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Arctic POPs

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Contents

Page

1 Introduction

Wind and sea currents transport organic chemicals from the high industrialised parts of the globe to the more pristine Arctic regions. Many of these chemicals exert toxic effects, are not easily water soluble and degradable, and may persist in the polar environment for long periods of time. These compounds are known as persistent organic pollutants (POPs). Due to their lipophilic character they tend to accumulate in lipid-rich organs of fish and animals.

Flame retardants are chemicals, which added to commercial and household products slow down or even suppress the combustion process. During the twentieth century, new materials such as plastics for appliances and polyurethane foam / fiber-based fillings for furniture, began to replace traditional materials such as wood and metal. While these new materials provided many benefits, they were unfortunately more flammable, and once alight, combusting more rapidly, giving people less time to escape (BSEF, Bromine Science and Environmental Forum, www.bsef.com). Halogenated flame retardants (containing chlorine or bromine atoms) act effectively by removing the $H^{\bullet}$ and $OH^{\bullet}$ radicals in the gas flame phase, which reduces the heat generation and the production of further gaseous flammable material. The effectiveness of the halogenated flame retardants depends on the halogen atoms they contain and also, on the control of the halogen release.

Major Brominated Flame Retardants Volume Estimates
Total Market Demand By Region in 1999

[MT]	Europe	Americas	Asia	Total
TBBPA	13,800	21,600	85,900	121,300
HBCD	8,900	3,100	3,900	15,900
Deca-BDE	7,500	24,300	23,000	54,800
Octa-BDE	450	1,375	2,000	3,825
Penta-BDE	210	8,290	--	8,500
Total	30,860	58,665	114,800	204,325
	15.1%	28.7%	56.2%	100%

Source: Bromine Science and Environmental Forum, July 2000

Table 1: Major brominated flame retardants volume estimates.

Despite the benefits flame retardants bring to society, concerns have also been raised internationally about certain flame retardants and the potential they may have to harm wildlife and humans. These compounds are used in a large number of products and are generally very stable in the environment. When the substance can accumulate in organisms and cause toxic effects, this combination of properties is of obvious concern. Special attention has been paid to chemicals that are very persistent and very bioaccumulative and the reason for that is that it is never possible to say that a compound is absolutely non-toxic. Compounds with such properties may give potential effects that are not known today. Endocrine disruption is one example, where we today see effects of compounds that were earlier thought to be safe.

PBDEs are commercially available as three products, two of which are mixtures of several congeners (Alaee et al., 2003). The so-called penta-product contains 2,2',4,4'-tetrabromodiphenyl ether (BDE47), 2,2',4,4',5-pentabromodiphenyl ether (BDE99), 2,2',4,4',6-pentabromodiphenyl ether (BDE100), 2,2',4,4',5,5'- hexabromodiphenyl ether (BDE153), and 2,2',4,4',5,6'-tetrabromodiphenyl ether (BDE154), where BDE47 and BDE99

are the dominating compounds. The octa-product contains several hexa- to nonabrominated congeners, and the deca-product is almost entirely composed of decabromodiphenyl ether (BDE-209) (Alaee et al., 2003).). The use of PBDEs has increased over the years, and annual sales are now ~70 000 t (t=metric ton) (Bromine Science and Environmental Forum. *Total Market Demand 2003*; available at www.bsef.com)**.** Concerns have largely been focused on Penta-BDE, mainly used for furniture foam. Both BDE47 and 99 are ubiquitous in the environment, most probably due to their widespread use and their lipophilic character (Hites, 2004)

Both Penta- and Octabromodiphenyl ether (Penta- and OctaBDE) have undergone a risk assessment within European Union and risks have been identified for both substances. Following the risk reduction strategy, a directive restricting the uses of both substances was published in February 2003 (Directive 2003/11/EC) and the substances will be banned in the European Community from August 2004. California ban of Penta- and OctaBDE is the first in the United States and will take effect in 2008 (McDonald, 2004). DecaBDE is the major PBDE product in use, but the most abundant congeners reported in biota are the lower brominated PBDEs, especially BDE47, 99 and 100. High concentrations of BDE209 have been detected in sediment and sewage sludge (de Wit, 2002). BDE209 was assumed not to be bioavailable because of its high molecular weight and size. However, lately BDE209 has been detected in human blood (Sjödin et al., 1999) and more recently in eggs from peregrine falcons (Lindberg, et al., 2004). Partly as a result of these findings and also the potential for degradation to lower brominated BDE-compounds (Stapleton et al., 2004), a risk assessment of the BDE209 product is currently in progress within the European Union.

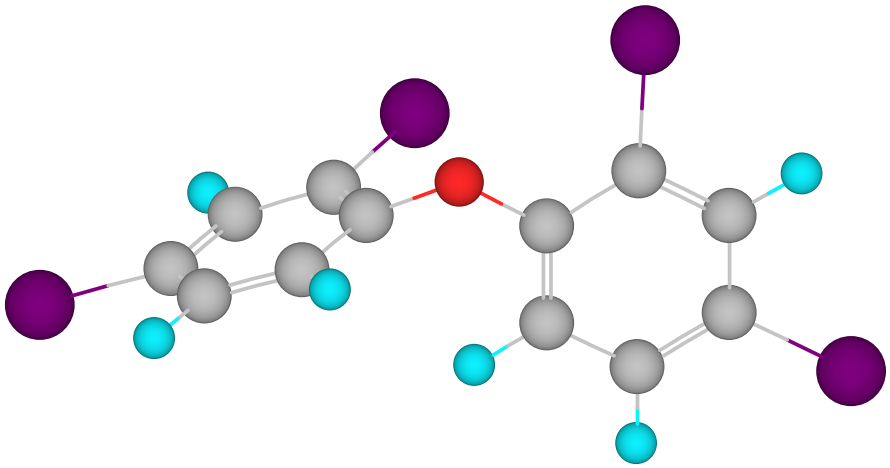
PentaBDEs have in general been increasing in human milk and environmental samples during the last decades (de Wit, 2002), while for instance PCBs have levelled off or decreased. These PBDEs may cause serious nervous system and liver problems, and disrupt thyroid hormones (Betts, 2001; Betts, 2003a). They also accumulate in women's breast tissue and mother's milk and may be passed on to nursing babies. Exposure to PBDE may also come from dust from PBDE–laden furniture, from diet, or from other sources (Betts, 2001; Betts, 2003b; Betts, 2004; Bocio et al., 2003).

A circumpolar project was initiated in 2001 based on an initiative from GLOBE Norway and NILU. The aim was to analyse so called "new POPs" such as BDE47 and BDE99 in the Arctic and to enlarge the knowledge and interest of basic and environmental sciences of the students in the involved schools. The projects aims to enlarge our knowledge on ecosystem health (fish health) due to POPs and also the risk of POPs exposure through fish consumption. There is clearly a need for both temporal and spatial trends of these compounds in the Arctic in order to assess distant and local sources, distribution and potential change with time, and to support ongoing research programs, regulatory agencies and decision makers with data and knowledge. Although this project only lasted for 4 years, implying too short time span and too small statistic data material for fully scientific assessment of time trends and spatial differences within Arctic, we hope and believe that the data set produced from this project will make important contribution to the Arctic monitoring and assessment program (AMAP).

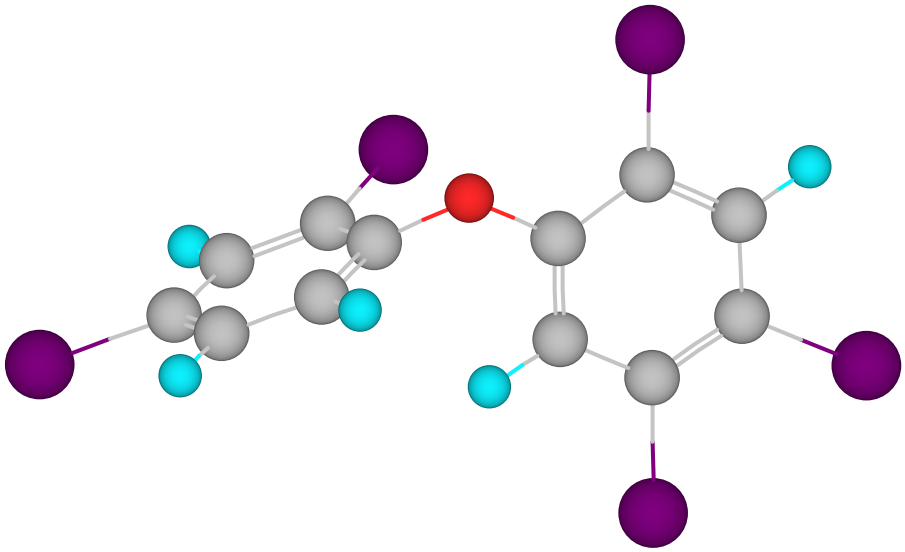
Figure 1: Example of sample preparation and collection of physiological data such as length, weight, gender, maturity and otoliths for age determination.

With the use of pre-cleaned equipment (scissors, forceps, scalpel handlers, scalpel blades, aluminium foil and glasses) and a written sampling protocol for fish from NILU, the students were doing scientifically correct cutting of fish organs such as liver or fillet (see Fig. 1). As part of the protocol, the students should also try to determine physiological parameters such as gender and maturity. In addition, the otoliths were sampled for age determination. NILU encouraged the teachers and pupils to contact national and local research scientists both for help, advice and communication. Implemented in the protocol, each sample was followed by a datasheet to be filled out during sampling and biopsies. The datasheet contained important data to be used for scientific ecotoxicological evaluation, such as sampling date, description of sampling location including GPS co-ordinates, type of fish species, Latin name, fish weight, fish length, gender and maturity. The biological data, time of season, geographical location etc. is important in order to scientifically evaluate the POP levels. The datasheet for each fish sample, envelope for otoliths or scales, were sent with the samples to NILU by courier service DHL or mail. The most dominating compounds of PBDEs in the environment, BDE47 and BDE99 belonging to the penta-product of PBDEs, were analysed in all fish samples. One of the most dominating PCB compounds in biological samples, CB153, was analysed as a reference compound.

In this science-based learning project, 15 GLOBE (Global Learning and Observations to Benefit the Environment) schools from 7 Arctic countries participated. Information about the project, presentations and fish sampling protocols, can be found at the project web-site www.nilu.no/web/arcticpops.



BDE47



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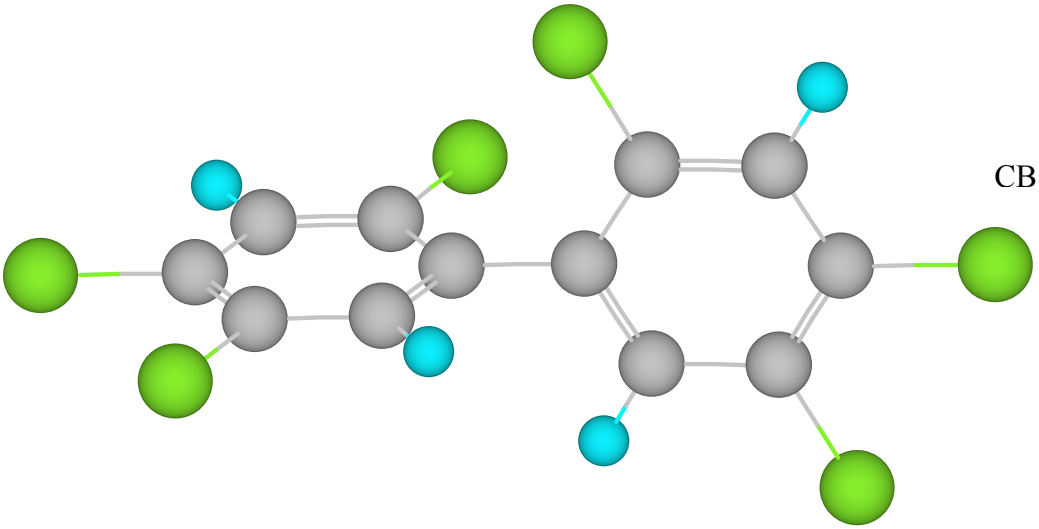

CB153

2 List of name of participating schools included abbreviation (ID's), longitude, latitude and elevation data:

Kodiak High School, Kodiak, AK, US **A-K**
57.7883 N, 152.4030 W, 35 m

Polaris K-12 School, Anchorage, AK, US **A-A**
61.1661 N, 149.8555 W, 44 m

Chief Zzeh Gittlet School, Old Crow, YT, CA **C-O**
67.5700 N, 139.8270 W, 260 m

Samuel Hearne Secondary H.S, Inuvik, NT, CA **C-I**
68.3570 N, 133.7230 W, 100 m

Attagoyuk School, Pangnirtung, NU, CA **C-N**
66.2900 N, 66.1600 W, 32 m

Pudas School, Tornio, FI **F-T**
65.8370 N, 24.1712 E, 9 m

Verkmenntaskólinn á Akureyri, Akureyri, IS **I-A**
65.6697 N, 18.0928 W, 77 m

Barnaskoli Vestmannaeyja, Vestmannaeyjar, IS **I-V**
63.4372 N, 20.2728 W, 29 m

Vestvågøy videregående skole, Leknes, NO **N-L**
68.1500 N, 13.6167 E, 20 m

Vannareid skole, Vannareid, NO **N-V**
70.1669 N, 19.5108 E, 30 m

Honningsvåg fiskarfagskole og vgs, Filial Kjøllefjord, **N-K**
Kjøllefjord, NO 70.5670 N, 27.2141 E, 20 m

Hjalmar Lundbohmsskolan, Kiruna, SE **S-K**
67.8488 N, 20.2317 E, 530 m

Laestadiusskolan, Pajala, SE, **S-P**
67.2100 N, 23.2800 E, 127 m

Gymnasium 1, Apatity Murmansk Region, RU **R-A**
68.4830 N, 33.3500 E, 115 m

The Murmansk Vocational Maritime lyceum 6, Murmansk, RU **R-M**
68.4830 N, 33.3500 E, 115 m

3 Methods and Materials

The students sampled two or three parallels during fall 2001, spring 2001, fall 2002 and fall 2003. NILU analysed two samples for each school each sampling period, a total of 47 samples of Atlantic cod, Pacific cod and haddock livers, 14 samples burbot liver, 5 samples of whitefish liver, 6 whitefish fillets, and 18 samples of Arctic char, Atlantic and Pacific salmon and Brown trout fillets. Table 2 shows school identifications (ID'es), type of fish sampled by each school each sampling period, and Figure 2 shows the approximate geographic location of the 15 schools.

For quantification of all compounds, crystalline reference material was obtained from Promochem (Wesel, Germany). As internal standards 13C-isotope labeled CB153 and BDE77 were used. All 13C-isotope labelled internal standards were purchased from Cambridge Isotope Laboratories (Woburn, MA, USA). Solvents of pesticide grade were employed (E. Merck, Darmstadt, Germany). Samples, consisting of approximately 1.5 g frozen liver or 5 g frozen fillet, were homogenized with a 10-fold amount of pretreated sodium sulfate (600 ^{o}C for 8 h). The homogenate was fitted in a glass column and extracted three times using 50 ml cyclohexane/acetone (3:1; v/v), 60 minutes each time. The amount of extractable lipid was determined gravimetrically. The main lipid removal step was performed on a gel permeation system consisting of a dual prepacked Waters Envirogel system (Bio beads SX3 resins, 37–75 mm id; column 1: 19 mm id, 150 mm length; column 2: 19 mm id, 300 mm length) with cyclohexane/ethyl acetate (1:1; v/v) at a flow rate of 5 ml/min. An additional fractionation was carried out on a silica column (2 g pretreated silica purchased from Merck; particle size 0.063–0.2 mm, heated for 8 h at 600 ^{o}C and deactivated with 1.5% w/w water). The column was eluted with: (1):25 ml n-hexane/ toluene (60:35; v/v) and (2):30 ml n-hexane/toluene (50:50; v/v) containing all POPs of interest. Fractions 1 and 2 were combined and reduced to 200 µl. To cover blind contamination, a double set of method blanks was run for each sample set. A CE Instruments 8560 Mega gas chromatograph (Milan, Italy) was equipped with a 30 m JW DB5-MS (0.25 mm id and 0.25 mm film thickness). Helium (He, 5.0 quality) was used as carrier gas at a flow rate of 1 ml/min. Temperature program: 60 ^{o}C, 2 min, 15 ^{o}C/min to 180 ^{o}C and 5 ^{o}C/min to 280 ^{o}C, 10 min isothermal. Quantification was carried out using a low resolution (LRMS) Finnigan MD800 quadrupole as detector in selected ion monitoring mode (SIM). Electron impact (EI) was used as ionisation method for the determination of PCBs and PBDEs. The average limit of detection, LOD, (three times signal/noise) varied between the four periods of analysis for CB153 and PBDEs, with a higher LOD for Fall 2002 samples due to instrument problems. The average LOD in liver was approximately 0.1 and 0.4, respectively. The LOD was lower for fillet samples. Results with recovery of internal standard below 30 % were not used.

Quality control

The use of isotopically labelled internal standards for quantification and the frequent control of complete method blank values insured a high quality of the analytical results. Blank values were not subtracted. Values lower than 10 x blank were marked with (b). Standard reference material (SRM 1588 cod oil) was used to monitor method performance.

Table 2: Fish species sampled fall 2001, spring 2002, fall 2002 and fall 2003 (– : no sampling).

Country	Location of school	ID	Fish species[1] fall 2001	Fish species spring 2002	Fish species fall 2002	Fish species fall 2003
Alaska, USA	*Anchorage*	A-A	Coho salmon fillet	Pacific cod liver	Coho salmon fillet	Coho salmon fillet
	Kodiak	A-K	Pacific cod liver	Pacific cod liver	Pacific cod liver	Pacific cod liver
Canada	*Old Crow*	C-O	Broad whitefish liver	-	-	-
	Inuvik	C-I	Burbot liver	-	-	-
	Nunavut	C-N	Arctic char fillet	Arctic char fillet	-	-
Finland	*Tornio*	F-T	Common whitefish fillet	Burbot liver	Burbot liver	Burbot liver
Iceland	*Akureyri*	I-A	Atlantic cod liver	Atlantic cod liver	Atlantic cod liver	Atlantic cod liver
	Vestmanna eyjar	I-V	Haddock liver	Haddock liver	Atlantic cod liver	Atlantic cod liver
Norway	*Kjøllefjord*	N-K	Atlantic cod liver	Atlantic cod liver	Atlantic cod liver	Atlantic cod liver
	Vannareid	N-V	Atlantic cod liver	Atlantic cod liver	Atlantic cod liver	Atlantic cod liver
	Leknes	N-L	Atlantic cod liver	Atlantic cod liver	Atlantic cod liver	Atlantic cod liver
Russia	*Apatity*	R-A	Lake whitefish liver	Lake whitefish liver	Lake whitefish fillet	Lake whitefish fillet
Sweden	*Kiruna*	S-K	Brown trout fillet	Brown trout, Whitefish fillet[2]	Brown trout fillet	Char fillet
	Pajala	S-P	Atlantic salmon fillet	Burbot liver	Burbot liver	Burbot liver

[1]*List of Latin names:*
Atlantic cod: *Gadus morhua*, Pacific cod: *Gadus macrocephalus* , Haddock: *Melanogrammus aeglefinus*, Burbot: *Lota lota*, Atlantic salmon: *Salmo salar*, Coho salmon (Pacific salmon): *Onocorhynchus kisutch*,, Brown trout: *Salmo trutta*, Arctic char: *Salvelinus alpinus,* Broad whitefish: *Coregonus nasus,* Lake whitefish*: Coregonus clupeaformis,* Common whitefish*: Coregonus lavaretus*, [2]Most probably *Coregonus acronis or Coregonus nilssoni*

Figure 2: Map showing the locations of the participating schools. Location of the schools and the ID's are shown in table 1.

4 Results and Discussion

Median wet weight and extractable organic material (EOM) data from the analysis of the four sampling campaigns in fall 2001, spring 2002, fall 2002 and fall 2003 are shown for liver and fillet samples in table 2 and 3, respectively. The number of samples (N) used for calculations of median values are valid for CB153, but not necessarily for BDE47 and BDE99 since some values are lower than limit of detection (LOD), see Table 7 for all analysed data. Levels for all analysed data are plotted in Figure 3a and b for wet weight concentrations for liver and fillet samples, respectively and Figure 4a and b show lipid normalized concentrations for liver and fillet samples, respectively.

Table 4, 5 and 6 give a comparison of literature data and results from this project for cod, salmonids and burbot, respectively.

Burbot liver:
The livers of burbot (*Lota lota*) from Sweden and Finland are characterized by the highest levels of CB153, BDE47 and BDE99, both on wet and lipid based weight. As a fish-eating predator it may have higher levels compared to fish lower in the food-chain. Since burbot is a limnic cod specie and a bottom feeder, it may be influenced by local pollution of some these freshwater systems. The highest level (119 ng/g wet weight) of BDE47 in this project is found in burbot liver.

Very high median levels of BDE47 in burbot liver of 849 ng/g wet weight and 144 ng/g wet weight in trout fillet from the Lake Mjøsa in southern part of Norway have been detected (Mariussen et al., 2003). These high values most probably were present in the fish due to PBDEs in wastewater from a wool textile factory using the penta- product as flame retardants in the products. The factory no longer uses PBDEs as flame retardants for wool textiles.

