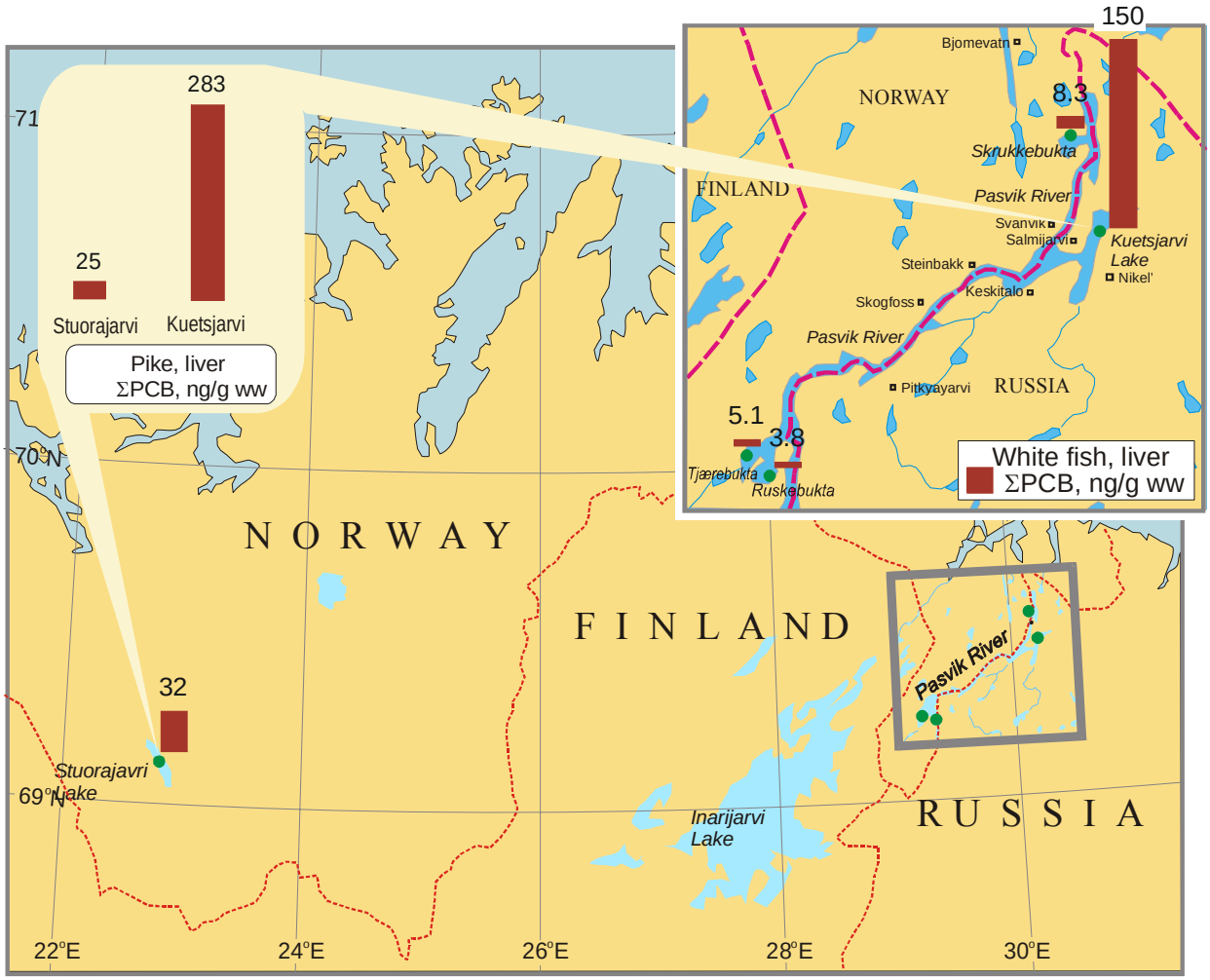

Figure 6 Distribution of ΣPCB hepatic levels in fish from the study area

Exposure and effects: Chronic low-level PCB exposures can cause liver damage, reproductive abnormalities, immune suppression, neurological and endocrine system disorders, retarded infant development, and stunted intellectual function. The International Agency for Research on Cancer ranks PCBs as a probable human carcinogen. In Russia PCBs listed as carcinogenic (List t of chemical compounds, products, industrial processes, natural and domestic factors which are carcinogenic for humans, 1998). Currently used MPC of PCB in fish is 2 mg/kg lipid weight (Sanitary-hygienic norms, 1996).

5.2 New environmental contaminants

Toxaphene

Toxaphene is a mixture of chlorobornanes, and it is a ubiquitous contaminant in freshwater ecosystems (Glassmeyer *et al.*, 1997).Toxaphene was one of the world's most widely used pesticides in the 1970s. In 1990, the EPA banned all uses of toxaphene in the United States because of scientific evidence that it harms humans and animals.

Toxaphene has never been used in Norway. In Russia toxaphene was banned in 1991. According to national statistics, toxaphene has not been used in the OSPAR region I - Barents Sea (OSPAR, 2000). The total toxaphene usage within the former Soviet Union was less than 100 000 tonnes (Voldner and Li, 1995) and was mostly applied in Ukraine (Kundiev and Kagan, 1993). However, the pesticide has been used extensively in cotton-producing countries, and is an example of a contaminant that is subject to long-range transport.

Results from toxaphene analyses in fish from the study area are summarise in *Tables 3.5* and *3.6.*, *Appendix 3*. The toxaphene distribution in hepatic tissues of fish from the study area is shown in *Figure 7*. The highest toxaphene levels were detected in liver from pike from Kuetsjarvi (139 ng/g ww) and in liver from whitefish from Tjærebukta (31 ng/g ww).

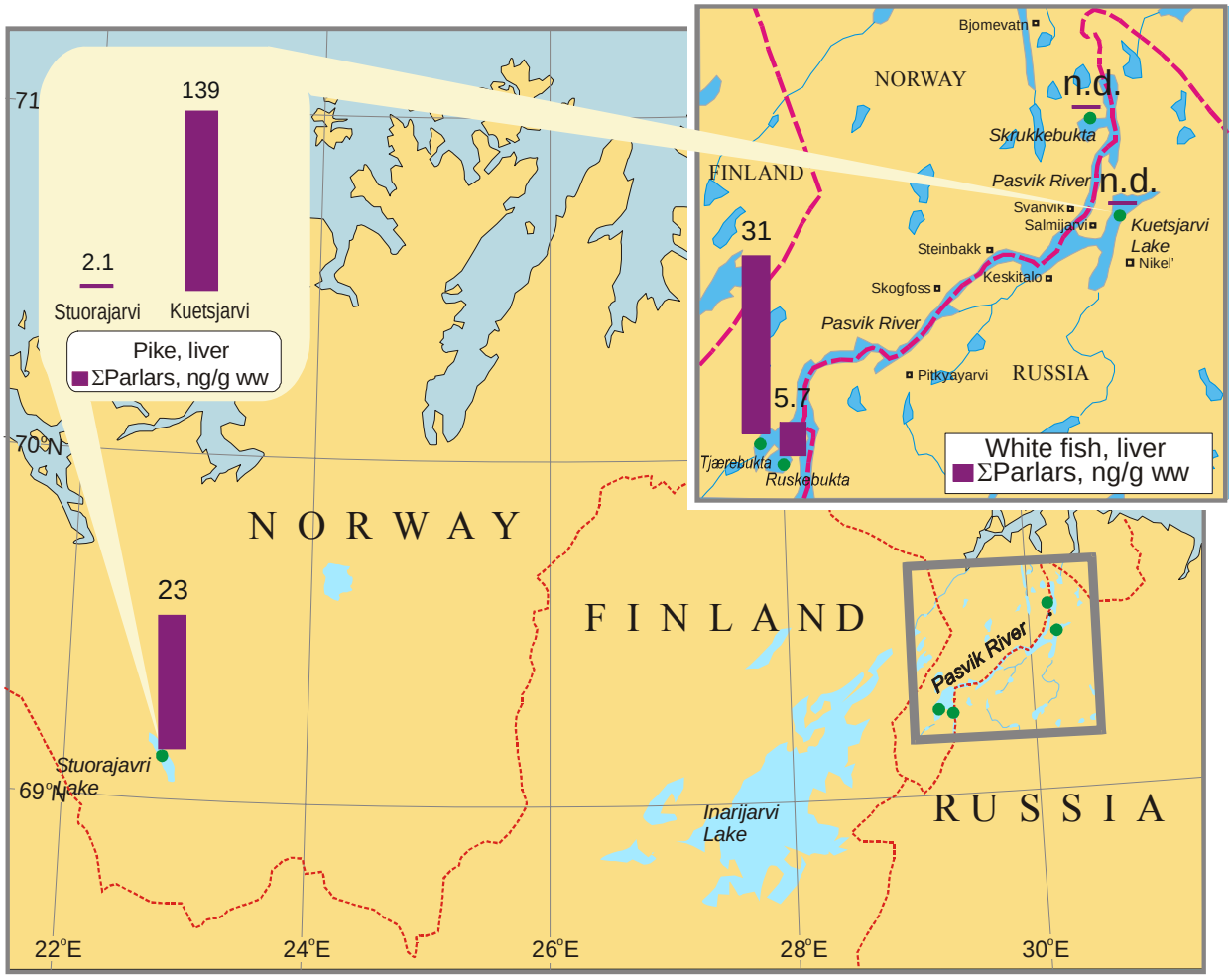

Figure 7. Distribution of Toxaphene hepatic levels in fish from the study area

Exposure and effects: Exposure may occur via food intake and drinking water from contaminated wells. At high exposures, toxaphene has been associated with kidney and liver damage, central nervous system effects, possible immune system suppression, and cancer (ATSDR, www.atcdr.cdc.gov/toxprofiles). IARC has classified toxaphene as a possible human carcinogen (group 2B) (IARC, 1987).

Polychlorinated dibenzo-*p*-dioxines and dibenzofurans (PCDD/PCDF)

Neither dioxins nor furans are produced commercially because they have no known use. These are by-products resulting from the production of other chemicals. Dioxins may also be released into the environment through the production of pesticides and other chlorinated substances. Furans are a major contaminant of PCBs. Both dioxins and furans can be produced during a variety of incineration reactions, and as a by-product in the synthesis and use of a variety of chemical products. Dioxins and furans have been detected in emissions from the incineration of coal, peat and wood, as well as from the incineration of wastes.

PCDD/PCDF levels in muscle and liver of fish from the Paz watercourse and Lake Stuorajavri are presented in *Tables 3.7* and *3.8*., *Appendix 3*. The distribution of PCDD/PCDF hepatic levels in fish from the study area is shown in *Figure 8*.

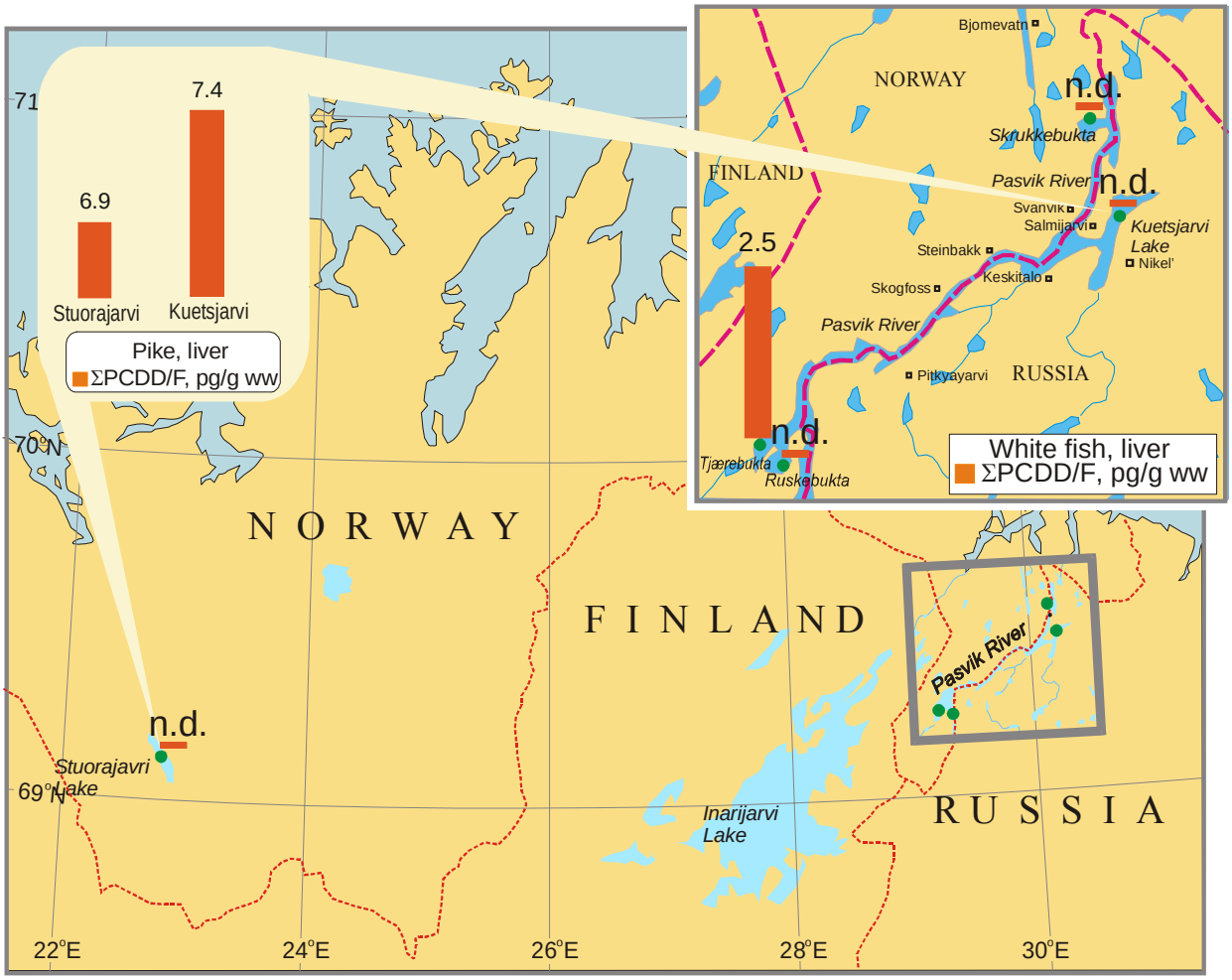

Figure 8. Distribution of PCDD/PCDF hepatic levels in fish from the study area

2,3,7,8-TCDD, the most commonly studied chlorinated dioxin was not found in any of the samples from the study area or the reference site. 2,3,7,8-TCDF and OCDD were found in highest concentrations in fish tissue from the study area.

Only limited data exists on PCDD/PCDF levels in whitefish and pike from other regions. In 1996, PCDD/PCDF levels were studied in fish from 14 localities along the River Kymijoki and its estuary in Finland. The concentrations were found to be low, in most samples below 1 pg/g Toxicity Equivalents (TEQ) (Korhonen *et al.,* 2001) (se below for explanation of TEQs). The concentrations of PCDD/F in pike muscle ranged from 0.2 to 0.8 pg/g ww TEQ in Finnish coastal areas in 1990 (Korhonen and Vartiainen, 1997) and were somewhat lower (about 0.1 - 0.4 pg/g ww TEQ) in Finnish lakes. The highest PCDD/PCDF levels in pike were detected in Kymijoki River, varying between 0.4 and 1.3 pg/g ww TEQ.

Exposure and effects: Of the 210 dioxins and furans, 17 contribute most significantly to the toxicity of complex of mixtures. In order to facilitate a comparison of mixtures, International Toxicity Equivalency Factors (TEQs) have been assigned to individual dioxins and furans based on a comparison of toxicity to 2,3,7,8-tetrachlorodibenzo-p-dioxin or TCDD. The IARC has determined that 2,3,7,8-TCDD can cause human cancer. These compounds are also

considered as carcinogenic in Russia (List of chemical compounds, products, industrial processes, natural and domestic factors which are carcinogenic for humans, 1998).

As with most other organochlorines, food is a major source of dioxins and furans for the general population. The tolerable daily intake (TDI) estimated by WHO is 10 pg TEQ/kg body weight for lifetime exposure (ATSDR, www.atcdr.cdc.gov/toxprofiles).

The Nordic Council of Ministers has recommended the Tolerable Daily Intake (TDI) of 35 TEQ pg/kg body weight/week (Ahlborg *et al.* 1988). According to this recommendation the consumption of fish from all studied areas are safe. The European Union (Commission Regulation (EC) No 466/2001) established Maximum levels of PCDD/PCDF in fish oil intended for human consumption at 2 pg WHO-PCDD/F-TEQ/g fat. However, in 2006 the Commission reviewed the provisions on dioxins in the light of new data on the presence of dioxins and dioxin-like PCBs, in particular with a view to the inclusion of dioxin-like PCBs in the levels to be set. New Maximum levels for Sum of dioxins, furans and dioxin-like PCBs (WHO-PCDD/F-PCB-TEQ) are 10.0 pg/g fat for marine fish body oil, fish liver oil. No EU requirements are available for freshwater fish.

Maximum permissible levels of PCDD/PCDF in Russia are presented by the Ministry of public health requirements and they are for fish and fish products: 11.0 ng/kg ww or 88.0 ng/kg lw. (Ministry of Public Health of RF, 1991).

Polybrominated diphenyl ethers (PBDEs)

Different mixtures of PBDEs are used as additive flame retardants in plastics and textiles. In contrast to reactive flame retardants, the additive ones are not covalently incorporated into polymeric materials but mixed with the polymer, and thus can diffuse more easily out of material (Bergman, 1989). Mixtures of different PBDEs are used under the names of their main PBDe components (e.g. “PentaPDE”).

