Statlig program for forurensningsovervåking

sft:

MAPPING SELECTED ORGANIC CONTAMINANTS IN THE BARENTS SEA 2007.

1021

2008

Akvaplan niva

NIFES NATIONAL INSTITUTE OF NUTRITION AND SEAFOOD RESEARCH

NILU

NIVA Norwegian Institute for Water Research

NORSK·POLARINSTITUTT

Norwegian Pollution Control Authority

SPFO-report: 1021/2008
TA-2400/2008
ISBN 978-82-577-5324-5

Client: Norwegian Pollution Control Authority (SFT)
Contractor: Norwegian Institute for Water Research

: Mapping selected organic contaminants in the Barents Sea 2007.

Report
1021/2008

Authors: Torgeir Bakke (NIVA), Stepan Boitsov (HI), Einar M. Brevik (NIVA), Geir Wing Gabrielsen (NP), Norman Green (NIVA), Lisa B. Helgason (NP), Jarle Klungsøyr (HI), Henriette Leknes (NILU), Cecilie Miljeteig (NP), Amund Måge (NIFES), Britt E Rolfsnes (NIFES), Tatiana Savinova (Akvaplan-niva), Martin Schlabach (NILU), Bent B Skaare (NIVA), Stig Valdersnes (NIFES)

NIVA Project no.: O-28054
NIVA Report no.: 5589-2008

Preface

The present document is a compiled report of the results from five projects on analysis of selected contaminants of concern in various types of samples from the Barents Sea region. Selection of sample types and pollutants has been done by SFT in cooperation with the responsible institutions, and on basis of recommendations given in the Norwegian Governmental White Paper No. 8, 2005-2006: "*Integrated Management of the Marine Environment of the Barents Sea and the Sea Areas off the Lofoten Islands*".

The report covers the following 5 projects.

Akvaplan-niva: *Contaminants in sediments in the Barents Sea*, covering chlorinated paraffins, alkylphenols, pentachlorophenol, cationic detergents, PCBs, trace metals, brominated flame retardants (PBDE, HBCDD, TBBPA), Bisphenol A, , DEHP, PCDD/PCDF, trichlorbenzene, HCB, musk xylene and musk ketone, siloksaner, PFCs, PAHs, and TBT in samples from the Russian Barents Sea and Pechora Sea.

HI and NILU: *Contaminants in sediments in the Barents Sea- Mareano*, covering the same compounds except trace metals and PAHs, and including DDT, toxaphene, chlordane, and HCH in samples from the Tromsøflaket region.

NIFES: *Contaminants in shrimp, capelin and polar cod*, covering PFCs, brominated flame retardants, toxaphene, and HCH. (polar cod samples could not be obtained for the project and hence stronger emphasis was put on shrimp and capelin).

NIVA: *Contaminants in cod and blue mussel*, covering PFCs, brominated flame retardants, toxaphene, chlordane, and PAHs.

NP: *Contaminants in Brünnich's guillemot*, covering PFCs, brominated flame retardants, PCBs (including dioxin-like), DDT, HCB , HCH, TBT, THC, chlordanes, toxaphenes, PAHs, a selection of trace elements, and stable isotopes of C and N.

Thanks are due to all who have participated in this project and especially to:

Akvaplan-niva AS:
Data analysis and reporting: Tatiana Savinova, Vladimir Savinov

All-Russia Research Institute for Geology and Mineral Resources of the World Ocean:
Sediment sampling, grain size measurements: Boris Vanshtein

Centre for Environmental Chemistry SPA "Typhoon", Obninsk, Russia:
Contaminant analysis: Lyudmila Alexeeva, Alexander Kochetkov, Dmitry Samsonov, Elena Pasynkova,

Institute of Marine Research (HI):
Sediment sampling and sample preparation: Grethe Tveit, Guri Nesje, Kjell Westrheim, Stepan Boitsov
Project coordinators: Stepan Boitsov, Jarle Klungsøyr.

Swedish Environmental Research Institute (IVL):
PFR analysis: Mikael Remberger

National Institute of Nutrition and Seafood Research (NIFES):
Sample preparation: Elin Kronstad
LC/MS-MS: Stig Valdersnes, Merat Behzadzadeh
GC/MS: Brit Elin Rolfsnes
Project coordinators: Amund Måge, Sylvia Frantzen

Norwegian Institute for Air Research (NILU):
Sample preparation: Inger-Christin Bråten, Iren Sturtzel, Javier Alarcon, Gerd Staff Knutsen
LC/MS: Christian Dye, Morten K. Moe, Henriette Leknes
GC/MS: Hans Gundersen, Anders Borgen, Mebrat Ghebremeskel
NILU Coordinators: Henriette Leknes, Martin Schlabach

Norwegian Institute for Water Research (NIVA):
Sampling and sample preparation: Merete Schøyen
Data analysis and reporting: Norman Green, Ling Shi,
Treatment of background information: Bent B. Skaare, Einar Brevik
Contaminant analysis: Olav Bøyum, Alfhild Kringstad
Project coordination: Norman Green
Final report production and coordination: Torgeir Bakke

Norwegian Polar Institue (NP):
Sampling: Geir Wing Gabrielsen, Hallvard Strøm
Data analysis and reporting: Lisa Bjørnsdatter Helgason, Cecilie Miljeteig,
Project coordination: Geir Wing Gabrielsen

Project coordinator at the Norwegian State Pollution Control Authority (SFT) has been Christine Daae Olseng.

NIVA, Oslo, 22. April 2008

Torgeir Bakke
Senior Research Scientist, Report Coordinator

Content

1. Summary

Purpose
The purpose of the present report is to present and discuss the results from five projects completed in 2007/2008 and dealing with analysis of selected contaminants in various sample types from the Barents Sea region. The contaminants are listed as being of particular environmental concern in Appendix 3, Figure 3.1. of the Governmental White Paper (Stortingsmelding) No 8, 2005-2206 " Integrated Management of the Marine Environment of the Barents Sea and the Sea Areas off the Lofoten Islands".

Samples and stations
The program includes one surface (0-1 or 0-3 cm) sediment sample from each of 11 stations taken in 2006/2007, one pooled sample of boiled shrimp tails from each of 5 stations sampled 2007, one pooled sample of 25 whole capelins from each of 5 stations sampled in 2007, one pooled sample of soft tissue from 60-300 blue mussels from each of 12 stations sampled in 1994 and 2006, 10-25 individual samples of cod liver from each of 4 stations sampled in 1994/1995 and 2005/2006, and 5 individual samples of Brünnich's guillemot eggs from each of 2 stations sampled in 1993, 2002, 2003, and 2007.

Analytical programme and laboratories
The analytical programme covered chlorinated paraffins, alkyl phenols and alkyl phenol etoxilates, pentachlorophenol, tensides, polyfluorinated organic compounds (PFC), polybrominated diphenylethers (PBDE), hexabromocyclododecane (HBCDD), tetrabromobisphenol A, bisphenol A, synthetic musk compounds, siloxanes, phosphorus flame retardants, diethylhexylphtalate, dioxins and furans, PCBs, organohalogens, biocides (toxaphenes, DDT, chlordanes, HCH, TBT), PAHs, trace metals and stable isotopes of C and N. The analytical programme varied with type of sample. For each compound and compound group an account of general structure, use, discharges, environmental distribution, effects, and remedial actions is given.

The chemical analyses were performed by a large number of laboratories: NIFES, NILU, NIVA, Unilab AS, Centre for Environmental Chemistry SPA "Typhoon", Obninsk, Russia, Analytical Environmental Chemistry Unit at the Stockholm University, Laboratory of Environmental Toxicology at the Norwegian School of Veterinary Science (NVH), Department of Chemistry, Norwegian University of Science and Technology (NTNU), Institute for Energy Technology (IFE), and the Swedish Environmental Research Institute (IVL).

Results and discussion
The results and conclusions are outlined below. An attempt to assess the results relative to previous relevant information from Norway and the Arctic region is made with emphasis on how the levels relate to known background concentrations and to limits of environmental effects. The main sources for comparison have been the contaminant assessments produced by AMAP in 1998 and 2002, the annual screening surveys for new contaminants made by SFT for 2004, 2006 and 2007, as well as the revised Norwegian classification system for contaminants in marine sediments. The latter presents chronic PNEC levels for a range of the compounds in the present survey, and comparison with these are made.

Short (SCCP) and medium (MCCP) chain chlorinated paraffins.

The chlorinated paraffins were only analysed in the sediment samples. There is strong indication of long range air transport of MCCP to the Arctic, still all levels in the present survey were below the LoD.The highest SCCP-level, 92 µg/kg d.w. Compared to levels in uncontaminated Alaskan lakes and Norwegian coastal sediment the present levels are above what should be expected as background for open sea sediments. They are still far less than the chronic PNEC for SCCP of 1000 µg/kg, and should not cause environmental concern.