Cod liver:
Levels of CB153 in liver from Atlantic cod (*Gadus morhua*) from Norway and Iceland are comparable with levels in liver from Pacific cod (*Gadus macrocephalus)* in Alaska, although with a tendency of higher values in the European Arctic. The levels of CB153 and PBDEs in cod liver from Kodiak seem to be significantly lower than the other cod liver data. The median values including minimum and maximum values of BDE47 in cod liver are higher in the European part of the Arctic (Norway and Iceland) compared to Alaska (especially the Kodiak data), and in average lower than levels detected in cod from the North Sea (de Wit, 2003; Boon et al., 2002).

Most of the median wet weight values for CB153 of cod liver in this project are lower or comparable to the median JAMP (Joint Monitoring and Assessment Programme) value of 76 based on 1174 individual cods sampled at reference localities along the Norwegian coast (Green & Knutzen, 2003). As seen for the JAMP stations in Lofoten, Hammerfest and Varangerfjorden (Table 4), which all are north of the polar circle, there are quite large variations between minimum and maximum values. Green and coworkers found a positive, but weak correlation between SumPCB7 vs fish length, also observed in other studies (Stange et al., 1996; Roose et al., 1998). However, data from Barents Sea also revealed highest PCB levels in young cod compared to old (Stange and Klungsøyr, 1997), and the authors discussed this in relation to possible effects of spawning. Green and Knutzen could not find any clear co-variation between PCB level and fat content in cod liver, while Roose et al. (1998) found a

positive correlation, whereas other results reported a negative correlation. No co-variation between PCB level and fat was found in the related fresh water species burbot (Green & Knutzen with references therein). It has also been observed no decrease in variance by lipid normalizing the data, often to contrary (Green et al. 2003 with references). The authors further conclude that the relationship of persistent organic pollutants to fat in organisms is more complex than assumed. Type of fat, methods of lipid extraction and quantification and difference between species all play a role.

So far, we have not seen any correlation between POP levels and length, weight or fat content within the Arctic POPs project. Age determination for all samples are planned within this year, but so far no clear connection to levels can be seen. The use of statistical methods is needed in order to fully explore co-variations between levels and biological parameters.

Salmonids (salmon, trout, char and whitefish):
The SumPBDE concentrations measured in archived fishes such as lake trout and walleye from the Great Lakes are on the order of 500-800 ng/g of lipid for the years 1996-2000 (Zhu and Hites, 2004). The reported values were similar to averageSumPBDE concentrations in other fishes from various other locations in North America, but about 5 times higher than averageSumPBDE concentrations measured in fishes from Europe (Hites et al, 2003). This difference is smaller but in the same direction as the difference between SumPBDE concentrations in humans in North America and Europe. In people, North Americans have about 20 times more PBDE in their blood as do Europeans (Hites et al., 2004).

The POP levels for trout, char, salmon and whitefish from the Arctic POPs project indicate more the opposite with higher European POP levels compared to North-America and Canada, although less verified due to a smaller amount of samples for some of the fish. The wet weight values BDE47 are comparable to levels in salmonids from mountain lakes in Europe (Vives et al., 2004a) and lower than what is found in Lake Michigan, USA and Mjøsa, Norway (Table 5). The analysis of different POPs, included PCBs, in muscle of trout and char from high mountain lakes in Europe shows that a proportion of their concentration variance depends on fish age and lake altitude. Interestingly, the magnitude of this share corresponds linearly with the log-transformed vapor pressure of the POPs (Vives, et al., 2004b).

Conclusions
The results from these four sampling campaigns reveal that brominated flame retardants such as BDE47 is present in fish all over the Arctic. There is a trend of higher levels of CB153 and PBDEs in the European Arctic compared to northern part of America. No clear seasonal trend or correlation with fish length or weight is present in this dataset. Age determination of the rest of the samples are planned to be done in near future. The levels of POPs indicate that long range air and ocean transport from distant sources are most potential, but some freshwater systems in Scandinavia may be influenced by local pollution from industrial and municipal waste water facilities as well. At present, we have no evidence that the detected levels of PCBs and PBDEs have toxic effects on the fishes or threaten the fish population. One assumes that acute toxic effects are unlikely since the levels are relatively low, but the chronic effects (low levels over long time) are potential. Dioxin is the most toxic POP chemical known today. The European Scientific Committee on Food (SCF) has recommended a Tolerable Weekly Intake (TWI) of 14 picogram per kilogram of bodyweight per week. This recommendation is in line with the provisional Tolerable Monthly Intake of 70 pg/kg bodyweight/month established by the Joint FAO/WHO Expert Committee on Food Additives (JECFA) at its meeting held in June 2001 (Verstraete, 2002) and falls within the lower end of

the range of 1−4 pg/kg bw/ day for dioxins and dioxin-like compounds established by a WHO Consultation in 1998.

Due to elevated levels of dioxin-like PCBs (non-ortho and mono-ortho chlorinated PCBs) in gull eggs and cod liver, food consumption advisories have been given by the Norwegian Food Control Authority. Children, women of child-bearing age, pregnant women and breastfeeding mothers are advised against eating fish liver or any fish liver products. The population in general should limit their intake of such food. In particular, they are advised not to eat fish liver from areas that are known to be polluted by PCB, especially in harbour areas and some Norwegian fjords. The National Institute of Nutrition and Seafood Research (NIFES) has investigated the content of dioxins in Norwegian salmon. The mean concentration of dioxins (PCDD/F) in Norwegian farmed salmon (n=35) is 0,58 (range 0.25-1.19) pg WHO-TEQ/g. EU's upper limit for dioxins in fish is 4 pg (PCDD/F) WHO-TEQ/g (EC 2375/2001) Norwegian farmed salmon is therefore below the limit set by the EU.

The Food and Drug Administration (FDA) in USA requires that infant foods, eggs, milk and other dairy products, fish and shellfish, poultry and red meat contain no more than 0.2-3 parts of PCBs per million parts (0.2-3 ppm) of food. Many states have established fish and wildlife consumption advisories for PCBs (ATSDR, 2000). Reference doses (RfDs) for decabromo-diphenyl ether, octabromodiphenyl ether, and pentabromodiphenyl ether are $1x10^{-2}$, $3x10^{-3}$, and $2x10^{-3}$ mg/kg/day, respectively (ATSDR, 2002). No regulations were located for PBBs and PBDEs for occupational safety and health standards, water quality, and food safety.

For PCB153 (non dioxin-like PCBs) and PBDEs that do not have the same mode of action, or do not bind to Ah-receptor in same extent as dioxins, furans and dioxin-like PCBs, no known WHO or EU food limits exist for these compound classes so far. There is an agreement within WHO and EU for the need of risk assessment of non dioxin-like PCBs in near future.

This science-based learning projects in schools reveals that youths managed the tasks of sampling, dissection of fish, logging and reporting, very well. Youths are therefore a valuable resource for research, but most important that the project seems to inspire the youths for environmental and social issues connected to the problem of toxic chemicals in environment and marine food items, and what this means for the risk of ecosystem and humans. The feedback and evaluation of the project from the teachers and the students have been positive. They felt that they were part of a real scientific research project and that the work they performed was valuable and an important contribution for the assessment of new pollutants at a circumpolar scale. In addition a link to local community was also created with the focus on local fish as a food item and the perception and evaluation of food advisories from the food control authorities in each country.

The workshops each year was very important for the social interaction and friendships between the circum-polar youths and adults. In addition these workshops was an arena for the knowledge transfer of local community habitats and history and for the discussion of social and environmental challenges in each community and common issues.

Table 2: Median concentrations (ng/g wet weight) of CB153 and BDE47 in fish livers with minimum (Min) and maximum (Max) values. Number of samples is given as N. The median value of extractable organic material (% EOM) in the samples with minimum and maximum is also given. Concentrations that are lower than limit of detection (LOD) are given as <LOD.

Fish species	COUNTRY	ID	N	CB153	Min	Max	BDE47	Min	Max	EOM	Min	Max
Pacific cod	ALASKA	A-K	8	5.6	3.7	9.1	1.0	0.4	1.6	33.1	7.5	74.8
Pacific cod	ALASKA	A-A	2	31.4	13.8	49.0	2.5	2.1	3.0	21.9	21.4	22.4
Atlantic cod	NORWAY	N-V	6	25.8	12.0	62.3	7.0	1.2	14.3	50.1	11	73.7
Atlantic cod	NORWAY	N-L	8	38.8	16.4	97.1	9.2	3.0	18.2	54.8	21.8	70
Atlantic cod	NORWAY	N-K	8	78.6	33.4	319.8	10.1	5.4	23.0	42.8	9.8	58.9
Atlantic cod	ICELAND	I-A	8	59.3	24.5	121.5	11.9	1.1	32.2	40.6	10	59
Atlantic cod	ICELAND	I-V	3	83.0	16.3	118.0	12.3	7.6	17.0	41.7	36	46.4
Haddock	ICELAND	I-V	4	28.5	10.7	236.2	1.8	0.6	18.2	38.3	26.1	47.9
Burbot	FINLAND	F-T	6	299.8	196.3	362.2	37.6	15.9	58.5	48.6	28	91
Burbot	SWEDEN	S-P	6	145.4	31.1	458.0	21.7	3.4	119.4	33.4	17.8	51.8
Burbot (Loche)	CANADA	C-I	2	11.3	9.0	13.7	0.5	0.4	0.6	32.2	30.6	33.8
Lake Whitefish	RUSSIA	R-A	4	25.9	2.5	57.1	0.2	0.1	1.7	6.7	6.2	7.1
Broad Whitefish	CANADA	C-O	1	3.7			0.1			16.8		

Table 3: Median concentrations (ng/g wet weight) of CB153 and BDE47 in fish fillets with minimum (Min) and maximum (Max) values. Number of samples is given as N. The median value of extractable organic material (% EOM) in the samples with inimum and maximum is also given. Concentrations that are lower than detection of limit (LOD) are given as <LOD.

Fish species	COUNTRY	ID	N	CB153	Min	Max	BDE47	Min	Max	EOM	Min	Max
Atlantic salmon	SWEDEN	S-P	2	40.2	17.3	63.2	4.4	2.3	6.5	6.8	4	9.5
Coho salmon	ALASKA	A-A	6	0.3	0.2	0.4	0.05	0.04	0.10	2.0	0.7	3.5
Brown trout	SWEDEN	S-K	5	3.8	0.3	21.0	0.5	0.4	0.6	1.8	1	7.5
Arctic char	SWEDEN	S-K	2	0.7	0.7	0.8	<LOD	<LOD	<LOD	0.8	0.6	1
Arctic char	CANADA	C-N	3	2.0	0.9	2.7	0.2	0.2	0.2	7.8	1.9	7.9
Whitefish	SWEDEN	S-K	1	13.9			0.3			7.0		
Lake whitefish	RUSSIA	R-A	4	0.4	0.2	4.6	<LOD	<LOD	<LOD	0.8	0.4	1.6
Common whitefish	FINLAND	F-T	1	5.0			0.5			0.6		

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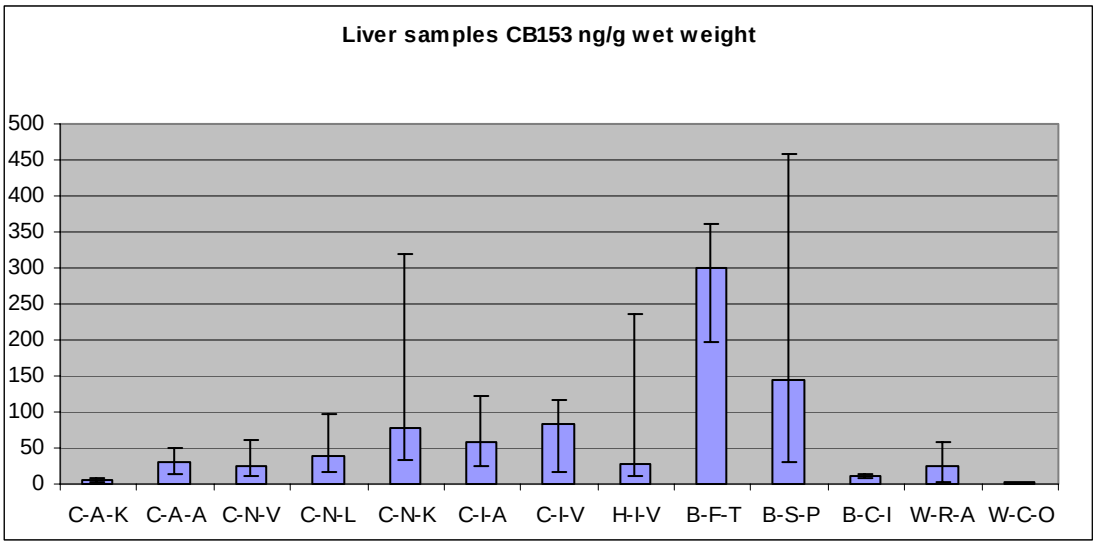
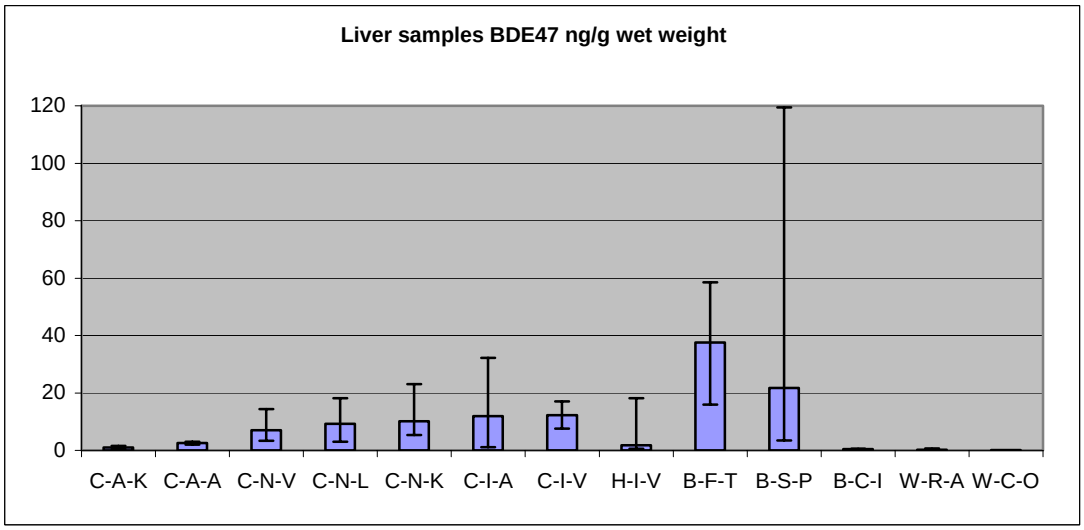
The Barents secretariat
Frammuseet, Norway
Coca Cola Comp.

Figure 3a: Wet weight concentrations for liver samples

Liver samples wet weight: C (cod), H (haddock), B (burbot) and W (whitefish) attached to school ID'es.





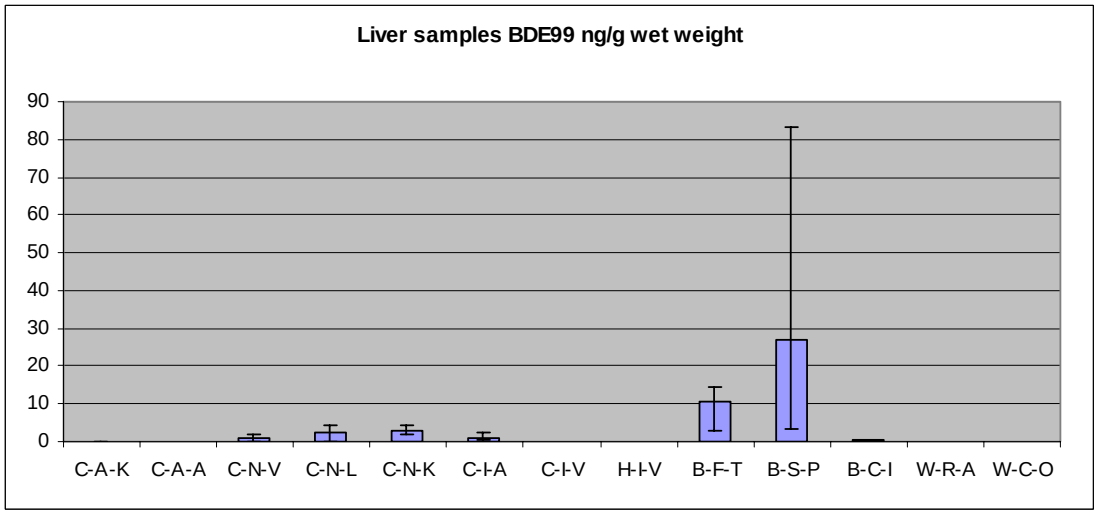
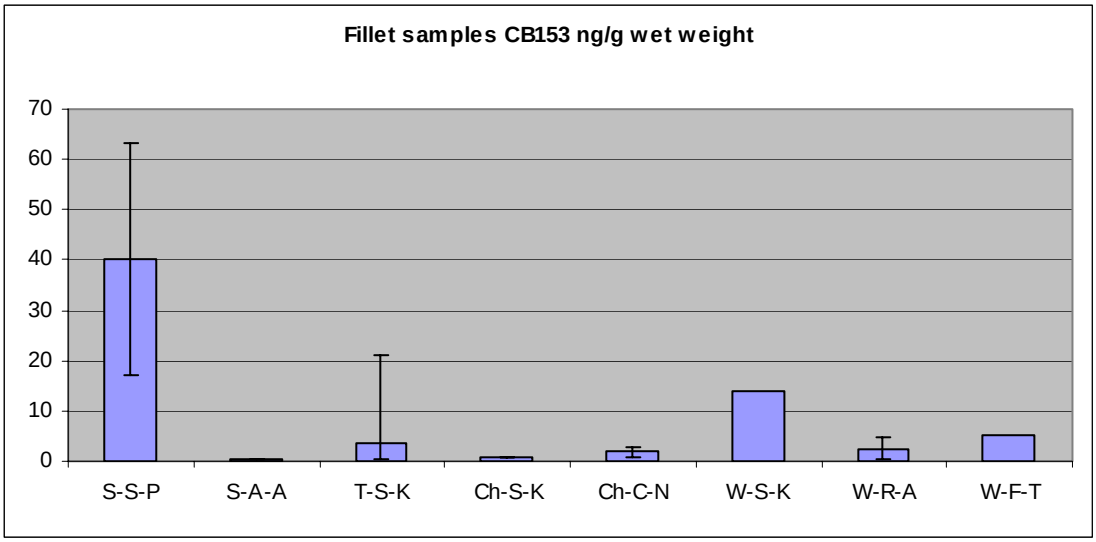
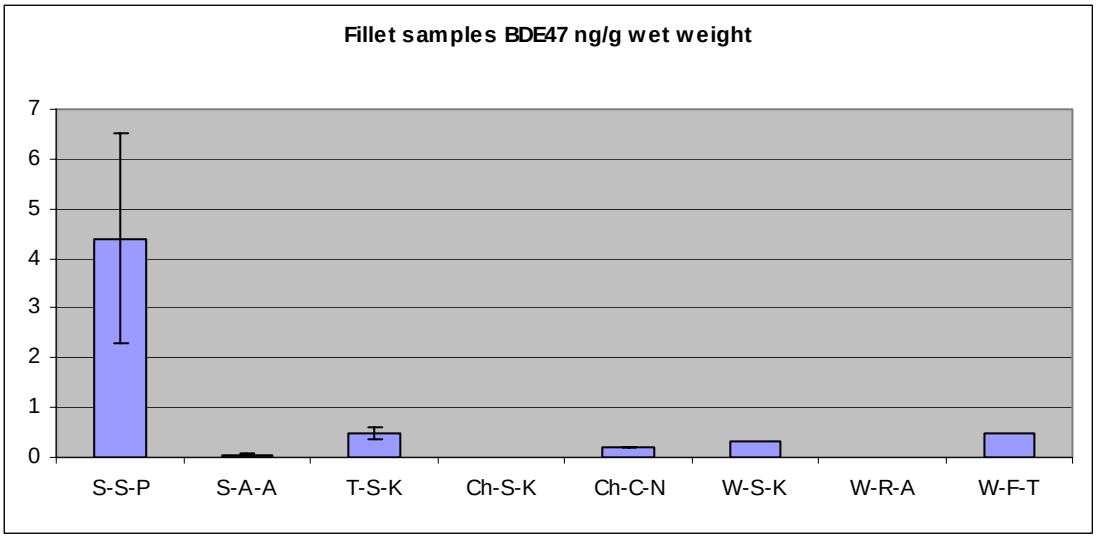


Figure 3b: Wet weight concentrations for fillet samples
Fillet samples wet weight: S (salmon), T (trout), Ch (char) and W (whitefish) attached to school ID's.