PBDE were detected in all whitefish- and pike-samples analysed. Levels and distribution of PBDEs in fish within the study area are presented in *Tables 3.9* and *3.10* (*Appendix 3*) and *Figure 9*. The dominant congener group in fish from all studied areas was tetraBDE, with the highest levels in liver. This is in a good agreement with experimental studies on tissue distribution of tetraBDe#47 in pike. Dietary exposure with BDE47 has shown that this compound is absorbed from the food and transported to, and stored in the most lipid rich tissues for considerable time (Burreau *et al*., 2000). The congener pattern was similar in all fish samples from the Paz watercourse, as well as in the reference lake. It was dominated by BDE47, followed by BDE99 and BDE100. The same congener pattern has been found in other studies with whitefish, for example in Swiss lakes (Zenneg *et al*., 2003). However, levels in whitefish from the Pasvik area were low compared to those from the Swiss lakes and other studies, where fish was collected near known or suspected point sources (Andersen and Blomkvist, 1981; Dodder *et al*., 2002).

PBDE congeners of all studied bromination degrees (except heptaBDEs) were detected in pike liver from Stuorajavri and Kuetsjarvi lakes. HeptaBDE was not detected in any of the whitefish samples. The levels of TetraBDE in whitefish from Lake Stuorajavri was relatively high compared levels measured in whitefish from other Norwegian sampling sites. However, the levels in fish from Stuorajavri were lower than those from the Lake Kuetsjarvi. Congeners BDE153 and BDE154 were found in comparable concentrations in Stuorajavri fish, in levels just below the levels of BDE100. BDE183 was only detected in liver of pike from Lake Stuorajavri. This pattern is similar to the congener pattern in a typical PePBE product, such as

Bromkal 70-5DE (Sjödin et al., 1998). However, the ratio of BDE47 to BDe99 detected in the whitefish and pike samples from Lake Stuorajavri and from Pasvik sites was about 2, while Bromkal 70-5DE shows a ratio of about one for those two congeners. The congener patterns in our samples are similar to the results reported by Zennegg *et al.* (2003) and Dodder *et al.* (2002). Other authors report somewhat different congener patterns, showing in contrast to our samples, about equal amounts of BDE99 and BDE100 (Hale *et al.*, 2001).

Male whitefish from Lake Stuorajavri contained higher levels of PBDEs than females, probably due to the lower elimination via gonad products.

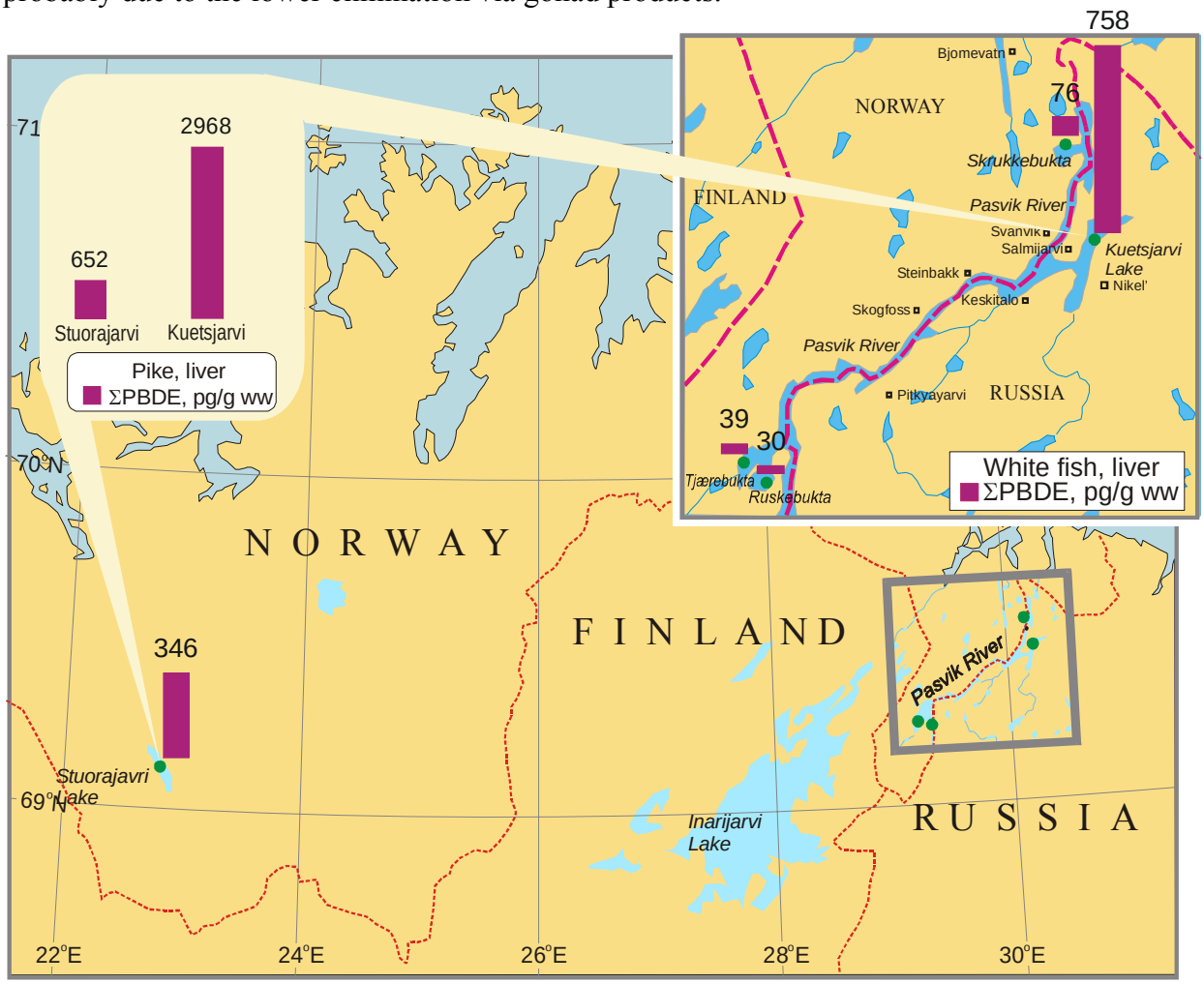

Figure 9. Distribution of PBDE hepatic levels in fish from the study area

Exposure and effects: There is evidence that some PBDEs bioaccumulate and exert toxic effects at low levels. The Environmental Protection Agency (EPA) has classified decabromodiphenyl ether as a possible human carcinogen. PBDEs are also endocrine disrupters. Some resemble the thyroid hormone thyroxin and others are estrogenic. It has also been shown that neurotoxic effects are enhanced when newborn mice are exposed to a combination of PBDEs and PCBs (Eriksson *et al., 2001*).

At the Norwegian side there have been two questionnaires (Bull-Berg, 1988), one in 1982 and one in 1988, about the use and importance of the fishing in the Pasvik River. Fishing is mainly carried out in the ice-free period, but some people occasionally fish from the ice. In 1982 the answers revealed that the fishing was mainly taking place in the area from Hestefoss to Vaggatem and the in Vaggatem and Svanevatn (Salmijervi). The answers from the 1988 questionnaire did not reveal any clear geographical preferences for fishing in the river, due to low number of answers (20 out of 100 questionnaires). In Russia, there are no good fishing

statistics. Since most inhabitants of Nikel and Zapolyarny are not allowed to use the Pasvik River for fishing, and since about 50 km of the river on the Russian side is protected, it is likely that only small amounts of fish are caught. In the Lake Kuetsjarvi there are some families performing household fishing and during the tourist season, sport fishing is popular (Aspholm, 1996; 2004).

Based on an average daily consumption of 20 g fish with a PBDE content of 2.9 ng/g (highest PBDE concentration detected in this study), a maximum daily intake of 0.07 µg PBDE was estimated. This number is lower than estimates for the total PBDE intake of the average Nordic consumer (0.2-0.7 µg/day) reported by Darnerud *et al.* (2001). Based on the current knowledge on PBDE, they consider the lowest observed adverse effect levels (LOAEL) of the PBDE group to be 1 mg/kg/day.

In the light of continued use of PBDEs in large quantities, monitoring levels of these compounds will continue to be an important issue in the study area.

5.3. Polycyclic aromatic hydrocarbon (PAHs) levels

PAHs are widespread environmental compound, mainly formed during incomplete combustion of wood and fossil fuel. Fish can rapidly take up PAHs, and like in mammals these are rapidly metabolized to more water-soluble substances that can be excreted, as reviewed by Varanasi *et al.* (1989). Levels and distribution of PAHs in fish within the study area are presented in *Tables 3.11* and *3.12* (*Appendix 3*) and *Figure 10.*

Of the PAHs, naphthalene and *2-methyl* naphthalene had the highest concentrations in whitefish from Lake Kuetsjarvi. Naphthalenes, phenanthrene and fluoranthene had the highest detection frequency in both Kuetsjarvi and Stuorajavri.

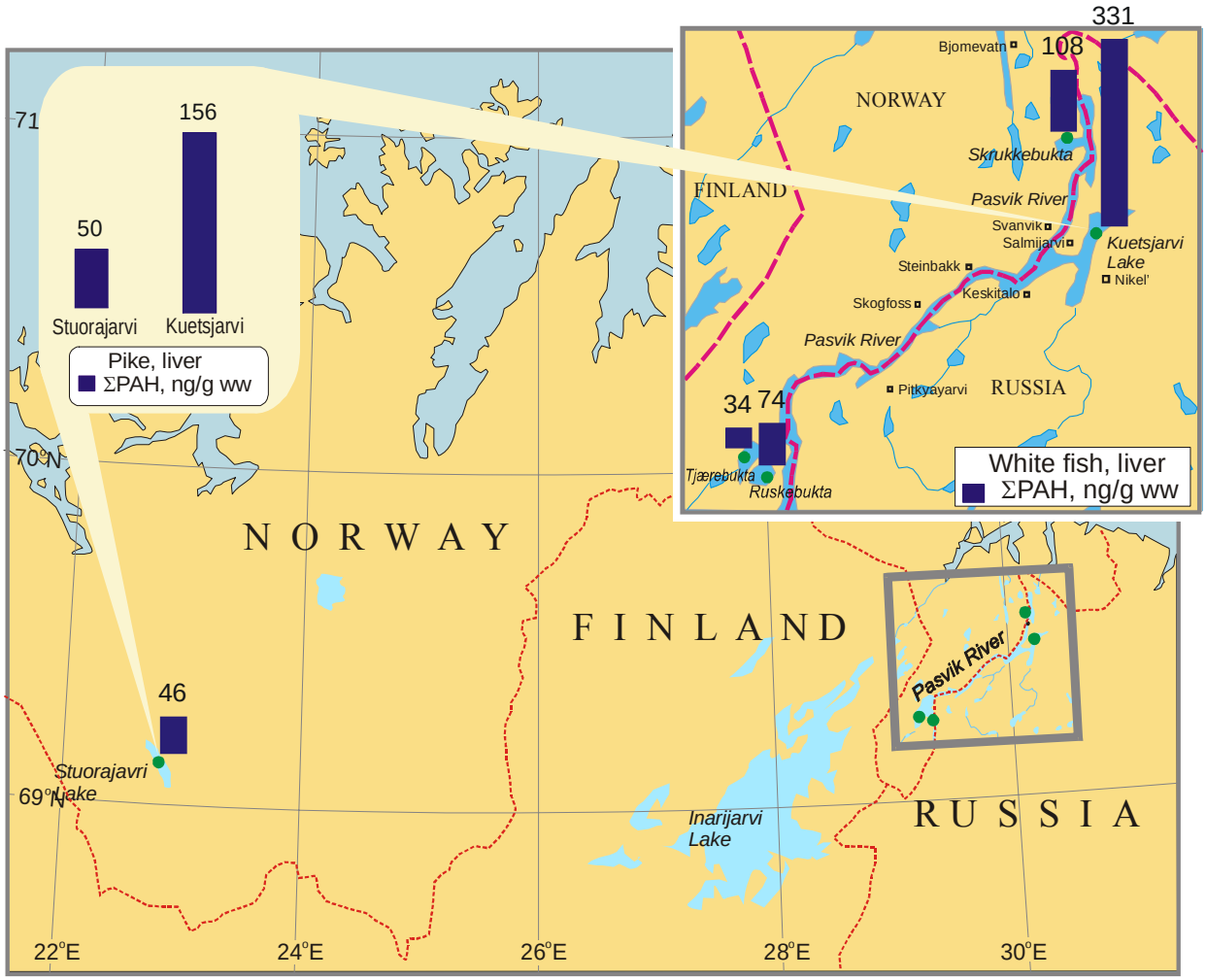

Figure 10. Distribution of PAH hepatic levels in fish from the study area

Exposure and effects:

New maximum levels of PAHs in foods have been introduced by the European Commission. PAHs are recognised as genotoxic carcinogens, and as such levels in food should be as low as reasonably achievable. Food manufacturers will need to carry out analysis to show compliance with the new limits, and to ensure that manufacturing processes do not result in PAH formation in their products. According to the Scientific Committee on Food, benzo(a)pyrene can be used as a marker for the occurrence and effect of carcinogenic PAH in food, including also benz(a)anthracene, benzo(b)fluoranthene, benzo(j)fluoranthene, benzo(k)fluoranthene, benzo(g,h,i)-perylene, chrysene, cyclopenta(c,d)pyrene, dibenz(a,h)anthracene, dibenzo(a,e)pyrene, dibenzo(a,h)pyrene, dibenzo(a,i)pyrene, dibenzo(a,l)pyrene, indeno(1,2,3-cd)pyrene and 5-methylchrysene. From April 2006 new maximum levels for benzo(a)pyrene in fish and meat products will be 5 µg/kg, in oils and fats 2.0 µg/kg and in children's foods 1 µg/kg. Maximum permissible level of benzo(a)pyrene is established also for smoked fish - 0.005 mg/kg (Commission Regulation (EC) No 208/2005).

In Russia several PAH compounds are considered as carcinogenic (List of chemical compounds, products, industrial processes, natural and domestic factors which are carcinogenic for humans, 1998), they are: Benzo(a)pyrene, Benzo(a)anthracene, and Dibenzo(a,h)anthracene. Maximum permissible level of benzo(a)pyrene in Russia is established only for smoked fish - 0.001 mg/kg (Sanitary-hygienic requirements, 2001).

6 Effect of contaminants: Biomarker studies

Two locations within the study area (Kuetsjarvi and Rajakoski) were selected for a screening of potential effects of contaminants on fish. Some selected biomarkers were chosen as indicators for effects. These were: cytochrome P450 hydroxylase activity level in liver microsomes and bile acids content in pike and whitefish.

A biomarker can be defined as a xenobiotically induced variation in cellular or biochemical components or processes, structures, or functions that are measurable in a biologic system or in samples (NRC, 1989).

Cytochrome P-450 (P450) is a superfamily of microsomal enzymes involved in the synthesis and degradation of steroids, fatty acids, and prostaglandins. Cytochrome P450s chemically transform xenobiotic compounds (PCBs, PAHs, etc.) and many contaminants also induce cyrochrome P450 activity. Cytochrome P450 can transform nonpolar hydrocarbons into more water soluble epoxide or hydroxyl metabolites through the addition of molecular oxygen. As a biomarker of exposure to PAHs, planar PCBs, and other environmental contaminants, cytochrome P450 has been used in numerous environmental assessment studies (Arctic Monitoring and Assessment Programme, Joint Monitoring and Assessment Programme etc.).

Another biochemical index to show early hepatic pathological changes is bile acids content in bile and in blood. Bile acids are useful indicators of a liver function. Normally, the liver is very efficient at capturing and removing bile acids from the hepatic-portal circulation. This is why circulating bile acid levels are quite low in healthy animals. The liver has tremendous reserve capacity and can easily meet the body's demand for bile acids despite severe disease. As a result of this reserve, the bile acid levels do not typically drop due to liver disease. Therefore, as liver function is compromised, more bile acids appear in the blood. The test for serum bile acids will detect liver changes before the formation of more advanced clinical signs of illness.

6.1. Cytochrome P-450 hydroxylase activity

The highest cytochrome P-450 activity was measured in females pike hepatic microsomes from Lake Kuetsjarvi. It is interesting to notice that pike males and females from relatively clean region (Rajakoski) have significantly different values of cytochrome P-450 activity, whereas no clear difference between the sexes were apparent in the samples from Lake Kuetsjarvi (*Figures 11-13*). Levels of male and female whitefish hydroxylase activities from Lake Kuetsjarvi were comparable (see (*Figure 12*). It is known from other studies that cytochrome P-450 activity is sex dependent and is highly related to the reproduction cycle of the fish.

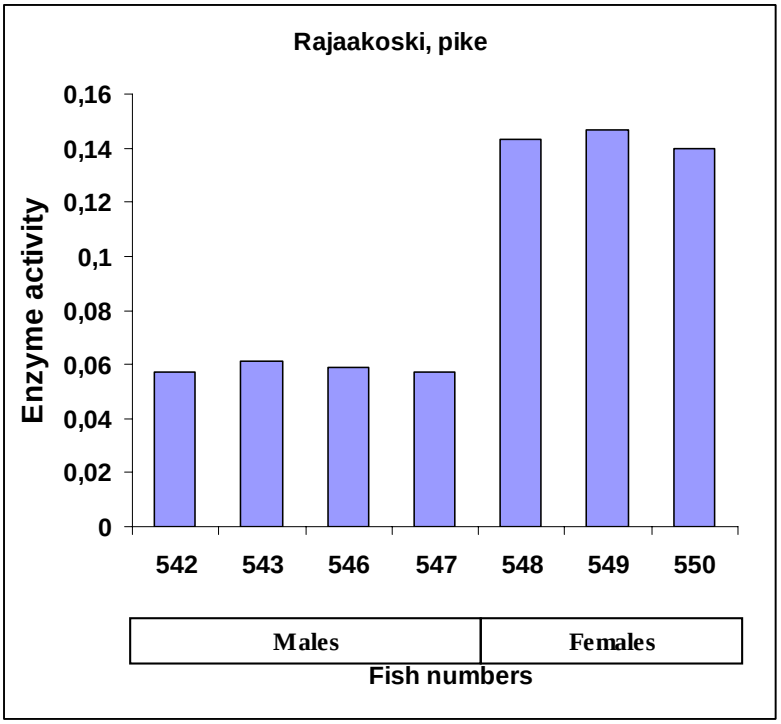

Figure 11. Cytochrome P-450 aniline hydroxylase activity from pike microsomes (Rajakoski).