Alkyl phenols and AP etoxilates (APEs)

AP and APE were only analysed in the sediment samples. None of the sediment samples had levels of alkyl phenols above the detection limit (LoD) which was lower than the chronic PNEC. APEs could be quantified but an overall geographical trend in was not found. Comparisons indicate that the AP levels found may represent background. The APE levels found seem slightly elevated compared to North Sea sediments, and they should therefore be monitored further.

Tensides

Tensides were only analysed in the sediment samples. Only DSDMAC could be quantified and had levels in the range <0,1 to 7,3 µg/kg d.w. No geographical trend was seen. No other data have been found to compare the DSDMAC levels with and background levels cannot be assessed.

Polyfluorinated compounds (PFCs)

Sediment

Only PFOS was above the LoD. The levels were similar to what has been found in sediments around offshore installations at Haltenbanken, but less than in coastal sediments. The PFOS levels found may at present be regarded as background concentrations. In comparison to the chronic PNEC for PFOS the environmental risk from the present Barents Sea sediment PFCs should be insignificant.

Shrimp

Highest sum PFCs was found at the two western stations suggesting an input via the coastal current. No comparable data for PFCs in shrimp has been found, but comparison with other invertebrates indicates that the shrimp may have elevated PFOS.

Capelin

The levels of sum PFCs were fairly equal to the cod liver concentrations in the present survey, but higher than in cod fillet from Kristiansandsfjorden. Since whole capelin levels were similar to liver levels from other Barents Sea fish species, it might suggest that capelin accumulate PFCs more strongly. Comparison with any known background was not possible.

Cod

Only 2 stations were covered, Varangerfjorden and Lofoten. Only PFOS could be quantified and only in samples from Lofoten. The levels here were equal to levels from outer Bømlo in 2007 and from Lofoten in 2006 and far less than in cod liver from the inner Oslofjord. The pattern suggest that coastal cod from the Barents Sea region have PFOS levels similar to cod from diffusely contaminated coastal areas elsewhere in Norway and in other Nordic countries. This probably represents background levels for PFOS in coastal regions.

Guillemot

The levels of PFOS were equal to or lower than in eggs from other arctic seabirds, and much lower than that reported in liver of seabirds from industrialised regions. No temporal or spatial trend was found. The levels were highest at Bjørnøya.

Overall assessment on the PFCs, mainly PFOS

Variation of PFOS levels among the species was small, but a slightly higher range was seen in the guillemot eggs than in the other tissues. In sediments, cod and guillemot eggs PFOS seemed to be on the lower side of previous comparable recordings. Shrimp tails and whole capelin had PFOS levels equal to cod liver. The latter was at level with earlier results from coastal cod, but far less than in cod liver from inner Oslofjord. For the moment one may assume that the lowest concentrations in the range for shrimp and fish represent background.

Polybrominated diphenyl ethers

Sediment

Sums of all PBDEs were in the range 1,5 - 1149,4 ng/kg d.w. These levels were 200-400 times lower than found earlier in sediments from the PBDE polluted Åsefjorden at Ålesund. Levels of BDE-47 were similar to Norwegian coastal sediments and far less than in the Drammensfjord. This suggests that the present levels may represent background, but comparable Arctic information is scanty. The penta-BDE levels were 620 times less than the chronic PNEC level and should represent an insignificant environmental risk. A clear difference in PBDE profile between the Tromsøflaket stations to the west and the Russian stations to the east suggests either analytical differences between the two laboratories involved or that the two regions may be influenced by different sources.

Blue mussel

Highest sum $PBDE_7$ was found at Skrova harbour in 1994. As a whole the results suggest that PBDE was at background for clean coastal areas, except for blue mussel from Skrova harbour that in 1994 appeared to be contaminated.

Shrimp

The Barents Sea shrimp samples had much lower concentrations of BDE-47 and sum $PBDE_7$ than earlier found in shrimps from the North Sea and the Skagerrak, and in cod fillet from Greenland. The levels may represent background, but the basis for stating this is too low.

Capelin

The levels of sum $PBDE_7$ in capelin were similar to what has earlier been found in fillets of plaice and lower than earlier found in fillets of redfish, but higher than earlier found in fillets of cod and saithe. The geographical pattern of the present results suggested a greater influence from pollution closer to the coast and in the western part of the Barents Sea than in the open sea areas to the north and east. It is still uncertain if the levels found represent background.

Cod

Sum $PBDE_7$ decreased at all stations from 1994 to 2005/2006, by an average of 63 %. The 2005/2006 levels in the present survey are at the lower side of the range found earlier in cod liver from open Norwegian coastal areas, Greenland and the North Sea, suggesting that the contamination level is low and could represents background conditions.

Guillemot

Average sums of all PBDEs were lower than that reported earlier for peregrine falcon eggs from Norway, South Greenland, and Sweden, and lower than in other studies of eggs from arctic seabird. The concentrations were lower in 2007 than in 1993, 2002 and 2003, but no spatial trend was apparent. A predominance of BDE-47 was found, which seems typical for seabird eggs.

Overall assessment of the PBDEs

Cod liver had PBDE levels around 2-3 orders of magnitude higher than in the other species. Lowest levels were found in shrimp tails, whereas mussels and capelin were about 10 times higher than in shrimp. Comparison with other studies still suggested that cod liver PBDEs were at background, whereas there is not enough information to assess this for the other species. A rough normalisation of the BDE-47 levels to typical lipid levels found elsewhere for these types of tissues suggested that the lowest lipid normalised BDE-47 occurred in shrimp and capelin. Blue mussel and guillemot eggs were 5-10 times higher and cod liver about 50 times higher than these.

Other bromoorganic flame retardants: HBCDD and TBBPA

Sediment

TBBPA was not above the LoD in any of the samples. For HBCDD only small differences were found among the samples. The chronic PNEC levels show that neither TBBPA nor HBCDD in the Barents Sea sediments represent an environmental risk.

Shrimp and capelin

TBBPA was not analysed. None of the samples had HBCDD levels above the LoD. A basis for assessing the adequacy of the LoDs is lacking.

Guillemot eggs

The total sum HBCDD was lower than in eggs from other Arctic seabird, but the basis for assessing if the present levels represent background or not is lacking. The levels were lower in 2007 than in 2002/2003. No spatial trend was found.

Bisphenol A

Bisphenol A was only analysed in the sediment samples. The BPA concentrations varied from 2,3 to 10,2 µg/kg d.w., highest at Tromsøflaket. Comparison with presumably uncontaminated sites and harbour sediments suggests that they may represent background Also comparison with the chronic PNEC for BPA suggests that the risk from the present sediment levels is acceptable.

Synthetic musk compounds

Synthetic musk compounds were only analysed in the sediment samples. The musk ketones were below the LoD. The levels of musk xylenes did not differ to any extent among the samples and were similar to Nordic arctic lake levels. No geographical trend could be seen.

Siloxanes

Siloxanes were only analysed in the sediment samples. The levels of D5-siloxane was clearly less than found in sediments from the inner Oslofjord, Stockholm harbour, and Helsinki harbour, but whether they represent background for open sea areas or not cannot be assessed.

Phosphorous flame retardants

PFRs were only analysed in the sediment samples. None of the samples had levels above the LoDs. Comparing these LoDs with coastal sediment levels elsewhere in Norway and from Japan suggests that the levels for TCEP and TCDP were low. The LoDs have, however, to be lowered if one shall determine real background concentrations.

DEHP

DEHP was only analysed in the sediment samples. The highest level, 57 mg/kg d.w at Tromsøflaket, was surprisingly 2-3 orders of magnitude higher than in sediments from contaminated fjords such as inner Oslofjord, Frierfjorden, and Kristiansandsfjorden. This is unlikely and the only plausible explanation is that secondary contamination has occurred. The results are deemed inconclusive and new analyses should be made.

Dioxins and furans

Doxins were only analysed in the sediment samples. The level was lowest at one of the open ocean stations and highest at the inshore station in Stjernøysund. PCDFs dominated over PCDDs as has been found in other Arctic sediments and in the contaminated Grenlandsfjords. The present levels correspond to the range given by AMAP (1998) for sum PCDD/PCDF and for TCDD alone in other Arctic sediments and less than TCDD levels in the North Sea suggesting that they may represent background. Also the chronic PNEC for sumPCDD/PCDF suggests that none of the present sediment levels pose any environmental risk.

PCB

Sediment

The congeners analysed differed between the Mareano (Tromsøflaket) and the Akvaplan-niva samples (the Russian Barents and Pechora Sea). The two data sets are therefore only weakly comparable, and one cannot conclude if the differences seen between the two groups of samples are real or not. Sum PCB_7 could only be determined in the samples from Tromsøflaket, and was at level with background concentrations of sum PCBs in other arctic sediments reported by AMAP. The chronic PNEC of sum PCB_7 suggests that the PCB levels in the present sediments are very low and represent background

Guillemot

The highest sum of all PCBs analysed was found in eggs from Kongsfjord 1993. The levels were within the range found earlier in other Arctic seabird eggs. A decrease in PCB concentrations from 2002/2003 to 2007 in the present survey also followed the trend seen for other seabird eggs.