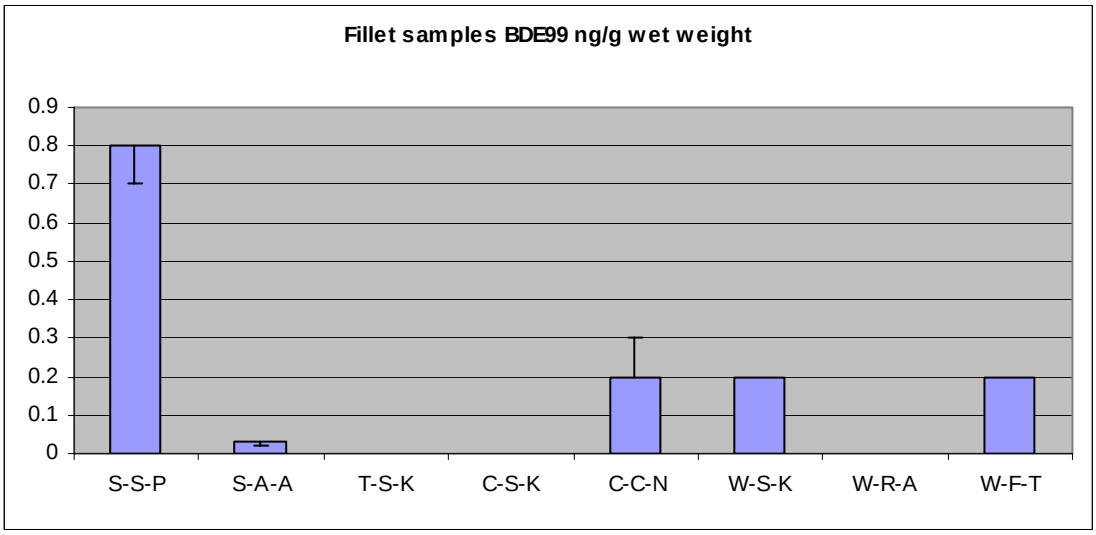
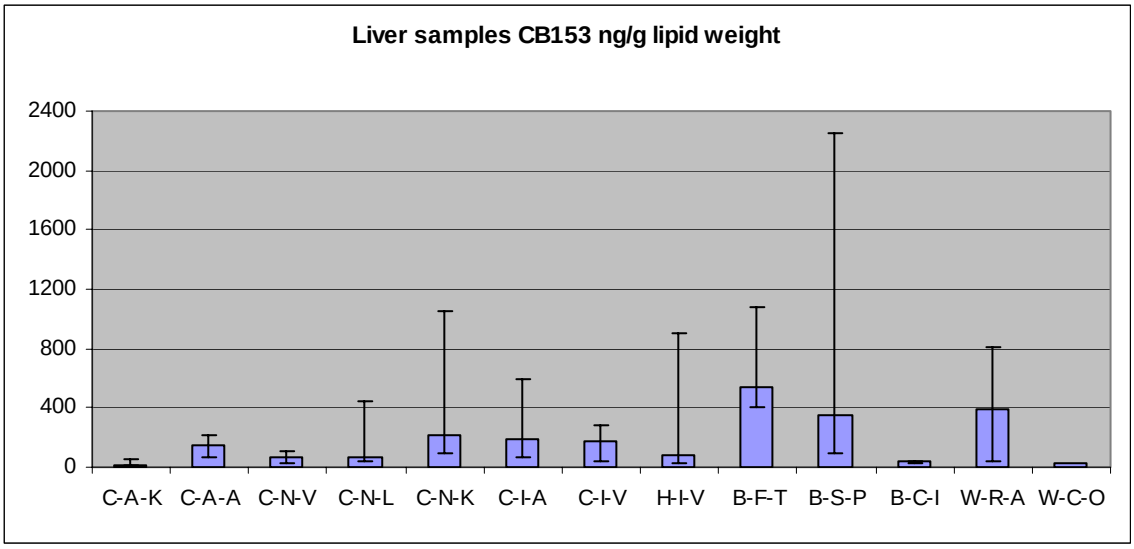
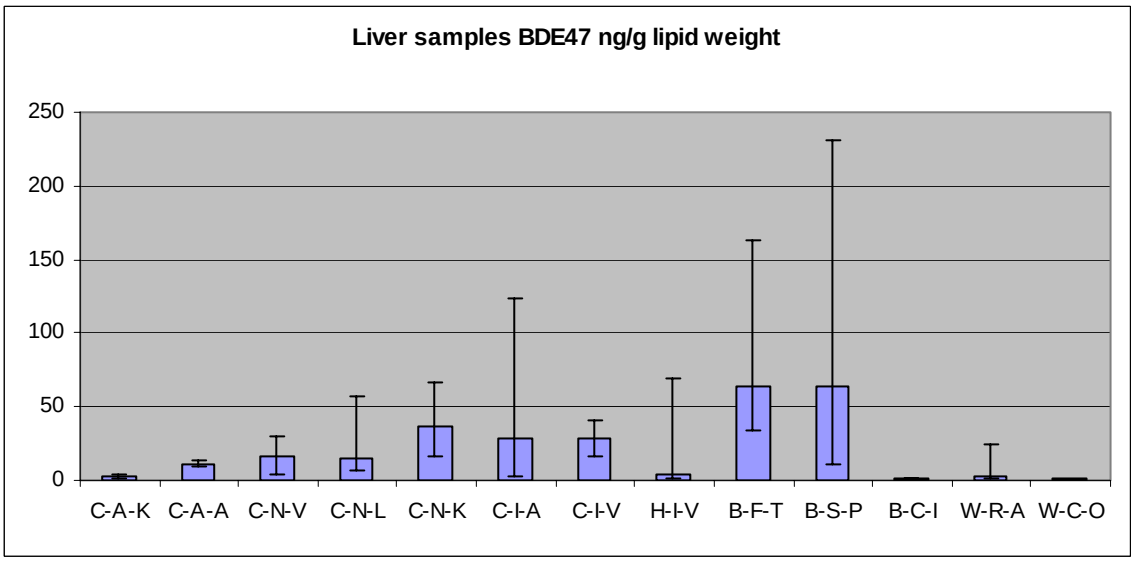


Figure 4a: Lipid normalised concentrations for liver samples
Liver samples lipid weight: C (cod), H (haddock), B (burbot) and W (whitefish) attached to school ID's.





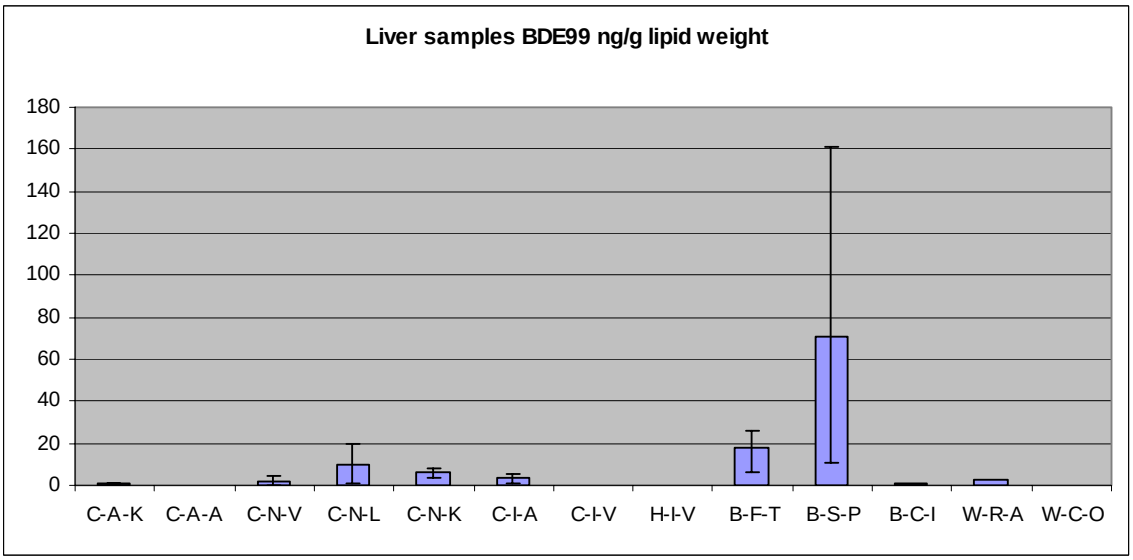


Figure 4b: Lipid normalised concentrations for fillet samples
Fillet samples lipid weight: S (salmon), T (trout), Ch (char) and W (whitefish) attached to school ID's.

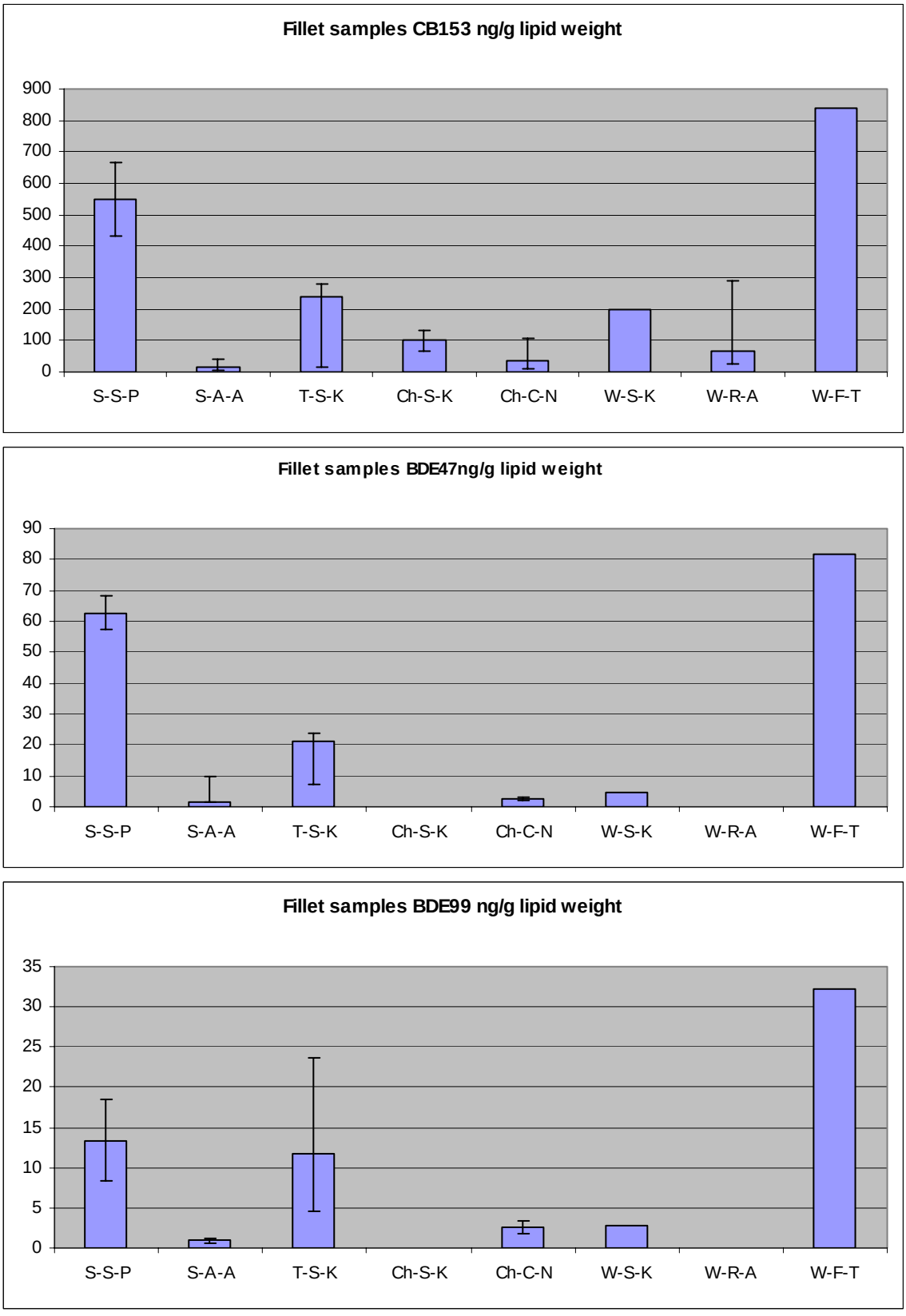


Table 4: Reported levels of PBDEs and PCBs in cod and comparison to Arctic POPs study

The table contains reported concentration data for BDE47, BDE99 and CB153.

Wet weight

Fish species	*Location*	*BDE47 ng/g ww*	*BDE99 ng/g ww*	*CB153 ng/g ww*
[2]Cod (liver) (n=1174)	Norwegian coast JAMP stations			(median) **76** (mean) **116**
[3]Cod (liver)	North Sea	**42**		
[4]Cod liver 2002 n=3	Svolvær	**7.9**		
[4]Cod liver 2002 n=3	Svolvær	**5.2**		
[4]Cod liver 2002 n=3	Svolvær	**5.4**		
[4]Cod liver 2002 n=3	Varangerfjorden	**4.8**		
[5]Cod liver Lofoten, NO		**15**		
[5]Cod liver Karihavet, NO		**19.5**		
[5]Cod liver Færder, NO		**32.3**		
[5]Cod liver Lista, NO		**48.8**		
[6]Cod (liver) JAMP page 151 n=25 1996	Hammerfest, NO 70°50.00N 23°44.00E			(mean) **68.4** 25-166
[7]Cod (liver) JAMP page 144 n=25 2000	Molla, Lofoten, NO 68°12.00N 14°48.00E			(mean) **110.1** 8.7-400
[7]Cod (liver) JAMP page 144 n=17 2001	Molla, Lofoten, NO 68°12.00N 14°48.00E			(mean) **50.7** 9.6-120
[6]Cod (liver) JAMP page 158 n=25 1997	Varangerfjorden, NO 69°56.00N 29°40.00E			(mean) **126.4** 24-505
[7]Cod (liver) JAMP page 155 n=20 2001	Varangerfjorden, NO 69°56.00N 29°40.00E			(mean) **33.1** 22-46
Cod (this project) Median values				
A-K	Kodiak, US n=8	**1**	**0.2**	**5.6** (3.7-9.1)
A-A	Anchorage, US n=2	**2.5**	**<LOD**	**31.4** (13.8-49)
N-K	Kjøllefjord, NO n=8	**10.1**	**3**	**78.6** (33.4-319.8)
N-V	Vannareid, NO n=6	**7**	**1**	**25.8** (12-62.3)
N-L	Leknes, NO n=8	**9.2**	**2.2**	**38.8** (16.4-97.1)
I-A	Akureyri, IS n=8	**11.9**	**1.1**	**59.3** (24.5-121.5)
I-V	Vestmannaeyar, IS n=3	**12.3**	**<LOD**	**83** (16.3-118)

Table 4 cont.
Lipid normalised values

Fish species	*Location*	*BDE47 ng/g lw*	*BDE99 ng/g lw*	*CB153 ng/g lw*
[1]Cod (liver)	North Sea	**170**		
[2]Cod (liver) n=1174	Norwegian coast stations (JAMP)			(median) **182** (mean) **377**
[2]Cod (liver)	4 JAMP stations,NO	**20, 29, 71, 122**		
[8]Cod (liver)	North sea	(median) **99** (mean) **133**	(median) **9** (mean) **15**	
Cod (this project) Median values				
A-K	Kodiak, US n=8	**2.1**	**0.6**	**19.7**
A-A	Anchorage, US n=2	**11.5**	**<LOD**	**141.6**
N-K	Kjøllefjord, NO n=8	**36.3**	**6.2**	**213**
N-V	Vannareid, NO n=6	**16.1**	**2.2**	**71.1**
N-L	Leknes, NO n=8	**14.4**	**9.8**	**64**
I-A	Akureyri, IS n=8	**28.4**	**3.5**	**193.9**
I-V	Vestmannaeyar, IS n=3	**28.6**	**<LOD**	**178.9**

Fish species	**Sum (PBDE47 & PBDE99) ng/g lw**
[1]**Cod (liver)** North Sea	**1.9-360**

[1]de Wit, C.A. 2002. *Chemosphere* 46, 583-624
[2]Green, N.W. and J. Knutsen. 2003. Marine Pollution Bulletin 46, 362-377.
[3]Vives I. et al., 2004. *Environ Sci Technol* 38, 2338-2344
[4]NIVA report. 2004. Screening of selected new organic contaminants - brominated flame retardants, chlorinated paraffins, bisphenol-A and trichlosan. Report 4809-2004. Fjeld E. et al.
[5]JAMP: Overvåking av miljøgifter i marine sedimenter og organismer 1981-1999. NIVA report: 4358-2001 TA-nr. 1797/2001
[6]JAMP: Contaminants in fish 1993-1997. Norwegian biota data. TA1668/1999. Serial no. 4084-99
[7]JAMP: Contaminants data for fish 1998-2001. TA-nr. 1920/2002. NIVA report no. 4601-2002.
[8]Boon JP et al. 2002. *Environ Sci Technol* 36, 4025-4032

Table 5: Reported levels of PBDEs and PCBs in salmonids and comparison to Arctic POPs study.

The table contains reported concentration data for BDE47, BDE99 and CB153.

Wet weight:

Fish species	*Location*	*BDE47 ng/g ww*	*BDE99 ng/g ww*	*CB153 ng/g ww*
[4]Salmon	Lake Michigan, USA	**52.1**	**9.3**	**149**
[7]Trout (n=15) muscle Sum (BDE47 and 99)	Norway	(average)**1.7** (median) **0.6**		
[7]Arctic char	Bjørnøya (Norway)		**16.3**	
[8]Arctic char liver	Lake Fergusson, Greenland	**0.45**		
[8]trout fillet	mountain lakes, Europe	**.033-0.38**		
[8]trout liver	mountain lakes, Europe	**.031-0.62**		
[8]Brown trout fillet	Lochnagar, high mountain lake, Scotland	**0.3**		
[8]Brown trout liver	Lochnagar, high mountain lake, Scotland	**4.1**		
[9]Trout muscle n=10	Mjøsa, NO	**130**		
[10]Arctic char muscle	Lake Ellasjøen, Bjørnøya, NO	**8.3**		
[10]Trout muscle	Lake Takvatn, NO	**0.1**		
Salmonids (this project) Median values				
S-P salmon	Pajala, SE n=2	**4.4**	**0.8**	**40.2**
A-A salmon	Anchorage, US n=6	**0.05**	**0.03**	**0.3**
S-K trout	Kiruna, SE n=5	**0.5**	**<LOD**	**3.8**
S-K char	Kiruna, SE n=2	**<LOD**	**<LOD**	**0.7**
C-N char	Attagoyuk, CA n=3	**0.2**	**0.2**	**2.0**
W-S-K whitefish	Kiruna, SE n=1	**0.3**	**0.2**	**13.9**
W-R-A whitefish liver	Apatity, RA n=4	**<LOD**	**<LOD**	**2.5**
W-F-T whitefish	Tornio, FI n=1	**0.5**	**0.2**	**5**

Table 5. cont.
Lipid normalised values

Fish species	***Location***	***BDE47 ng/g lw***	***BDE99 ng/g lw***	***CB153 ng/g lw***
[1]Salmon-muscle	Umeå river, SE	**167**	**52**	
[2]Salmon- muscle	Dalälven, SE	**200**	**54**	**1100**
[3]Whitefish	SE, n=35	**15**	**7.2**	
[3]Arctic char	Lake Vättern, SE, n=15	**400**	**64**	
[3]Trout	Dalsland Canal, SE	**120-460**	**64-590**	
[6]Trout (whole fish)	Lake Ontario	**267**	**64**	
[6]Trout (whole fish)	Lake Erie	**70**	**9**	
[6]Trout (whole fish)	Lake Huron	**135**	**39**	
[9]Trout muscle	Mjøsa, NO n=10	(mean) **1333**		
[11]Rainbow trout 2002 n=4	Switzerland	**11.5**	**2.3**	
[11]Whitefish 1996 n=3	Slocan river, US	**4.2**	**4.7**	
[11]Whitefish 2000 n=12	Columbia river, US	**179**	**227**	
[11]Trout 1996 n=6	Lake Michigan, US	**1700**	**600**	
[11]Lake Trout 2000 n=40	Great Lakes	**151**	**37**	
[11]Sole 2000 n=60	Canada, BC	**48.5**	**16.8**	
Salmonids (this project) Median values				
S-P salmon	Pajala, SE n=2	**62.8**	**13.4**	**548.5**
A-A salmon	Anchorage, US n=6	**1.6**	**0.9**	**14.5**
S-K trout	Kiruna, SE n=5	**21.1**	**11.7**	**239.3**
S-K char	Kiruna, SE n=2	**<LOD**	**<LOD**	**99.7**
C-N char	Attagoyuk, CA n=3	**2.6**	**2.5**	**35.1**
W-S-K whitefish	Kiruna, SE n=1	**4.4**	**2.7**	**198.6**
W-R-A whitefish	Apatity, RA n=4	**<LOD**	**<LOD**	**68.3**
W-F-T whitefish	Tornio, FI n=1	**81.7**	**32.2**	**839.7**

[1]Haglund P.S. et al., 1997. *Environ Sci Technol* 31, 3281-3287- ng/g lipid weight
[2]Asplund L. et al., 1999. *Ambio* 28, 67-76- ng/g lipid weight
[3]Darnerud P.O. et al, 2001. *Environ Health Perpect* 109, 49-68 -muscle samples- μg/kg lipid weight
[4]Manchester- Nessvig J.B. et al., 2001. *Environ Sci Technol* 35, 1072-1077 - Lake Michigan- average values - ng/g wet weight
[5]de Wit, C.A. 2002. *Chemosphere* 46, 583-624
[6] Luross J.M. et al. 2002. *Chemosphere* 46, 665-672.
[7]NIVA report: Halogenerte organiske miljøgifter og kvikksølv i norsk ferskvannsfisk 1995-1999. Report no. 4402-01. Fjeld E. et al.
[8]Vives I. et al., 2004. *Environ Sci Technol* 38, 2338-2344
[9]NIVA report. 2004. Screening of selected new organic contaminants - brominated flame retardants, chlorinated paraffins, bisphenol-A and trichlosan. Report 4809-2004. Fjeld E. et al.
[10]AMAP Assessment 2002:Persistent Organic Pollutants in the Arctic. Annex Table17.
[11]Hites, R.A. (2004). Polybrominated Diphenyl Ethers in the Environment and in People: A Meta-Analysis of Concentrations. *Environ. Sci Technol* **38**, 945-956

Table 6: Reported levels of PBDEs and PCBs in burbot liver and comparison to Arctic POPs study.

The table contains reported concentration data for BDE47, BDE99 and CB153 for our projects, but BDE47, BDE99 and SumPCBs for reference values.