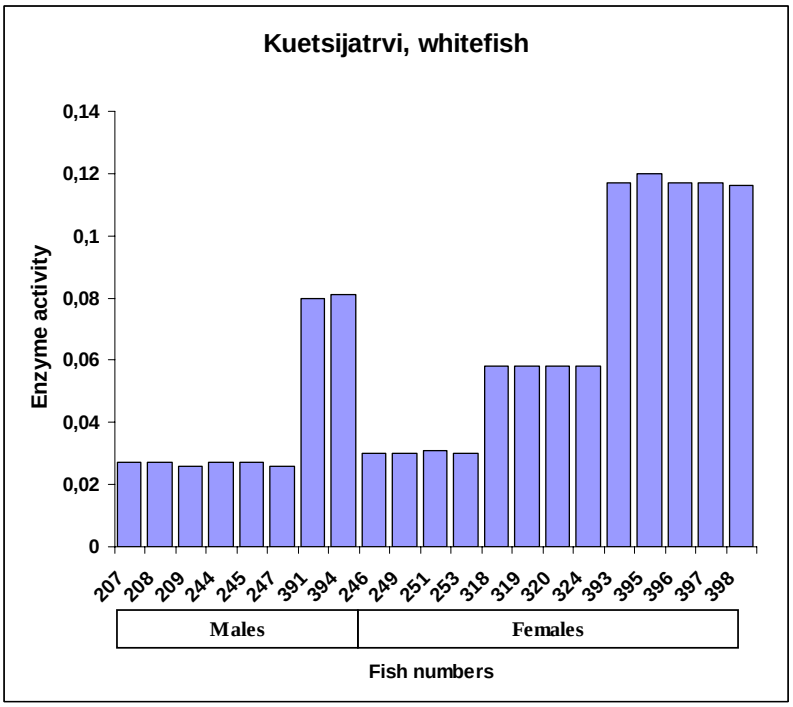

Figure 12. Cytochrome P-450 aniline hydroxylase activity from whitefish microsomes (Kuetsjarvi).

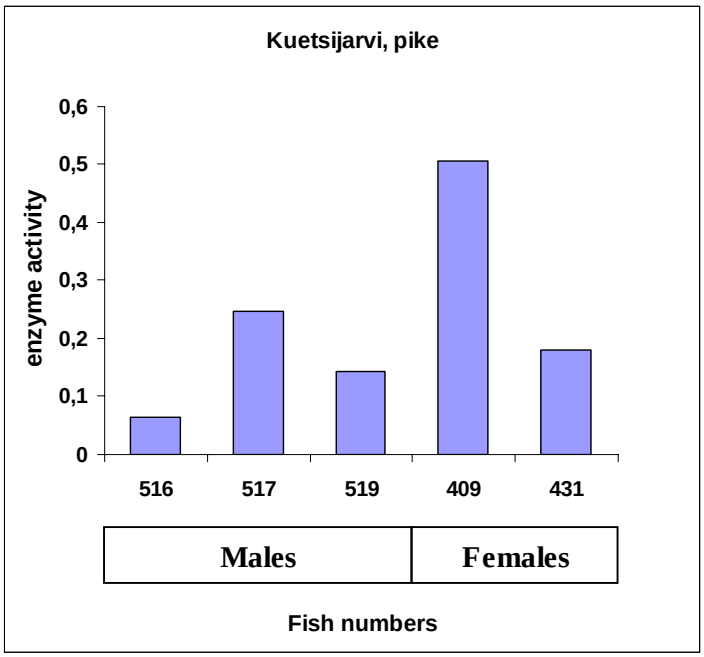

Figure 13. Cytochrome P-450 aniline hydroxylase activity in pike microsomes (Kuetsjarvi).

Cytochrome P-450 activity were higher in pike (females and males) from Lake Kuetsjarvi, which had the highest contaminant levels, compared to males and females from Rajakoski. This indicate an activation of a protective detoxification mechanism by the monooxygenase system, which can reduce unfavourable effects on fish.

6.2. Bile acids in fish bile

The data on bile acids are presented as cholate index–relation between cholic acid content (mg/ml) and total quantity of bile acids (mg/ml) in bile per cent (ChI%). The analytical results showed that male bile acid profiles varied a lot. Male and female pike had a lower Cholate Index (ChI%) than whitefish (see *Figure 14* and *Figure 15*). Bile from male whitefish from the most contaminated area was characterized by lower level of ChI% than bile from male whitefish from the area with lowest contamination levels (*Figure 15* and *Figure 16*).

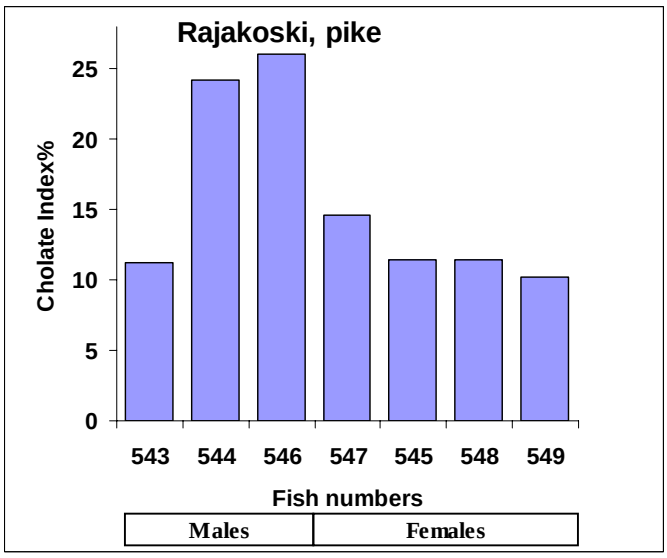

Figure 14. Bile acids content in pike bile (Rajakoski)

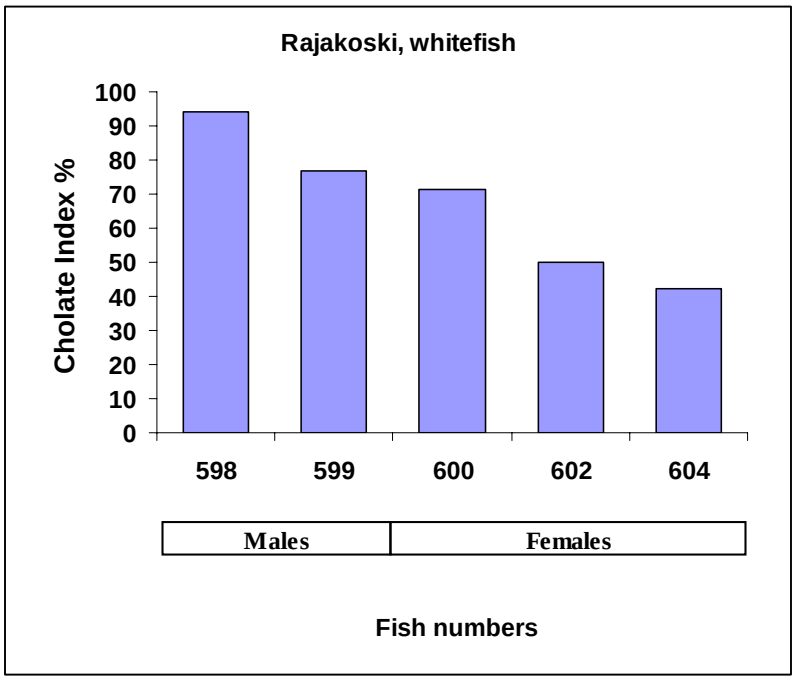

Figure 15. Bile acids content in whitefish bile (Rajakoski)

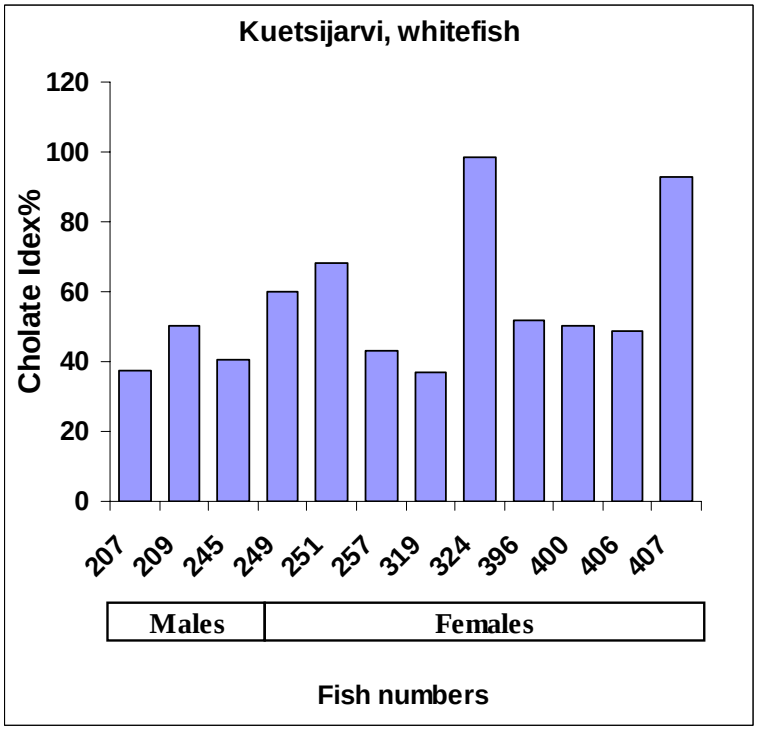

Figure 16 Bile acids content in whitefish bile (Kuetsjarvi)

The bile acid content in whitefish from Lake Kuetsjarvi and from Rajakoski were characterized by a large range (minimum of Cholate Index 36.82%, maximum – 71.5% (Kuetsjarvi)). The reason for this variability may be the physiological adaptation of the fish to unfavorable conditions. In whitefish bile from the relatively clean region (Rajakoski) a tendency towards

higher values in males than females was observed. This can be explained by different biosynthesis speed of cholic acid in males and females liver and differences in excretion via the bile. Bile acid content analysis in pike, caught from the relatively clean region (Rajakoski), revealed significant variance in cholic acid content relative to other species. However, it is important to notice that the measured values in pike were low; much higher Cholate Indexes have been measured in pike from other lakes in earlier studies (Sidorov, Popova, 1978). Therefore, it is possible that some physiological processes may have prevented normal biosynthesis of cholic acid by the liver and normal excretion in the bile in the pikes included in the present study.

The screening of biomarkers showed that these effect indicators may be used as an assessment tool for evaluating the impact of contaminants on fish and as early diagnostic tools. However, additional studies are required prior to the use of them in the future environmental monitoring programmes.

7 Conclusions/recommendations

- The highest levels of all detected legacy POPs were found in fish from Lake Kuetsjarvi - A tendency of decreasing of POPs with a distance from the smelter was observed.
- Petrogenic PAHs were the major contaminants in fish analysed.
- Levels of POPs in fish tissues did not exceed known Russian and International food quality criteria.
- Increased cytochrome P450 activity was found in fish from the Lake Kuetsjarvi compared to those in fish from less contaminated areas.
- Integrated biomarker studies have shown promise as an assessment tool for evaluating the impact of contaminants on fish.
- It is recommended that POPs and biomarkers are included in a future monitoring programme for the Paz watercourse.

8 Acknowledgements

The authors wish to thank the INTERREG project and the Environmental Committee of Finnmark County for their financial support. Field work and biological measurements of fish were carried out in cooperation with Norwegian College of Fishery Science (NCFS) and Professor Per-Arne Amundsen and colleagues are highly appreciated for the collaboration.

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Appendix 1

Methods for determination of POPs and selected trace elements in sediment and fish tissue samples from Pasvik area

The following persistent pollutants have been determined in the bottom sediment and fish samples:

- - chlorinated pestcides and industrial organochlorines: DDT-group (*o,p*`- and *p,p'*-DDE, *o,p*`- and *p,p'*-DDD, *o,p*`- and *p,p'*-DDT), HCH (α-, β- and γ- isomers of HCH), Hexachlorobenzene (HCB), chlordanes (Heptachlor, Heptachlor epoxide, Oxychlordane, *trans*- and *cis*-Nonachlors, , *trans*- and *cis*-Chlordanes), mirex, endrin and dieldrin;
- *ortho*-substituted congeners of polychlorinated biphenyls;
- planar and *non-ortho*-substituted congeners of PCBs (IUPAC): # 77, 81, 105, 114, 118, 123, 126, 156, 157, 167, 169, 189, as well as PCB congeners # 170 and 180;
- toxaphene compounds Parlar-26, Parlar-50, Parlar-62;
- brominated flame-retardants 2,4,4`–TrBDE (#28); 2,2`,4,4`-TeBDE (#47); 2,2`,4,4`,5-PBDE (#99); 2,2`,4,4`,6-PBDE (#100); 2,2',4,4',5,5'- HeBDE (#153); 2,2',4,4',5,6-HeBDE (#154); 2,2',3,4,4',5,6-HpBDE (#183);
- polychlorinated dibenzo-*p*-dioxines and dibenzofurans (PCDD/PCDF);
- -40 individual polycyclic aromatic hydrocarbons (PAHs), included alkyl-homologues and 16 PAHs recommended by EPA

Samples have been analyzed in the analytical batches, which included laboratory procedural blanks, spiked blank samples and samples of standard reference material of mussel tissue SRM 2977 of NIST, US and dogfish muscle certified reference material for trace metals DORM-2, National Research Council Canada. To control recovery of analytes surrogate isotope-labelled substances have been used, which were introduced into samples before extraction. Extracts have been analyzed using GC/MS.

Sub-samples were analysed for quality control purpose at analytical laboratory of University of Michigan (Environmental Health Sciences).

Sample preparation for analysis of POPs

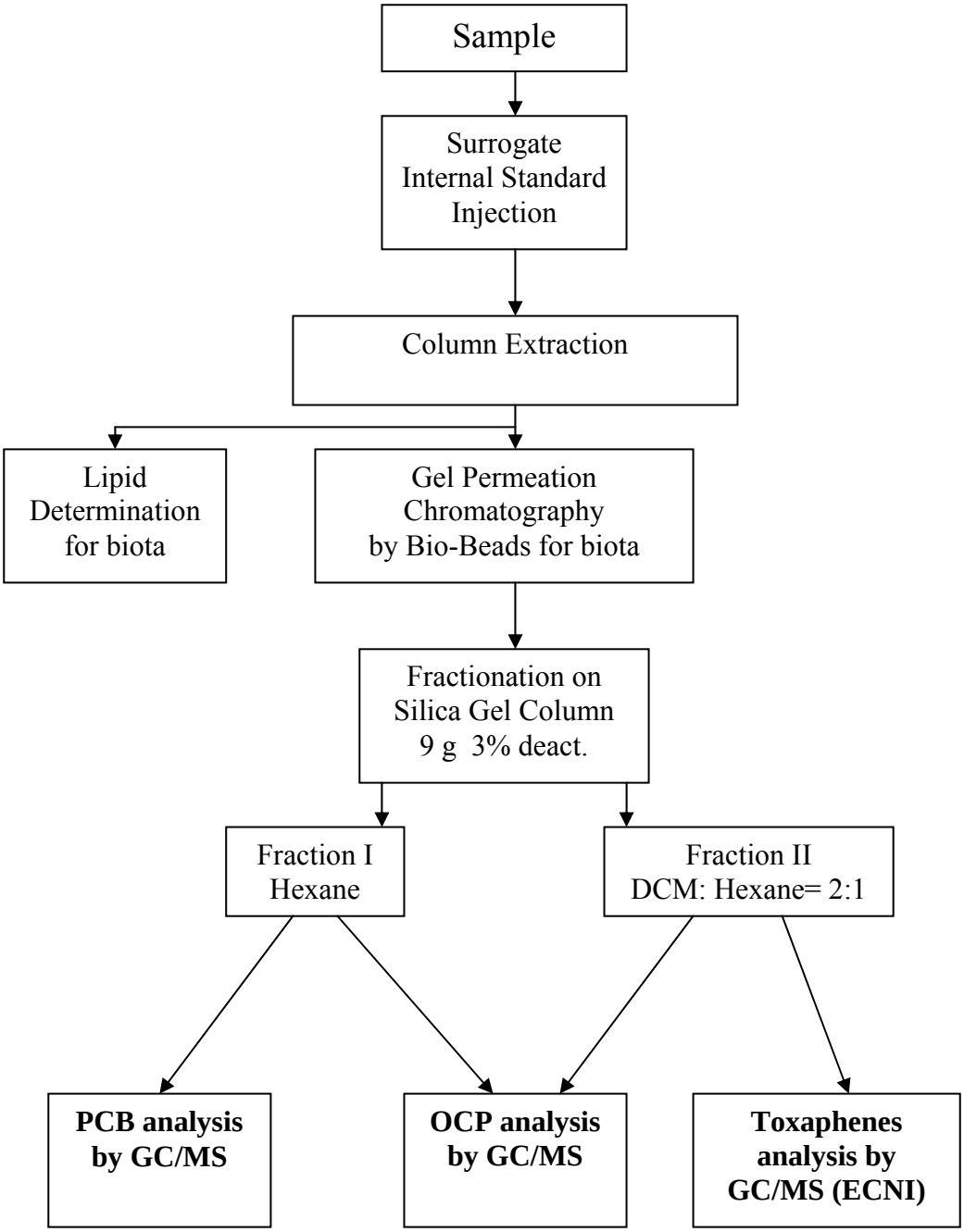
Before analysis samples were refrozen and homogenized. The samples of bottom sediments were dried. Extraction of bottom sediments was carried out in Soxhlet apparatus using solvent mixture benzene-ethanol during 16 hours. Determinations of PCBs, chlorinated pesticides and toxaphenes, PCDD/PCDFs, PBDEs and planar congeners of PCBs were carried out from the same extract. Base digestion and ultrasonic extraction procedures were used to determine PAHs. Schemes of clean-up for all types of extracts are presented in *Figures 1.1, 1.2, 1.3* and *1.4*.