Organohalogens

Sediment

PCP was below the LoD in all samples. The PeCB and sum TCB levels were similar to what has been found earlier in Norwegian coastal and fjord sediments. Both these and HCBD were safely below the chronic PNECs given in the sediment classification system. HCB was only found in 3 samples spread unsystematically all over the eastern Barents and Pechora Seas. The levels corresponded to background levels for HCB reported by AMAP. In general the organohalogen levels in the sediments should not represent an environmental risk.

Guillemot

The lipid normalised HCB levels found in the guillemot eggs were equal to or somewhat lower than found earlier in other Arctic seabird eggs. There were no spatial or temporal trends in HCB concentrations.

Biocides

Sediment

Analysis was only done on the Tromsøflaket samples. Toxaphenes were below the LoD in all samples and deemed to represent background. Sum HCHs and DDT were highest at Stjernøysundet, the only nearshore station. According to PNEC values neither HCH nor DDT should represent any environmental risk and are judged to be at background. Corresponding limits for chlordanes have not been developed.

Shrimp

Highest toxaphene concentration was found in shrimp from the open sea south-east of Spitsbergen. When compared to the range in toxaphenes reported by AMAP for arctic marine invertebrates in general, the shrimp levels must be considered to be very low.

Capelin

Highest toxaphene concentration, found in capelin caught outside Troms, was similar to levels reported by AMAP for whole polar cod from Lancaster Sound, Canada, but far less than reported for turbot from Baffin Island, Canada.

Cod

Toxaphene and chlordane were analysed in liver samples from 2 coastal stations. Highest levels were found in Varangerfjorden for both biocides. Similar level of toxaphenes has been reported by AMAP in liver of turbot from Baffin Island, Canada. We have found no comparable data on chlordanes.

Guillemot

The levels of HCH, chlordanes, toxaphenes, DDTs and Mirex were similar to or lower than found earlier in other Arctic seabird eggs. The levels of sum HCHs, sum chlordanes, Mirex, p,p'-DDE, p,p'-DDT and sum toxaphenes were all lower in 2007 than in 2002/2003, which corresponds with a trend seen in seabird from northern Norway as well.

Overall assessment of biocides

The only biocide analysed in all media was toxaphene. Toxaphene levels in cod liver were about one order of magnitude higher than in whole capelin, which again were about one order of magnitude higher than in shrimp tails. These differences are probably linked to differences in lipid content in these types of samples, and do not necessarily suggest differences in exposure to toxaphenes. An attempt to normalise against typical lipid levels for these types of tissues suggests equal levels of toxaphenes per lipid unit in shrimp tails, whole capelin and guillemot eggs, and 2-3 times higher in cod liver.

PAH

Sediment

The sum PAH_{16} was within the background levels for Norwegian coastal regions and far below the chronic PNEC. The PAHs in these sediments do therefore not represent an environmental risk.

Blue mussel

The highest level of sum PAH_{16} was found at in mussels taken close to the city of Honningsvåg. These mussels were classified as moderately polluted (SFT Class II). The other samples were at background (SFT Class I).

Guillemot

Sum of all PAHs ranged from 0,2 to 7,5 ng/g. Naphtalene was the prevailing compound. The levels of naphtalene were generally lower in 2007 than in 2002/2003. No other corresponding analyses of PAHs in Arctic seabird eggs have been found.

Trace metals

Sediment

Trace metals were only analysed in the Russian Barents and Pechora Sea samples. Cu, Cd, Pb, and Hg levels were all at background for Norwegian coastal areas and far below their chronic PNECs. Cr was just at the border of background, but still well below the chronic PNEC value. Arsenic exceeded the coastal background range at 2 of the stations, and exceeded the chronic PNEC of 52 mg/kg d.w. in the sample from the Shtokman region station. However, elevated natural levels of As have been reported earlier in sediments from the eastern Barents Sea. The Ba levels were slightly higher than found e.g. in sediments around the Snøhetta offshore field at Tromsøflaket. No geographical trends in trace metal distribution were seen.

Guillemot

Hg in eggs from Kongsfjord was higher than in eggs from Bear Island, and highest in 2002 at both sites. The Hg levels were still lower than found earlier in arctic seabird eggs from Canada. The other metals were found at similar or lower levels than found earlier in other arctic seabirds and seabird eggs.

Organotin compounds, primarily TBT

Sediment

Organotin compounds were only analysed in the Russian Barents and Pechora Sea samples. All levels were below the LoD. TBT was close to background for coastal sediments and should not represent an environmental risk.

Guillemot

TBT was not found above the detection limit in any samples.

Stable carbon and nitrogen isotopes

Guillemot

Levels of $\delta^{13}C$ and $\delta^{15}N$ varied little among the samples. There was no statistical significant relationship between $\delta^{13}C$ and any of the contaminants. A significant relationships was, however, found between $\delta^{15}N$ and HBCDD, sum toxaphenes, sum HCH, sum chlordanes, Mirex, p,p-DDE, p,p-DDT, tetra- to nonaPCBs, sumPCBs and sum PCB_{MO}. This confounds the interpretation of the temporal trends.

Overall status for various media.

In the sediments the SCCP levels were above what should be expected as background. APE levels were also elevated relative to North Sea levels and should be monitored further. For tensides, siloxanes, and chlordanes the levels relative to background cannot be assessed. The DEHP results are deemed inconclusive and new analyses should be made. For all the other contaminants the sediment levels were at assumed background. PAH in blue mussel were at background except outside Honningsvåg. Also present levels of PBDE were at assumed background. In shrimp and whole capelin the lowest levels of PFOS represented background. The other contaminants analysed were also at assumed background. Toxaphene in cod liver was at level with other Arctic fish, but status with respect to background cannot be assessed. The other contaminants analysed in cod liver were at assumed background. In Brünnich's guillemot eggs all contaminants were within the range found earlier in other Arctic seabird eggs, some at the low side of this range. Basis for assessing levels relative to background is lacking. For most contaminants a decrease with time was observed. TBT in eggs was not above the detection limit.

2. Sammendrag

Tittel:	Kartlegging av utvalgte organiske miljøgifter fra Barentshavet 2007.
År:	2008
Forfattere:	Torgeir Bakke, Stepan Boitsov, Einar M. Brevik, Geir Wing Gabrielsen, Norman Green, Lisa B. Helgason, Jarle Klungsøyr, Henriette Leknes, Cecilie Miljeteig, Amund Måge, Britt E Rolfsnes, Tatiana Savinova, Martin Schlabach, Bent B Skaare, Stig Valdersnes
Kilde:	Norsk institutt for vannforskning, Rapport nr 5589-2008, SFT TA-2400/2008, SPFO-rapport nr 1021/2008, ISBN 978-82-577-5324-5

Målsetning

Rapportens målsetning er å presentere og diskutere resultatene fra fem prosjekter utført i 2007/2008 som omfattet analyse av utvalgte miljøgifter i prøver fra Barentshav-regionen. Dette er miljøgifter spesielt i fokus i Vedlegg 3, figur 3.1 i Stortingsmelding nr 8, 2005-2006: ”Helhetlig forvaltning av det marine miljø i Barentshavet og havområdene utenfor Lofoten (forvaltningsplan)”.

Prøver og stasjoner

Programmet omfatter en prøve av øvre del av bunnsedimentet (0-1 eller 0-3 cm sjikt) på 11 stasjoner samlet i 2006/2007, en blandprøve av rekehaler samlet i 2007 fra hver av 5 stasjoner, en blandprøve av lodde (hel fisk) samlet i 2007 fra hver av 5 stasjoner, en blandprøve av bløtdelene fra 60-300 blåskjell samlet i 1994 og 2007 fra 12 stasjoner, 10-25 individuelle leverprøver av torsk samlet i 1994/1995 og 2005/2006 fra 4 stasjoner og en prøve a 5 egg av polarlomvi samlet i 1993, 2002, 2003 og 2007 fra to stasjoner.

Analyseprogram og laboratorier

De kjemiske analysene dekker klorerte parafiner, alkylfenoler, alkylfenol-etoksilater, pentaklorfenol, tensider, polyfluorerte organiske stoffer (PFC), bromerte difenyletere (PBDE), heksabromsyklododekan (HBCDD), tetrabrombisfenol A, bisfenol A, syntetiske muskstoffer, siloksan, fosforerte flammehemmere, dietylheksylftalat (DEHP), dioksiner og furaner, PCB, organoklorforbindelser, plantevernmidler (toxafen, klordan, HCH) timmorganiske forbindelser, PAH, spormetaller og stabile isotoper av karbon og nitrogen. Analyseprogrammet varierte noe mellom prøvetypene. For hvert stoff eller stoffgruppe gir rapporten også en kort beskrivelse av kjemisk oppbygging, bruk, utslipp, fordeling i miljøet, effekter og planlagte/gjennomførte tiltak.