Wet weight:

Fish species	***Location***	***BDE47 ng/g ww***	***BDE99 ng/g ww***	***SumPCBs ng/g ww***
[1]Burbot liver n=11 Year 2000	Fort Good Hope, NWT	**620±629**	**320±274**	
[1]Burbot liver n=1	Lake Hurdal, NO	**149**	**43**	
[1]Burbot liver n=1	Mjøsa/Furnes, NO	**1040**	**332**	
[1]Burbot liver n=1	Lake Grensefoss, NO	**9.7**	**10.6**	
[2]Burbot liver n=9 Year 1998	Fairbanks, Alaska			**(median) 540 270-1400**
[2]Burbot liver n=3 Year 1998	Yukon Flats, Alaska			**(median) 420 160-950**
[2]Burbot liver n=20 Year 2000	Fort Good Hope, NWT (Mackenzie river)			**54.6±36.2**
[2]Burbot liver n=11 Year 1999	Lake Laberge, Yukon			**1630±727**
[2]Burbot liver n=7 Year 1997	Quite Lake, Yukon			**48.3±7.2**
[2]Burbot liver n=6,7 2 pools Year 1997	Kola Peninsula, RU			**62.3±5.4**
[2]Burbot liver n=2-6 3 pools Year 2001	Dudinka, Taymir Peninsula, RU			**516±55.7**
Burbot liver (this project) Median values		***BDE47 ng/g ww***	***BDE99 ng/g ww***	***CB153 ng/g ww***
F-T	Tornio, FI n=6	**37.6 15.9-58.5**	**10.9 2.9-14.2**	**299.8 196.3-362.2**
S-P	Pajala, US n=6	**21.7 3.4-119.4**	**26.9 3.6-83.5**	**145.4 31.1-458**
C-I	Inuvik, Canada n=2	**0.5 0.4-0.6**	**0.4**	**11.3 9-13.7**

[1]AMAP Assessment 2002: Persistent Organic Pollutants in the Arctic. Annex Table 17.
[2]AMAP Assessment 2002: Persistent Organic Pollutants in the Arctic. Annex Table 7

Table 7: All analysed data for CB153, BDE47 and BDE99.
Fall 2001: samples with numbers 1-99, Spring 2002: samples with numbers 100-199, Fall 2002: samples with numbers 200-299, Fall 2003: samples with numbers 300-399. Cod liver (CL), Haddock liver (HL), Burbot/Loche liver (BL, LL), Salmon fillet (SF), Trout fillet (TF), Char fillet (CF), Whitefish liver (WL), Whitefish fillet (WF). Concentrations are given as ng/g wet weight and lipid normalized concentrations. Age1: P. Skau, Inst. for biology, University of Tromsø. Determination of Age 1 was done one year after Age2 and some determinations may be uncertain caused by dried otoliths etc. Age2: Robert F. Gerlach, VMD, State of Alaska, Department of Environmental Conservation, Anchorage, G-M: Gender (G) and maturity (M){Gender: Female (F) Male (M); Maturity: Mature (m), Immature (im), Spent (s)}. Data for samples where recovery of internal standard is below 40 %, but above 30 % are marked (g). Concentrations less than 10 times laboratory blank values are marked with (b).

		Wet weight levels				Lipid normalised levels							
Samples	ID	CB153	BDE47	BDE99	%Lipid	CB153	BDE47	BDE99	Weight	Length	Age1	Age2	G-M
CL01VND	N-V	26.7	7.8	1.8	43.1	61.9	18.1	4.2	3180	740			F-im
CL02VND	N-V	26.3	6.2	(b) 0.2	73.7	35.7	8.4	0.2	2545	630			F-im
CL101VND	N-V	25.3	1.2	<LOD	31.5	80.4	3.9	<LOD	980	480	3	3	M-s
CL102VND	N-V	12.0	3.3	<LOD	11	109.3	30.2	<LOD	1510	523	4	4	F-im
CL201VND	N-V	21.9	9.9	<LOD	70	31.3	14.2	<LOD	3980	810	7	7	F-m
CL202VND	N-V	62.3	14.3	<LOD	57	109.3	25.1	<LOD	3150	720	7	7	F-m
CL03VVO	N-L	(b) 16.4	3.0	(b) 0.2	46.9	35.0	6.4	(b) 0.5	1500	500			
CL04VVO	N-L	97.1	12.5	4.2	21.8	445.3	57.3	19.1	1500	510			
CL103VVO	N-L	96.4	8.2	<LOD	52	185.5	15.8	<LOD	8500	1010	9	9	M-m
CL104VVO	N-L	46.1	4.3	<LOD	55.2	83.6	7.8	<LOD	5500	810	7	7	F-m
CL203VVO	N-L	(g) 36.5	(g) 18.2	<LOD	70	52.1	26.0	<LOD	8300	900			F-im
CL204VVO	N-L	(g) 25.7	(g) 9.2	<LOD	70	36.7	13.1	<LOD	5500	800			F-im
CL303VVO	N-L	30.8	9.2	<LOD	69.8	44.2	13.1	<LOD	6500	830			F-m
CL304VVO	N-L	41.2	12.3	<LOD	54.3	75.8	22.7	<LOD	8500	860			F-m
CL05KFD	N-K	40.2	8.7	1.7	43.5	92.4	19.9	4.0	1160	505			F-im
CL06KFD	N-K	71.3	19.8	4.2	50.3	141.8	39.3	8.4	1675	580			M-m
CL105KFD	N-K	146.3	9.8	<LOD	58.9	248.4	16.6	<LOD	2209	650	6	6	M-m
CL106KFD	N-K	319.8	20.2	<LOD	30.3	1055.3	66.7	<LOD	1692	572	5	5	F-m
CL205KFD	N-K	82.5	23.0	<LOD	49	168.4	47.0	<LOD	1366	524			M-m
CL206KFD	N-K	74.6	10.3	<LOD	42	177.6	24.6	<LOD	1959	600			M-m
CL305KFD	N-K	85.1	9.9	<LOD	29.8	285.7	33.3	<LOD	1938	605			M-s
CL306KFD	N-K	33.4	5.4	<LOD	9.8	340.8	55.5	<LOD	314	345			F-im
CL13VMA	I-A	24.5	1.1	(b) 0.3	36.7	66.7	3.1	0.9	418	360			F-im
CL14VMA	I-A	25.4	10.0	2.2	40.2	63.3	24.9	5.6	259	300			F-im
CL113VMA	I-A	117.8	13.4	1.8	46.3	254.4	28.9	3.9	889	455	3		F-m
CL114VMA	I-A	89.8	11.4	1.3	40.9	219.6	27.9	3.2	926	440	3		F-im
CL213VMA	I-A	59.6	12.4	<LOD	10	596.3	124.1	<LOD	745	430	3		F-im
CL214VMA	I-A	58.4	2.9	<LOD	59	99.0	4.9	<LOD	1277	470	4		F-im
CL313VMA	I-A	59.0	20.5	(b) 0.9	35.1	168.2	58.3	2.6	653	410			F-im
CL314VMA	I-A	121.5	32.2	(b) 0.5	45.4	267.7	71.0	1.1	1019	490			F-im
HL15BVA	I-V	10.7	0.6	<LOD	47.9	22.3	1.2	<LOD	754	424			M-im
HL16BVA	I-V	15.9	2.2	<LOD	40.7	39.0	5.3	<LOD	1156	480			F-m
HL116BVA	I-V	236.2	18.2	<LOD	26.1	904.2	69.8	<LOD	1580	575	7	7	F-m
HL115BVA	I-V	41.2	1.4	<LOD	35.9	114.7	3.8	<LOD	950	449	4	4	im
CL215BVA	I-V	16.3	<LOD	<LOD	36	45.3	<LOD	<LOD	1460	515			F-im
CL315BVA	I-V	118.0	16.96	<LOD	41.7	283.0	40.7	<LOD	1275	514			im
CL316BVA	I-V	83.0	7.63	<LOD	46.4	178.9	16.4	<LOD	1490	530			m?
CL07KHS	A-K	(b) 5.3	(b) 0.4	(b) 0.2	28.3	18.7	1.4	0.7	4000	680			M-m
CL08KHS	A-K	(b) 5.1	0.9	(b) 0.1	21.8	23.4	4.1	0.5	4200	715			M-m
CL107KHS	A-K	(g) 6.0	<LOD	<LOD	14	42.6	<LOD	<LOD	1850	560	4		F-m
CL108KHS	A-K	3.7	<LOD	<LOD	7.5	48.7	<LOD	<LOD	2000	545	3		M-m
CL207KHS	A-K	7.3	<LOD	<LOD	45	16.2	<LOD	<LOD	3000	670	6	4	F-m
CL208KHS	A-K	9.1	<LOD	<LOD	44	20.6	<LOD	<LOD	3500	690	5	3	M-m
CL307KHS	A-K	4.6	1.1	<LOD	37.9	12.2	2.8	<LOD	2815	610			F-im
CL308KHS	A-K	6.6	1.6	<LOD	74.8	8.9	2.1	<LOD	2406	570			M-m
CL123POK	A-A	49.0	2.1	<LOD	22.4	218.8	9.2	<LOD	3624	760	7	7	M-m
CL124POK	A-A	13.8	3.0	<LOD	21.4	64.4	13.8	<LOD	3511	730	8	8	M-m

Table 7 cont.

		Wet weight levels				Lipid normalised levels							
Samples	ID	CB153	BDE47	BDE99	%Lipid	CB153	BDE47	BDE99	Weight	Length	Age1	Age2	G-M
LL09SHS	C-I	(b) 9.0	(b) 0.4	(b) 0.05	30.6	29.5	1.2	0.2	3650	755			M-m
LL10SHS	C-I	(b) 13.7	0.6	(b) 0.4	33.8	40.5	1.7	1.2	2000	700			
BL117PUS	F-T	341.4	19.6	8.1	31.5	1083.8	62.2	25.7	989	553	5		F-im
BL118PUS	F-T	245.9	15.9	2.9	47.2	520.9	33.7	6.1	902	537	6		
BL217PUS	F-T	362.2	58.5	14.2	91	398.0	64.3	15.6	878	575			F-im?
BL218PUS	F-T	(g) 196.3	(g) 45.8	<LOD	28	701.1	163.5	<LOD	784	540			F-im
BL317PUS	F-T	276.6	36.9	10.9	49.9	554.3	73.9	21.9	1129	585			M-m
BL318PUS	F-T	322.9	38.4	12.0	67.3	479.9	57.1	17.9	956	580			M-m
BL125LAE	S-P	162.6	119.4	83.5	51.8	313.9	230.5	161.2	600	456	6		F-s
BL126LAE	S-P	458.0	37.4	29.2	20.3	2256.4	184.2	143.8	850	550	8		M-m
BL225LAE	S-P	116.4	21.3	30.0	43	270.7	49.6	69.8	415	400	7		F-im
BL226LAE	S-P	(g) 128.2	(g) 22.1	(g) 24.5	34	377.0	65.0	72.1	378	407	6		F-im
BL325LAE	S-P	31.1	3.4	3.6	32.7	95.2	10.3	10.9	625	475			F-m
BL326LAE	S-P	171.2	11.3	7.7	17.8	961.7	63.3	43.1	294	339			M-m
SF19ATT	C-N	2.7	0.2	0.1	7.8	35.1	2.2	1.7	820	435			M-lm
SF20ATT	C-N	0.9	0.2	0.3	7.9	11.7	2.9	3.4	1120	496			M-lm
SF120ATT	C-N	2.0	<LOD	<LOD	1.9	105.3	<LOD	<LOD	380	380	4		F
TF21HJS	S-K	3.6	0.4	0.2	1.8	201.2	21.1	11.7	917	420			M-m
TF22HJS	S-K	3.9	0.5	0.3	1.4	277.4	39.0	23.7	742	415			M-m
TF121HJS	S-K	21.0	0.6	0.3	7.5	279.4	7.4	4.6	879	445	5		M-m
TF221HJS	S-K	(b) 0.3	<LOD	<LOD	2	(b) 17	<LOD	<LOD	1810	565			M-m
TF222HJS	S-K	<LOD	<LOD	<LOD	1	<LOD	<LOD	<LOD	648	387	4		M-m
CF321HJS	S-K	0.8	<LOD	<LOD	0.6	133.3	<LOD	<LOD	759	412			F-s/m
CF322HJS	S-K	0.7	<LOD	<LOD	1	66.0	<LOD	<LOD	783	420			F-m
WF122HJS	S-K	13.9	(b) 0.3	(b) 0.2	7	198.6	4.4	2.7	698	405	6		M-m
SF23POK	A-A	0.2	0.04	0.02	3.5	6.7	1.3	0.6	1620	570			M-m
SF24POK	A-A	0.2	0.05	0.03	2.9	7.8	1.6	1.2	2750	680			M-m
SF223POK	A-A	(b) 0.4	<LOD	<LOD	2	18.0	<LOD	<LOD	3400	710			F-m
SF224POK	A-A	(b) 0.3	<LOD	<LOD	1	32.0	<LOD	<LOD	3400	670			F-m
SF323POK	A-A	0.3	0.1	<LOD	0.7	42.9	10.0	<LOD	2200	620			M-m
SF324POK	A-A	0.2	<LOD	<LOD	2	11.0	<LOD	<LOD	1950	600			M-m
SF25LAE	S-P	17.3	2.3	0.7	4	431.4	57.2	18.5	13150	1090			M-m
SF26LAE	S-P	63.2	6.5	0.8	9.5	665.7	68.5	8.3	1950	630			M-m
WL27GYM	R-A	(b) 19.9	(b) 0.2	(b) 0.2	6.2	321.3	3.0	2.9	1200	340			
WL28GYM	R-A	(b) 2.5	(b) 0.1	<LOD	6.3	39.0	1.2	<LOD	3200	290			
WL127GYM	R-A	57.1	1.7	<LOD	7	815.1	24.3	<LOD	310	32			F-im
WL128GYM	R-A	32.0	<LOD	<LOD	7.1	450.4	<LOD	<LOD	300	30			M-im
WF227GYM	R-A	0.3	<LOD	<LOD	1	27.0	<LOD	<LOD	480	360			
WF228GYM	R-A	4.6	<LOD	<LOD	1.6	290.0	<LOD	<LOD	300	310			
WF327GYM	R-A	0.2	<LOD	<LOD	0.4	50.0	<LOD	<LOD					
WF328GYM	R-A	0.5	<LOD	<LOD	0.6	86.7	<LOD	<LOD					
WL12CZS	C-O	3.7	0.1	0.2	16.8	22.3	0.8	1.1	975	424			M-m
WF17PUS	F-T	5.0	0.5	0.2	0.6	839.7	81.7	32.2	540	405			M-m

Appendix A

Sampling guidelines

Sampling guidelines

OSPAR
www.ospar.org/eng/html/welcome.html
Measures - Agreements
JAMP Guidelines for Monitoring Contaminants in Biota
Reference Number: Agreement 1999-02

Quasimeme Sampling handling, report from workshop
www.quasimeme.marlab.ac.uk/QUASH/reportfl.pdf

EPA- 7. Laboratory Procedures I Sample Handling (PDF)
www.epa.gov/ost/fishadvice/volume1/

Biological Assessment Unit - Fish Tissue SOP (PDF file)
http://www.esb.enr.state.nc.us/BAU.html
or direct link: http://www.esb.enr.state.nc.us/BAUwww/Tissue%20webSOP.pdf

TCEQ - Texas Commision on Environmental Quality
Surface Water Quality Monitoring Procedures Manual-
Chapter 6- Equipment - p. 5
http://www.tnrcc.state.tx.us/admin/topdoc/gi/252/covfrt.pdf

Lake Whatcom Watershed Cooperative Drinking Water Protection Project: Results of 1998 Water, Sediment and Fish Tissue Sampling - Click 'View this puclication'
http://www.ecy.wa.gov/biblio/99337.html

Puget Sound Protocols and Guidelines
http://www.wa.gov/puget_sound/Publications/protocols/protocol.html

Nordic Environmental Specimen Banking Homepage
http://esb.naturforvaltning.no/

Biological Sampling Manual for Salmonids
www.pac.dfo-mpo.gc.ca/ops/biosample/chapt_2/chapt_2.htm

Appendix B

Transport routes of POPs

Transport routes of POPs

Background information on persistent organic pollutants (POPs)
http://www.cep.unep.org/gpa/pops.htm#background

Inputs of POPs in The Marine Environment *(good educational page)*
http://pops.gpa.unep.org/031marin.htm

Look also in general at:
http://pops.gpa.unep.org/

Physical pathways of contaminant transport
http://www.amap.no/assess/soaer3.htm#physical%20pathways%20of

Look also in general at:
http://www.amap.no/assess/soaer-cn.htm

Sources of Arctic Contaminants
http://www.itk.ca/english/itk/departments/enviro/ncp/sources.htm

How contaminants get to the North
http://cine.mcgill.ca/TF/tfCOm.htm

Dominating wind currents
http://www.grida.no/db/maps/prod/level3/id_1246.htm

Transport routes of POP and concerned areas
http://www.grida.no/db/maps/prod/level3/id_1188.htm

Ocean current and sea ice extend
http://www.grida.no/db/maps/prod/level3/id_1178.htm

The Link between Persistence and Long-Range Transport
http://www.cefic.be/icca/pops/en/pops1002.htm

The significance of long range transport of persistent organic pollutants by migratory animals

PDF file:
http://www.scar.utoronto.ca/~wania/reports/WECC3-1998.pdf

HTML :
http://216.239.53.100/search?q=cache:lCSNxSGJwHMC:www.scar.utoronto.ca/~wania/reports/WECC31998.pdf+%22transport+routes%22+POPs&hl=no&ie=UTF-8

The Wania group - downloads
http://www.scar.utoronto.ca/~wania/downloads3.html

FACT SHEET: Overview on Persistent Organic Pollutants (POPs): What The United States Has Done and What The Global Convention Will Do
http://usinfo.state.gov/topical/global/environ/00112901.htm

Persistent Organic Pollutants- Funder: European Training and Assessment Foundation
http://www.york.ac.uk/inst/sei/pops/pops.html

Persistent Organic Pollutants: Criteria and Procedures for Adding New Substances to the Global Pops Treaty (con't)
http://www.worldwildlife.org/toxics/progareas/pop/pop_criteria2.html

PROTOCOL TO THE 1979 CONVENTION ON LONG-RANGE TRANSBOUNDARY AIR POLLUTION ON PERSISTENT ORGANIC POLLUTANTS
http://www.unece.org/env/lrtap/protocol/98p_dec.htm

Long-Range Transport in the Environment

PDF file
http://www.scientificjournals.com/db/pdf/espr%2F8%2Fespr8_3_149.pdf

HTML
http://216.239.39.100/search?q=cache:6T4zoC5bVy4C:www.scientificjournals.com/db/pdf/espr%252F8%252Fespr8_3_149.pdf+%2Blong+%2Brange+%2Btransport+%2BPOPs&hl=no&ie=UTF-8

Transboundary Arctic Contaminants
http://www.nativescience.org/html/contaminants.html

Contaminant Pathways
The Arctic is a focus for major atmospheric, riverine, and marine pathways which result in the long-range transport of contaminants into and within the Arctic. The Arctic is, therefore, a potential contaminant storage reservoir and/or sink. Various processes remove these contaminants from the atmosphere, oceans and rivers and make them available to plants and animals. Food chains are the major biological pathways for selective uptake, transfer, and sometimes magnification of contaminants by Arctic plants and animals, many of which are subsequently consumed by Arctic peoples.

- Strong south to north air flows, particularly over west Eurasia in winter, transport contaminants, e.g. sulfur and nitrogen compounds, POPs and radionuclides, from lower latitudes. Special mechanisms selectively favor the accumulation of PCBs and certain pesticides in the Arctic.

- Arctic rivers are a significant pathway for contaminant transport to the Arctic, often associated with extreme seasonal fluctuations due to freeze-up and meltwater flushing characteristics. Suspended solids carry high levels of PCB and DDT in the Ob and Yenisey river deltas, as do sediments in the Indigirka and Pechora rivers. Sedimentation processes play a critical role in depositing particles in estuaries, deltas and Arctic coastal shelves. These riverine pathways lead to local and regional dispersal of radionuclides, some heavy metals and oil.

- Ocean waters are a major storage reservoir and transport medium for water and soluble POPs. Sea ice may be important in transporting POPs and other contaminants from coastal sediments during the winter, and from deposition from the atmosphere, with subsequent redistribution during ice melt.

- Long distance marine transport of radionuclides from previous mid-latitude releases resulted in accumulations in Arctic sediments. Radionuclides from current releases from spent fuel storage and wastes dumped at sea tend to remain local, although low-active wastes dumped previously in the Arctic marine environment have been distributed more widely.

Arctic Pollution: How Much is Too Much?
http://www.carc.org/pubs/v18no3/1.htm

Transport of Pollutants

Pollution from lower latitudes is carried into the Arctic by atmospheric circulation and ocean currents. Global atmospheric circulation patterns are such that eastward-moving air masses in northern mid-latitudes become polluted near the surface and then may get carried at moderate or higher elevations to the arctic regions, where they descend and may deposit their impurities. *The main pathways by which airborne pollutants reach the Arctic are over northern Europe and Asia and then across the Arctic Ocean to northern Canada and Alaska, although excursions of polluted air from the industrialized midwest of North America into northern Canada and the Arctic Ocean are not uncommon.*

The rapid transport of radioactive contaminants from Chernobyl in the southwestern U.S.S.R. to northern Scandinavia, and its incorporation into vegetation and the flesh of reindeer, is a recent unfortunate but convincing demonstration of the effectiveness of transport of pollutants from southern latitudes into the Arctic. Careful analysis of impurities in snow from various parts of arctic Canada, Alaska, and Spitzbergen has shown that some of the chemicals whose origin can be identified with reasonable confidence have come from industrial sources in western Europe and the western Soviet Union, or from agricultural chemicals typically used in India and southeast Asia.