Extraction of fish tissues samples

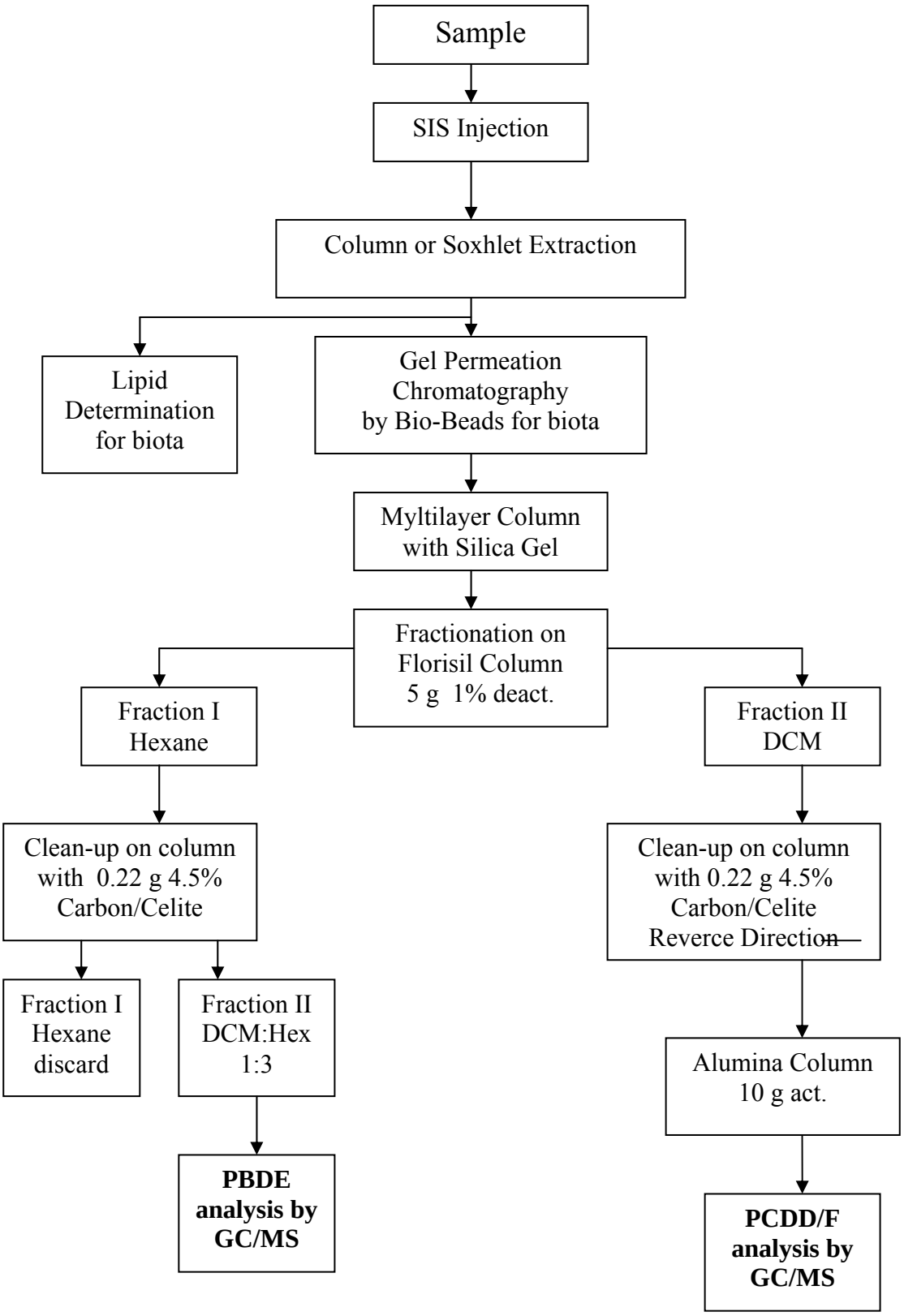
Extraction of PCBs, PBDEs, PCDD/Fs, OCPs and toxaphenes

POPs from fish tissue samples were extracted by column extraction method. As extragent the mixture of solvents – hexane : dichlormethane = 1:1 (v/v) was used. Lipid content was determined by gravimetric method from 10% of extract volume. The 50 % of extract volume was used for clean up for PCDD/Fs and PBDEs analysis. The 15 % of extract volume was used for clean up for planar congeners of PCB analysis. The 25 % of extract volume was used for clean up for another POPs analysis.

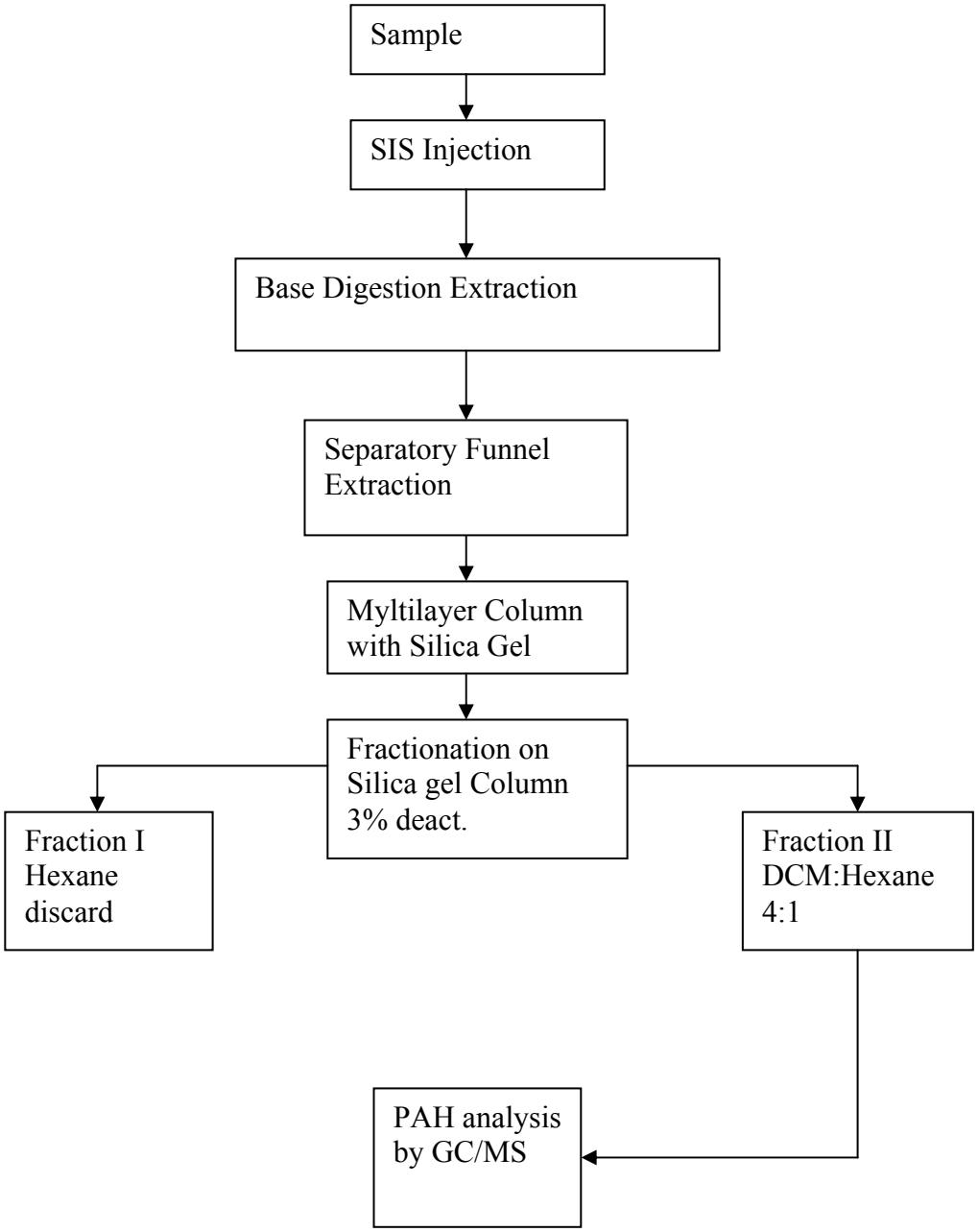
Extraction of PAH Extraction of PAH from the samples of the tissues of fish was carried out using base digestion with methanol and 50% KOH solution. The analytes from base solution were extracted with two portions of hexane in separatory funnel.



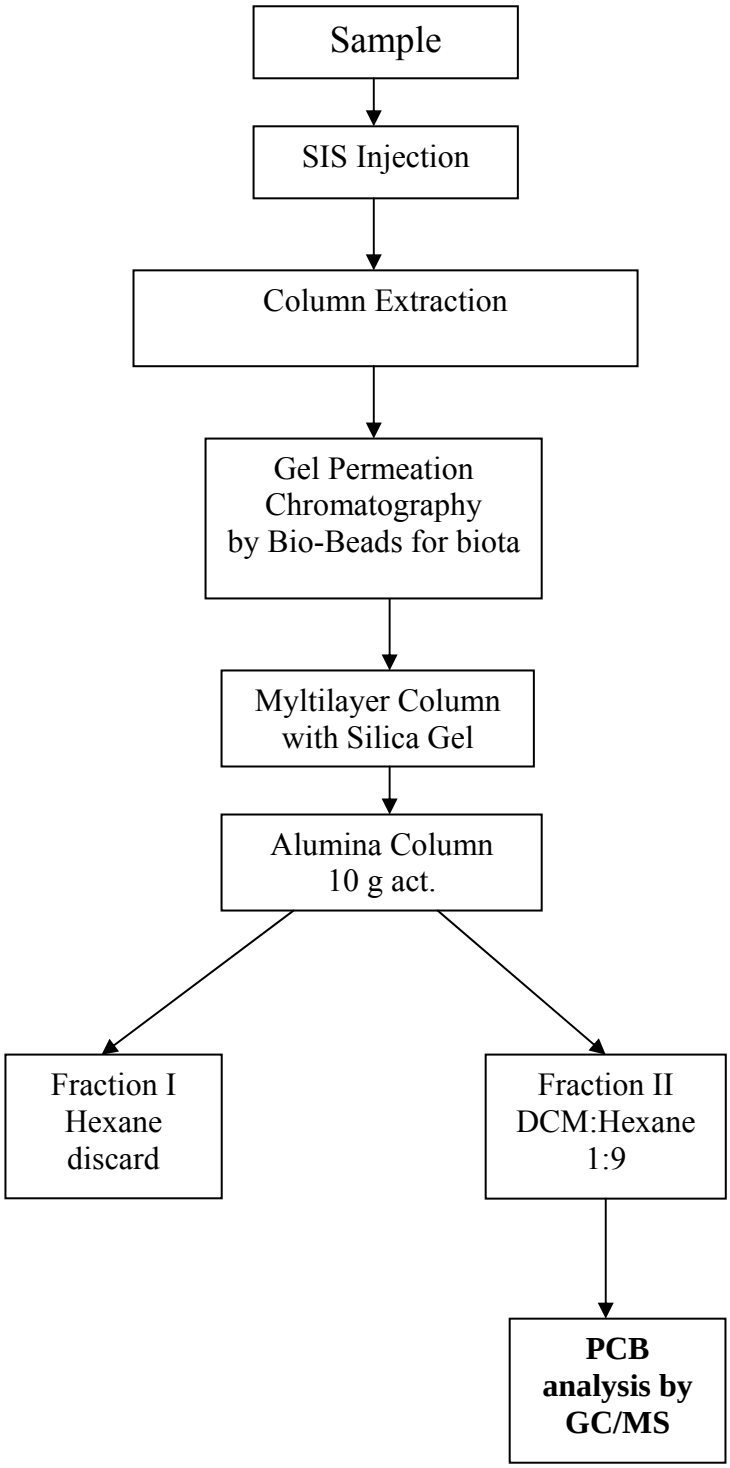
Appendix Figure 1.1 Analysis scheme for OCP and toxaphenes



Appendix Figure 1.2. Analysis scheme for PCDD/PCDF and PBDE



Appendix Figure 1.3. Analysis scheme for PAH



Appendix Figure 1.4 Analysis scheme for PCB.

Instrumental analysis (HRGC/LRMS)

Polychlorinated biphenyls and OCPs

The analysis was performed with *GC/MS Varian Saturn 2200 T*. Calibration of the instrument was carried out using a standard mixture of biphenyls BP-MS, Wellington Laboratories and SRM-1492, NIST. Results of analyses were processed with software package Varian 5.2.

Toxaphenes, Polychlorinated dibenzo-p-dioxins/dibenzofurans and Polybrominated diphenyl ethers

The analysis was performed with GC/MS Varian Saturn 1200 using chemical ionization with detection of negative ions (NCI) in the selective ion monitoring (SIM) mode. The reagent gas was methane.
Calibration of the instrument was carried out using standard solutions of Toxaphenes TOX 482, PROMOCHEM, standard solutions of PCDD/PCDF prepared on the base of the mixture EDF 7999 Cambridge Isotope Lab.and standard solutions of PBDE prepared on the base of the mixture EO-4980, Cambridge Isotope Lab.

Analysis of trace elements

The trace element analyses were carried out by AAS method after decomposition of the bottom sediment samples with nitric acid.

Cd, Ni and Pb were measured by a furnace technique on Perkin Elmer Z-3030 with Zeeman correction of background.

Zn and Cu were measured by AAS method by flame procedure on Perkin Elmer B-3030.

Hg was measured in bottom sediment and fish samples by method of “cold vapor” on MHS 15 after a decomposition of a sample by mixture of sulphuric and nitric acids.

QA/QC results

The internal QA/QC program in samples analysis for organic pollutants involved control for possible contamination of samples during sample preparation and measurements.
The analysis was performed in batches. Each batch included a procedural blank, spiked blank sample with the known content of added analytes.

Recovery of analytes was controlled using isotope-labelled analogues of determined analytes.
QA/QC results are presented in the Tables 1.1 - 1.14.

Quality assurance and quality control for heavy metals included analyses of blanks, analyses of duplicates, use of reference materials and matrix spike recoveries. Results on QA/QC analysis for biota samples are presented in table 1.15-1.16.

Table 1.1

QA/QC DATA REPORT for congeners of PCB in sediment

Compound	Procedural Blank PBS 02, ng	Method Detection Limit, ng/g	Certified Reference Materials of NWRI EC-5, ng/g	
			Detected	Reference Value
#1 [CL1]	n.d.	0.02	–	–
#3 [CL1]	n.d.	0.02	–	–
#4/#10 [CL2]	n.d.	0.02	–	–
#8 [CL2]	n.d.	0.02	–	–
#19 [CL3]	n.d.	0.02	–	–
#17/#18 [CL3]	n.d.	0.02	4.1	3.0 ± 1.1
#15 [CL2]	n.d.	0.02	–	–
#28/#31 [CL3]	0.24	0.04	6.2	5.3 ± 1.3
#54 [CL4]	n.d.	0.05	–	–
#33 [CL3]	n.d.	0.05	–	–
#22 [CL3]	n.d.	0.05	–	–
#52 [CL4]	n.d.	0.02	10.9	13.3 ± 4.1
#49 [CL4]	n.d.	0.02	–	–
#104 [CL5]	n.d.	0.02	–	–
#44 [CL4]	n.d.	0.02	5.9	7.3 ± 2.4
#37 [CL3]	n.d.	0.02	–	–
#74 [CL4]	n.d.	0.02	–	–
#70 [CL4]	n.d.	0.02	–	–
#95 [CL5]	n.d.	0.02	–	–
#155 [CL6]	n.d.	0.02	–	–
#101 [CL5]	n.d.	0.05	27.3	24.6 ± 6.0
#99 [CL5]	n.d.	0.02	–	–
#119 [CL5]	n.d.	0.02	–	–
#87 [CL5]	n.d.	0.02	10.1	9.6 ± 1.4
#110 [CL5]	n.d.	0.10	26.4	33.3 ± 11.9
#151 [CL6]	n.d.	0.02	8.3	8.4 ± 2.8
#149 [CL6]	n.d.	0.02	–	–
#123 [CL5]	n.d.	0.02	–	–
#118 [CL5]	n.d.	0.07	10.9	17.0 ± 7.4
#188 [CL7]	n.d.	0.02	–	–
#153/#168 [CL6]	n.d.	0.02	25.3	27.2 ± 5.5
#105 [CL5]	n.d.	0.05	9.0	7.6 ± 2.7
#138/#158 [CL6]	n.d.	0.05	27.6	28.6 ± 9.1
#178 [CL7]	n.d.	0.05	–	–
#155 [CL6]	n.d.	0.05	–	–
#187 [CL7]	n.d.	0.05	–	–
#183 [CL7]	n.d.	0.05	6.8	7.2 ± 2.8
#128 [CL6]	n.d.	0.05	5.0	5.5 ± 2.3
#167 [CL7]	n.d.	0.05	–	–
#177 [CL7]	n.d.	0.05	–	–
#202 [CL8]	n.d.	0.05	–	–
#171 [CL7]	n.d.	0.05	–	–

Cont. table 1.1

QA/QC DATA REPORT for congeners of PCB in sediment

Compound	**Procedural Blank** PBS 02**, ng**	**Method Detection Limit, ng/g**	**Certified Reference Materials EC-5, ng/g**		
			Detected	**Reference Value**	
#156 [CL6]	n.d.	0.05	–	–	
#201 [CL8]	n.d.	0.05	3.5	5.7 ± 2.7	
#157 [CL5]	n.d.	0.05	–	–	
#180 [CL7]	n.d.	0.05	26.4	22.3 ± 7.6	
#191 [CL7]	n.d.	0.02	–	–	
#170 [CL7]	n.d.	0.02	10.0	10.1 ± 1.6	
#199 [CL8]	n.d.	0.05	–	–	
#189 [CL7]	n.d.	0.02	–	–	
#208 [CL9]	n.d.	0.05	–	–	
#194 [CL8]	n.d.	0.02	9.6	8.1 ± 10.1	
#205 [CL9]	n.d.	0.05	–	–	
#206 [CL9]	n.d.	0.05	2.1	2.2 ± 0.9	
#209 [CL10]	n.d.	0.10	1.6	1.20 ± 0.9	
Surrogate Internal Standards, % Recovery			**Detected, ng**	**Added, ng**	**% Recovery**
#28 [CL3] C^{13}	*88*	0.02	12.0	15.6	*77*
#52 [CL4] C^{13}	*82*	0.02	12.2	15.6	*78*
#101 [CL5] C^{13}	*83*	0.02	14.7	15.6	*94*
#153 [CL6] C^{13}	*104*	0.02	17.0	15.6	*109*
#138 [CL6] C^{13}	*93*	0.02	16.8	15.6	*108*
#180 [CL7] C^{13}	*88*	0.02	16.4	15.6	*105*