De kjemiske analysene ble utført av en rekke laboratorier: NIFES, NILU, NIVA, Unilab AS, Centre for Environmental Chemistry SPA “Typhoon”, Obninsk, Russland, Miljøkjemisk analyseenhet ved Stockholm Universitet, NVH, Kjemisk institutt NTNU, IFE og IVL, Sverige.

Resultater og diskusjon

Analyseresultater og diskusjonen av disse er sammenfattet nedenfor. Resultatene er sammenliknet med tidligere relevant informasjon fra norsk arktisk region, med fokus på hvordan de funne miljøgiftnivåene er i forhold til bakgrunnsnivå og grenser for miljøvirkninger. Hovedkilden til informasjon å sammenlikne med er sammenfatninger produsert av AMAP, SFTs årlige screening-undersøkelser av nye miljøgifter for 2004, 2006 og 2007, samt det reviderte norske klassifiseringssystemet for miljøgifter i marine sedimenter.

Sistnevnte angir kroniske og akutte PNEC-verdier for en rekke av stoffene behandlet i prosjektet, og disse er brukt i sammenlikningene.

Kortkjedede (SCCP) og mellomkjedede (MCCP) klorerte parafiner.

Klorerte parafiner ble bare analysert i sedimentprøvene. MCCP lå under deteksjonsgrensen i alle prøvene til tross for at det er klar indikasjon på langtransportert atmosfærisk transport av MCCP til Arktis. Sammenlikning med nivåer i uforurendes innsjøer i Alaske og norske kystsedimenter indikerer at nivåene av SCCP er høyere enn forventet bakgrunn for åpne havområder, men de ligger likevel langt under kronisk PNEC for SCCP på 1000 µg/kg, og bør derfor ikke utgjøre noen miljørisiko.

Alkylfenoler(AP) og alkylfenoletoksilater APE)

AP og APE ble bare analysert i sedimentprøvene. Ingen av sedimentprøvne hadde AP over deteksjonsgrensen som igjen var lavere enn den kroniske PNEC-verdien for sedimenter. APE kunne kvantifiseres, men det ble ikke funnet noe geografisk mønster i nivåene. Sammenlikninger med andre resultater indikerte at AP lå på bakgrunnsnivå. APE-nivåene var likevel litt høyere enn det som er funnet i sedimenter fra den åpne delen av Nordsjøen og bør derfor overvåkes videre.

Tensider

Tensider ble bare analysert i sedimentprøvene. Det var bare DSDMAC som kunne kvantifiseres, og nivåene var fra <0,1 til 7,3 g/kg t.v. Noe geografisk mønster kunne ikke påvises. Vi kjenner ikke til andre data å sammenlikne med og bakgrunnsnivå kan ikke bedømmes.

Polyfluorerte organiske forbindelser (PFC)

Sediment

Kun PFOS hadde nivåer over deteksjonsgrensen. Nivåene tilsvarte det som er funnet i bunnsedimentene rundt offshoreinstallasjoner på Haltenbanken, men lavere enn det som er funnet i kystnære sedimenter. PFOS-nivåene som ble funnet kan foreløpig ansees å representere bakgrunn i ikke forurensede sedimenter. Sammenlikning med den kroniske PNEC-verdien for PFOS tilsier at miljørisikoen fra PFCer i de analyserte sedimentene er ubetydelig.

Reker

Høyeste sum PFCer ble funnet i rekehaler fra de to vestlige stasjonene, noe som kan indikere tilførsel via kyststrømmen. Relevante reke-data å sammenlikne med er ikke funnet, men sammenlikning med andre evertebrater indikerer at de analyserte rekene kan ha forhøyet nivå av PFOS.

Lodde

Nivåene av sum PFCer var omtrent som nivåene funnet i torskelever-prøvene, men høyere enn i torskefilet tidligere analysert fra Kristiansandsfjorden. Siden disse prøvene av hel lodde også hadde PFC på nivå med det som er funnet i leverprøver fra andre fiskeslag fra Barentshavet, kan det være at lodde akkumulerer PFC i større grad. Sammenlikning med kjent bakgrunn for PFC var ikke mulig.

Torsk

Programmet dekket kun analyse av leverprøver fra 2 stasjoner, i Varangerfjorden og Lofoten. Det var bare PFOS som kunne kvantifiseres og nivåene var på linje med det som ble funnet i torskelever fra ytre Bømlo og fra Lofoten i 2006 og langt lavere enn i torskelever fra indre Oslofjord. Mønsteret tyder på at kysttorsk fra Barentsregionen har PFOS-nivåer tilsvarende torsk fra diffust belastede områder for øvrig i Norge og fra andre nordiske land. Dette representerer antakelig bakgrunn for PFOS i lever av kysttorsk.

Polarlomvi
De funne PFOS-nivåene var lavere enn det som er funnet i egg fra andre arktiske sjøfugl, og mye lavere enn nivåene i sjøfugl-lever fra industrialiserte områder. Ingen tidstrend eller geografisk mønster ble funnet. Nivåene var høyest i egg fra Bjørnøya.

Sammenlikning av PFOS i de ulike prøvene
Forskjellen i PFOS-nivå mellom artene var liten, men svakt høyere i polarlomvi-egg enn i de andre vevsprøvene. Bunnsedimentene, torsk og polarlomvi synes å ha PFOS i nedre del av intervallet tidliger funnet i sammenliknbare prøver. Rekehaler og lodde hadde PFOS på nivå med torskelever, som igjen var på nivå med tidligere resultater fra kysttorsk, men langt lavere enn i torskelever fra indre Oslofjord. I øyeblikket bør man kunne anta at de laveste konsentrasjonene funnet i reker og fisk representerer bakgrunn.

Polybromerte difenyletere
PBDEer brukes som flammehemmere i plast, tekstiler, byggeskum, elektriske artikler, biler, osv. Det er knyttet klar bekymring mht persistens, bioakkumulerbarhet og giftighet hos noen av stoffene. Deka-BDE virker antakelig hormonforstyrrende og som utviklingsrelatert nervegift. Kunnskapen om nivåer av bromerte flammehemmere i miljøet øker raskt.

Sediment
Summen av alle PBDEene lå i området 1,5 - 1149,4 ng/kg t.v. Dette er 200-400 ganger lavere enn det som er funnet i sedimenter fra den PBDE-forurensede Åsefjorden i Ålesund. Nivåer av BDE-47 tilsvarte det som er funnet i norske kystsedimenter og langt lavere enn i Drammensfjorden. Dette indikerer at de funne nivåene representerer bakgrunn, men sammenliknbare arktiske nivåer mangler. Penta-BDE hadde nivå 620 ganger lavere enn den kroniske PNEC-verdien for stoffet og utgjør en ubetydelig miljørisiko. En klar forskjell i PBDE-profil mellom Tromsøflak-prøvene i vest og prøvene fra russisk område i øst kan enten skyldes analyseforskjeller eller antyde at disse to regionene kan være påvirket av ulike kilder.

Blåskjell
Høyeste sum $PBDE_7$ ble funnet i skjellprøven fra Skrova havn i 1994. Med unntak av denne prøven som synes å være forurenset indikerer resultatene at PBDE-nivåene i blåskjellprøvene representerer bakgrunn for rene kystområder.

Reker
Rekehaleprøvene fra Barentshavet hadde mye lavere konsentrasjon av enkeltstoffet BDE-47 og sum $PBDE_7$ enn tidligere funnet i reker fra Nordsjøen og Skagerrak og i torskefilet fra Grønland. Nivåene kan representere bakgrunn, men grunnlaget for å konkludere dette er for svakt.

Lodde
Nivåene av sum $PBDE_7$ i lodde tilsvarte det som tidligere er funnet i filét av rødspette, lavere enn i filét av uer, men høyere enn tidligere funnet i filét av torsk og sei. Det geografiske mønsteret i denne undersøkelsen antyder en større forurensningsbelastning nær kysten og i de

vestlige delene av Barentshavet enn i de åpne havområdene mot nord og øst. Det er uklart om de funne nivåene representerer bakgrunn for PBDE.

Torsk
Sum $PBDE_7$ har sunket på alle stasjonene fra 1994 til 2005/2006, gjennomsnittlig 63 %. Nivåene i 2005/2006 var noe lave i forhold til det som tidligere er funnet i torskelever fra åpne norske kystområder, Grønnland og Nordsjøen, noe som tyder på at PBDE-forurensningen i prøvene fra denne undersøkelsen var lave og kan representere bakgrunnsforhold.

Polarlomvi
De gjennomsnittlige summene av alle de analyserte PBDEene var lavere enn det som tidligere er rapportert for egg av vandrefalk fra Norge, sørlige Grønland og Sverige, og lavere enn i andre undersøkelser av arktiske sjøfugleegg. Konsentrasjonen var også lavere i 2007 enn i 1993, 2002 og 2003, men noen geografisk forskjell kunne ikke spores. Enkeltstoffet BDE-47 dominerte, noe som synes typisk for sjøfugleegg.