By the marine route, pollutants reach the Arctic through one major point of entry, the northeast Atlantic. Chemically stable or slow-reacting pollutants from industrialized eastern North America are carried by winds or rivers into the Atlantic Ocean and then northward by the Gulf Stream and North Atlantic Drift into the Arctic Ocean.

Augmented by drainage and winds from Europe and by north-flowing Siberian rivers, they are carried under the arctic ice where they remain protected from sunlight and vigorous oxygenation which otherwise would hasten their chemical break-down. By these means, much of the far-travelled and persistent waste products of the industrialized world appear to be ultimately deposited in arctic regions. A portion of these, to which may be added materials deposited directly from the atmosphere, becomes incorporated in the upper layers of Arctic Ocean waters and returned to the Northwest Atlantic, where they sink to lower ocean depths and are carried slowly southward as the Atlantic Deep Water Current, eventually spreading at depth throughout the World Ocean.

Appendix C

Fish links

Fish links

Fishbase search
* http://www.fishbase.org/search.cfm

Fish names in 5 languages (introduction in Norwegian)
* http://www.geocities.com/chappleby/fiskenavn.htm

Biological Sampling Manual for Salmonids
Source: Fisheries and Oceans Canada
Chapter 1- Adult Species Identification
* http://www.pac.dfo-mpo.gc.ca/ops/biosample/chapt_1/chapt_1.htm
Chapter 2 - Biological Event Attributes
* http://www.pac.dfo-mpo.gc.ca/ops/biosample/chapt_2/biologic/biologic.htm
Color plates of different salmonids:
* http://www.pac.dfo-mpo.gc.ca/ops/biosample/chapt_1/chapt_1.htm
Useful figures:
* http://www.pac.dfo-mpo.gc.ca/ops/biosample/chapt.htm

Fish (good educational background and nice pictures):
*http://www.school.discovery.com/homeworkhelp/worldbook/atozscience/f/198340.html

External and internal anatomy of a salmon:
* http://www.state.ak.us/adfg/sportf/region2/ie/anatomy.pdf

FISH SAMPLING PROCEDURES:
* http://www.for.gov.bc.ca/ric/pubs/aquatic/fishcol/fish-3.htm#fish.3.3

Fish links:
http://www.newberg.k12.or.us/ey/html/fishlinks.html

http://www.odysseyexpeditions.org/indexfh.asp

Classroom salmon dissection:
http://www.state.ak.us/adfg/sportf/region2/ie/dissectn.htm

Getting into a fish:
http://www.northcoast.com/~fishhelp/edu_f/dissect.html#external

Atlantic salmon:
http://www.asf.ca/Overall/atlsalm.html

Fish anatomy:
http://www.enchantedlearning.com/subjects/fish/printouts/Fishcoloring.shtml

Fish-age determination:
http://www.wh.whoi.edu/fbi/age-man.html

How should you clean and cook fish that might contain PCBs?:
http://sites.state.pa.us/PA_Exec/Fish_Boat/qpcb2000.htm

Links to marine biology:
http://www.meer.org/

General Biology links
http://education.zefex.com/biology2.htm
http://www.nsta.org/onlineresources/site/

The school page - The Educator's Resource:
http://www.theschoolpage.com/

Appendix D

Arctic links

Arctic links

UNEP- Arctic portal
http://arctic.unep.net/

Arctic Environmental Atlas
http://maps.grida.no/arctic/

UNEP- GRIDA- Arctic themes- graphics
http://www.grida.no/db/maps/prod/level1/70401.htm

Arctic maps
http://www.athropolis.com/links/maps.htm

Online Map Creation
http://www.aquarius.geomar.de/omc/omc_intro.html

Arctic theme page
http://www.arctic.noaa.gov/maps.html

Geography network
Write in Arctic in the 'Find' (ctrl f) window
http://www.geographynetwork.com/free.cfm

Arctic Council -links
http://www.arctic-council.org/links.asp

Arctic bulletin - downloadable PDF files
http://www.ngo.grida.no/wwfap/core/publications/arctic_bulletin.html#ab

AMAP- Arctic Monitoring and Assessment Programme
www.amap.no

AMAP, 2004. AMAP Assessment 2002: Persistent Organic Pollutants in the Arctic. Arctic Monitoring and Assessment Programme (AMAP), Oslo, Norway. xvi+310 pp.
http://amap.no/documents/index.cfm?dirsub=%2FAMAP%20Assessment%202002%3A%20Persistent%20Organic%20Pollutants%20in%20the%20Arctic&sort=default

Arctic Pollution Issues:
A State of the Arctic Environment Report:
http://www.amap.no/assess/soaer-cn.htm

UNEP: What are POPs?
http://pops.gpa.unep.org/

UNEP, Persistent Toxic Substances
http://www.chem.unep.ch/pts/default.htm

UNEP- Regional reports
http://www.chem.unep.ch/pts/regreports/regreports_copy(1).htm

Appendix E

Fish advisories, tolerable intake and effects of POPs

Fish advisories, tolerable intake and effects of POPs

EPA: Fish advisories

http://www.epa.gov/waterscience/fish/
http://www.epa.gov/waterscience/fish/forum/2004/
http://www.epa.gov/waterscience/fish/advisory.html

US EPA IRIS- Reference Dose

http://www.epa.gov/iris/rfd.htm

The reference dose (RfD) and uncertainty factor (UF) concepts have been developed by the RfD Work Group in response to many of the problems associated with ADIs and SFs, as previously outlined in Section 1.2. The RfD is a benchmark dose operationally derived from the NOAEL by consistent application of generally order-of-magnitude uncertainty factors (UFs) that reflect various types of data sets used to estimate RfDs. For example, a valid chronic animal NOAEL is normally divided by an UF of 100. In addition, a modifying factor (MF), is sometimes used which is based on a professional judgment of the entire data base of the chemical. These factors and their rationales are presented in Table 1.

The RfD is determined by use of the following equation:

RfD = NOAEL / (UF x MF)

which is the functional equivalent of Equation 1. In general, the RfD is an estimate (with uncertainty spanning perhaps an order of magnitude) of a daily exposure to the human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious effects during a lifetime. The RfD is generally expressed in units of milligrams per kilogram of bodyweight per day (mg/kg/day).

The RfD is useful as a reference point from which to gauge the potential effects of the chemical at other doses. Usually, doses less than the RfD are not likely to be associated with adverse health risks, and are therefore less likely to be of regulatory concern. As the frequency and/or magnitude of the exposures exceeding the RfD increase, the probability of adverse effects in a human population increases. However, it should not be categorically concluded that all doses below the RfD are "acceptable" (or will be risk-free) and that all doses in excess of the RfD are "unacceptable" (or will result in adverse effects).

EPA-Fish and Wildlife Advisory News

http://map1.epa.gov/html/newsfeb.htm#A2

EPA: Polychlorinated Biphenyls (PCBs) Update: Impact on Fish Advisories

http://www.epa.gov/waterscience/fish/pcbs.pdf

EPA: Fish consumption advisory due to elevated PBDE levels

http://www.epa.gov/waterscience/fish/forum/pdfs/NC_pbdTX.pdf

Toxicity of PBDEs

The toxicity values for PBDEs were researched within the US EPA Integrated Risk Information System (on-line at http://www.epa.gov/iris). The following values and toxicity data were obtained.

PBDEs	Reference Dose (dose not likely to result in noncancer health effects)	Carcinogenicity Data
Pentabromodiphenyl ether	2 ug/kg-day (induction of liver enzymes in rats)	Class D (not classifiable because of no human or animal data)
Octabromodiphenyl ether	3 ug/kg-day (induction of liver enzymes in rats)	Class D (not classifiable because of no human or animal data)
Decabromodiphenyl ether	10 ug/kg-day (no adverse effects observed)	Class C (possible human carcinogen based on increased incidences of neoplastic liver nodules in rats and increased incidences of hepatocellular adenomas or carcinomas in mice)
Tetrabromodiphenyl ether	Not available	Class D (not classifiable because of no human or animal data)

Summary

Average PBDE Level (ppb)	Recommendations to State Health Director
<5,000 ppb	No recommendations warranted –safe for unrestricted consumption
5,000 pbb to < 10,000 ppb	(Species) in (waterbody) contains higher than normal levels of PBDEs. Consumption of (species) should be limited to no more than two meals per person per month.
10,000 ppb	(Species) in (waterbody) contains higher than normal levels of PBDEs. No consumption of (species) is recommended.

Food consumption recommendations of PCB
http://www.atsdr.cdc.gov/tfacts17.html
The Food and Drug Administration (FDA) requires that infant foods, eggs, milk and other dairy products, fish and shellfish, poultry and red meat contain no more than 0.2-3 parts of PCBs per million parts (0.2-3 ppm) of food. Many states have established fish and wildlife consumption advisories for PCBs.

ToxFAQs™ for Polybrominated Biphenyls and Polybrominated Diphenyl Ethers (PBBs AND PBDEs)
http://www.atsdr.cdc.gov/tfacts68.html

Toxicological Profile for Polybrominated Biphenyls and Polybrominated Diphenyl Ethers (PBBs AND PBDEs) September 2002
http://www.atsdr.cdc.gov/toxprofiles/tp68.html#8
http://www.atsdr.cdc.gov/toxprofiles/tp68-c8.pdf

Chemical risks in food
http://www.who.int/foodsafety/chem/en/

WHO Consultation on Risk Assessment of Non-Dioxin-Like PCBs
http://www.who.int/pcs/docs/consultation_%20pcb.htm
In 1998, WHO established a revised TDI range of 1-4 pgTEQ/kg bw, which included dioxins, furans and the 12 dioxin-like PCBs (Consultation on Assessment of the Health Risk of Dioxins, 2000). This approach obviously covers dioxin-like activities only, and does not address non-dioxin-like effects of PCB-congeners. Whether or not this approach is protective of non-dioxin-like PCB effects remains unclear. Unlike for the dioxin-like PCBs, a corresponding TEF concept cannot be applied to the non-dioxin-like PCB-congener due the lack of major criteria, the most important being the lack of a common mechanism of action that results in all different types of toxic outcomes.

Non-dioxin-like PCBs are of relevance, since many of them persist and accumulate in the food chain and represent a major part of PCB congeners found in human tissues. They elicit a wide spectrum of toxic responses in experimental animals, including neurotoxic/neurodevelopmental effects, tumour promotion and endocrine changes.

Chapter 5.10 Polychlorinated biphenyls (PCBs)
http://www.euro.who.int/document/aiq/5_10pcbs.pdf

HEALTH RISKS OF PERSISTENT ORGANIC POLLUTANTS FROM LONG RANGE TRANSBOUNDARY AIR POLLUTION (2003)
http://www.euro.who.int/Document/e78963.pdf
p. 138 PCBs
It has not yet been possible, based on the available data, to reach a scientifically justified agreement on a TDI of either PCB mixtures or of any individual non-dioxin-like PCB congener. IARC (1987) has classified PCBs as probably carcinogenic to humans (group 2A).

p. 207 PBDEs
Therefore, mice ingesting an average daily dose of 15.5 µg/kg bw would eventually achieve a body burden similar to that associated with a LOAEL for neurodevelopmental effects. If the DD was reduced 10-fold to approximate a NOAEL (1.55 µg/kg bw per day), this would result in margin of safety values of only 0.03–1.1 when compared to the European Union's probabilistic exposure estimates. (Note: PBDE 99 was assigned 40% of the total PBDE intake estimation.)

4.3/ Previous risk assessments
USEPA has established oral reference doses for commercial deca-, octa- and penta-BDEs of 10.0, 3.0 and 2.0 µg/kg bw per day, respectively. **To address the issue of contaminated fish, an interim reference dose for tetra-BDE has been suggested at 1.0 µg/kg bw per day.**

HAZARDOUS CHEMICALS IN HUMAN AND ENVIRONMENTAL HEALTH
http://www.who.int/pcs/training_material/hazardous_chemicals/contents.htm

ASSESSING HUMAN HEALTH RISKS OF CHEMICALS
http://www.who.int/pcs/training_material/hazardous_chemicals/section_4.html

The **NAOEL** is the greatest concentration or dose of a chemical which produces no observed adverse effects in the test population. It is the cornerstone of risk assessment and is the foundation of health based tolerable levels of exposure for humans

TDI = Tolerable Daily Intake - an estimate of the daily intake of a chemical that can occur over a lifetime without appreciable health risk

The **Acceptable Daily Intake (ADI)** is an estimate of the daily maximum intake of a substance over a lifetime that will not result in adverse effects at any stage in the human life span.

The ADI concept is used for food additives, veterinary drugs and pesticides that have useful food production purposes. The term "tolerable" and the **TDI concept** is **intended for trace contaminants** which have no useful purpose. The term "tolerable" is intended to signify permissibility rather than acceptability.

WHO - International Programme on Chemical Safety (IPCS)
http://www.who.int/pcs/

Environmental Backgrounder: Pesticides and Food Safety
http://pmep.cce.cornell.edu/issues/foodsafety-issues.html
The Reference Dose or Acceptable Daily Intake (ADI) Level
Using the NOEL, an acceptable daily intake (ADI) level -- which scientists now call a reference dose -- can be proposed for humans by applying a suitable safety factor. The safety factor is intended to allow an extra margin of safety to compensate for (l) the scientific uncertainty inherent in the process of extrapolating human risk projections from animal data, and (2) the possibility of differing sensitivities to the pesticide in individuals or subgroups (such as children) among the general population. The magnitude of this factor may vary, depending on the toxicological effects observed in laboratory animals, and the amount of toxicity data available, but a 100-fold safety factor is used in most instances. In general, the ADI or reference dose can be defined as an estimate of a daily exposure to the human population (including sensitive subgroups) that is likely to be without an appreciable risk of adverse effects.

Brominated Flame Retardants (PBDE and PBB) in Sludge – a Problem ?
http://biosolids.policy.net/relatives/23481.pdf
LD50, NOEL and LOEL for PBDE in page 11- LOEL and ADI in page 12
PentaBDE: LOEL: 1mg/kg/day, ADI: 0.002 mg/kg/day

US EPA (see EPA-IRIS) has presented acceptable daily intake, ADI, for some PBDE. These values and the estimations of LOEL by EPA are shown below:

	LOEL(mg/kg/d)	ADI (mg/kg/d)
DecaBDE	100	0,01
OctaBDE	2	0,003
PentaBDE	1	0,002

Contamination of whale meat and blubber (PDF file)
http://whales.greenpeace.org/reports/pops_minke.pdf

AMAP: Tolerable daily intake for persistent organic contaminants
www.amap.no
Left margin: Assessment Results
AMAP's Assessments
Scientific Background Reports (AARs)
AMAP Assessment Report: Arctic Pollution Issues (1998)
Chapter 12: Pollution and Human Health, AAR-Ch12.pdf

http://amap.no/documents/index.cfm?dirsub=/AMAP%20Assessment%20Report:%20Arctic%20Pollution%20Issues&sort=default

Page 777

Substance	*TDI in µg/kg body weight/day*	*Reference*
Total PCB	1.0	Provisional TDI, Health Canada 1996

Table 12-1. Toxicological characteristics of persistent organic pollutants.

Contaminant	Acute oral lethality (LD_{50} rats, mg/kg bw)	Human carcinogenicity (IARC 1987)[f]	Acceptable/tolerable daily intakes, µg/kg bw/d	Main sources of exposure
DDT	113[a]	2B	20[b]	Fish, marine mammals
DDE	880[a]	n.a.[c]	20[b]	
Toxaphene	80-90[d]	2B	0.2[e]	
Dioxins (2,3,7,8-TCDD)	0.022-0.340[f]	2B	0.000015	
Furans (2,3,7,8-TCDF)	n.a.	n.a.	0.000015	
Mirex	365-3000[k]	2B	0.07[e]	
Chlordane	127-430[l]	3	0.05 (total)[i]	
Heptachlor	71[k]	3	0.1 (total)[i]	
HCH	88 (γ-HCH)[m]	2B (mixture)	0.3 (total)[i] 8 (γ-HCH)[e]	
PCBs	1010-4250 (various Aroclors)[o]	2A	1.0 (total PCBs)[e]	
HCB	1000-10000[q]	2B	0.27[e]	
PAH (benzo[a]pyrene)	n.a.	2A	n.a.	Tobacco smoke, smoked foods, home fuel combustion (wood)

a. ATSDR 1994a. b. WHO 1984b. c. n.a.: not available. d. ATSDR 1994b. e. Provisional TDI (PTDI) Health Canada 1996. f. WHO 1989b. g. WHO 1992b. h. WHO 1984c. i. ATSDR 1993a. j. TDI Health Canada 1996. k. ATSDR 1993b. l. WHO 1991c. m. ATSDR 1992. n. WHO 1989c. o. ATSDR 1995. p. Group 1: The agent is carcinogenic to humans. Group 2A: The agent is probably carcinogenic to humans. Group 2B: The agent is possibly carcinogenic to humans. Group 3: The agent is not classified as to its carcinogenicity to humans. Group 4: The agent is probably not carcinogenic to humans. q. Government of Canada 1993.

Determine NOEL, ADI, MTD

http://www.outreach.uiuc.edu/FSHN494B/law/tsld083.htm

Highest level of exposure with no effects = No Observed Effect Level

Calculate Acceptable Daily Intake

ADI = NOEL / 100

Overview- units- bioaccumulation- toxicity (PDF file)

http://web.jjay.cuny.edu/~acarpi/ENV/

http://web.jjay.cuny.edu/~acarpi/ENV/handout.pdf

SUMMARY

Adverse ecological effects from environmental pollutants occur at all levels of biological organization, but most information about these effects has been obtained with single species. The effects can be global or local, temporary or permanent, or short-lived (acute) or long-term (chronic). The most serious effects involve loss in production, changes in growth, development and/or behavior, altered diversity or community structure, changes in system processes (such as nutrient cycling), and losses of valuable species. These ecological losses in turn may be economically, aesthetically, or socially important. Hence, ecological effects are of serious concern in regulating pollutants and a variety of tests have been devised to help evaluate the potential for adverse ecological effects. Developing an understanding of how these tests and other information can be used to prevent environmental problems caused by pollutants is the basis for ecological risk assessment research.

EU- Endocrine effects of chemicals (also PBDEs) PDF file

http://europa.eu.int/comm/environment/docum/bkh_annex_07.pdf

Synopsis on dioxins and PCBs

http://www.ktl.fi/dioxin/

http://www.ktl.fi/dioxin/rtoz.html

TCDD, 2,3,7,8-tetrachlorodibenzo-*p*-dioxin, the most potent of polychlorinated dibenzo-*p*-dioxins. For properties, see *PCDD/F - specific items*).

TEF (TCDD equivalency factor, toxic equivalency factor), a relative toxicity factor of a PCDD/F or PCB congener as related to TCDD. TEF values vary from 1 to 0.00001 or 0 (Table 4; see also *TEq*). The latest re-evaluation of TEF values was that by WHO in 1998, and these TEF values have been used in this booklet as WHO-TEF for PCDD/Fs and PCB-TEF for PCBs. TEq = $\Sigma TEF_i * C_i$, where Ci is the amount (or concentration) of congener i.

tolerable daily intake dose (TDI), a theoretical concept of regulatory toxicology giving the highest dose of a chemical which can be assured to be safe even if one is exposed to the chemical through the whole lifetime. Most TDI values have been estimated on the basis of animal experiments. Usually the TDIs include safety margins to guarantee safety even if human being should be more sensitive than the animal. The safety margin is often 100-fold, but could be larger, if research data is not satisfactory. If the chemical is *carcinogenic* (see this), different methods are used in different countries. Some countries use large safety margin (e.g. 1000-fold), some use mathematical *extrapolations* (see this) to reach a level deemed safe (e.g. a maximum likelihood of one in a million chance of contracting cancer due to a lifetime exposure to the chemical). The important point is that the purpose of TDI is to serve regulators in administrative work, and not individual persons. It does not predict the likelihood of individual's health effect in any reliable way, if the limit is exceeded. TDIs of dioxins set by various authorities in different countries vary by more than thousandfold, which illustrates the difficulties in dioxin risk assessment. The latest recommendation for TDI for the sum of dioxins and dioxin-like PCBs is 1 to 4 pg/kg/day (WHO-TEq per b.w.), in other words, in 70-kg person 70 to 280 pg/day. This should be understood as the average intake over a long period of time (see *cumulation*).