Table 1.2

QA/QC DATA REPORT for congeners of PCB in biota

Compound	**Procedural Blank** PBB 01, **ng**	**Method Detection Limit, ng/g**	**Duplicate Difference, %D**	**Spiked Blank Sample** SMB 01		
				Detected, ng	**Added, ng**	**% Recovery**
8[CL2]	n.d.	0.10	–	–	–	–
18[CL3]	n.d.	0.10	–	–	–	–
16[CL3]	n.d.	0.10	–	–	–	–
26[CL3]	n.d.	0.10	24	–	–	–
25[CL3]	0.88	0.10	–	–	–	–
(31+28)[CL3]	n.d.	0.10	–	0.90	0.83	*109*
33[CL3]	n.d.	0.10	–	–	–	–
52[CL4]	n.d.	0.10	25	0.80	0.83	*96*
49[CL4]	4.17	0.10	25	–	–	–
47[CL4]	n.d.	0.10	–	–	–	–
44[CL4]	n.d.	0.10	–	–	–	–
37[CL3]	n.d.	0.10	–	–	–	–
41[CL4]	n.d.	0.10	–	–	–	–
74[CL4]	n.d.	0.10	–	–	–	–
70[CL4]	n.d.	0.10	–	–	–	–
66[CL4]	n.d.	0.10	–	–	–	–
95[CL5]	0.41	0.10	–	–	–	–
60[CL4]	n.d.	0.10	–	–	–	–
99[CL5]	0.29	0.10	–	0.84	0.83	*101*
97[CL5]	n.d.	0.10	–	–	–	–
87[CL5]	n.d.	0.10	–	–	–	–
151[CL6]	n.d.	0.10	–	–	–	–
135[CL6]	n.d.	0.10	–	0.81	0.83	*97*
146[CL6]	n.d.	0.10	–	–	–	–
153[CL6]	n.d.	0.10	–	0.61	0.83	*74*
105[CL5]	0.57	0.10	–	–	–	–
141[CL6]	n.d.	0.10	–	–	–	–
138[CL6]	0.50	0.10	–	0.63	0.83	*76*
126[CL5]	n.d.	0.10	–	–	–	–
187[CL7]	n.d.	0.15	–	0.62	0.83	*75*
183[CL7]	n.d.	0.15	–	–	–	–
174[CL7]	n.d.	0.15	–	–	–	–
177[CL7]	n.d.	0.15	–	–	–	–
180[CL7]	n.d.	0.15	–	0.63	0.83	*76*
170[CL7]	n.d.	0.15	–	0.76	0.83	*91*

Cont. table 1.2

QA/QC DATA REPORT for congeners of PCB in biota

Compound	**Procedural Blank** PBB 01, **ng**	**Method Detection Limit, ng/g**	**Duplicate Difference, %D**	**Spiked Blank Sample** SMB 01		
				Detected, ng	**Added, ng**	**% Recovery**
199[CL8]	n.d.	0.15	–	–	–	–
(196+203)[CL8]	n.d.	0.15	–	–	–	–
189[CL7]	n.d.	0.15	–	–	–	–
195[CL8]	n.d.	0.15	–	–	–	–
194[CL8]	n.d.	0.15	–	–	–	–
206[CL9]	n.d.	0.15	–	–	–	–
209[CL10]	n.d.	0.15	–	–	–	–
Surrogate Internal Standards, % Recovery						
#28 [CL3] C^{13}	*73*	0.02	–	12.0	15.6	*77*
#52 [CL4] C^{13}	*85*	0.02	–	13.1	15.6	*84*
#101 [CL5] C^{13}	*88*	0.02	–	12.5	15.6	*80*
#153 [CL6] C^{13}	*79*	0.02	–	11.5	15.6	*74*
#138 [CL6] C^{13}	*74*	0.02	–	11.9	15.6	*76*
#180 [CL7] C^{13}	*82*	0.02	–	12.2	15.6	*78*

Table 1.3

QA/QC DATA REPORT for planar and mono-orthosubstituted congeners of PCB in sediment

Compound	**Procedural Blank** PBS 02**, ng/g**	**Method Detection Limit, ng/g**	**Spiked Blank Sample** SMS 02		
			Detected, ng	**Added, ng**	**% Recovery**
#CL4 81	n.d.	0.010	3.32	4.00	*83*
#CL4 77	n.d.	0.010	3.36	4.00	*84*
#CL5 123	n.d.	0.010	3.84	4.00	*96*
#CL5 118	0.19	0.10	3.48	4.00	*87*
#CL5 114	n.d.	0.010	3.52	4.00	*88*
#CL5 105	n.d.	0.030	3.08	4.00	*77*
#CL5 126	n.d.	0.010	3.84	4.00	*96*
#CL6 167	n.d.	0.020	3.36	4.00	*84*
#CL6 156	n.d.	0.011	3.48	4.00	*87*
#CL6 157	n.d.	0.015	3.96	4.00	*99*
#CL6 169	n.d.	0.010	3.8	4.00	*95*
#CL7 180	n.d.	0.010	4.08	4.00	*102*
#CL7 170	n.d.	0.010	3.84	4.00	*96*
#CL7 189	n.d.	0.010	3.72	4.00	*93*
Surrogate Internal Standards, % Recovery					
#CL4 81 C^{13}	*44*	0.005	3.20	5.00	*64*
#CL4 77 C^{13}	*43*	0.005	4.25	5.00	*85*
#CL5 123 C^{13}	*66*	0.005	4.35	5.00	*87*
#CL5 118 C^{13}	*82*	0.005	3.90	5.00	*78*
#CL5 114 C^{13}	*77*	0.005	4.45	5.00	*89*
#CL5 105 C^{13}	*87*	0.005	4.20	5.00	*84*
#CL5 126 C^{13}	*66*	0.005	4.75	5.00	*95*
#CL6 167 C^{13}	*106*	0.005	4.80	5.00	*96*
#CL6 156 C^{13}	*117*	0.010	3.95	5.00	*79*
#CL6 157 C^{13}	*108*	0.005	3.85	5.00	*77*
#CL6 169 C^{13}	*99*	0.010	4.50	5.00	*90*
#CL7 180 C^{13}	*95*	0.015	5.25	5.00	*105*
#CL7 170 C^{13}	*99*	0.005	4.65	5.00	*93*
#CL7 189 C^{13}	*114*	0.005	4.95	5.00	*99*

Table 1.4

QA/QC DATA REPORT for planar and mono-orthosubstituted congeners of PCB in biota

Compound	**Procedural Blank** PBB 02**, ng**	**Method Detection Limit, ng/g**	**Duplicate Difference, %D**	**Spiked Blank Sample** SMB 02		
				Detected, ng	**Added, ng**	**% Recovery**
#CL4 81	1.10	0.01		3.28	3.69	*89*
#CL4 77	n.d.	0.01		3.10	3.69	*84*
#CL5 123	n.d.	0.04		3.54	3.69	*96*
#CL5 118	n.d.	0.20		3.62	3.69	*98*
#CL5 114	n.d.	0.01		3.58	3.69	*97*
#CL5 105	0.57	0.10		3.76	3.69	*102*
#CL5 126	n.d.	0.01		3.51	3.69	*95*
#CL6 167	n.d.	0.01		2.84	3.69	*77*
#CL6 156	n.d.	0.03		2.95	3.69	*80*
#CL6 157	n.d.	0.01		3.10	3.69	*84*
#CL6 169	n.d.	0.01		3.54	3.69	*96*
#CL7 180	n.d.	0.05		3.65	3.69	*99*
#CL7 170	n.d.	0.02		2.92	3.69	*79*
#CL7 189	n.d.	0.01		3.80	3.69	*103*
Surrogate Internal Standards, % Recovery						
#CL4 81 C^{13}	*44*	0.005		3.35	5.00	*67*
#CL4 77 C^{13}	*43*	0.005		3.00	5.00	*60*
#CL5 123 C^{13}	*66*	0.005		3.95	5.00	*79*
#CL5 118 C^{13}	*82*	0.005		5.35	5.00	*107*
#CL5 114 C^{13}	*77*	0.005		4.80	5.00	*96*
#CL5 105 C^{13}	*87*	0.005		5.65	5.00	*113*
#CL5 126 C^{13}	*66*	0.005		4.30	5.00	*86*
#CL6 167 C^{13}	*106*	0.005		6.60	5.00	*132*
#CL6 156 C^{13}	*127*	0.005		6.80	5.00	*136*
#CL6 157 C^{13}	*108*	0.005		6.15	5.00	*123*
#CL6 169 C^{13}	*99*	0.005		5.15	5.00	*103*
#CL7 180 C^{13}	*95*	0.005		5.15	5.00	*103*
#CL7 170 C^{13}	*99*	0.005		4.95	5.00	*99*
#CL7 189 C^{13}	*114*	0.005		5.80	5.00	*116*

Table 1.5

QA/QC DATA REPORT for Chlorinated Pesticides in sediment

Compound	**Procedural Blank** PBS 02**, ng/g**	**Method Detection Limit, ng/g**	**QOR076MS (Quasimeme)**		
			Detected, ng/g	**Assigned Value, ng/g**	**Assigned Error, %**
HCB	0.05	0.03	0.61	0.74	16
α-HCH	n.d.	0.05	0.09	0.13	31
β-HCH	n.d.	0.05	0.15	0.11	–
γ-HCH	n.d.	0.05	0.38	0.34	20
Heptachlor	n.d.	0.05	–	–	–
Heptachlor epoxide	n.d.	0.10	–	–	–
Oxychlordane	n.d.	0.08	–	–	–
trans-Chlordane	n.d.	0.03	–	–	–
cis-Chlordane	n.d.	0.03	–	–	–
trans-Nonachlor	n.d.	0.01	8.90	8.36	–
cis-Nonachlor	n.d.	0.01	–	–	–
2,4`-DDE	n.d.	0.03	–	–	–
4,4`-DDE	n.d.	0.03	17.4	17.02	13
2,4`-DDD	n.d.	0.03	–	–	–
4,4`-DDD	n.d.	0.03	14.2	9.47	13
2,4`-DDT	n.d.	0.08	0.10	0.14	–
4,4`-DDT	n.d.	0.08	9.80	11.53	13
Endrin	n.d.	0.10	–	–	–
Dieldrin	n.d.	0.05	1.70	1.86	14
Mirex	n.d.	0.03	–	–	–
Surrogate Internal Standards, % Recovery					
HCB C^{13}	*69*	0.005	8.52	12.0	*71*
γ-HCH C^{13}	*100*	0.005	9.20	12.1	*76*
4,4`-DDE C^{13}	*77*	0.005	8.28	11.5	*72*
4,4`-DDT C^{13}	*72*	0.010	9.61	11.3	*85*

Table 1.6

QA/QC DATA REPORT for Chlorinated Pesticides in biota

Compound	**Procedural Blank** PBB 02**, ng**	**Method Detection Limit, ng/g**	**Duplicate Difference, %D**	**Spiked Blank Sample** SMB 02		
				Detected, ng	**Added, ng**	**% Recovery**
HCB	0.74	0.03	6	4.47	5.20	*86*
α-HCH	n.d.	0.05	–	5.24	4.72	*111*
β-HCH	n.d.	0.05	–	5.33	4.72	*113*
γ-HCH	n.d.	0.05	–	5.29	4.72	*112*
Heptachlor	n.d.	0.05	–	3.63	4.72	*77*
Heptachlor epoxide	n.d.	0.10	–	5.05	4.72	*107*
Oxychlordane	n.d.	0.08	–	14.3	12.2	*117*
trans-Chlordane	n.d.	0.03	–	6.27	5.50	*114*
cis-Chlordane	n.d.	0.03	–	–	–	–
trans-Nonachlor	n.d.	0.01	0	8.83	7.68	*115*
cis-Nonachlor	n.d.	0.01	–	3.08	2.80	*110*
2,4`-DDE	n.d.	0.03	–	–	–	–
4,4`-DDE	n.d.	0.03	–	4.39	4.72	*93*
2,4`-DDD	n.d.	0.03	–	–	–	–
4,4`-DDD	n.d.	0.03	–	4.96	4.72	*105*
2,4`-DDT	n.d.	0.08	–	–	–	–
4,4`-DDT	n.d.	0.08	–	4.63	4.72	*98*
Endrin	n.d.	0.10	–	4.48	4.72	*95*
Dieldrin	n.d.	0.05	–	4.48	4.72	*95*
Mirex	n.d.	0.03	–	2.27	2.80	*81*
Surrogate Internal Standards, % Recovery						
HCB C^{13}	*66*	0.005	–	10.1	15.5	*65*
γ-HCH C^{13}	*69*	0.005	–	8.84	10.4	*85*
4,4`-DDE C^{13}	*72*	0.005	–	9.58	10.3	*93*
4,4`-DDT C^{13}	*94*	0.005	–	12.3	10.5	*117*

Table 1.7

QA/QC DATA REPORT for Polycyclic Aromatic Hydrocarbons in sediment

Compound	**Procedural Blank** PBS 03**, ng/g**	**Method Detection Limit, ng/g**	**Duplicate Difference, %D**	**Certified Reference Materials of NWRI EC-5, ng/g**	
				Detected	**Reference Value**
Naphthalene	0.15	10.0	20	19.6	26 ± 6
1 -Methylnaphthalene	1.13	5.0	23	–	–
2 -Methylnaphthalene	0.06	5.0	24	–	–
Acenaphthylene	n.d.	0.3	–	32.4	41 ± 9
Acenaphthene	n.d.	0.3	–	28.5	29 ± 9
Fluorene	n.d.	0.3	–	62.9	84 ± 26
Phenanthrene	n.d.	0.3	22	585.9	612 ± 57
Anthracene	n.d.	0.3	25	93.7	113 ± 17
Fluoranthene	n.d.	0.3	8	799.0	823 ± 74
Pyrene	n.d.	0.3	13	742.0	987 ± 134
Benzo(a)anthracene	n.d.	0.3	–	460.0	503 ± 47
Chrysene	n.d.	0.3	–	549.0	619 ± 60
Benzofluoranthenes	n.d.	0.5	24	764.0	899 ± 137
Benzo(e)pyrene	n.d.	0.5	–	414.0	440 ± 76
Benzo(a)pyrene	n.d.	0.5	25	469.0	449 ± 61
Perylene	n.d.	1.5	10	198.0	187 ± 28
Indeno(1,2,3cd)pyrene	n.d.	1.5	–	368.0	386 ± 66
Dibenz(a,h)anthracene	n.d.	1.5	–	161.0	195 ± 44
Benzo(g,h,i)perylene	n.d.	1.5	–	352.0	333 ± 53
Surrogate Internal Standards, % Recovery				**Detected, ng**	**Added, ng**	**% Recovery**
Naphthalene d_8	*77*	0.05	–	0.16	0.20	*81*
Acenaphthene d_{10}	*84*	0.05	–	0.20	0.20	*98*
Phenanthrene d_{10}	*59*	0.05	–	0.18	0.20	*92*
Chrysene d_{12}	*60*	0.05	–	0.16	0.20	*78*
Perylene d_{12}	*65*	0.10	–	0.10	0.20	*52*

Table 1.8

QA/QC DATA REPORT for Polycyclic Aromatic Hydrocarbons in biota

Compound	**Procedural Blank** PBB 01, **ng**	**Method Detection Limit, ng/g**	**Duplicate Difference, %D**	**Spiked Blank Sample** SMB 01		
				Detected, ng	**Added, ng**	**% Recovery**
Naphthalene	n.d.	15.0	–	1040	1000	*104*
1 -Methylnaphthalene	n.d.	6.00	–	–	–	–
2 -Methylnaphthalene	n.d.	6.00	–	–	–	–
Acenaphthylene	n.d.	0.70	–	710	1000	*71*
Acenaphthene	n.d.	0.70	–	850	1000	*85*
Fluorene	n.d.	0.70	–	990	1000	*99*
Phenanthrene	n.d.	1.00	–	890	1000	*89*
Anthracene	n.d.	0.20	–	840	1000	*84*
Fluoranthene	n.d.	0.20	–	1180	1000	*118*
Pyrene	n.d.	0.30	–	1150	1000	*115*
Benzo(a)anthracene	n.d.	0.30	–	1190	1000	*119*
Chrysene	n.d.	0.50	–	1090	1000	*109*
Benzofluoranthenes	n.d.	0.50	–	2000	2000	*100*
Benzo(e)pyrene	n.d.	0.80	–	–	–	–
Benzo(a)pyrene	n.d.	0.80	–	770	1000	*77*
Perylene	n.d.	0.80	–	–	–	–
Indeno(1,2,3cd)pyrene	n.d.	1.50	–	1000	1000	*100*
Dibenz(a,h)anthracene	n.d.	1.50	–	890	1000	*89*
Benzo(g,h,i)perylene	n.d.	1.50	–	1020	1000	*102*
Surrogate Internal Standards, % Recovery						
Naphthalene d_8	*67*	0.05	–	0.28	0.40	*71*
Acenaphthene d_{10}	*74*	0.05	–	0.45	0.40	*113*
Phenanthrene d_{10}	*84*	0.05	–	0.42	0.40	*106*
Chrysene d_{12}	*98*	0.05	–	0.46	0.40	*116*
Perylene d_{12}	*40*	0.10	–	0.19	0.40	*47*