Sammenlikning mellom artene
Torskelverprøvene hadde PBDE-nivåer 2-3 ganger høyere enn i de andre artene. Laveste nivåer ble funnet i rekehaler. Blåskjell og lodde hadde omtrent 10 ganger høyere nivå enn reke. Sammenlikning med andre studier tyder likevel på at nivåene i torskelever representerer bakgrunn, men det er ikke nok informasjon til en tilsvarende bedømmelse av de andre artene. En normaliserng av konsentrasjonene til typiske verdier for fettinnhold funnet i andre undersøkelser av disse typene prøver,, antyder at de laveste fettnormaliserte nivåene av BDE-47 fantes i reke og lodde. Blåskjell og polarlomviegg hadde fettnormalisert nivå 5-10 ganger høyer enn dette og torskelever omtrent 50 ganger høyere.

Andre bromorganiske flammehemmere: HBCDD og TBBPA

Sediment.
TBBPA var under deteksjonsgrensen i alle sedimentprøvene. For HBCDD var det liten forskjell mellom prøvene. De kroniske PNEC-verdene viser at verken TBBPA eller HBCDD i disse sedimentprøvene utgjør noen miljørisiko.

Reker og lodde
TBBPA ble ikke analysert, og ingen av prøvene hadde HBCDD over deteksjonsgrensen. Basis for å bedømme om deteksjonsgrensen for HBCDD var tilstrekkelig lav finnes ikke.

Polarlomvi
Nivåene av sum HBCDDer var lavere enn i egg fra andre arktiske sjøfugler, men basis for å bedømme om de representerer bakgrunn mangler. Nivåene var lavere i 2007 enn i 2002/2003. Ingen geografisk forskjell ble funnet.

Bisfenol A

Bisfenol A ble bare analysert i sedimentprøvene. BPA-konsentrasjonene varierte fra 2,3 til 10,2 µg/kg t.w., høyest på Tromsøflaket. Sammenlikning med antatt uforurensede områder og havnesedimenter tyder på at de funne nivåene representerer bakgrunn. I forhold til den kroniske PNEC for BPA bør miljørisikoen være akseptabel.

Syntetiske muskforbindelser

Muskforbindelser ble bare analysert i sedimentprøvene. Muskketoner var under deteksjonsgrensen i alle prøvene. Nivåene av muskxylener varierte lite og tilsvarte det som tidligere er funnet i nordiske innsjøer. Det var ikke noe geografisk mønster i nivåer av muskxylen.

Siloxaner

Siloxaner ble bare analysert i sedimentprøvene. Nivåene av D5-siloxan i Barentshav-prøvene var entydig lavere enn det som er funnet i sedmenter fra indre Oslofjord, Stockholm og Helsinfors havn. Hvorvidt de representerer bakgrunnsnivå kan ikke fastslås.

Fosforiserte flammehemmere (PFR)

Fosforiserte flammehemmere ble bare analysert i sedimentprøvene. Ingen av sedimentprøvene hadde PFR over deteksjonsgrensen. En sammenlikning av deteksjonsgrensene med nivåer i kystsedimenter andre steder i Norge og i Japan indikerer at nivåene av TCEP og TCDP i Barentssedimentene var lave. Deteksjonsgrensen bør minidlertid senkes dersom man skal kunne bestemme hva som er virkelig bakgrunnskonsentrasjon av PFR.

DEHP

DEHP ble bare analysert i sedimentprøvene. Det høyeste nivået, 57 mg/kg t.v. i sediment fra Tromsøflaket, var overraskende 2-3 størrelsesordner høyere enn i sediment fra forurensede fjorder som Oslofjorden, Frierfjorden og Kristiansandsfjorden. Et slikt forhold er usannsynlig og den eneste plausible forklaring er at det har forekommet sekundærforurensning av prøvene. Resultatene bedømmes som upålitelige og nye sedimentanalyser bør gjennomføres.

Dioksiner og furaner

Dioksiner ble bare analysert i sedimentprøvene. Nivået av sum PCDD/PCDF var lavest i sediment fra en av stasjonene i åpent hav og høyest i sediment fra Stjernøysund. PCDF dominerte over PCDD, noe som også er funnet i andre arktiske sedimenter og i de dioksinforurensede Grenlandsfjordene. De funne nivåene av sum PCDD/PCDF og av enkeltforbindelsen TCDD tilsvarer det som tidligere er rapportert av AMAP fra andre arktiske marine sedimenter og lavere enn nivåene i Norsdjøen. Dette tyder på at de representerer bakgrunn. Etablert kronisk PNEC for sum PCDD/PCDF tilsier at de funne nivåene ikke utgjør noen miljørisiko.

PCB

PCB omfatter et stort antall polyklorerte bifenyler som hadde utstrakt og variert anvendelse mellom ca 1930 og 1980 på grunn av deres motstandsdyktighet mot kjemiske endringer. Informasjonsmengden mht kilder, transportveier, nivåer i miljøet og effekter er svært stor.

Sediment

PCB-kongenerene er forskjellige i analysene av hhv Tromsøflaket-prøvene og østlige Barents/Pechora-prøvene. Resultatene kan derfor i liten grad sammenliknes og man kan ikke fastlå om forskejllene i nivå mellom de to prøvesettene er reelle eller ikke. Sum PCB_7 kunne bare beregnes i prøvene fra Tromsøflaket og nivåene var på linje med det som er rapportert av AMAP for andre arktiske sedimenter. Den reviderte klassifiseringen av sum PCB_7 i marine sedimenter viser at de analyserte sedimentene lå på bakgrunn og at PCB-nivået i prøvene ikke utgjør noen miljørisiko.

Polarlomvi
Høyeste sum av alle de analyserte PCB-kongenerene ble funnet i egg fra Kongsfjord i 1993. Nivåene tilsvarte det som tidligere er funnet i egg av andre arktiske sjøfugl. En nedgang i PCB-konsentrasjoner ble funnet fra 2002/2003 til 2007 og dette tilsvarer tendensen påvist i andre sjøfuglegg også.

Utvalgte organoklorforbindelser
Sediment.
PCP var under deteksjonsgrensen i alle sedimentprøvene. Nivåene av PeCB og sum TCB tilsvarte det som tidligere er funnet i norske kyst- og fjordsedimenter. Både disse stoffene og HCBD lå langt under de kroniske PNEC-verdiene i den norske sedimentklassifiseringen. HCB kunne bare kvantifiseres i 3 av prøvene, alle fra det østlige Barentshavet og Pechorahavet. Nivåene tilsvarte bakgrunn for HCB rapportert av AMAP. Generelt utgjør neppe de funne nivåene av organoklorforbindelser noen miljørisko

Polarlomvi
Fettnormaliserte HCB-nivåer i eggprøvene av polarlomvi var lik eller litt lavere enn det som tidligere er funnet i egg av andre arktiske sjøfugl. Det var ikke noe geografisk eller tidsmessig mønster i nivåene.

Plantevernmidler
Sediment
Kun Tromsøflaket-prøvene ble analysert. Toxafen var under deteksjonsgrensen i alle prøvene og bedømt til å representere bakgrunn. Sum HCH og DDT var høyest i sedimentet fra Stjernøysund, den eneste stasjonen på kysten. I følge PNEC-verdier for sediment bør verken HCH eller DDT utgjøre noen miljørisiko og er antatt å ligge på bakgrunn. Tilsvarende grenser for klordan er ikke utarbeidet.

Reker
Den høyeste toxafen-konsentrasjonen ble funnet i rekehaler fra havområdet sørøst for Svalbard. Sammenliking med nivåene av toxafen rapportert av AMAP for evertebrater tilsier at nivåene i rekeprøvene må ansees som lave.

Lodde
Den høyeste toxafen-konsentrasjonen ble funnet i lodde fanget utenfor Troms. Den var på nivå med det som er rapportert av AMAP for hel polartorsk fra Lancaster Sound, Canada, men langt lavere enn i piggvar fra Baffin Island, Canada

Torsk
Toxafen og klordan ble analysert i torskelever fra 2 av kystasjonene. Høyest nivå ble funnet i Varangerfjorden for begge stoffgruppene. Tilsvarende nivåer av toxafen er rapportert av AMAP i lever av piggvar fra Baffin Island, Canada. Vi har ikke funnet relevante data for klordan å sammenlikne med.

Polarlomvi
Nivåene av HCH, klordan, toxafen, DDT og Mirex var lik eller levere enn tidligere funnet i egg av andre arktiske sjøfugl. Nivåene var alle lavere i 2007 enn i 2002/2003, noe som samsvarer med utviklingen påvist i sjøfugl fra Nord-Norge.