Table 4. Toxic equivalency factors for all PCDD/Fs and PCBs that have a TEF>0. Other congeners are not supposed to have dioxin-like effects. IUPAC numbers for PCBs are given in parenthesis

Congener	WHO-TEF
PCDDs	
2,3,7,8-TCDD	1
1,2,3,7,8-PeCDD	1
1,2,3,4,7,8-HxCDD	0.1
1,2,3,6,7,8-HxCDD	0.1
1,2,3,7,8,9-HxCDD	0.1
1,2,3,4,6,7,8-HpCDD	0.01
OCDD	0.0001
PCDFs	
2,3,7,8-TCDF	0.1
1,2,3,7,8-PeCDF	0.05
2,3,4,7,8-PeCDF	0.5
1,2,3,4,7,8-HxCDF	0.1
1,2,3,6,7,8-HxCDF	0.1
1,2,3,7,8,9-HxCDF	0.1

2,3,4,6,7,8-HxCDF 1,2,3,4,6,7,8-HpCDF 1,2,3,4,7,8,9-HpCDF OCDF	0.1 0.01 0.01 0.0001
Non-ortho-PCBs 3,3',4,4'-TCB (77) 3,4,4',5-TCB (81) 3,3',4,4',5-PeCB (126) 3,3',4,4',5,5'-HxCB (169)	 0.0001 0.0001 0.1 0.01
Mono-ortho-PCBs 2,3,3',4,4'-PeCB (105) 2,3,4,4',5-PeCB (114) 2,3',4,4',5-PeCB (118) 2',3,4,4',5-PeCB (123) 2,3,3',4,4',5-HxCB (156) 2,3,3',4,4',5'-HxCB (157) 2,3',4,4',5,5'-HxCB (167) 2,3,3',4,4',5,5'-HpCB (189)	 0.0001 0.0005 0.0001 0.0001 0.0005 0.0005 0.00001 0.0001

cumulation, accumulation of a drug or chemical in the body. If a chemical enters the body continuously, its amount in the body increases until the elimination will reach the same rate as the intake; in other words the same amount of chemical is eliminated per unit of time as is entering the body. This is called the steady state. If elimination is very fast, this steady state level is reached quickly, but if elimination is very slow (in other words *half-life* [see this] is very long), a long time is needed to reach steady state. As a thumb rule, the body burden in a steady state is the daily dose multiplied by 1.5 times half-life (in days), e.g. in the case of PCDD/Fs, about 5000 daily doses.

A bathtub with a leaking bottom plug can illustrate this. If the leak is large, pouring water from a tap to the bathtub at a constant rate will raise the water level rapidly to such a relatively low height that as much pours out through the leak as is coming in from the tap. But if the leak is little, water level will rise longer and to a higher level, until the pressure will increase the output of water through the small leak to match the rate of the incoming water. Dioxins and PCBs leak out of the body very slowly, and therefore they keep cumulating even for decades until the elimination rate will finally be as great as the intake rate. The half-time of cumulation (the time during which 50% of steady state level will be reached) is the same as the half-life of elimination of the chemical. The half-life of TCDD is 7 to 8 years. This means that at a constant intake rate the body burden (the total amount of chemical in the body) will reach 50% of steady state in 7-8 years, 75 % in about 15 years and reach the steady state only in 40 to 50 years.

Food safety Risk analysis Clearinghouse

Hazard > Chemical Hazard > Contaminants > Dioxin/PCB

http://www.foodrisk.org/dioxin_pcb.cfm#fsp

European Food Safety Authority
http://efsa.eu.int/index_en.html

http://europa.eu.int/rapid/pressReleasesAction.do?reference=SPEECH/04/69&format=HTML&aged=0&language=EN&guiLanguage=en

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Fact Sheet on dioxin in feed and food, Brussel 20 July , 2001
http://europa.eu.int/comm/dgs/health_consumer/library/press/press170_en.pdf

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EU- Community strategy for dioxins, furans and PCBs
http://europa.eu.int/scadplus/leg/en/lvb/l21280.htm

Objectives of the strategy
The Commission considers that the integrated approach devised by the strategy should permit it to control the problem of dioxins and PCBs in the next ten years. The three major objectives of the strategy are:

- to assess the current state of the environment and of the ecosystem;
- to reduce human exposure to these substances in the short term and to maintain it at safe levels in the medium to long term;
- to reduce environmental effects.

The strategy also establishes a quantitative objective, namely to reduce the human intake levels of these substances to below a certain threshold **(14 picograms WHO-TEQ per kilogram body weight per week)**.

COUNCIL REGULATION (EC) No 2375/2001
of 29 November 2001, amending Commission Regulation (EC) No 466/2001 setting maximum levels for certain contaminants in foodstuffs
http://europa.eu.int/eur-lex/pri/en/oj/dat/2001/l_321/l_32120011206en00010005.pdf

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Interim Report 5 – Study of dioxin-like PCB levels in fatty fish from Sweden 2000-2002
http://www.slv.se/upload/dokument/Mat_Halsa/Saker_mat/interim%20report%205%20pcb%20slutlig.pdf

Harmonised EU maximum levels have been established for polychlorinated dibenzo-p-dioxins (PCDDs) and dibenzofurans (PCDFs), and the **maximum level set** for fish and fishery products is **4 pg WHO-PCDD/F-TEQ/g fresh weight** (Council Regulation (EC) No 2375/2001). For dioxin-like PCBs common EU maximum levels have not yet been established. However, during 2004 the Commission will review the present maximum levels for dioxins in the light of new data, with a particular aim to include dioxin-like PCBs in the levels to be set.

COUNCIL REGULATION
amending Commission Regulation (EC) No 466/2001 setting maximum levels for certain contaminants in foodstuffs
http://www.foodlaw.rdg.ac.uk/pdf/com2001_0495.pdf

page 10:

ANNEX

In Annex I, the following section 5 is added :

"Section 5: Dioxin (sum of polychlorinated dibenzo-*para*-dioxins (PCDDs) and polychlorinated dibenzofurans (PCDFs) expressed in World Health Organisation (WHO) toxic equivalents, using the WHO –TEFs (toxic equivalency factors, 1997)

Products	**Maximum levels (PCDD + PCDF)** [25] **(pg WHO-PCDD/F-TEQ/g fat or product)**	**Performance criteria for sampling**	**Performance criteria for the methods of analysis**
5.1.1 Meat and meat products ([28]) originating from			
- Ruminants (bovine animals, sheep)	3 pg WHO-PCDD/F-TEQ /g fat[26,27]	Directive 2001/../EC	Directive 2001/../EC
- Poultry and farmed game	2 pg WHO-PCDD/F-TEQ /g fat[26,27]	Directive 2001/../EC	Directive 2001/../EC
- Pigs	1 pg WHO-PCDD/F-TEQ /g fat[26,27]	Directive 2001/../EC	Directive 2001/../EC
5.1.2 Liver and derived products	6 pg WHO-PCDD/F-TEQ /g fat[26,27]	Directive 2001/../EC	Directive 2001/../EC
5.2. Muscle meat of fish and fishery products ([29]) and products thereof	4 pg WHO-PCDD/F-TEQ /g fresh weight[26]	Directive 2001/../EC	Directive 2001/../EC
5.3. Milk ([30]) and milk products, including butter fat	3 pg WHO-PCDD/F-TEQ /g fat[26,27]	Directive 2001/../EC	Directive 2001/../EC
5.4 Hen eggs and egg products ([31,32])	3 pg WHO-PCDD/F-TEQ /g fat[26,27]	Directive 2001/../EC	Directive 2001/../EC
5.5.Oils and fats			
- Animal fat			
- from ruminants	3 pg WHO-PCDD/F-TEQ /g fat[26]	Directive 2001/../EC	Directive 2001/../EC
– from poultry and farmed game	2 pg WHO-PCDD/F-TEQ /g fat[26]	Directive 2001/../EC	Directive 2001/../EC
– from pigs	1 pg WHO-PCDD/F-TEQ /g fat[26]	Directive 2001/../EC	Directive 2001/../EC
– mixed animal fat	2 pg WHO-PCDD/F-TEQ /g fat[26]	Directive 2001/../EC	Directive 2001/../EC
- Vegetable oil	0.75 pg WHO-PCDD/F-TEQ /g fat[26]	Directive 2001/../EC	Directive 2001/../EC
- fish oil intended for human consumption	2 pg WHO-PCDD/F-TEQ /g fat[26]	Directive 2001/../EC	Directive 2001/../EC

JOINT FAO/WHO FOOD STANDARDS PROGRAMME
CODEX COMMITTEE ON FOOD ADDITIVES AND CONTAMINANTS
Thirty-sixth Session
Rotterdam, The Netherlands, 22 - 26 March 2004
POSITION PAPER ON DIOXINS AND DIOXIN-LIKE PCBs
http://www2.minlnv.nl/lnv/algemeen/vvm/codex/documenten/2003/CCFAC/fa36_32e.pdf

Fish

4. Fish and fish-products form a most heterogeneous food group, due to the large number of different species and geographical differences in the level of contamination of the various fishing grounds. The concentrations of dioxins and dioxin-like PCBs vary considerably. Many fish species contain dioxins and dioxin-like PCBs at a level below 1 pg I-TEQ/g and 1 pg PCB-TEQ/g wet weight respectively. In some fish species however, such as crab, eel, and whitefish, higher concentrations can be found. In addition, fish caught in relatively polluted areas also have higher levels of dioxins and dioxin-like PCBs (SCOOP, 2000). In general, fish is more contaminated with PCBs than with dioxins, with a 2 tot 5-fold difference in general. Differences between lower-, medium, and upperbound levels of fish are small.

	PCDD and PCDF pg TEQ/g product	*Dioxin like PCBs pg WHO-TEQ/g product*	*Dioxins and dioxin-like PCBs pg TEQ/g product*
Europe	0.01-8.9	0.03-9	
North America	0.033-0.53	0.11-0.28	
South America			5-12.5
Asia	0.002- 10.2	0.004-2.0	
Australia-New Zealand	0.02-0.12	0.03-0.16	
Africa			

Global Assessment of Organic
Contaminants in Farmed Salmon
http://www.pewtrusts.com/pdf/salmon_study.pdf

Summary of Investigation of Dioxins, Furans and PCBs in Farmed Salmon, Wild Salmon, Farmed Trout and Fish Oil Capsules, March 2002. (The Food Safety Authority of Ireland)
http://www.fsai.ie/surveillance/food/surveillance_food_summarydioxins.asp

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Dioxins in farmed salmon: is there a health risk?
http://130.37.129.100/english/o_o/instituten/IVM/envirofacts/fb_fish.htm

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UK- Food standards agency
http://www.foodstandards.gov.uk/multimedia/faq/dioxins_qanda/

Fishmeal Information Network (FIN)
DIOXIN AND DIOXIN-LIKE PCBs IN FISH AND FISHMEAL
A Fish Meal Information Network Issue Summary
At 21 January 2004
http://www.gafta.com/fin/findioxin.html#anchor248285

CONTAMINANTS IN SOIL:
COLLATION OF TOXICOLOGICAL DATA AND
INTAKE VALUES FOR HUMANS.
DIOXINS, FURANS AND DIOXIN-LIKE PCBs
http://www.deq.state.mi.us/documents/deq-rrd-uk-soil-dioxins-intake.pdf

WHO:
Applying an uncertainty factor of 10 to the range of LOAELs of 14–37 pg TCDD kg^{-1} bw day^{-1} generated a TDI (rounded, and expressed as a range) of 1–4 pg WHO-TEQ
kg^{-1} bw, which was said to be applicable to dioxins and dioxin-like compounds. The
WHO emphasised that the upper limit of the range (4 pg WHO-TEQ kg^{-1} bw) should be considered a maximum tolerable daily intake on a provisional basis, and the ultimate goal should be to reduce intakes to levels less than 1 pg WHO-TEQ kg^{-1} bw day^{-1}.

USEPA:
As regards cancer, the epidemiological literature was described as being generally consistent with what was seen in laboratory animals, where dioxin-like compounds are both multi-site carcinogens and tumour promotors. The information available on doseresponses did not provide "consistent or compelling" support for a dose threshold and therefore the default of linear extrapolation of risk down to zero exposure was adopted. Based on both the epidemiological and laboratory animal data (and again using body burden as the measure of dose), the upper bound life-time cancer risk was estimated to be about 1×10^{-3} per pg TCDD kg^{-1} bw day^{-1}.

EPA, Environmental Protection Agency
Integrated Risk Information System (IRIS)
Online: http://www.epa.gov/iris/

The European Chemicals Bureau (ECB)
http://ecb.jrc.it/

WHO Consultation on Risk Assessment of Non-Dioxin-Like PCBs 2001
http://www.who.int/pcs/docs/consultation_%20pcb.htm

In 1998, WHO established a revised TDI range of 1-4 pgTEQ/kg bw, which included dioxins, furans and the 12 dioxin-like PCBs (Consultation on Assessment of the Health Risk of Dioxins, 2000). This approach obviously covers dioxin-like activities only, and does not address non-dioxin-like effects of PCB-congeners. Whether or not this approach is protective of non-dioxin-like PCB effects remains unclear. Unlike for the dioxin-like PCBs, a corresponding TEF concept cannot be applied to the non-dioxin-like PCB-congener due the lack

of major criteria, the most important being the lack of a common mechanism of action that results in all different types of toxic outcomes.
Non-dioxin-like PCBs are of relevance, since many of them persist and accumulate in the food chain and represent a major part of PCB congeners found in human tissues. They elicit a wide spectrum of toxic responses in experimental animals, including neurotoxic/neurodevelopmental effects, tumour promotion and endocrine changes.

HEALTH RISKS OF PERSISTENT ORGANIC POLLUTANTS FROM LONG RANGE TRANSBOUNDARY AIR POLLUTION (2003)
http://www.euro.who.int/Document/e78963.pdf

p. 138 PCBs
It has not yet been possible, based on the available data, to reach a scientifically justified agreement on a TDI of either PCB mixtures or of any individual non-dioxin-like PCB congener. IARC (1987) has classified PCBs as probably carcinogenic to humans (group 2A).

p. 207 PBDEs
Therefore, mice ingesting an average daily dose of 15.5 µg/kg bw would eventually achieve a body burden similar to that associated with a LOAEL for neurodevelopmental effects. If the DD was reduced 10-fold to approximate a NOAEL (1.55 µg/kg bw per day), this would result in margin of safety values of only 0.03–1.1 when compared to the European Union's probabilistic exposure estimates. (Note: PBDE 99 was assigned 40% of the total PBDE intake estimation.)

4.3/ Previous risk assessments
USEPA has established oral reference doses for commercial deca-, octa- and penta-BDEs of 10.0, 3.0 and 2.0 µg/kg bw per day, respectively. To address the issue of contaminated fish, an interim reference dose for tetra-BDE has been suggested at 1.0 µg/kg bw per day.

Appendix F

Sampling datasheets

Sampling datasheet

GLOBE project POPs in the Arctic

The sampling datasheet consists of the following for the POP project:

The Appendix will be replaced by specific sheets depending on what to sample each year, but tables 1-5 will be kept as they are.

1. Key facts	
Name of school	
Country	
Sample type*	
Sample year	
ID of animal/fish/bird**	
NILU sample number***	

*What type of sample, water, air, fish bird etc. for biological sample, what part of the animal, fish/bird

**In sampling one might take several samples from same animal/bird/fish. E.g from one fish one might take several samples, one filet, one liver sample etc. To be able to keep track of which samples comes from which animal/fish/bird the individual must be given an ID. This could be like "Cod1-liver" or "salmon1-muscle", but needs to be done and the samples should be marked with this ID no.

***To be filled in by NILU

2. School/class facts	
Name of school	
Post address	
Country	
Telephone	
Telefax	
E-mail school	
Teacher	
E-mail teacher	
Name of school class	
E-mail school class	

3. Sampling location facts	
Name of location	
Region/county	
Community	
Longitude, latitude and elevation*	
Type of location	
Nearest city/town/village	
Distance to city/town/village	
Near industry (if, which industry)	
Distance to industry	
Description of location	

*Use GLOBE GPS Protocol if possible or use maps to give the data. The format is to be given with dots in accordance with the GLOBE GPS protocol: http://archive.globe.gov/sda-bin/wt/ghp/tg+L(en)+P(GPS/HowToPerform

4. Sampling performance	
Sampling method in field	
Date of sampling in field	
Location for sample preparation	
Date of packing/freezing sampling	
Approx. weight of sample sent (optional)	
Date of sending sample	
Date sample received at NILU*	
Condition of received sample*	

*To be filled in by NILU

5. Sample identification names	
Local name of species **	
Latin name of species **	

** If biological sample

6. Additional information about sampling, transport, preparation etc.

Appendix 1: Fish specific facts

Name of school	
ID of fish sample	
Total weight of species (in whole grams)	
Total length of fish (in mm)	
Sampled otoliths (YES/NO)	
Sampled scales (YES/NO)	
Female/Male/Unknown	
Length of gonad (if possible)	
Weight of gonad (if possible)	
Mature/Immature/Spent	
General or unusual observations ***(for example if there is a large scar on the fish, tumors, heavy parasite load, odd coloring etc.)***	

Appendix G

Datasheet for fishing and preparation

Fill in the datasheet with a pencil during fishing and preparation

Name of school	
Address	
E-mail (teacher/class)	
Sampling method in field	
Date of sampling	
Type (and name) of sampling area	
Latitude and longitude (*GLOBE GPS Investigation)	
Nearest city/town/village	
Near industry (if, which industry)	
Type of fish species	
Local name of species	
Latin name of species	
ID of fish sample	
Total body weight of fish (in whole grams)	
Total length of fish (in mm)	
Sampled otoliths (YES/NO)	
Sampled scales (YES/NO)	
Immature/Mature/Spent	
Length of gonad (if possible)	
Weight of gonad (if possible)	
Female/Male/Unknown	
General or unusual observations (for example if there is a large scar on the fish, tumors, heavy parasite load, odd colouring etc.)	

Appendix H

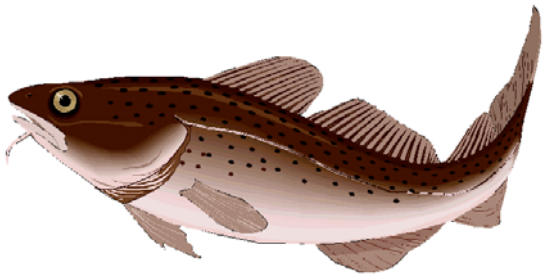
The GLOBE Program – Arctic POPs

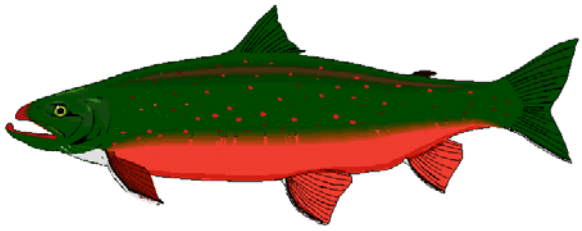
The GLOBE Program

Arctic POPs

Protocol 1: PCBs and PBDEs in local fish

Fall 2001





Content

Introduction to FISH POPs Protocol

The purpose of this protocol is to investigate the level of selected PCBs and brominated flame retardants in fish used for local consumption in the various Arctic countries. For PCBs we do expect to find relative high levels due to existing scientific investigations, but on the flame retardants we do not know if we will find them at all in measurable quantities. So this first protocol in the Arctic POP project will give us a broad screening on what to expect and thereby help us setting up the protocols for the coming years.

The fish POP protocol consists of 4 main phases:

- **Phase I: Fish sampling**
- **Phase II: Chemical analysis**
- **Phase III: Evaluating results**
- **Phase IV: Writing**

Phase I, III and IV are done at the school, while phase II is done at NILU in Norway, but there is a full description on what is being done given in the protocol suitable for teaching options.

Short description of each phase:

Phase I: Sampling
The schools are given the task to identify and sample a suitable fish based on certain criteria. Then to prepare samples for the chemical analysis by cutting and packing defined organs of the fish and send this to NILU. A specific sample sheet is to be used in the process.

The sampling is to be one by all involved schools in the same predefined week.

Phase II: Chemical analysis
NILU analyses the samples in during 8 weeks time and submits the results on the web pages.

Phase III: Evaluating results
Each school will then be given a specific task in evaluating their results. Either compared to other schools or scientific literature.

Phase IV: Writing
The schools should then write a report of their performance of the protocol including the results of their evaluation of the analytic results and submit this on the web page.

Based on all the reports, NILU will look into the most suitable follow-up protocol and prepare it for the next year. Furthermore the results will be used for publications in scientific journals and forums.

The GLOBE Program

Arctic POPs

Protocol 1: PCBs and PBDEs in local fish

Phase I: Fish sampling

The Phase I of the protocol, fish sampling, consists of fish catching, recording data, high quality sample preparation and to collect biological data. The fieldwork is to get suitable fish, record sampling location data and taking photos. Sample preparation and recording biological data may also be done in the field or at the school. Packing and freezing the samples should also be done in a scientifically correct way before shipping the samples to NILU in Norway.

The recording of data is to be done by filling out a sampling data sheet.

1 Objectives

The purpose of this part is to find a good representative fish for this project, to prepare samples in a scientifically correct manner and to record all relevant information useful for the evaluation of the results. The ID of the sample is the most important parameter that should follow the sample when packing and to be filled in the datasheet for each of the 3 fish. The ID should tell the name of the species, the number 1, 2 or 3 and what kind of sample. Examples: cod1-liver, cod2-liver, cod3-liver or salmon1-muscle, salmon2-muscle or salmon3-muscle.

2 Field work

The schools are to identify a suitable local fish and then either catch it themselves by ordinary equipment or get it from local fishermen. The fish must be fresh when retrieved and the sample preparation should preferentially be prepared in the field or at school the same or the next day (store refrigerated). Fish from fish farming is not an option; it must be wild fish.

2.1 Which fish and location to choose

The selection of fish should be as close as possible to the following criteria

Species	**cod, salmon, trout or char.** If none of these are relevant for you, choose the most common fish type for local consumption in your community.
Sample type	The purpose of fish sampling is to have a representative organ to analyze POPs. Salmonids (salmon, trout, char) are fat-rich fish, where the muscle (fillet) is a representative sample, whereas cod is a lean fish where liver is a representative fat-rich organ for the analyses of POPs.
Size	2-3 years old fish, preferable female Find out by local expertise what this age corresponds to of length and weight of the fish.
Number	Get at least 4 fishes of same species. 3 are to be used for sample preparation, and it is nice with one extra to test the protocol on. Remember, if you are testing fillet cutting or removal of liver on the test fish, use your own equipment and not the equipment sent by NILU.