Table 1.9

QA/QC DATA REPORT for toxaphenes in sediment

Compound	**Procedural Blank** PBS 02**, ng**	**Method Detection Limit, µg/kg**	**Spiked Blank Sample** SMS 02		
			Detected, ng	**Added, ng**	**% Recovery**
Parl 26	n.d.	0.0001	6.83	8.43	*81*
Parl 50	n.d.	0.0002	6.83	8.43	*81*
Parl 62	n.d.	0.0020	7.00	8.43	*83*

Table 1.10

QA/QC DATA REPORT for toxaphenes in biota

Compound	**Procedural Blank** PBB 02**, ng**	**Method Detection Limit, ng/kg**	**Duplicate Difference, %D**	**Spiked Blank Sample** SMB 02		
				Detected, ng	**Added, ng**	**% Recovery**
Parl 26	n.d.	0.30	14	6.32	8.43	*75*
Parl 50	n.d.	0.30	16	7.08	8.43	*84*
Parl 62	n.d.	2.00	–	7.00	8.43	*83*

Table 1.11

QA/QC DATA REPORT for Polybrominated diphenyl ethers in sediment

Compound	**Procedural Blank** PBS 02**, ng**	**Method Detection Limit, ng/kg**	**Spiked Blank Sample** SMS 02		
			Detected, ng	**Added, ng**	**% Recovery**
PBDE # 28	n.d.	0.10	2.00	2.20	*91*
PBDE # 47	n.d.	2.00	1.53	1.96	*78*
PBDE # 99	n.d.	1.50	1.62	2.00	*81*
PBDE # 100	n.d.	0.30	–	–	–
PBDE # 153	n.d.	0.30	1.57	1.92	*82*
PBDE # 154	n.d.	0.20	–	–	–
PBDE # 183	n.d.	0.80	–	–	–

Table 1.12

QA/QC DATA REPORT for Polybrominated diphenyl ethers in biota

Compound	**Procedural Blank** PBB 01**, ng**	**Method Detection Limit, ng/kg**	**Duplicate Difference, %D**	**Spiked Blank Sample** SMB 01		
				Detected, ng	**Added, ng**	**% Recovery**
PBDE # 28	n.d.	0.10	11	1.89	2.20	*86*
PBDE # 47	0.14	5.00	3	1.71	1.96	*87*
PBDE # 99	n.d.	0.10	4	1.88	2.00	*94*
PBDE # 100	n.d.	0.10	9	–	–	–
PBDE # 153	n.d.	0.20	25	1.73	1.92	*90*
PBDE # 154	n.d.	0.20	2	–	–	–
PBDE # 183	n.d.	0.50	–	–	–	–

Table 1.13

QA/QC DATA REPORT for Polychlorinated dibenzo-p-dioxins and polychlorinated dibenzofurans in sediment

Compound	**Proce-dural Blank** PBS 02**, ng**	**Method Detection Limit, ng/kg**	**Spiked Blank Sample** SMS 02		
			Detected, ng	**Added, ng**	**% Recovery**
2,3,7,8-TCDD	n.d.	2.00	0.04	0.04	*89*
1,2,3,7,8-PeCDD	n.d.	0.20	0.17	0.20	*87*
1,2,3,4,7,8-HxCDD	n.d.	0.05	0.17	0.20	*84*
1,2,3,6,7,8- HxCDD	n.d.	0.05	0.17	0.20	*85*
1,2,3,7,8,9- HxCDD	n.d.	0.05	0.15	0.20	*76*
1,2,3,4,6,7,8-HpCDD	n.d.	0.05	0.14	0.20	*72*
OCDD	n.d.	0.05	0.34	0.40	*84*
2,3,7,8-TCDF	n.d.	0.10	0.04	0.04	*96*
1,2,3,7,8-PeCDF	n.d.	0.10	0.16	0.20	*78*
2,3,4,7,8-PeCDF	n.d.	0.10	0.20	0.20	*99*
1,2,3,4,7,8-HxCDF	n.d.	0.05	0.15	0.20	*77*
1,2,3,6,7,8- HxCDF	n.d.	0.05	0.17	0.20	*85*
2,3,4,6,7,8-HxCDF	n.d.	0.05	0.16	0.20	*80*
1,2,3,7,8,9-HxCDF	n.d.	0.05	0.17	0.20	*86*
1,2,3,4,6,7,8-HpCDF	n.d.	0.05	0.19	0.20	*96*
1,2,3,4,7,8,9-HpCDF	n.d.	0.05	0.19	0.20	*93*
OCDF	n.d.	0.05	0.32	0.40	*79*
Surrogate Internal Standards, % Recovery					
($^{13}C_{12}$)2,3,7,8-TCDD	*93*	2.00	0.95	1.25	*76*
($^{13}C_{12}$)2,3,7,8-TCDF	*100*	0.10	1.05	1.25	*84*
($^{13}C_{12}$)1,2,3,7,8-PeCDD	*99*	0.20	1.19	1.25	*95*
($^{13}C_{12}$)1,2,3,7,8-PeCDF	*90*	0.10	0.94	1.25	*75*
($^{13}C_{12}$)1,2,3,6,7,8- HxCDD	*89*	0.05	1.04	1.25	*83*
($^{13}C_{12}$)1,2,3,6,7,8- HxCDF	*103*	0.05	1.00	1.25	*80*
($^{13}C_{12}$)1,2,3,4,6,7,8-HpCDD	*100*	0.05	1.18	1.25	*94*
($^{13}C_{12}$)1,2,3,4,6,7,8-HpCDF	*95*	0.05	1.24	1.25	*99*
($^{13}C_{12}$)OCDD	*90*	0.05	2.23	2.50	*89*

Table 1.14

QA/QC DATA REPORT for Polychlorinated dibenzo-p-dioxins and polychlorinated dibenzofurans in biota

Compound	**Procedural Blank** PBB 01, **ng**	**Method Detection Limit, ng/kg**	**Duplicate Difference, %D**	**Spiked Blank Sample** SMB 01		
				Detected, ng	**Added, ng**	**% Recovery**
2,3,7,8-TCDD	n.d.	0.30	–	0.03	0.04	*77*
1,2,3,7,8-PeCDD	n.d.	0.20	–	0.18	0.20	*89*
1,2,3,4,7,8-HxCDD	n.d.	0.10	–	0.17	0.20	*84*
1,2,3,6,7,8- HxCDD	n.d.	0.10	–	0.17	0.20	*87*
1,2,3,7,8,9- HxCDD	n.d.	0.10	–	0.19	0.20	*96*
1,2,3,4,6,7,8-HpCDD	n.d.	0.10	–	0.19	0.20	*93*
OCDD	n.d.	0.10	–	0.29	0.40	*73*
2,3,7,8-TCDF	n.d.	0.20	–	0.03	0.04	*84*
1,2,3,7,8-PeCDF	n.d.	0.20	–	0.21	0.20	*105*
2,3,4,7,8-PeCDF	n.d.	0.20	–	0.20	0.20	*99*
1,2,3,4,7,8-HxCDF	n.d.	0.10	–	0.20	0.20	*98*
1,2,3,6,7,8- HxCDF	n.d.	0.10	–	0.16	0.20	*79*
2,3,4,6,7,8-HxCDF	n.d.	0.10	–	0.15	0.20	*77*
1,2,3,7,8,9-HxCDF	n.d.	0.10	–	0.16	0.20	*80*
1,2,3,4,6,7,8-HpCDF	n.d.	0.10	–	0.17	0.20	*84*
1,2,3,4,7,8,9-HpCDF	n.d.	0.10	–	0.18	0.20	*90*
OCDF	n.d.	0.10	–	0.38	0.40	*96*
Surrogate Internal Standards, % Recovery						
($^{13}C_{12}$)2,3,7,8-TCDD	*79*	0.30	–	1.24	1.25	*99*
($^{13}C_{12}$)2,3,7,8-TCDF	*85*	0.20	–	1.19	1.25	*95*
($^{13}C_{12}$)1,2,3,7,8-PeCDD	*87*	0.20	–	1.09	1.25	*87*
($^{13}C_{12}$)1,2,3,7,8-PeCDF	*96*	0.20	–	1.11	1.25	*89*
($^{13}C_{12}$)1,2,3,6,7,8- HxCDD	*84*	0.10	–	1.20	1.25	*96*
($^{13}C_{12}$)1,2,3,6,7,8- HxCDF	*90*	0.10	–	1.18	1.25	*94*
($^{13}C_{12}$)1,2,3,4,6,7,8-HpCDD	*95*	0.10	–	1.13	1.25	*90*
($^{13}C_{12}$)1,2,3,4,6,7,8-HpCDF	*96*	0.10	–	1.00	1.25	*80*
($^{13}C_{12}$)OCDD	*93*	0.10	–	2.13	2.50	*85*

Table 1.15

QA/QC DATA REPORT for metals in biota

Ingredient	Procedu-ral Blank, mg/kg	Duplicate Difference, %D	Matrix Spike Recovery, % R	Detection Limit, mg/kg	Certified Reference Material, mg/kg			
					DORM-2		SRM 2977	
					Certified Value	Detected Value	Certified Value	Detected Value
Hg	< 0.003	11.8	92.3	0.003	4.64 ± 0.26	4.59	0.101 ± 0.004	0.103

%R= ((SSR-SR)/ SA)X100
SSR- Spiked Sample Result,
SR- Sample Result,
SA- Spike Added
Control Limit %R= 80-120 %

%D=((SR_1-SR_2)/SR) X100
SR_1 - Sample Result 1
SR_2 - Sample Result 2
SR=(SR_1+SR_2)/2
Control Limit %D= 20 %

Table 1.16

Analytical methods in determination of metals

Metals	Sediment			Biota		
	Technique	Method of analysis	Detection Limit, mg/kg	Technique	Method of analysis	Detection Limit, mg/kg
Cd	GFAA	SW-846 #7131A	0.005	GFAA	SW-846 #7131A	0.001
Cu	FLAA	SW-846 # 7210	1.5	FLAA	SW-846 # 7210	0.20
Ni	FLAA	SW-846 #7520	5.0	GFAA	SW-846 #7521	0.01
Pb	FLAA	SW-846 #7421	8.0	GFAA	SW-846 #7420	0.01
Hg	CVAA	SW-846 #7471A	0.005	CVAA	Russian	0.005
Li	FLAA	SW-846 #7430	4.0	-	-	-
Zn	FLAA	SW-846 #7950	0.8	FLAA	SW-846 #7950	0.10

Appendix 2

BILE ACIDS QUANTIFICATION

Bile acids quantification in bile was measured using the method described by Ripatti P.O. et al. (1969).

Reagents. Concentrated sulphur acid; n-hexane (1 liter / one analysis) (purified from peroxides); sulphur ester (1 liter / analysis) (purified from peroxides); cholic acid; chenodeoxic acid; NaOH (natrium hydroxide) (crystalline); HCL (hydrochloric acid) (5 N solution); ethanol (96% (volume per cent)); potassium permanganate ($KMnO_4$) for purification sulphur ester and n-hexane.

Isolation of bile acids. The samples were heated on water bath for 5 min, filtered and washed 2-3 times by hot ethanol. The spirit extract was evaporated in retorts and this retorts were dried under the oxide of phosphorus (P_2O_5) until constant weight. The sediments were weighed. Fixed weigh and volume for further study was taken.

Obtaining free bile acids. The ethanol solutions were evaporated until dry. Every sediments were dissolved in 3 ml natrium hydroxide solution (1,25 M NaOH) and removed into teflon retorts. Teflon retorts have been closed up hermetically and stayed in thermostat at 120 ^oC for 4 hours. After hydrolysis this alkaline solution were removed in glass retorts with glass cork (or into separating funnel). Teflon retorts were washed 3 times (2 ml every times) by bidistillate water. This volume was added into this glass retorts. The acidity of these solutions was adjusted to pH 2-3. Then samples were extracted by ether (sulphur ether) 3 times (6-10 ml every times). Ether fraction were washed 2 times and evaporated until dry. Then samples were dissolved into 8 ml of 70% ethanol and washed 3 times (6 ml every time) by n-hexane. Spirit solutions were evaporated until dry. Samples were dissolved in definite volume of 96% (volume per cent) ethanol.

Spectrophotometrical measurements. Definite volumes of these samples in spirit were removed into glass flasks with glass cork. It was added 5 ml of sulphur acid after full evaporation of ethanol in every flask. Samples were incubated in thermostat at 65^oC for 1 hour and measured by spectrophotometer at 347 nm and 389 nm wave lengths.

DETERMINATION OF ANILINE HYDROXYLASE ACTIVITY

Aniline hydroxylase activity was measured using the method described by Mazel (1972).

Reagents. Glucose-6-phosphate; nicotinamide (the amide of nicotinic acid); magnesium chloride ($MgCl_2$); NADPH (nicotinamideadeninedinucleotide phosphate reduced); carbonate of natrium (Na_2CO_3); 2-substituted hydrophosphate of natrium (Na_2HPO_4) (crystalline); 1-substituted dihydrophosphate of potassium (KH_2PO_4) (crystalline); chloride of potassium (KCl); phenol (crystalline); NaOH (natrium hydroxide) (crystalline); trichloracetic acid (CCl_3COOH) (crystalline or 50-20% volume per cent); aniline hydrochloride $C_6H_5NH_2 \bullet HCl$ (crystalline); p-aminophenol $C_6H_4NH_2OH$ (crystalline).

Enzyme separation. Frozen samples of tissue were homogenised in special buffer (1,15% KCl solution in 0,01 M K^+/Na^+ phosphate buffer) until homogeny solution. Samples were centrifuged by ultracentrifuge (12000 promptness/ min (10000 g)). Supernatant fractions were removed in flasks and stored on ice until incubation procedure.

Incubation procedure. Supernatant fractions were added into flasks which contain: a) experiment flasks: aniline (5μmole/ 4 ml); glucose-6-phosphate (10μmole/ 4 ml); nicotinamide (50 μmole/ 4 ml); magnesium chloride (25μmole/ 4 ml); b) control flasks: glucose-6-phosphate; nicotinamide; magnesium chloride (the same amounts of reagents). Flasks with incubation mixture and supernatant fraction have been incubated for 30 min at 37^{o}C in thermostat.

Activity measurement

The reaction was stopped by 20% trichloracetic acid. Then, these samples were centrifuged by centrifuge (2500 – 3000 promptness/ min). After that supernatant fraction were removed in flasks. It was added 10% natrium carbonate, 2% phenol in 0,2 N NaOH solutions. Samples have been incubated for 30 min at 37^{o}C in thermostat to allow colour to develop. Then samples were measured at 640 nm by spectrophotometer.

Appendix 3.
Analytical data

Table 3.1. OCs (ng/g wet weight) in pooled tissue samples of whitefishes and pikes from lakes located in Pasvik River area. N is number of sub-samples.

OCs	White fish								Pike	
	Tjærebukta		Skrukkebukta		Ruskebukta		Kuetsjarvi		Kuetsjarvi	
	4-5 years, Wt 100-500 g		3-5 years, Wt 100-300 g		4-6 years, Wt 300-500 g		3-5 years, Wt 50-140 g			
	Muscle	Liver	Muscle	Liver	Muscle	Liver	Muscle	Liver	Muscle	Liver
	N=10	N=10	N=5	N=5	N=5	N=5	N=10	N=15	N=10	N=10
Lipids, %	0.66	14.1	0.88	5.25	0.54	7.94	1.86	6.99	0.41	25.9
Hexachlorobenzene	n.d.	1.23	0.28	0.69	0.15	0.97	0.58	2.81	0.20	3.71
α-HCH	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0.12	n.d.	n.d.	1.68
β-HCH	n.d.	n.d.	0.07	n.d.	n.d.	n.d.	0.12	1.51	n.d.	3.12
γ-HCH	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0.05	n.d.	n.d.	0.70
[1]ΣHCH	n.d.	n.d.	0.07	n.d.	n.d.	n.d.	0.29	1.51	n.d.	5.50
Heptachlor	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Heptachlor epoxide	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0.20
Oxychlordane	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0.40
trans-Chlordane	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0.30
cis-Chlordane	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0.05	0.46	n.d.	0.55
trans-Nonachlor	n.d.	0.30	n.d.	n.d.	n.d.	n.d.	0.13	n.d.	0.02	1.55
cis-Nonachlor	0.17	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0.03	n.d.
[2]ΣCHL	0.17	0.30	n.d.	n.d.	n.d.	n.d.	0.18	0.46	0.05	3.00
o,p`-DDE	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	2.27
p,p`-DDE	3.44	1.67	0.32	2.60	n.d.	1.07	14.4	75.3	2.16	55.4
o,p`-DDD	n.d.	0.05	n.d.	n.d.	n.d.	n.d.	0.21	1.54	0.03	4.51
p,p`-DDD	0.15	0.24	n.d.	0.87	n.d.	0.59	1.91	9.51	0.26	33.2
o,p`-DDT	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
p,p`-DDT	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0.95	1.73	1.14	13.8
[3]ΣDDT	3.59	1.96	0.32	3.47	n.d.	1.66	17.5	88.1	3.59	109.2
Endrin	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Dieldrin	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0.45
Mirex	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0.05

[1]ΣHCH is sum of α-HCH, β-HCH, and γ-HCH, [2] ΣCHL is sum of heptachlor, heptachlor epoxide, oxychlordane, *trans*-chlordane, *cis*-chlordane, *trans*-nonachlor and *cis*-nonachlor; [3]ΣDDT is sum of *o,p`*-DDE, *p,p`*-DDE, *o,p`*-DDD, *p,p`*-DDD, *o,p`*-DDT and *p,p`*-DDT; n.d.=not detected.

Table 3.2. OCs (ng/g wet weight) in pooled tissue samples of whitefishes and pikes from Stuorajavri Lake in 2005. N is number of sub-samples.