Sammenlikning av toxafen i de ulike artene

Eneste felles plantevernmiddel i alle analysene var toxafen. Toxafen-nivåene i torskelever var ca 10 ganger høyere enn i lodde, som igjen var ca 10 ganger høyere enn i rekehaler. Disse forskjellene er antakelig knyttet til forskjeller i fettinnhold i de ulike artene og trenger ikke skyldes ulik eksponeringsgrad. En normalisering mot typisk fettinnhold funnet i annen sammenheng for disse prøvetypene antyder at rekehaler, lodde og egg av polarlomvi hadde samme fettnormaliserte toxafen-nivå, mens torskelever lå 2-3 ganger høyere.

PAH

Sediment

Sum PAH_{16} tilsvarte bakgrunnsnivå i norske kystnære sedimenter og lå langt under kronisk PNEC-verdi. PAH-innholdet i disse sedimentene utgjør derfor ikke noen miljørisiko.

Blåskjell

Høyeste nivå av sum PAH_{16} ble funnet i skjell tatt nær Honningsvåg. Disse muslingene ble klassifisert som moderat forurenset (SFT klasse II). De andre prøvene representerte bakgrunnsnivå (SFT klasse I).

Polarlomvi

Gjennomsnittlig sum av alle de analyserte PAH-forbindelsene for hver stasjon varierte fra 0,2 til 7,5 ng/g. Naftalen var dominerende forbindelse. Nivåene av naftalen var generelt lavere in 2007 enn i 2002/2003. Ingen andre data for PAH i arktiske sjøfuglegg er funnet.

Spormetaller

Sediment

Spormetaller ble bare analysert i prøvene fra russisk Barentshav og Pechorahavet. Nivåene av Cu, Cd, Pb, og Hg var alle på bakgrunn for norske kystområder og langt under kronisk PNEC. Cr lå på øvre grense for bakgrunn, men fortsatt langt under kronisk PNEC. Arsen lå over bakgrunn for kystområdene på to av stasjonene og overskred kronisk PNEC på 52 mg/kg t.v. i prøven fra Shtokman-regionen. Relativt høye naturlige nivåer av As har imidlertid tidligere blitt i funnet sedimenter fra det østlige Barentshavet. Barium-nivåene var litt høyere enn det som tidligere er funnet rundt Snøhvit-feltet på Tromsøflaket. Det ble ikke funnet noe geografisk mønster i spormetallnivåene.

Polarlomvi

Hg-nivå i egg fra Kongsfjord var høyere enn i egg fra Bjørnøya og høyest i 2002 på begge lokaliteter. Hg-nivåene var likevel lavere enn det som er funnet i egg fra arktiske sjøfugl i Canada. De andre metallene hadde nivå på linje med eller lavere enn tidligere funnet i sjøfugl og sjøfuglegg.

Tinnorganiske forbindelser og primært TBT.

Sediment

Tinnorganiske forbindelser ble bare analysert i prøvene fra russisk Barentshav og Pechorahavet. Alle nivåene var under deteksjonsgrensen. Dette innebærer at nivåene var nær bakgrunn for kystnære sedimenter og ikke representerer noen miljørisiko.

Polarlomvi

TBT var under deteksjonsgrensen i alle eggprøvene.

Stabile isotoper av karbon og nitrogen

Polarlomvi

Nivåene av $\delta^{13}C$ and $\delta^{15}N$ varierte lite mellom prøvene. Det var ikke noen statistisk signifikant sammenheng mellom $\delta^{13}C$ og noen av miljøgiftene. Signifikant sammenheng ble imidlertid funnet mellom $\delta^{15}N$ og HBCDD, sum toxafen, sum HCH, sum klordan, Mirex, DDT, enkeltkongenerer og sumPCB samt sum mono-*ortho* PCB. Dette vanskeliggjør tokningen av tidstrender for miljøgiftene.

Generell miljøgiftstatus for ulike prøvetyper

SCCP i sediment var høyere enn forventet bakgrunn. APE-nivåene var også høyere enn i Nordsjøen og bør følges fortsatt. For tensider, siloxaner og klordan var grunnlaget for å bedømme status i forhold til bakgrunn for lite. DEHP-resultatene var ansett som upålitelige og nye analyser bør gjøres. De andre miljøgiftene i sediment lå på antatt bakgrunn. PAH i blåskjell var på bakgrunn bortsett fra i nærheten av Honningsvåg. PBDE i blåskjell var på bakgrunn. I reke og lodde var de laveste PFOS-nivåene ansett som bakgrunn. Andre miljøgifter var også på antatt bakgrunn. Toxafen i torskelever var på nivå med annen arktisk fisk, men grunnlaget for å bedømme om dette er bakgrunn er for svakt. Andre miljøgifter i torskelever representerte antatt bakgrunn. I egg av polarlomvi var alle miljøgiftene innen konsentrasjonsintervallet funnet i egg av annen arktisk sjøfugl, og flere i den lavere del av intervallet, men grunnlaget for å bedømme dette i forhold til bakgrunn mangler. De fleste miljøgiftene viste en nedgang over tid. TBT lå under deteksjonsgrensen i alle eggprøvene.

3. Background and purpose

The purpose of the present report is to present and discuss the results from five projects completed in 2007/2008 and dealing with analysis of selected contaminants in various sample types from the Barents Sea region. Where information is available on background levels and range in environmental concentrations from comparable sample types elsewhere and on limits for toxic effects under chronic exposure, the report attempts to assess the likely environmental severity of the contaminant levels found.

The sample types and compounds included are listed as being of particular environmental concern in Appendix 3, Figure 3.1. of the Governmental White Paper (Stortingsmelding) No 8, 2005-2206 “ Integrated Management of the Marine Environment of the Barents Sea and the Sea Areas off the Lofoten Islands”. For most of the compounds the information on environmental levels is fragmentary, especially regarding Arctic marine environments, and the White Paper recommends that they are considered for inclusion in future monitoring programmes.

4. Compounds and compound groups

Table 1 gives an overview of the compounds covered by the present survey. Not all compounds are analysed in all subprojects (cf. Table 10). In this chapter a brief introduction to the various compounds/compound groups are given with information on use and discharges, environmental dispersion and effects, and remedial actions taken in Norway to prevent environmental damage. One important source for this introduction is the State of the Environment Norway which can be found at http://www.environment.no/.

Table 1. Overview of the compounds investigated.

Compound name	**Abbreviation**	**CAS-no,**
Chlorinated paraffins		
Short chained chlorinated paraffin, sum	SCCP	Not applicable
Medium chained chlorinated paraffin, sum	MCCP	Not applicable
Alkyl phenols and alkyl phenol etoxilates		
Octylphenol		
Nonylphenol		
Dodecylphenol		104-43-8
Octylphenol mono-ethoxylate	OPE1O	
Octylphenol di-ethoxylate	OPE2O	
Nonylphenol mono-ethoxylate	NPE1O	104-35-8
Nonylphenol di-ethoxylate	NPE2O	20427-84-3
Nonylphenol tri-ethoxylate	NPE3O	
Nonylphenol tetra-ethoxylate	NPE4O	
Pentachlorophenol	**PCP**	
Tensides		
dimethyl ditallow ammonium chloride	DTDMAC	68783-78-8
Octadecanaminium dimethyl octadecy chloride	DSDMAC	107-64-2
Ditallow dimethyl ammonium chloride	DHTMAC	61789-80-8
Polyfluorinated compounds	**PFCs**	
Volatile PFCs		
n-methyl perfluorooctane sulfonamide	N-Me-FOSA	31506-32-8
n-ethyl perfluorooctane sulfonamide	N-Et-FOSA	4151-50-2
n-methyl perfluorooctane sulfonamidoethanol	N-Me-FOSE	24448-09-7
n-ethyl perfluorooctane sulfonamidoethanol	N-Et-FOSE	1691-99-2
Ionic PFCs	**PFAS**	
Sulfuramid or N-ethyl-1,1,2,2,3,3,4,4,5,5,6,6,7,7,8,8,8-heptadecafluoro-1-octanesulfonamide	PFOSA	4151-50-2 754-91-6
perfluorobutane sulfonate	PFBS	2795-39-3
perflurorohexanoic sulfonate	PFHxS	432-50-7
perfluoroctanoic sulfonate /perfluorooctane sulfonate	PFOS	2795-39-3
Perfluorodecanoic sulfonate	PFDcS	67906-42-7
perflurorohexanoic acid	PFHxA	307-24-4
perfluroroheptanoic acid	PFHpA	375-85-9
perfluoroctanoic acid	PFOA	335-67-1
perfluorononanoic acid	PFNA	375-95-1
Perfluorodecanoic acid	PFDcA	335-76-2
Perfluorundecanoic acid	PFUnA	2058-94-8
Perfluorododecanoic acid	PFDoA	
Perfluorotridecanoic acid	PFTriA	
Perfluorotetradecanoic acid	PFTeA	
Perfluoropentadecanoic acid	PFPeDA	
Polybrominated diphenylethers	**PBDE**	
2,2',4-tribromodiphenyether	BDE -17	
2,4,4'-tribromodiphenyether	BDE -28	41318-75-6
2,2',4,5'-tetrabromodiphenyether	BDE -49	
2,3',4',6-tetrabromodiphenyether	BDE -71	
2,2',4,4'-tetrabromodiphenyether	BDE -47	5436-43-1
2,3'4,4'-tetrabromodiphenylether	BDE -66	187084-61-5
2,2',4,4',6-pentabromodiphenylether	BDE -100	189084-64-8