Fishing equipment	Use ordinary available fishing tackle as rod, line etc. As clean equipment as possible.
Type of water	It can be either fresh water or salt water
Surroundings	The absolute best is an area away from local industry and sewage discharges. We want to know the background level in your area.

2.2 Fill out datasheet

Please ensure to have all necessary facts to fill out relevant parts of the sampling data sheets. The one page "Field-Datasheet" is to be used when performing the protocol for each of the 3 fish. Use pencil to fill in the "Field-Datasheet" during fieldwork outside (in case of rain). Use this one-page "Field-Datasheet" to finally fill in the large 5 pages "Sample Datasheet" afterwards for each of the 3 samples. However, put both "Field-Datasheet" and "Sample Datasheet" for each fish in one plastic bag before sending. Take photos when performing the different parts of the protocol!

OBS! A separate sampling data sheet is to be completed for each of the 3 samples!

Sampling should be done in week 41.

2.3 Sample preparation in the field or at school:

All schools should do the sampling in week 41 (8.-12.10.01)

Equipment
Balance(s) for total body weight and possible gonad weight
Square (angle iron) or similar equipment for measuring total length
Gloves,
One scalpel handle for each fish,
One scalpel blade for each fish,
One pair of scissors for each fish,
One large pair of forceps for each fish,
One knife and one small pair of forceps for otoliths for all 3 fish,
Aluminum foil (plastic free foil),
One page datasheet for each fish sample,
One 5 pages Sample datasheet for each fish sample
Camera
White paper, pencil, permanent pen
2 ziplock plastic bags for each fish; one for the sample and one for the two datasheets and scale envelope.

Note: Students should not attach or change scalpel blades due to the very sharp blades. The teachers are responsible for attaching scalpel blades to the scalpel handlers.

It is very important not to mix the equipment used for sample preparation of the 3 fish. If necessary, mark the 3 scalpel handlers, 3 large pair of forceps and the 3 pair of scissors with fish1, fish2 and fish3, respectively. You can write on some tape and put it on parts of the equipment that is in contact with your hands and not the sample.

The protocol can be performed at the same day out in the field at the sampling site. Remember to have the datasheet and camera available out in the field. Also, remember to measure the total body weight (and the total length) before cutting the samples. The preparation of samples in field is most important for salmonids to avoid contamination of the surface layer of the muscle tissue during handling and transport. If necessary, the samples may be cleaned with ambient water, that is the same water as they came from.

If the sampling preparation is not possible at the same day the fish are caught, keep the fish cold in the refrigerator or frozen to the next day. The filleting may actually be easier when the surface layer of the muscle tissue is half frozen. This may also be the case for removal of the cod liver. We would anyway prefer that the preparations of samples are done the same day the fish are caught. The students can test the protocol by using some additional "test fish", but remember not to use the same scalpel handlers, scalpel blades, scissors and large forceps that are to be used for preparation of the 3 fillet or liver samples.

Cover all areas as cutting boards and balances with aluminum foil that will be in contact with the fish and change after each fish. If the samples are prepared of frozen or partially frozen fish, do the sampling quite fast and immediately transfer the packed and marked samples to the freezer (-20 °C) to avoid water and fat loss during potential melting.

Salmonids (salmon, trout, char)
Sample preparations of the salmonids should preferentially be performed out at the sampling site to avoid unnecessary transport that may contaminate the surface layer of the fillet. **Remember to measure the weight of the fish before cutting the fillets**. If transported to the school before sample preparation, cover a washed and clean stainless steel bucket or similar equipment with aluminum foil, wrap aluminum foil around each fish and put them into the bucket.

2.4 Cod or similar fish

Cod and similar lean fish where the internal organ liver is the representative sample, can be transported to the school for sample preparation without taking any strong precautions about contamination. Although, we will recommend that the fish are wrapped into aluminum foil before they are put into plastic bags or buckets for transportation.

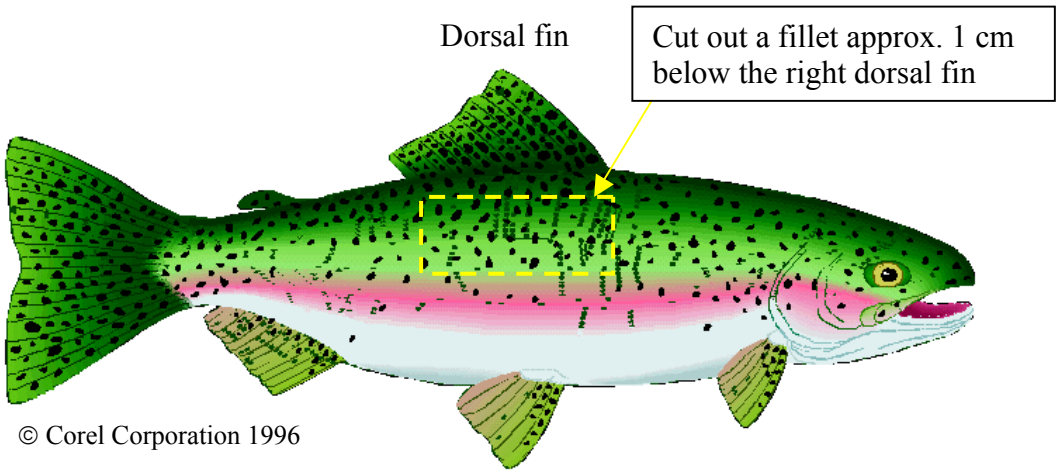
2.5 Procedure for sample preparation

DO NOT MIX THE EQUIPMENT FOR THE 3 FISH!

1. Measure **total body weight** of the fish before you do anything else. Use gloves. Avoid touching the fish where the fillet (muscle) of salmonids should be cut.

2. The **total length** (the distance from the most anterior part of the head to the tip of the longest caudal fin ray) of salmonids may be measured after filleting if contamination is potential. For cod, measure the total length before sampling the liver. Use squares, angle iron or similar equipment to be able to measure the total length correctly (see Appendix).

3. ***For salmonids***: cut a fillet (~ 100 g or more) beneath the right dorsal fin. If the fish is small, cut out fillets on both sides. Use one new scalpel blade and pair of forceps for each fish, and immediately transfer the sample to aluminum foil and close properly.



4. ***For cod***: Carefully cut the fish open with a **pair of scissors** up from the anus to the bottom of the jaw, taking care not to cut into the fish's internal organs. Also avoid cutting into the gall bladder nearby the liver. **Remove the liver** of each fish.
   Use the forceps to handle the liver for each fish, avoid touching the liver with the hands, and immediately transfer the sample to aluminum foil and close properly.

5. Put a **pencil written paper** with **ID, Name of School and Date** on top of the closed foil packed samples and wrap around more aluminum foil so the sample is fully covered. Write the ID, Name of School and Date on a ziplock plastic bag with a permanent pen before putting the foil packed sample into it. Carefully check that the sample is fully covered by foil and that nothing of the sample is in directly contact with the plastic. Close the plastic bag properly. Do this for each of the 3 samples. Put the samples immediately in the freezer. **The samples (3 fish fillets or 3 fish livers) should be kept frozen at –20^{o} C before sending. Do not forget to put the freezing elements into the freezer before or at the same time you freeze the samples.**

6. Open the fish with a pair of scissors, find the gonad if it is visible and measure the length of the gonad. If possible, measure the weight of the gonad. If the gonad is very small, this would require a fine (letter) balance. See Appendix for more information. Fill in the datasheet.

7. If possible, try to sample the otoliths. Wrap soft paper around them and put them into the scale envelope. If you cannot find the otoliths then sample fish scales, see appendix for preferred areas of salmonids. Scales should be sampled for pacific salmon. Put the scales in the same envelope as the otoliths. Write in the information on the scale envelope. The ID is the very most important parameter. Put the filled in datasheet and the fish scale envelope for each fish sample into a plastic bag and lock it.

2.6 Documentation

In general, it is desirable to have real hands-on documentation for practical projects like this you perform in the field and at school. Therefore, a pocket disposable camera will be sent together with the equipment for this purpose.

Following events should be taken pictures of:

- Sampling site
- During fishing (or of fishermen/women)
- Biological data – picture of the internal organs
  - Fish lying next to measuring tape
  - Fish during weighting
  - Cutting of fillet or liver
  - Dissection of head for otoliths
  - Length of gonad (gonads lying next to fish)
- Packing and marking samples

This will require approximately 12-14 pictures. The rest of the pictures on the film can be taken as the class/school choose, and a set of all pictures will be sent back to the schools after the film is developed.

2.7 Sending the fish samples

Put the 3 plastic bags with foil packed fish samples into the polystyrene box. Add cooling or freezing elements into this box to keep the samples at as low temperatures as possible during transport. If enough space in the box, put the 3 plastic bags with the datasheets and envelope on the top of the polystyrene box. Close the box with solid tape. If not enough space, put them into a large envelope. The box and eventually the large envelope are now ready to be picked up by courier service.

Sending by Courier

NILU is setting up courier service for this project and will provide information how this will going to be done at each school. The courier service will be prepaid and the courier agency will pick the polystyrene box at the school during opening hours and twill then ensure an express delivery directly the laboratory of NILU. All the details for this service will be available on the Internet web page for the project and also by e-mail.

2.8 Sending the equipment

Wash the 3 scalpel handlers, the 3 large pair of forceps, the small pair of forceps, the 3 pair of scissors, dry them and wrap some clothing or paper around to avoid sharp edges from the small pair of forceps, scissors etc. Pack it securely and put the equipment into some ordinary cardboard box and send it to NILU by mail.

Address: NILU, Norwegian Institute for Air Research
Polar Environmental Centre
Hjalmar Johansens gt. 14
NO-9296 Tromsø, NORWAY

Contact and questions:

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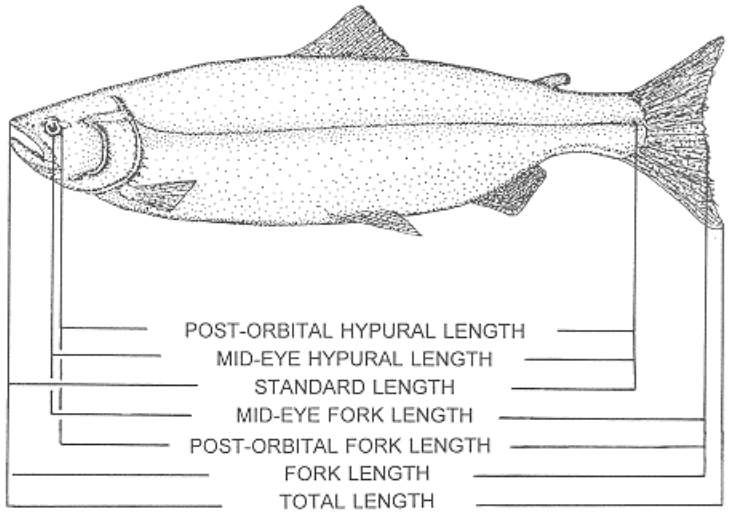
E-mail: Eldbjorg.Sofie.Heimstad@nilu.no

Appendix to Phase I

1 Length of fish

Source: Fisheries and Oceans Canada

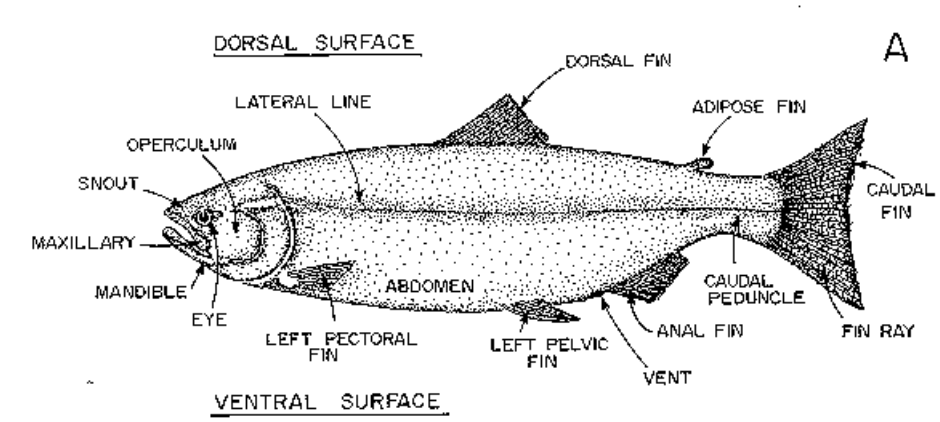
Measure the TOTAL LENGTH of the fish

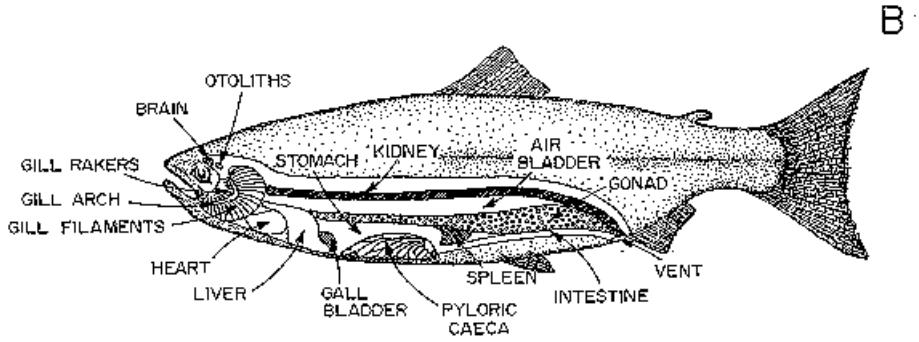


2 Anatomical Features of a Typical Salmonid

Source: Fisheries and Oceans Canada

Locate the liver, gonad and otoliths on figure B.





3 Additional fish data: Gonads, otoliths and scales

The removal of gonads and otoliths is done after you have sampled the fillet or liver. This part does not require sterile equipment since neither otoliths nor gonads are used in chemical analysis of organic pollutants. A knife may be better than a scalpel for the dissection of the fish head. Use the small forceps to remove the otoliths from the cranial grooves.

The gonad of female fish is the ovary (hard roe/spawn) and the testis (milt) of male fish. The maturation stage (length and weight of gonads) and age (otoliths, scales) will provide important information for use in scientific evaluation and comparison of POPs levels in fish. However, otoliths may be difficult to locate and to remove, and the gonad may be absent if the fish is very young. If the gonad is very small, a small letter balance may be necessary for determining the weight. The weight is therefore optional, but please measure the length with a ruler if the gonad is visible. The gonads for immature fish appear as thin ribbons of tissue only a few centimeters in length with almost no volume. As the fish grows and matures the gonads elongate and the testes and ovaries become easily distinguishable. The ovaries will have a granular appearance (developing eggs) in comparison to the testes, which will appear smooth and whiter in color than the ovaries. The ovaries eventually take on a red or light orange color while the testes will appear translucent to white. Use the Maturity figure in Appendix to estimate if the fish is immature, mature or spent and mark the sample datasheet with Mature, Immature or Spent, also use the code I-V if desirable. Shortly described; the fish is approximately mature if the ovaries or testis fill up more than the half of the body cavity.

3.1 Female/male

The sex can be easy to determine. Among most fish types the female fish has yellow or orange ovaries where one can find some eggs. The eggs can be just tiny small corns until 5 mm in diameter. The testicles of the male fish are usually less colorful and the content is more homogenous in structure. For younger fish where the gonads hardly can be seen, the sex does not matter.

For more detailed information on maturity, otoliths and scales:
Biological Sampling Manual for Salmonids, Chapter 2 - Biological Event Attributes
http://www.pac.dfo-mpo.gc.ca/ops/biosample/chapt_2/biologic/biologic.htm

If the school wants to do an age determination from otoliths, catch one additional fish for that purpose. A good idea is to take contact with a freshwater-/marine researcher if not the knowledge and equipment for age determination is present within the school. This is however an optional task since NILU will be responsible for the age determination.

4 Schematic outline of the maturity, trout (salmonids)

Use this figure to estimate the maturity of the fish.

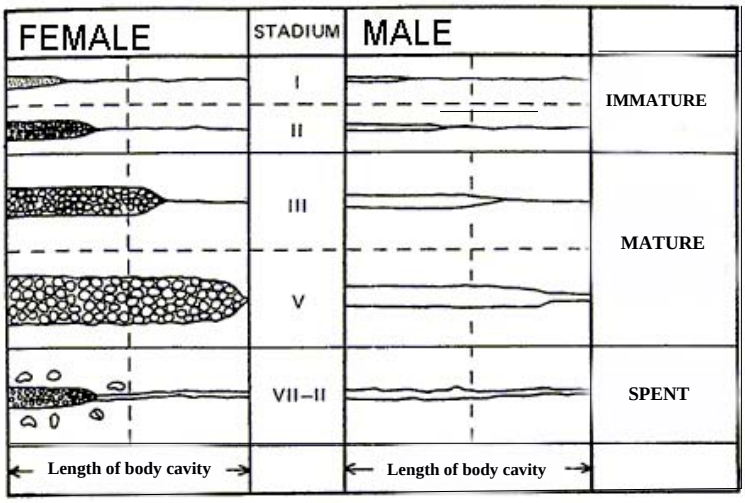
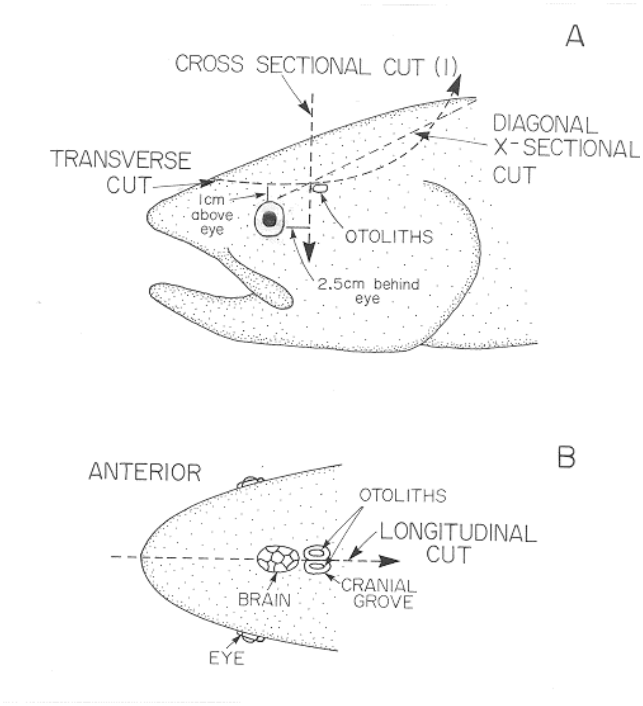


Figure adopted from
http://miljolare.uib.no/fagstoff/vann/artikler/kompendier/fiskekompendiet/kjonnsmodning.php

and translated into English

5 Otolith location and removal in salmon

Source: Fisheries and Oceans Canada
Otolith removal; **A)** the 3 common cuts used to remove the paired otoliths from the cranium; and, **B)** the otoliths are located in cranial grooves directly behind the brain.



There are many ways to remove a pair of otoliths. Here is one way:
See: http://www.mar.dfo-mpo.gc.ca/science/mfd/otolith/english/remove.htm

1) Use a knife with at least a 15-20 cm blade. It should be as sharp as possible. You'll also need a pair of forceps or tweezers about 10 cm long.

2) Grip the head of the fish by putting your thumb and forefinger in its eye sockets (it IS dead remember!). Lay the body of the fish on a counter with the tail pointing away from you.

3) Put the knife blade on the top of the fish's head about 1 eye diameter behind the eyes. Slant the blade AWAY from you, at about a 30° angle.

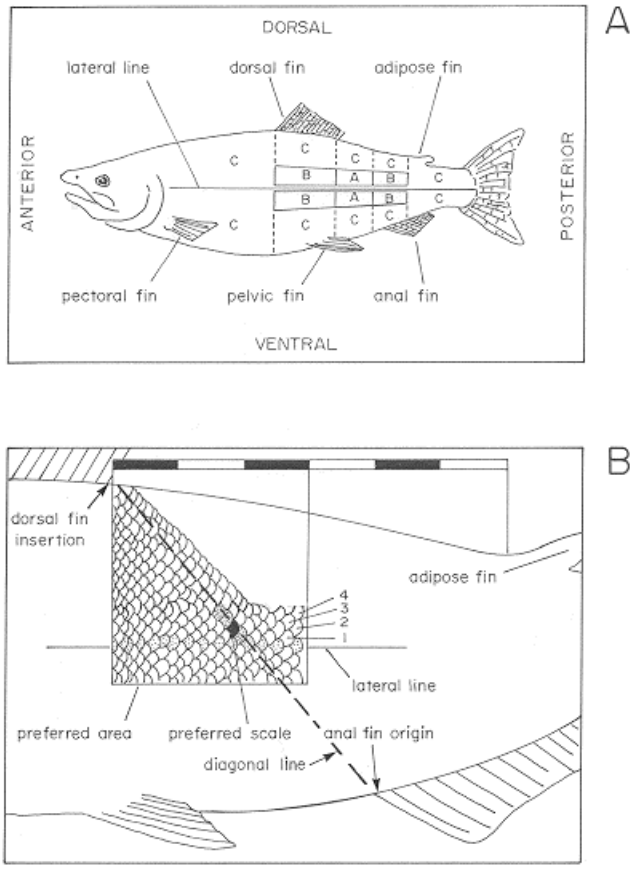
4) Slice back and down about one head length. You should feel the knife cut through the top of the skull. For flatfish and some other species, a vertical cut through the top of the skull directly over the preopercle (the curved line 3/4 of the way back on the gill flap) also works well.