OCs	Whitefish, female						Whitefish, male				Pike, M&F	
	N=13		N=6		N=9		N=10		N=6		N=5	
	Wt=100-200g		Wt=300-400 g		Wt=400-500g		Wt=100-200g		Wt=200-300g			
	Muscle	Liver	Muscle	Liver	Muscle	Liver	Muscle	Liver	Muscle	Liver	Muscle	Liver
Lipid, %	0.71	3.05	0.50	3.60	0.76	8.40	0.44	3.06	0.55	3.17	0.32	6.86
Hexachlorobenzene	0.27	1.39	0.2	1.3	0.16	0.2	0.28	2.19	0.22	1.11	0.18	2.07
α-HCH	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
β-HCH	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
γ-HCH	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
[1]ΣHCH	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Heptachlor	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Heptachlor epoxide	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Oxychlordane	n.d.	2.29	n.d.	4.90	n.d.	n.d.	n.d.	5.06	0.74	3.57	0.57	1.62
trans-Chlordane	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0.20
cis-Chlordane	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0.06	0.44	n.d.	n.d.	n.d.	0.38
trans-Nonachlor	0.10	0.22	n.d.	n.d.	0	0.1	0.09	0.91	0.08	0.24	0.03	1.17
cis-Nonachlor	n.d.	0.20	n.d.	n.d.	n.d.	n.d.	0.08	0.47	n.d.	0.14	n.d.	0.57
[2]ΣCHL	0.10	2.71	n.d.	4.90	0	0.11	0.23	6.88	0.82	3.95	0.60	3.94
o,p`-DDE	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
p,p`-DDE	0.35	1.65	0.2	1.1	n.d.	0.60	0.41	2.79	0.37	1.54	0.24	4.84
o,p`-DDD	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0.28	n.d.	0.13	n.d.	0.18
p,p`-DDD	n.d.	0.22	n.d.	n.d.	n.d.	n.d.	n.d.	0.80	0.08	0.41	n.d.	0.69
o,p`-DDT	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
p,p`-DDT	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0.10	n.d.	n.d.	0.16
[3]ΣDDT	0.35	1.87	0.2	1.1	n.d.	0.60	0.41	3.87	0.55	2.08	0.24	5.87
Endrin	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Dieldrin	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0.18
Mirex	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.

[1]ΣHCH is sum of α-HCH, β-HCH, and γ-HCH, [2] ΣCHL is sum of heptachlor, heptachlor epoxide, oxychlordane, *trans*-chlordane, *cis*-chlordane, *trans*-nonachlor and *cis*-nonachlor; [3]ΣDDT is sum of *o,p`*-DDE, *p,p`*-DDE, *o,p`*-DDD, *p,p`*-DDD, *o,p`*-DDT and *p,p`*-DDT; n.d.=not detected.

Table 3.3. PCBs (ng/g wet weight) in pooled tissue samples of whitefishes and pikes from lakes located in Pasvik River area, and TCDD-equivalents (TEQ_{PCB}) (pgTEQ/g wet weight) calculated using toxic equivalency factors (TEFs) according to (Ahlborg et al., 1994). N is number of sub-samples. Non-ortho and mono-ortho CB congeners are marked by bolt font.

PCBs	White fish								Pike	
	Tjærebukta		Skrukkebukta		Ruskebukta		Kuetsjarvi		Kuetsjarvi	
	Muscle	Liver	Muscle	Liver	Muscle	Liver	Muscle	Liver	Muscle	Liver
	N=10	N=10	N=5	N=5	N=5	N=5	N=10	N=15	N=10	N=10
Lipids, %	0.66	14.1	0.88	5.25	0.54	7.94	1.86	6.99	0.41	25.9
PCB-8	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
PCB-16	0.09	n.d.	n.d.	n.d.	n.d.	n.d.	0.05	n.d.	n.d.	0.18
PCB-18	0.07	n.d.	n.d.	n.d.	n.d.	n.d.	0.05	n.d.	n.d.	0.67
PCB-25	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
PCB-26	0.54	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0.31
PCB-31/28	0.09	n.d.	n.d.	0.12	n.d.	0.06	0.41	1.43	0.07	4.63
PCB-33	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0.31
PCB-37	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
PCB-41	0.07	n.d.	n.d.	n.d.	n.d.	n.d.	0.21	1.22	n.d.	2.63
PCB-44	0.07	0.13	n.d.	0.18	n.d.	0.15	0.24	1.96	0.05	3.15
PCB-47	n.d.	0.13	n.d.	n.d.	n.d.	n.d.	0.30	0.99	n.d.	3.06
PCB-49	0.69	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	1.35
PCB-52	0.13	n.d.	n.d.	1.43	n.d.	n.d.	0.37	0.68	n.d.	5.45
PCB-60	n.d.	0.11	n.d.	0.15	0.05	0.15	1.77	13.7	0.16	18.1
PCB-66	n.d.	0.10	n.d.	0.17	n.d.	n.d.	0.79	2.83	0.18	8.95
PCB-70	0.14	0.21	0.06	0.20	0.05	0.22	0.69	3.85	0.18	7.99
PCB-74	0.13	0.07	n.d.	0.21	n.d.	0.22	0.51	2.48	0.14	6.38
PCB-77	**0.09**	**n.d.**	**n.d.**	**n.d.**	**n.d.**	**n.d.**	**0.09**	**n.d.**	**0.06**	**1.17**
PCB-81	**0.06**	**n.d.**	**n.d.**	**n.d.**	**n.d.**	**n.d.**	**n.d.**	**n.d.**	**0.15**	**0.53**
PCB-87	n.d.	0.27	0.05	0.22	0.08	0.17	n.d.	n.d.	n.d.	n.d.
PCB-95	0.08	0.29	n.d.	0.17	n.d.	0.17	0.39	2.99	0.11	5.70
PCB-97	n.d.	0.13	n.d.	0.16	n.d.	0.07	0.26	2.41	0.10	5.30
PCB-99	0.21	0.24	n.d.	0.44	0.11	0.29	1.26	9.55	0.36	16.4
PCB-105	**n.d.**	**1.15**	**0.17**	**1.50**	**0.24**	**n.d.**	**1.21**	**###**	**1.25**	**20.4**
PCB-114	**n.d.**	**n.d.**	**n.d.**	**n.d.**	**n.d.**	**n.d.**	**0.15**	**n.d.**	**0.03**	**1.33**
PCB-118	**1.02**	**n.d.**	**0.20**	**n.d.**	**0.12**	**n.d.**	**3.30**	**17.1**	**0.75**	**25.7**
PCB-123	**n.d.**	**n.d.**	**n.d.**	**n.d.**	**n.d.**	**n.d.**	**0.65**	**n.d.**	**0.12**	**8.19**
PCB-126	**n.d.**	**n.d.**	**n.d.**	**n.d.**	**n.d.**	**n.d.**	**n.d.**	**n.d.**	**0.03**	**0.08**
PCB-135	n.d.	0.08	0.06	0.08	0.12	0.09	0.18	2.04	0.06	4.84
PCB-138	0.35	0.78	0.22	1.44	0.07	0.79	2.43	23.2	0.71	25.1
PCB-141	n.d.	0.08	n.d.	0.10	n.d.	0.06	0.25	2.56	0.06	5.41
PCB-146	n.d.	0.20	n.d.	0.16	n.d.	0.12	0.33	2.54	0.06	6.07
PCB-151	0.09	0.09	n.d.	0.11	n.d.	0.10	0.27	2.58	0.08	4.91
PCB-153	0.38	0.90	0.18	1.25	0.09	0.93	2.18	21.0	0.69	24.6
PCB-156	**n.d.**	**n.d.**	**n.d.**	**n.d.**	**n.d.**	**n.d.**	**0.26**	**n.d.**	**0.15**	**4.29**
PCB-157	**n.d.**	**n.d.**	**n.d.**	**n.d.**	**n.d.**	**n.d.**	**n.d.**	**n.d.**	**n.d.**	**1.19**
PCB-167	**0.12**	**n.d.**	**n.d.**	**n.d.**	**n.d.**	**n.d.**	**0.29**	**2.76**	**0.07**	**5.58**
PCB-169	**n.d.**	**n.d.**	**n.d.**	**n.d.**	**n.d.**	**n.d.**	**n.d.**	**n.d.**	**n.d.**	**0.34**
PCB-170	0.25	n.d.	n.d.	n.d.	n.d.	n.d.	0.40	2.54	0.06	8.25
PCB-174	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0.10	1.17	n.d.	3.01
PCB-177	n.d.	0.14	n.d.	n.d.	n.d.	n.d.	0.10	0.49	n.d.	3.55
PCB-180	0.27	n.d.	n.d.	n.d.	n.d.	n.d.	0.88	7.33	0.16	19.0
PCB-183	n.d.	n.d.	n.d.	0.11	n.d.	0.06	0.14	1.98	n.d.	4.59
PCB-187	n.d.	n.d.	n.d.	n.d.	n.d.	0.09	0.25	3.46	n.d.	5.67
PCB-189	**n.d.**	**n.d.**	**n.d.**	**n.d.**	**n.d.**	**n.d.**	**n.d.**	**n.d.**	**n.d.**	**n.d.**
PCB-194	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0.06	0.38	n.d.	2.52
PCB-195	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0.31	n.d.	1.16
PCB-196/203	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0.10	0.83	n.d.	2.72
PCB-199	n.d.	n.d.	n.d.	n.d.	n.d.	0.05	0.05	0.53	n.d.	1.77
PCB-206	n.d.	n.d.	n.d.	0.12	n.d.	n.d.	n.d.	0.65	n.d.	0.64
PCB-209	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
[1]Σ(n,m-o)PCB	1.29	1.15	0.37	1.50	0.36	0.00	5.95	32.0	2.61	68.8
[2]ΣPCB	4.94	5.1	0.94	8.32	0.93	3.79	21	150	5.84	283
TEQ_{PCB}	0.18	0.12	0.04	0.15	0.04	n.d.	0.82	3.27	3.34	21.9

n.d.=not detected. [1]Σ(n,m-o)PCB is sum of non-*ortho* and mono-*ortho* CBs; [2]ΣPCB is sum of 53 PCB congeners.

Table 3.4. PCBs (ng/g wet weight) in pooled tissue samples of whitefish and pike from Stuorajavri Lake and TCDD-equivalents (TEQ_{PCB}) (pgTEQ/g wet weight) calculated using toxic equivalency factors (TEFs) according to (Ahlborg et al., 1994). N is number of sub-samples, Wt is weight range. Non-ortho and mono-ortho CB congeners are marked by bolt font.

PCBs	Whitefish, female						Whitefish, male				Pike, M&F	
	N=13		N=6		N=9		N=10		N=6		N=5	
	Wt=100-200g		Wt=300-400 g		Wt=400-500g		Wt=100-200g		Wt=200-300g			
	Muscle	Liver	Muscle	Liver	Muscle	Liver	Muscle	Liver	Muscle	Liver	Muscle	Liver
Lipid, %	0.71	3.05	0.50	3.60	0.76	8.40	0.44	3.06	0.55	3.17	0.32	6.86
PCB-8	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	1.7	n.d.	n.d.	n.d.	n.d.
PCB-16	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
PCB-18	n.d.	n.d.	n.d.	n.d.	n.d.	0.22	n.d.	0.99	n.d.	n.d.	n.d.	n.d.
PCB-25	n.d.	1.54	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0.91	n.d.	n.d.	1.58
PCB-26	0.44	n.d.	n.d.	n.d.	0.34	0.63	n.d.	1.65	n.d.	4.33	1.07	n.d.
PCB-31/28	0.24	0.27	n.d.	0.49	n.d.	0.11	0.12	1.29	0.35	0.67	n.d.	0.37
PCB-33	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0.25	n.d.	n.d.	n.d.	0.5
PCB-37	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
PCB-41	n.d.	0.19	n.d.	n.d.	n.d.	0.14	n.d.	0.32	n.d.	n.d.	n.d.	n.d.
PCB-44	0.2	0.22	n.d.	n.d.	n.d.	0.13	n.d.	0.43	n.d.	0.32	n.d.	n.d.
PCB-47	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
PCB-49	0.21	9.8	1.22	1.9	0.45	0.66	n.d.	n.d.	3.86	12.9	2.32	6.17
PCB-52	0.16	2.35	0.13	0.32	0.45	1.28	0.39	1.08	0.83	4.67	0.87	2.5
PCB-60	n.d.	0.5	n.d.	0.36	n.d.	n.d.	n.d.	0.79	n.d.	0.36	n.d.	n.d.
PCB-66	0.11	0.21	0.13	0.18	n.d.	0.31	0.13	0.52	0.19	0.3	0.13	0.31
PCB-70	0.11	0.44	0.13	0.37	n.d.	0.24	0.16	0.72	0.15	0.7	0.15	0.36
PCB-74	n.d.	0.14	n.d.	0.21	n.d.	n.d.	n.d.	0.31	n.d.	n.d.	n.d.	0.37
PCB-77	**n.d.**	**n.d.**	**n.d.**	**0.13**	**n.d.**	**n.d.**	**n.d.**	**n.d.**	**n.d.**	**n.d.**	**n.d.**	**n.d.**
PCB-81	**n.d.**	**n.d.**	**n.d.**	**n.d.**	**n.d.**	**0.02**	**n.d.**	**n.d.**	**n.d.**	**n.d.**	**n.d.**	**n.d.**
PCB-87	0.21	0.69	0.22	0.57	n.d.	0.5	0.16	1.21	0.35	1.59	n.d.	n.d.
PCB-95	n.d.	0.29	n.d.	n.d.	n.d.	0.12	0.12	0.45	n.d.	n.d.	n.d.	n.d.
PCB-97	n.d.	0.22	0.12	0.25	n.d.	0.17	n.d.	0.48	n.d.	n.d.	n.d.	n.d.
PCB-99	n.d.	0.49	0.1	0.23	n.d.	0.24	n.d.	1.16	0.14	0.44	n.d.	n.d.
PCB-105	**0.05**	**0.29**	**0.19**	**0.44**	**n.d.**	**0.16**	**0.12**	**0.94**	**0.10**	**0.62**	**0.11**	**1.03**
PCB-114	**n.d.**	**n.d.**	**n.d.**	**n.d.**	**n.d.**	**n.d.**	**n.d.**	**n.d.**	**n.d.**	**n.d.**	**n.d.**	**0.30**
PCB-118	**0.29**	**1.27**	**0.46**	**1.21**	**0.29**	**1.01**	**0.42**	**2.69**	**0.33**	**2.71**	**0.50**	**2.68**
PCB-123	**n.d.**	**n.d.**	**n.d.**	**n.d.**	**n.d.**	**0.08**	**n.d.**	**n.d.**	**n.d.**	**n.d.**	**n.d.**	**0.15**
PCB-126	**n.d.**	**n.d.**	**n.d.**	**n.d.**	**n.d.**	**n.d.**	**n.d.**	**n.d.**	**n.d.**	**n.d.**	**n.d.**	**n.d.**
PCB-135	n.d.	0.15	n.d.	n.d.	n.d.	0.12	n.d.	0.64	n.d.	n.d.	n.d.	n.d.
PCB-138	0.31	1.1	n.d.	0.55	n.d.	0.43	0.41	3.87	0.35	1.13	0.26	3.18
PCB-141	n.d.	0.29	n.d.	0.12	n.d.	n.d.	n.d.	0.63	n.d.	0.42	n.d.	0.35
PCB-146	n.d.	0.22	n.d.	0.2	n.d.	n.d.	n.d.	0.75	n.d.	0.32	n.d.	0.43
PCB-151	n.d.	0.24	n.d.	0.13	n.d.	0.13	n.d.	0.91	n.d.	0.54	n.d.	n.d.
PCB-153	0.25	0.82	0.12	0.47	n.d.	0.63	0.42	3.8	0.32	0.96	0.2	2.88
PCB-156	**n.d.**	**n.d.**	**n.d.**	**n.d.**	**n.d.**	**n.d.**	**n.d.**	**n.d.**	**n.d.**	**n.d.**	**n.d.**	**n.d.**
PCB-157	**n.d.**	**n.d.**	**n.d.**	**n.d.**	**n.d.**	**n.d.**	**n.d.**	**n.d.**	**n.d.**	**n.d.**	**n.d.**	**n.d.**
PCB-167	**n.d.**	**n.d.**	**n.d.**	**n.d.**	**n.d.**	**n.d.**	**n.d.**	**n.d.**	**n.d.**	**n.d.**	**n.d.**	**0.35**
PCB-169	**n.d.**	**n.d.**	**n.d.**	**n.d.**	**n.d.**	**n.d.**	**n.d.**	**n.d.**	**n.d.**	**n.d.**	**n.d.**	**n.d.**
PCB-170	n.d.	0.18	n.d.	n.d.	n.d.	n.d.	n.d.	0.42	n.d.	0.14	n.d.	0.40
PCB-174	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0.52	n.d.	n.d.	n.d.	n.d.
PCB-177	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0.38	n.d.	n.d.	n.d.	n.d.
PCB-180	n.d.	0.70	n.d.	n.d.	n.d.	n.d.	n.d.	1.75	n.d.	0.72	n.d.	0.89
PCB-183	n.d.	0.18	n.d.	n.d.	n.d.	n.d.	n.d.	0.68	n.d.	n.d.	n.d.	n.d.
PCB-187	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
PCB-189	**n.d.**	**n.d.**	**n.d.**	**n.d.**	**n.d.**	**n.d.**	**n.d.**	**n.d.**	**n.d.**	**n.d.**	**n.d.**	**n.d.**
PCB-194	n.d.	0.19	n.d.	n.d.	n.d.	n.d.	n.d.	0.27	n.d.	n.d.	n.d.	n.d.
PCB-195	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
PCB-196/203	n.d.	0.18	n.d.	n.d.	n.d.	n.d.	n.d.	0.34	n.d.	n.d.	n.d.	0.49
PCB-199	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0.31	n.d.	n.d.	n.d.	n.d.
PCB-206	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
PCB-209	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
[1]Σ(n,m-o)PCB	0.34	1.56	0.65	1.78	0.29	1.27	0.54	3.63	0.43	3.33	0.61	4.51
[2]ΣPCB	2.58	23.2	2.82	8.13	1.53	7.33	2.45	32.3	7.88	33.8	5.61	25.3
TEQ_{PCB}	0.74	3.23	0.57	3.83	0.79	8.53	0.49	3.48	0.59	3.52	0.38	7.45

n.d.=not detected. [1]Σ(n,m-o)PCB is sum of non-*ortho* and mono-*ortho* CBs; [2]ΣPCB is sum of 53 PCB congeners.