2,2’,4,4’,5-pentabromodiphenylether	BDE -99	60348-60-9
2,2’,3,4,4’-pentabromodiphenylether	BDE -85	182346-21-0
2,2’,4,4’,5,6’-hexabromodiphenylether	BDE -154	207122-15-4
2,2’,4,4’,5,5’-hexabromodiphenylether	BDE -153	68631-49-2
2,2’,3,4,4’,5’-hexabromodiphenylether	BDE -138	182677-30-1
2,2’,3,4,4’,5’,6-heptabromodiphenylether	BDE -183	
2,3,3’,4,4’,5,6,-heptabromodiphenylether	BDE -190	
2,2′,3,3′,4,4′,5,6′-octabromodiphenylether	BDE -196	32536-52-0
2,2′,3,3′,4,5,5′,6,6′-nonabromodiphenylether	BDE -208	
2,2′,3,3′,4,4′,5,6,6′-nonabromodiphenylether	BDE -207	
2,2′,3,3′,4,4′,5,5′,6-nonabromodiphenylether	BDE -206	
2,2′,3,3′,4,4′,5,5′,6,6′-decabromodiphenylether	BDE -209	1163-19-5
Hexabromocyclododecane	**HBCDD**	
α- hexabromocyclododecane	α-HBCDD	
β- hexabromocyclododecane	β-HBCDD	
γ- hexabromocyclododecane	γ-HBCDD	
Tetrabromobisphenol A	**TBBPA**	79-94-7
Bisphenol A		80-05-7
Synthetic musk compounds		
Musk xylene	MX	81-15-2
Musk ketone	MK	81-14-1
Siloxane		
Cyclotetrasiloxane	D4-siloxane	556-67-2
Cyclopentasiloxane	D5-siloxane	541-02-6
Cyclohexasiloxane	D6-siloxane	540-97-6
Phosphorus Flame Retardants	**PFR**	
tri-*iso*-butylphosphate	TIBP	126-71-6
tributylphosphate	TBP	126-73-8
Tri(2-chloroethyl)phosphate	TCEP	115-96-8
Tri(1-chloro-2-propyl)phosphate	TCPP	13674-84-5
Tri(1,3-dichloro-2-propyl)phosphate	TDCP	13674-87-8
Tri(2-butoxyethyl)phosphate	TBEP	78-51-3
Triphenylphosphate	TPhP	115-86-6
2-ethylhexyl-di-phenylphosphate	EHDPP	1241-94-7
Tetrekis(2-chlorethyl)dichloroisopentyldiphosphate	V6	38051-10-4
Phtalates		
Di-2-ethyhexylphtalate	DEHP	117-81-7
Dioxins and furanes	**PCDD/PCDF**	
2,3,7,8-tetrachlorodibenzo-p-dioxin	TCDD	1746-01-6
1,2,3,7,8-pentachlorodibenzo-p-dioxin	PeCDD	40321-76-4
1,2,3,4,7,8-hexachlorodibenzo-p-dioxin	1,2,3,4,7,8-HxCDD	39227-28-6
1,2,3,6,7,8- hexachlorodibenzo-p-dioxin	1,2,3,6,7,8-HxCDD	57653-85-7
1,2,3,7,8,9- hexachlorodibenzo-p-dioxin	1,2,3,7,8,9-HxCDD	19408-74-3
1,2,3,4,6,7,8- heptachlorodibenzo-p-dioxin	HpCDD	35822-46-9
Octachlorodibenzo-p-dioxin	OCDD	3268-87-9
2,3,7,8- tetrachlorodibenzofuran	TCDF	51207-31-9
1,2,3,7,8-pentachlorodibenzofuran	1,2,3,7,8-PeCDF	57117-41-6
2,3,4,7,8-pentachlorodibenzofuran	2,3,4,7,8-PeCDF	57117-31-4
1,2,3,4,7,8-hexachlorodibenzofuran	1,2,3,4,7,8-HxCDF	70648-26-9
1,2,3,6,7,8- hexachlorodibenzofuran	1,2,3,6,7,8-HxCDF	57117-44-9
2,3,4,6,7,8- hexachlorodibenzofuran	2,3,4,6,7,8-HxCDF	60851-34-5
1,2,3,7,8,9- hexachlorodibenzofuran	1,2,3,7,8,9-HxCDF	72918-21-9
1,2,3,4,6,7,8-heptachlorodibenzofuran	1,2,3,4,6,7,8-HpCDF	67562-39-4
1,2,3,4,7,8,9- heptachlorodibenzofuran	1,2,3,4,7,8,9-HpCDF	55673-89-7
Octachlorodibenzofuran	OCDF	39001-02-0
Polychlorinated biphenyls	**PCB IUPAC no:**	
2,4,4’-trichlorobiphenyl	PCB-28	
2,2’,5,5’-tetrachlorobiphenyl	PCB-52	
2,2’,4,4’-tetrachlorobiphenyl	PCB-47	
2,4,4’,5- tetrachlorobiphenyl	PCB-74	
2,3’,4,4’- tetrachlorobiphenyl	PCB-66	
2,2’,4,5,5’-pentachlorobiphenyl	PCB-101B	
2,2’,3,5,5’,6-hexachlorobiphenyl	PCB-151	
2,2’,3,4’,5’,6-hexachlorobiphenyl	PCB-149B	

2,2’,3,4,5,5’-hexachlorobiphenyl	PCB-141	
2,2’,3,4,4’,5-hexachlorobiphenyl	PCB-137 (di-ortho)	
2,2’,3,4’,5,5’,6-heptachlorobiphenyl	PCB-187	
2,2’,3,3’,4,4’-hexachlorobiphenyl	PCB-128 (di-ortho)	
2,2’,3,3’,4,4’,5,5’-octachlorobiphenyl	PCB194 (di-ortho)	
2,2’,3,3’,4,4’,5,5’,6-nonachlorobiphenyl	PCB206	
3,4,4’,5-tetrachlorobiphenyl	PCB-81 (non-ortho)	
3,3’,4,4’-tetrachlorobiphenyl	PCB-77 (non-ortho)	
2’,3,4,4’,5-pentachlorobiphenyl	PCB-123 (mono-ortho)	
2,3’,4,4’,5-pentachlorobiphenyl	PCB-118 (mono-ortho)	
2,3,4,4’,5-pentachlorobiphenyl	PCB-114 (mono-ortho)	
2,3,3’,4,4’-pentachlorobiphenyl	PCB-105 (mono-ortho)	
3,3’,4,4’,5-pentachlorobiphenyl	PCB-126 (non-ortho)	
2,3’,4,4’,5,5’-hexachlorobiphenyl	PCB-167 (mono-ortho)	
2,3,3’,4,4’,5-hexachlorobiphenyl	PCB-156 (mono-ortho)	
2,3,3’,4,4’,5’-hexachlorobiphenyl	PCB-157 (mono-ortho)	
3,3’,4,4’,5,5’-hexachlorobiphenyl	PCB-169 (non-ortho)	
2,2’,3,4,4’,5,5’-heptachlorobiphenyl	PCB-180 (di-ortho)	
2,2’,3,3’,4,4’,5-heptachlorobiphenyl	PCB-170 (di-ortho)	
2,3,3’,4,4’,5,5’-heptachlorobiphenyl	PCB-189 (mono-ortho)	
2,2’,4,4’,5-pentachlorobiphenyl	PCB-99	
2,2’,4,4’,5,5’-hexachlorobiphenyl	PCB-153 (di-ortho)	
2,2’,3,4,4’,5’-hexachlorobiphenyl	PCB138 (di-ortho)	
2,2’,3,4,4’,5’,6-heptachlorobiphenyl	PCB-183	
Organohalogens		
1,3,5-trichlorobenzene	1,3,5-TCB	108-70-3
1,2,4-trichlorobenzene	1,2,4-TCB	120-82-1
1,2,3-trichlorobenzene	1,2,3-TCB	87-61-6
Pentachlorobenzene	PeCB	608-93-5
Hexachlorobenzene	HCB	118-74-1
Hexachloro-1,3-butadiene	HCBD	87-68-3
Pentachlorophenol	PCP	87-86-5
Biocides		
DDT		
Dichlorodiphenyltrichloroethane	DDT	50-29-3
Dichlorodiphenyldichloroethane	DDD	72-54-8
Dichlorodiphenylchloroethane	DDE	
Toxaphenes		
Ethylene Glycol Ethers	TX26	109-86-4, 110-80-5, 111-76-2
Methylene Bis(thiocyanate)	TX32	6317-18-6
b-Bromo-b-Nitrostyrene and 1,1,1-Trichloroethane	TX40-41	7166-19-0, 71-55-6
?	TX42A	
o-Nitrotoluene and o-toluidine hydrochloride	TX44	88-72-2, 636-21-5
Cyclohexanone Oxime	TX50	100-64-1
(No name found for TX62)	TX62	
Chlordanes		
Trans-Chlordane	TCDAN	5103-74-2
Cis-Chlordane	CCDAN	5103-71-9
Trans-Nonachlor	TNONC	39765-80-5
Cis-nonachlor	CNONC	5103-73-1
Oxy-chlordane	OCDAN	27304-13-8
Other biocides		
1,2,3,4,5,6-hexachlorocyclohexane	HCH	608-73-1
Perchloropentacyclodecane	Mirex	2385-85-5
Organotin compounds		
Monobutyltin	MBT	2273-43-0
Dibutyltin	DBT	1002-53-5
Tributyltin	TBT	688-73-3
Monophenyltin	MPhT	
Diphenyltin	DPhT	
Triphenyltin	TPhT	668-34-8
Polycyclic aromatic hydrocarbons	**PAH**	