5) Check to see if you've cut the top off the skull. If you haven't, make another slightly deeper cut. An ideal cut removes the top of the skull, revealing the full length of the soft white brain underneath. Note that the brain joins the much narrower (but still white) spinal cord at the rear. Once the brain is visible, expose the brain even more by pressing the nose and body down and towards each other. This should "snap" a portion of the skull, and push the brain and otoliths up. Very often, this exposes the otoliths and allows them to be removed immediately.

6 Preferred areas for scale removal for salmonids

Source: Fisheries and Oceans Canada

A) area A is the primary preferred area; area B is the second preferred area if no scales in area A; and, area C is the non-preferred area. B) Close up of the preferred area with the preferred scale in solid black. It is located 2 rows up from the lateral, on a diagonal from posterior the dorsal fin insertion to the origin of the anal fin.



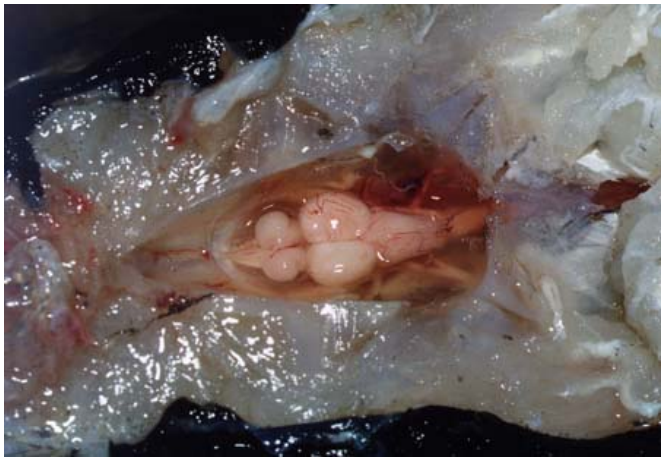
7 Dissection of cod head – location and removal of otoliths

1. The head is ready to be examined

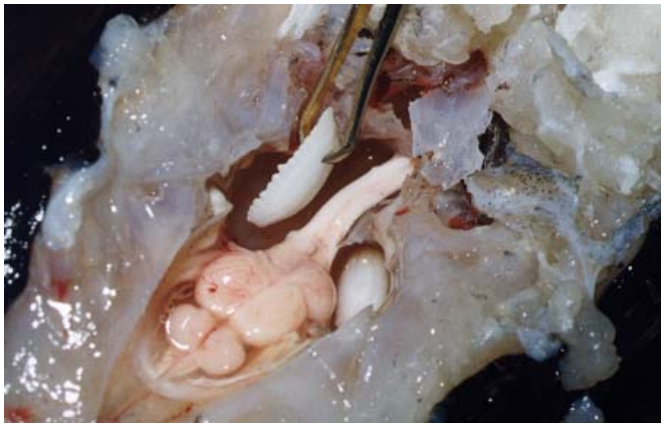
2. Cut thin slices of the forehead from the eyes and backwards

3. The first cut

4. After 2-3 thin slices one can see the brain



5. The brain with membranes and fluid



6. Otoliths are part of the fish vestibular apparatus and reside in the cranial cavity. They are composed of calcium carbonate and protein and are formed by the process of biomineralization. Otoliths function as sound receptors and are also used by the fish for balance and orientation.
Otoliths can provide useful information on age, growth rate, life history, recruitment, and taxonomy.

Adopted from http://www.miljolare.uib.no/fagstoff/vann/artikler/dyr/marint/torskehode.php (in Norwegian)

8 Learning activities

A. Fish and biology links

Links marked with stars are recommended

Biological Sampling Manual for Salmonids
Source: Fisheries and Oceans Canada
Chapter 1- Adult Species Identification
* http://www.pac.dfo-mpo.gc.ca/ops/biosample/chapt_1/chapt_1.htm
Chapter 2 - Biological Event Attributes
* http://www.pac.dfo-mpo.gc.ca/ops/biosample/chapt_2/biologic/biologic.htm
Color plates of different salmonids:
* http://www.pac.dfo-mpo.gc.ca/ops/biosample/chapt_1/chapt_1.htm
Useful figures:
* http://www.pac.dfo-mpo.gc.ca/ops/biosample/chapt.htm

Fish (good educational background and nice pictures):
* http://www.school.discovery.com/homeworkhelp/worldbook/atozscience/f/198340.html

External and internal anatomy of a salmon:
* http://www.state.ak.us/adfg/sportf/region2/ie/anatomy.pdf

FISH SAMPLING PROCEDURES:
* http://www.for.gov.bc.ca/ric/pubs/aquatic/fishcol/fish-3.htm#fish.3.3

Fishbase:
http://www.fishbase.org/home.htm

Fish links:
http://www.newberg.k12.or.us/ey/html/fishlinks.html

http://www.odysseyexpeditions.org/indexfh.asp

Classroom salmon dissection:
http://www.state.ak.us/adfg/sportf/region2/ie/dissectn.htm

Getting into a fish:
http://www.northcoast.com/~fishhelp/edu_f/dissect.html#external

Atlantic salmon:
http://www.asf.ca/Overall/atlsalm.html

Fish anatomy:
http://www.enchantedlearning.com/subjects/fish/printouts/Fishcoloring.shtml

Fish-age determination:
http://www.wh.whoi.edu/fbi/age-man.html

How should you clean and cook fish that might contain PCBs?:
http://sites.state.pa.us/PA_Exec/Fish_Boat/qpcb2000.htm

Links to marine biology:
http://www.meer.org/

General Biology links
http://education.zefex.com/biology2.htm
http://www.nsta.org/onlineresources/site/

The school page - The Educator's Resource:
http://www.theschoolpage.com/

A. POPs links

AMAP
http://www.amap.no
i) Click on: AMAP's Assessment , SOAER Text (HTML)
ii) Click on: Online documentation, AMAP Fact Sheets and AMAP/ACAP project reports

Bromine Science & Environmental Forum
http://www.bsef.com/

An introduction to brominated flame retardants
http://www.ebfrip.org/download/weeeqa.pdf

The PBDEs: An Emerging Environmental Challenge and Another Reason for Breast-Milk Monitoring Programs
http://ehpnet1.niehs.nih.gov/docs/2000/108p387-392hooper/hooper-full.html

Brominated flame retardants -endocrine disruption
http://website.lineone.net/~mwarhurst/bfr.html

Describing the Flows of Synthetic Musks and Brominated Flame Retardants in the Environment: A New Ecotoxicological Problem?
http://newstrategy.ecotox.lu.se/Publications/AtSIntrou.html

The Swedish National Chemical Inspectorate, "Phase out of PBDEs and PBBs", mars 99.
http://www.kemi.se/aktuellt/pressmedd/1999/flam_e.pdf

BRIEFING NOTE ON PERSISTENT ORGANIC POLLUTANTS (POPs)
http://irptc.unep.ch/pops/iccappops.html

The Arctic Council
http://www.arctic-council.org/index.asp

Contaminants in Alaska
http://www.state.ak.us/dec/deh/contaminants.htm

What is ecotoxicology?
http://www.pestmanagement.co.uk/special/ecotox/eco_int.html

Physical-chemical properties of POPs
http://www.es.lancs.ac.uk/kcjgroup/model.html#PCHTML

US EPA- Pollutants/Toxic
http://www.epa.gov/ebtpages/pollutants.html

The GLOBE Program
Arctic POPs

Protocol 1: PCBs and PBDEs in local fish

Phase II: Chemical analysis

1 Homogenization First the fish sample (min.5 g liver, 10-25 g muscle, depending on the lipid content) is cut into small pieces and mixed with sodium sulfate in a conventional food processor. This is to dry and to increase the surface area of the sample. The simple combination of sodium sulfates high capacity to bind water in combination with mechanic homogenization lead to the sample dryness as well as accessibility of the compounds for extraction.	
2 Extraction A part of the homogenized sample is added internal standard. An internal standard* is a compound that resembles the analytes as much as possible. It is used for quantification of the analytes, and then also for correction of losses during sample preparation. The fat is then extracted with an organic solvent, a mixture of cyclohexane and ethyl acetate. PCB and PBDE, along with all the other halogenated organic pollutants, are fat-soluble. *At NILU we use stable isotope labeled PCBs and pesticides in the preparation and quantification. That is: analyte and internal standard are the same but the carbon atoms in the internal standard are substituted with 13C carbon atoms.	

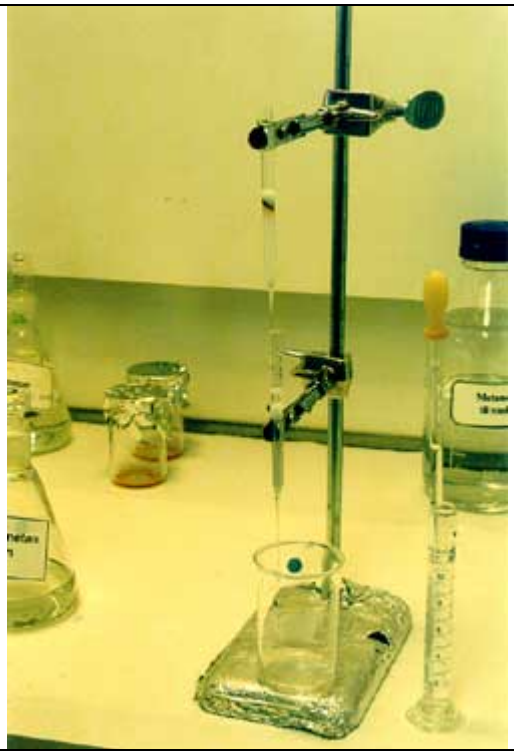
3 Fat removal

The sample extract has to be cleaned before it is possible to analyze it. The first step is to remove fat, without removing analytes. This is done by Gel Permeation Chromatography (GPC), a very common fat removal system. Chromatography means in this case separation. The sample is put onto a column, filled with a porous packing material (a polystyrene polymer), and pushed through the column by organic solvents. The different components of the sample are roughly separated according to molecular size, and fat comes out first.

4 Final cleanup

Biological materials contain fat, proteins, peptides etc, which disturb the analytical procedure. These substances must be removed before trace analysis takes place.

The final step, in the cleanup of the samples, is chromatography on a column system filled with aluminum oxide. The remaining compounds that could be a problem during analyses will be removed in this stage. Analytes are being pushed through the column with organic solvents



5 Volume reduction

The volume of this cleaned extract has to be reduced so that the concentrations of the analytes are high enough to be detected. A system that vaporizes and removes the organic solvents is used here. The analytes will not disappear in this case because their boiling points are much higher than the organic solvents. The samples are now ready for analysis, and are added a recovery standard. This standard is used for determination of the recovery of the internal standard, which was added before cleanup.

6 Analysis and quantification

The samples are then analyzed on a gas chromatograph coupled to a mass spectrometer. This is probably the most common system used for chemical analyses. The samples are quantified by comparing the areas under the peaks in the chromatograms of the samples and the standards.

After extraction a volume of about 150 mL is reduced to 0.5 mL there are several reduction steps during a sample preparation. Before quantification the extract (ca. 20 mL) is reduced again to 0.2 mL. In general the volume reduction during the sample preparation process is about **10 000 x**

The GLOBE Program
Arctic POPs

Protocol 1: PCBs and PBDEs in local fish

Phase III: Evaluation of analytical results

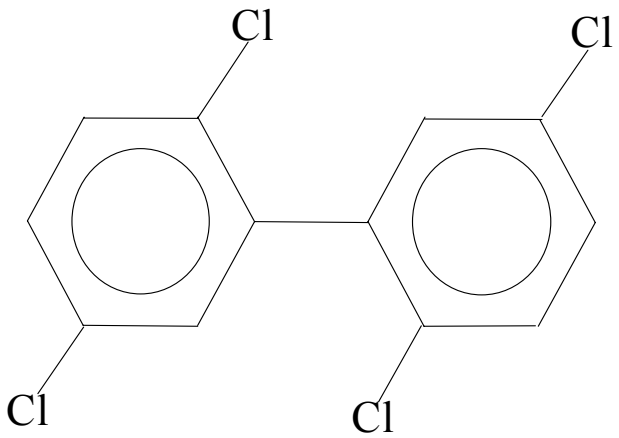
When phase II (Chemical Analysis) is done, the result for each sample will look like the pages attached. (Appendix 1 for the PCB isomers and appendix 2 for the Brominated flame-retardants). What we in this protocol is looking for is twofold:

1. The level of well-known POPs. PCBs which we know are distributed in the whole Arctic ecosystem
2. The level of "new" POPs. Brominated flame retardants, which we do not know if exist in the entire Arctic ecosystem, part of the ecosystem or not.

1 Compounds selected

Both of these compounds, PCBs and Brominated flame retardants, are not one specific type of chemical but group of chemicals with very similar chemical structure (for PCBs there are 209 different molecules (congeners).

Figure 1: Example of individual PCB:



The figure show 2,2`,5,5´-polychlorinatedbiphenyl called PCB 52.

2 Congeners to be measured

When one analyzes PCBs and Brominated flame-retardants as described in phase II chemical analysis, one is identifying and quantifying the individual congeners one by one and also given the sum of the quantities.

When PCBs and Brominated flame-retardants are discharged into the environment, the individual congeners have different fate. Some are more persistent than others, some more fat-soluble, some are more toxic or with different biological effects etc. The longer we are from the source of origin, the more "treated by natural processes" the compounds are. Over the years the scientific community have developed several standard PCB measuring options, and some other more specific for different areas/biota's. In this protocol we are to use a selected group of 7 PCB congeners which we know there are plenty of results for in the scientific literature and also are likely compounds to be found in reasonable quantities in the Arctic. These are:

PCB compounds selected:	
Structure	**IUPAC-no.***
2,4,4'-TriCB	28
2,2',5,5'-TetCB	52
2,2',4,5,5'-PenCB	101
2,3',4,4',5-PenCB	118
2,2',3,4,4',5'-HexCB	138
2,2',4,4',5,5'-HexCB	153
2,2',3,4,4',5,5'-HepCB	180

*IUPAC-no is a specific number given for easier identifications and communication internationally by the International Union of Pure and Applied Chemistry

For Brominated flame-retardants the knowledge of their fate in the environment and in particular in the Arctic is not very well known, one major reason for this protocol in the first phase. Here we have selected congeners from the PBDE group (polybrominated diphenyl ethers). They are the focus for concern for several reasons. The selected congeners are the ones produced in highest amount and most commonly found in environmental samples. We want to know if they are present in the Arctic in measurable quantities, where in the Arctic, and how they are distributed in the ecosystem. The levels can then be compared with levels found elsewhere.

PBDE compounds selected:	
Structure	**IUPAC-no.***
2,2',4,4'-TetBDE	47
2,2',4,4',5-PenBDE	99
2,2',4,4',6-PenBDE	100

*IUPAC-no is a specific number given for easier identifications and communication internationally by the International Union of Pure and Applied Chemistry,

3 Understanding the received result sheets

As can be seen from the attached sheets the results are given in a table and in a graph.

The first part is information on the sample itself, reference number, dates type of sample etc. Very important is the reference to the protocol data sheet "School sampling data sheet" which contains all the additional facts on the sample. For the evaluation the students are to use both the Analysis result sheets and the Sampling data sheet.

3.1 Reference facts:

School:	Name of school
Country:	Name of country where school is located
Sampling date:	Date of the samples was taken by the school
Type of sample:	Medium (water (salt or fresh), air, soil (type) etc) Species + organ if biological
Sample received at NILU:	Date when the sample was received
NILU sample number:	A reference ID given by NILU
Sample amount:	Amount of sample used by NILU
Concentration units:	Measurement unit used (see explanations to table)
Date of analysis:	Date when chemical analysis was completed
Data file:	Name of file in NILU archive

Table:

Compound structure		This is the official chemical name.
IUPAC no.		IUPAC-no is a specific number given for easier identifications and communication Internationally by IUPAC.
Concentration		This is the measured concentration of the individual compounds in the given concentration units. The compounds are given as either ppm, ppb, ppt levels or µg/g, ng/g, pg/g. for biological samples. Please see appendix 3 for details on this. Concentrations in biological samples can be either given as grams molecule/gram flesh or grams molecule/gram fat. Every organ in an animal contains fat. The POPs are stored in the fat. Let say we have 1 kg of liver and in this liver there are 100 gram of fat and in this fat there are 1 gram of PCBs in total. This can either be reported as 1 g/kg ww (meaning wet weight) or 10 g/kg of lipid (lw)
Recovery %		This is for information purposes only. The % recovery is how much of an added internal ^{13}C-standard is found in the end of the analytical phase. It tells how "difficult" the sample was to work with and the results are corrected for this recovery percentage.

4 Graph:

The graph is only a visualization of the data in the table for easier reading and comparison between different samples. The results entered in the table automatically create the table.

5 Evaluation of the results

NILU scientists will evaluate the results after the samples are analyzed. Based on this, NILU will post the result sheet on the web site for the respective school and give each school an evaluation task. These evaluations are to be written in the report in phase IV.

The details of the task for each school cannot be given before the results are available but it will follow a standard format where all schools should do some general evaluations.

Example of specific tasks school can be given:

PCBs

1. Look at your data sheets for PCBs and compare the levels with the previous years result of your school. Are the results from different compartments/animals different? Can you by studying relevant literature give an explanation for the different levels observed?

2. Look at all PCB data from fish samples for all the Arctic schools. The levels are different. Please discuss the possible reasons for this based on geographical distribution and different biology of the analyzed fish.

3. Look at the levels for PCBs in gull eggs you have found and compare this to scientific articles on PCB levels in gulls in your area if existing, and in Arctic in general. Also look for reported time trends and see where your result fit in.

PBDEs

1. In your data we did find all the PBDEs investigated. Find relevant scientific articles on PBDE levels and discuss if your levels are different from these reports, and try to discuss a reason for this difference.
2. In your data we did not find any PBDEs but in 3 of the other schools. Discuss how this can be the case by studying existing information on POPs distribution in the Arctic.

The GLOBE Program
Arctic POPs

Protocol 1: PCBs and PBDEs in local fish

Phase IV: Writing report

The background for writing the reports are the work done in phase I and III. The aim of this phase is to learn how to report properly as well as collecting the evaluations and lessons learned in order to improve the protocols as well as ensuring the scientific use of the evaluations.

1 Format of report

The reports are to be maximum 15 pages long, including pictures and figures. The report should be made in Microsoft Word.

The report should contain the following sections:

1. Preface
2. Content list
3. Summary (half page)
4. Report of sampling (Phase I)
    a. Description of how it was done (pictures can be included)
    b. What was good and what can be improved
5. Report on PCB/PBDE evaluation (Phase III)
    a. Description of tasks given
    b. How the task was solved
    c. Discussion
    d. Conclusion
    e. Reference list
6. OPTIONAL: Report on other teaching activities resulting from this protocol
7. Resources used (institutes, resources persons, web sites, agencies, NGOs etc)

2 How and when to submit the report

The report are to be sent on e-mail to esh@nilu.no within 8 weeks from when the results and evaluation task where given to each school.

Norwegian Institute for Air Research (NILU)
P.O. Box 100, N-2027 Kjeller, Norway

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	NILU PROJECT NO. O-100112
AUTHOR(S) Eldbjørg S. Heimstad and Dorte Herzke	CLASSIFICATION * B
	CONTRACT REF.

REPORT PREPARED FOR
GLOBE Arctic POPs

ABSTRACT

Results from a four year (2001-2004) project reveal that brominated flame retardants such as polybrominated diphenyl ethers are present in fish all over Arctic with a tendency of higher levels in European Arctic compared to American Arctic (Alaska and Canada). This science based learning educational project involved 15 GLOBE schools from 7 countries in Arctic; Alaska, Canada, Finland, Iceland, Norway, Russia and Sweden. Based on a written "hands-on" fish protocol made by NILU, the involved school sampled two or three parallels during fall 2001, spring 2001, fall 2002 and fall 2003. NILU analysed two samples for each school each sampling period, a total of 47 samples of Atlantic cod, Pacific cod and haddock livers, 14 samples burbot liver, 5 samples of whitefish liver, 6 whitefish fillets, and 18 samples of Arctic char, Atlantic and Pacific salmon and Brown trout fillets. Reported data of PCB153, BDE47 and BDE99 are given with a comparison to other international data. Appendix with sampling protocol and additional useful Internet links for different themes such as transport and effects of POPs, food advisories, fish species and sampling is attached.

NORWEGIAN TITLE

Arctic POPs

KEYWORDS		
Brominated flame retardants	Arctic	

ABSTRACT (in Norwegian)

Resultater fra et 4 års (2001-2004) prosjekt viser at bromerte flammehemmere som polybromerte difenyletere er funnet i store deler av Arktis, med en tendens av høyere nivåer i europeiske nordområder sammenlignet med amerikanske (Alaska og Canada). I dette forskningsbaserte læringsprosjektet deltok 15 GLOBE skoler fra 7 land i Arktis: Alaska, Canada, Finland, Island, Norge, Russland og Sverige. Skolene gjorde vitenskapelig korrekt prøvetaking av fisk basert på en protokoll utarbeidet av NILU. NILU analyserte 2 fiskeprøver per skole som ga totalt 47 leverprøver av torsk og hyse, 14 prøver av lakelever, 5 leverprøver fra sik, 6 filéter fra sik og 18 filétprøver fra laks, røye og ørret. Konsentrasjonsdata av PCB153, BDE47 og BDE99 er rapportert. Sammenligning til andre nasjonale og internasjonale rapporterte konsentrasjoner er også foretatt. Appendiks er vedlagt med prøvetakings-protokoll og nyttige web linker som omhandler fiskearter og prøvetaking, Arktis, miljøgifttransport og effekter samt kostholdsråd.

** Classification* *A* *Unclassified (can be ordered from NILU)*
B *Restricted distribution*
C *Classified (not to be distributed)*