Table 3.5. Selected toxaphene congeners (Parlar et al., 1995) (ng/g wet weight) in pooled tissue samples of whitefish and pike from lakes located in Pasvik River area. N is number of sub-samples.

Toxaphenes	White fish								Pike	
	Tjærebukta		Skrukkebukta		Ruskebukta		Kuetsjarvi		Kuetsjarvi	
	Muscle	Liver	Muscle	Liver	Muscle	Liver	Muscle	Liver	Muscle	Liver
	N=10	N=10	N=5	N=5	N=5	N=5	N=10	N=15	N=10	N=10
Lipids, %	0.66	14.1	0.88	5.25	0.54	7.94	1.86	6.99	0.41	25.9
Parlar#26	n.d.	6.89	n.d.	n.d.	n.d.	n.d.	1.82	n.d	n.d.	45.8
Parlar#50	3.24	23.8	n.d.	n.d.	n.d.	5.73	4.45	n.d.	3.24	93.1
Parlar#62	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
ΣParlars	3.24	30.7	n.d.	n.d.	n.d.	5.73	6.27	n.d.	3.24	138.9

n.d. = not detected.

Table 3.6. Selected toxaphene congeners (Parlar et al., 1995) (ng/g wet weight) in pooled tissue samples of whitefish and pikes from Stuorajavri Lake in 2005. N is number of sub-samples, Wt is weight range.

Toxaphenes	Whitefish, female						Whitefish, male				Pike, M&F	
	N=13		N=6		N=9		N=10		N=6		N=5	
	Wt=100-200g		Wt=300-400 g		Wt=400-500g		Wt=100-200g		Wt=200-300g			
	Muscle	Liver	Muscle	Liver	Muscle	Liver	Muscle	Liver	Muscle	Liver	Muscle	Liver
Lipid, %	0.71	3.05	0.50	3.60	0.76	8.40	0.44	3.06	0.55	3.17	0.32	6.86
Parlar#26	2.17	5.45	0.4	1.70	0.49	2	1.66	10.8	0.99	4.31	0.63	20.4
Parlar#50	4.20	4.78	0.7	2.1	0.73	2.2	3.31	12.1	1.88	3.31	0.85	26.3
Parlar#62	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
ΣParlars	6.37	10.2	1.1	3.8	1.22	4.3	4.97	22.9	5.16	1.04	5.26	2.06

n.d.=not detected.

Table 3.7. Polychlorinated dibenzo-p-dioxins (PCDD) and polychlorin,ated dibenzofurans (PCDF) (pg/g wet weight) in pooled tissue samples of whitefish (Coregonus lavaretus) and pike (Esox lucius) from lakes located in Pasvik River area, and TCDD-equivalents ($TEQ_{PCDD/F}$) (pgTEQ/g wet weight) calculated using toxic equivalency factors (TEFs) of the international (I-TEF) model (NATO/CCMS, 1988). N = number of sub-samples.

PCDD/Fs	White fish male								Pike, M&F	
	Tjærebukta		Skrukkebukta		Ruskebukta		Kuetsjarvi		Kuetsjarvi	
	4-5 years, Wt 100-500 g		3-5 years, Wt 100-300 g		4-6 years, Wt 300-500 g		3-5 years, Wt 50-140 g			
	Muscle	Liver	Muscle	Liver	Muscle	Liver	Muscle	Liver	Muscle	Liver
	N=10	N=10	N=5	N=5	N=5	N=5	N=10	N=15	N=10	N=10
Lipids, %	0.66	14.1	0.88	5.25	0.54	7.94	1.86	6.99	0.41	25.9
2,3,7,8-TCDD	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
1,2,3,7,8-PeCDD	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
1,2,3,4,7,8-HxCDD	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
1,2,3,6,7,8-HxCDD	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
1,2,3,7,8,9-HxCDD	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
1,2,3,4,6,7,8-HpCDD	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
OCDD	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
2,3,7,8-TCDF	n.d.	0.50	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	2.11
1,2,3,7,8-PeCDF	n.d.	0.24	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	1.82
2,3,4,7,8-PeCDF	n.d.	0.21	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	1.51
1,2,3,4,7,8-HxCDF	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
1,2,3,6,7,8-HxCDF	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
2,3,4,6,7,8-HxCDF	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
1,2,3,7,8,9-HxCDF	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
1,2,3,4,6,7,8-HpCDF	n.d.	0.47	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0.70
1,2,3,4,7,8,9-HpCDF	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
OCDF	n.d.	1.10	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	1.25
ΣTCDD/F	n.d.	2.52	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	7.39
$TEQ_{PCDD/F}$		0.17								1.06

n.d. = not detected.

Table3.8. Polychlorinated dibenzo-p-dioxins (PCDD) and polychlorinated dibenzofurans (PCDF) (pg/g wet weight) in pooled tissue samples of whitefish (Coregonus lavaretus) and pike (Esox lucius) from Stuorajavri Lake in 2005, and TCDD-equivalents ($TEQ_{PCDD/F}$) (pgTEQ/g wet weight) calculated using toxic equivalency factors (TEFs) of the international (I-TEF) model (NATO/CCMS, 1988).

PCDD/F	Whitefish, female						Whitefish, male				Pike, M&F	
	N=13		N=6		N=9		N=10		N=6		N=5	
	Wt=100-200g		Wt=300-400g		Wt=400-500g		Wt=100-200g		Wt=200-300g			
	Muscle	Liver	Muscle	Liver	Muscle	Liver	Muscle	Liver	Muscle	Liver	Muscle	Liver
Lipid, %	0.71	3.05	0.50	3.60	0.76	8.40	0.44	3.06	0.55	3.17	0.32	6.86
2,3,7,8-TCDD	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
1,2,3,7,8-PeCDD	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
1,2,3,4,7,8-HxCDD	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
1,2,3,6,7,8-HxCDD	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
1,2,3,7,8,9-HxCDD	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
1,2,3,4,6,7,8-HpCDD	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
OCDD	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
2,3,7,8-TCDF	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
1,2,3,7,8-PeCDF	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
2,3,4,7,8-PeCDF	0.25	n.d.	0.20	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0.20	n.d.
1,2,3,4,7,8-HxCDF	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
1,2,3,6,7,8-HxCDF	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
2,3,4,6,7,8-HxCDF	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
1,2,3,7,8,9-HxCDF	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
1,2,3,4,6,7,8-HpCDF	1.01	n.d.	1.29	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	1.13	n.d.
1,2,3,4,7,8,9-HpCDF	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
OCDF	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
ΣPCDD/F	1.26	n.d.	1.49	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	1.33	n.d.
$TEQ_{PCDD/F}$	0.14	n.d.	0.11	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0.11	n.d.

n.d.=not detected.

Table 3.9. Polybrominated diphenyl ethers (PBDEs) (pg/g wet weight) in pooled tissue samples of whitefishes and pikes from lakes located in Pasvik River area. N is number of sub-samples.

PBDEs	White fish								Pike	
	Tjærebukta		Skrukkebukta		Ruskebukta		Kuetsjarvi		Kuetsjarvi	
	Muscle	Liver	Muscle	Liver	Muscle	Liver	Muscle	Liver	Muscle	Liver
	N=10	N=10	N=5	N=5	N=5	N=5	N=10	N=15	N=10	N=10
Lipids, %	0.66	14.1	0.88	5.25	0.54	7.94	1.86	6.99	0.41	25.9
TriBDE#28	n.d.	1.6	0.65	2.75	n.d.	2.57	3.14	15.9	n.d.	49.1
TetraBDE#47	n.d.	30.3	8.30	57.9	n.d.	22.8	89.1	462.0	20.0	1726
PentaBDE#99	1.72	7.54	2.32	14.8	0.50	4.92	42.7	262.0	9.42	1014
PentaBDE#100	n.d.	n.d.	0.60	n.d.	n.d.	n.d.	2.10	18.3	n.d.	131
HexaBDE#153	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	37.2
HexaBDE#154	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	10.9
HeptaBDE#183	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
ΣPBDE	1.72	39.4	11.9	75.5	0.50	30.3	137.0	758.2	29.4	2968.2

n.d.=not detected.

Table3.10. Polycyclic aromatic hydrocarbons (PAH, ng/g wet weight) in pooled tissue samples of whitefish (Coregonus lavaretus) and pike (Esox lucius) from lakes located in Pasvik River area in 2005 and TCDD-equivalents for dioxin-like PAHs (TEQ_{PAH}) (pgTEQ/g wet weight) calculated using toxic equivalency factors (TEFs) proposed by Klimm et al. (1997). N is number of sub-samples.

PAHs	White fish								Pike	
	Tjærebukta		Skrukkebukta		Ruskebukta		Kuetsjarvi		Kuetsjarvi	
	4-5 years, Wt 100-500 g		3-5 years, Wt 100-300 g		4-6 years, Wt 300-500 g		3-5 years, Wt 50-140 g			
	Muscle	Liver	Muscle	Liver	Muscle	Liver	Muscle	Liver	Muscle	Liver
	N=10	N=10	N=5	N=5	N=5	N=5	N=10	N=15	N=10	N=10
Lipids, %	0.66	14.1	0.88	5.25	0.54	7.94	1.86	6.99	0.41	25.9
Naphthalene	n.d.	n.d.	n.d.	28.3	n.d.	19.7	n.d.	102.0	n.d.	39.5
1-Methylnaphtalene	n.d.	13.3	7.20	33.3	6.26	23.1	n.d.	90.5	n.d	13.8
2-Methylnaphtalene	n.d.	7.97	n.d.	15.5	n.d.	11.4	n.d.	83.6	n.d.	31.4
C2-Naphtalenes	n.d.	10.6	n.d.	22.4	n.d.	17.7	n.d.	44.9	n.d.	23.9
C3-Naphtalenes	n.d.	n.d.	n.d.	6.75	n.d.	n.d.	n.d.	n.d.	n.d.	20.6
C4-Naphtalenes	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	8.55
Acenaphthylene	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Acenaphthene	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Fluorene	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0.5	n.d.	n.d.	2.98
C1-Fluorenes	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	2.62
C2-Fluorenes	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
C3-Fluorenes	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Phenanthrene	n.d.	1.45	n.d.	1.23	n.d.	1.22	1.24	6.82	n.d.	7.32
Anthracene	n.d.	0.24	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0.38
C1-Phens/Anths	n.d.	n.d.	0.66	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
C2-Phens/Anths	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
C3-Phens/Anths	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
C4-Phens/Anths	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Dibenzothiophene	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
C1-Dibenzothiophenes	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
C2-Dibenzothiophenes	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
C3-Dibenzothiophenes	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Fluoranthene	n.d.	0.56	n.d.	0.63	n.d.	0.46	0.62	2.88	n.d.	3.24
Pyrene	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0.62	0.34	n.d.	1.22
C1-Flanths/Pyrs	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
C2-Flanths/Pyrs	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
C3-Flanths/Pyrs	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Benzo(a)anthracene	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Chrysene	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
C1-Chrysenes	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
C2-Chrysenes	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
C3-Chrysenes	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Benzo(b+j)fluoranthene	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Benzo(k)fluoranthene	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Benzo(e)pyrene	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Benzo(a)pyrene	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Perylene	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Indeno(1,2,3-c,d)pyrene	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Dibenzo(a,h)anthracene	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Benzo(g,h,i)perylene	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
ΣPAH	n.d.	34.12	7.86	101.86	6.26	73.58	2.48	286.14	n.d.	155.5
TEQ PAH	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.

Table 3.11.Polycyclic aromatic hydrocarbons (PAH, ng/g wet weight) in pooled tissue samples of whitefish (Coregonus lavaretus) and pike (Esox lucius) from Stuorajavri Lake in 2005 and TCDD-equivalents for dioxin-like PAHs (TEQ_{PAH}) (pgTEQ/g wet weight) calculated using toxic equivalency factors (TEFs) proposed by Klimm et al. (1997). N is number of sub-samples, Wt is weight range.

PAHs	Whitefish, female						Whitefish, male				Pike, M&F	
	N=13		N=6		N=9		N=10		N=6		N=5	
	Wt=100-200g		Wt=300-400g		Wt=400-500g		Wt=100-200g		Wt=200-300g			
	Muscle	Liver	Muscle	Liver	Muscle	Liver	Muscle	Liver	Muscle	Liver	Muscle	Liver
Lipid, %	0.71	3.05	0.50	3.60	0.76	8.40	0.44	3.06	0.55	3.17	0.32	6.86
Naphthalene	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
1-Methylnaphtalene	n.d.	8.91	n.d.	n.d.	n.d.	n.d.	n.d.	14.8	n.d.	22.2	n.d.	11.4
2-Methylnaphtalene	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	6.28	n.d.	6.64	n.d.	n.d.
C2-Naphtalenes	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
C3-Naphtalenes	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
C4-Naphtalenes	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Acenaphthylene	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Acenaphthene	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Fluorene	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
C1-Fluorenes	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
C2-Fluorenes	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
C3-Fluorenes	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Phenanthrene	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	4.02	n.d.	2.89	n.d.	1.90
Anthracene	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
C1-Phens/Anths	1.44	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
C2-Phens/Anths	1.84	4.21	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	2.11	5.54
C3-Phens/Anths	5.23	10.3	n.d.	n.d.	n.d.	n.d.	n.d.	7.82	n.d.	n.d.	7.87	2.88
C4-Phens/Anths	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Dibenzothiophene	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
C1-Dibenzothiophenes	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
C2-Dibenzothiophenes	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
C3-Dibenzothiophenes	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Fluoranthene	0.36	1.14	n.d.	n.d.	n.d.	n.d.	0.25	2.01	n.d.	n.d.	0.70	1.17
Pyrene	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	1.65	0.85
C1-Flanths/Pyrs	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
C2-Flanths/Pyrs	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
C3-Flanths/Pyrs	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Benzo(a)anthracene	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	1.62	1.31	1.21
Chrysene	0.31	0.78	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	2.75	0.73	0.80
C1-Chrysenes	0.53	2.17	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
C2-Chrysenes	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
C3-Chrysenes	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Benzo(b+j)fluoranthene	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Benzo(k)fluoranthene	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Benzo(e)pyrene	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Benzo(a)pyrene	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Perylene	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Indeno(1,2,3-c,d)pyrene	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Dibenzo(a,h)anthracene	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Benzo(g,h,i)perylene	4.92	23.4	n.d.	n.d.	n.d.	n.d.	n.d.	11.3	n.d.	33.8	7.63	24.5
ΣPAH	14.6	50.9	n.d.	n.d.	n.d.	n.d.	0.25	46.2	n.d.	69.9	22	50.3
TEQ_{PAH}	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0.044	0.035	0.033

n.d.=not detected.

Table 3.10. Polycyclic aromatic hydrocarbons (PAH, ng/g wet weight) in pooled tissue samples of whitefish and pike from Stuorajavri Lake in 2005 and TCDD-equivalents for dioxin-like PAHs (TEQ_{PAH}) (pgTEQ/g wet weight) calculated using toxic equivalency factors (TEFs) proposed by Klimm et al. (1997). N is number of sub-samples, Wt is weight range.

PAHs	Whitefish, female						Whitefish, male				Pike, M&F	
	N=13		N=6		N=9		N=10		N=6		N=5	
	Wt=100-200g		Wt=300-400g		Wt=400-500g		Wt=100-200g		Wt=200-300g			
	Muscle	Liver	Muscle	Liver	Muscle	Liver	Muscle	Liver	Muscle	Liver	Muscle	Liver
Lipid, %	0.71	3.05	0.50	3.60	0.76	8.40	0.44	3.06	0.55	3.17	0.32	6.86
Naphthalene	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
1-Methylnaphtalene	n.d.	8.91	n.d.	n.d.	n.d.	n.d.	n.d.	14.8	n.d.	22.2	n.d.	11.4
2-Methylnaphtalene	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	6.28	n.d.	6.64	n.d.	n.d.
C2-Naphtalenes	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
C3-Naphtalenes	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
C4-Naphtalenes	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Acenaphthylene	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Acenaphthene	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Fluorene	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
C1-Fluorenes	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
C2-Fluorenes	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
C3-Fluorenes	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Phenanthrene	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	4.02	n.d.	2.89	n.d.	1.90
Anthracene	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
C1-Phens/Anths	1.44	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
C2-Phens/Anths	1.84	4.21	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	2.11	5.54
C3-Phens/Anths	5.23	10.3	n.d.	n.d.	n.d.	n.d.	n.d.	7.82	n.d.	n.d.	7.87	2.88
C4-Phens/Anths	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Dibenzothiophene	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
C1-Dibenzothiophenes	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
C2-Dibenzothiophenes	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
C3-Dibenzothiophenes	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Fluoranthene	0.36	1.14	n.d.	n.d.	n.d.	n.d.	0.25	2.01	n.d.	n.d.	0.70	1.17
Pyrene	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	1.65	0.85
C1-Flanths/Pyrs	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
C2-Flanths/Pyrs	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
C3-Flanths/Pyrs	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Benzo(a)anthracene	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	1.62	1.31	1.21
Chrysene	0.31	0.78	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	2.75	0.73	0.80
C1-Chrysenes	0.53	2.17	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
C2-Chrysenes	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
C3-Chrysenes	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Benzo(b+j)fluoranthene	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Benzo(k)fluoranthene	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Benzo(e)pyrene	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Benzo(a)pyrene	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Perylene	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Indeno(1,2,3-c,d)pyrene	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Dibenzo(a,h)anthracene	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Benzo(g,h,i)perylene	4.92	23.4	n.d.	n.d.	n.d.	n.d.	n.d.	11.3	n.d.	33.8	7.63	24.5
ΣPAH	14.6	50.9	n.d.	n.d.	n.d.	n.d.	0.25	46.2	n.d.	69.9	22	50.3
TEQ_{PAH}	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0.044	0.035	0.033

n.d.=not detected.

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