Naphthalene	NAP	91-20-3
1-Methylnaphtalene	NAP1M	90-12-0
2-Methylnaphtalene	NAP2M	91-57-6
C2-Naphtalenes	NAPC1	
C3-Naphtalenes	NAPC2	
C4-Naphtalenes	NAPC3	
Acenaphthylene	ACNLE	208-96-8
Acenaphthene	ACNE	83-32-9
Fluorene	FLE	86-73-7
C1-Fluorenes	FLEC1	
C2-Fluorenes	FLEC2	
C3-Fluorenes	FLEC3	
Phenanthrene	PA	85-01-8
Anthracene	ANT	120-12-7
C1-Phenanthrene/Anthracene	PAC1	
C2- Phenanthrene/Anthracene	PAC2	
C3- Phenanthrene/Anthracene	PAC3	
C4- Phenanthrene/Anthracene	PAC4	
Dibenzothiophene	DBT	
C1-Dibenzothiophenes	DBTC1	
C2-Dibenzothiophenes	DBTC2	
C3-Dibenzothiophenes	DBTC3	
Fluoranthene	FLU	
Pyrene	PYR	
C1- Fluoranthene / Pyrene	FLUC1	
C2- Fluoranthene / Pyrene	FLUC2	
C3- Fluoranthene / Pyrene	FLUC3	
Benzo(a)anthracene	BAA	
Chrysene	CHR	
C1-Chrysenes	CHRC1	
C2-Chrysenes	CHRC2	
C3-Chrysenes	CHRC3	
Benzo(b+j)fluoranthene	BJKF	
Benzo(k)fluoranthene	BKF	
Benzo(e)pyrene	BEP	1718-52-1
Benzo(a)pyrene	BAP	
Perylene	PER	
Indeno(1,2,3-c,d)pyrene	IDCP	
Dibenz(a,h)antracene	DBAHA	
Benzo(g,h,i)perylene	BGHIP	
Trace metals		
Copper	Cu	
Cadmium	Cd	
Lead	Pb	
Mercury	Hg	
Chromium	Cr	
Barium	Ba	
Arsenic	As	
Lithium	Li	
Nickel	Ni	
Rubidium	Rb	
Selenium	Se	

4.1 Chlorinated paraffins

General
This is a large group of alkane hydrocarbons where the hydrogens have been more or less substituted by chlorine. They are by size divided into short chained (SCCP, C10-C13), medium chained (MCCP, C14-17) and long chained (LCCP, >C17) chlorinated paraffins, of which the former two are covered by the present survey.

Use and discharges
Norwegian discharges of SCCP were reduced by more than 70 % from 17 tons in 1995 to 6 tons in 2003. The discharge in 2003 was 0,3 tons. The compounds, primarily MCCP, are used as softeners and flame retardants in plastic material.

Distribution and effects
CPs degrade slowly and may bioaccumulate especially the SCCPs. Use of SCCP is prohibited in Norway with the result that the use of MCCP has risen from 50 tons in 1995 to 1100 tons in 2003. SCCP and MCCP are found in most environmental samples, and there is strong indication of long range air transport to the Arctic. SCCP is highly toxic to aquatic organisms and classified as potentially carcinogenic. MCCP has been proposed to be given the same classification.

Remedial action
Any production, import, export, and trading of SCCP is prohibited in Norway. Also trading of products with more than 0,1 weight % of SCCP is prohibited. The aim of the authorities is that the use of MCCP shall be significantly reduced within 2010.

4.2 Alkyl phenols including etoxilates

General
Alkyl phenols (AP) are phenols where one hydrogen has been substituted by an alkane chain. The present survey covers octyl-(C8), nonyl-(C9), and dodecyl-(C12)phenol and the ethoxylates of the former two. Ethoxylation is a chemical process in which ethylene oxide is added to one or more positions in the alkane chain in order to make the product more soluble in water.

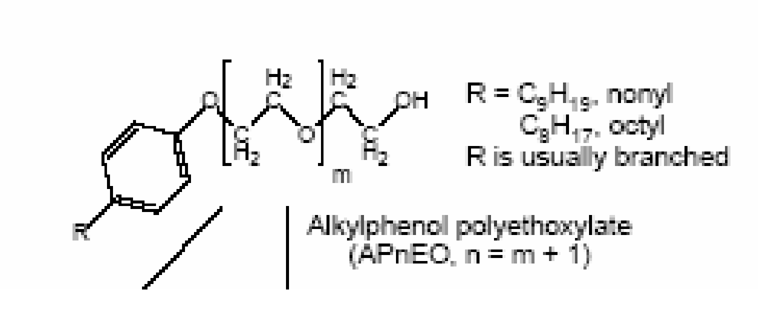


Figure 1. Molecular structure of AP ethoxylates

Use and discharges

Alkylphenol ethoxylates (APE) are synthetic surfactants (non-ionic tensides) used in some detergents and cleaning products. APEs are made from and break down into alkylphenols, which by themselves are used as antioxidants in plastics and rubber products. APEs and/or other alkyphenol derivatives are also used in pesticides, lube oil, hair dyes and other hair care products, and as nonoxynol-9 in spermicides. The most common APEs are nonylphenol ethoxylates. Plastic products made in Norway do not longer contain these compounds, as opposed to some imported products. As a result of the ban on AP and APE the discharges have been reduced by 94 % from 1995 to 2003.

Distribution and effects

APEs are easily degraded to AP in the environment, primarily nonylphenol and octylphenol. Although APEs themselves can be toxic, their breakdown products are generally around ten times more toxic than the original compounds. APs are slowly degradable and will bioaccumulate, and they are very toxic to aquatic organisms. They are known as hormone disruptors in fish causing reproductive damage. Nonylphenol can also cause reproductive and foetal damage in mammals.

Remedial action

APs and APEs are in Norway prohibited in most products except paints and lubricants. The aim of the authorities is that discharges should be stopped within 2005, and the control to remove illegal products was intensified from 2006.

4.3 Pentachlorophenol

General

Pentachlorophenol, PCP, is a synthetic product with no natural origin in the nature. The mol weight is 266,36 g. Pure PCP are colourless crystals, whereas darker products indicate content of impurities. The molecular structure is shown in Figure 2.

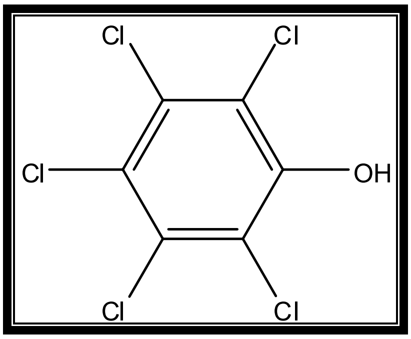


Figure 2. Molecular structure of PCP.

Use and discharges

In Norway PCP has been used in the paper industry and as a preservative in textiles. PCP has been more widely used elsewhere, e.g. as biocide in concrete. The Norwegian Food Safety

Authority recorded the import of PCP from 1974 to 1978. At present no direct discharge of PCP is likely in Norway, but PCP in textiles, leather and wood products may occur.

Distribution and effects
Freshwater sediments from 3 localities in Norway (the Lågen river delta in Oppland and the lakes Mjøsa og Selbusjøen) have been screened for PCP with little or no trace found. In Denmark PCP was still in use in 2004, and an investigation by the Environmental authorities concluded that treated woodwork still in use contained 1,2 tons of PCP. PCP in woodwork may produce dioxins when burned, and in 2005 Norway decided that a screening for PCP in wood was necessary.

PCP is slowly degradable and may bioaccumulate. The chemical is very toxic to aquatic organisms and may cause long term effects. PCP is also classified as toxic and possibly cancerogenic. Exposure may irritate eyes, skin, and the respiratory system, and may seriously damage the liver, nerve system and immune system.

Remedial action
PCP ought to have been phased out within 2005. It is regulated by the product regulations based on an EU directive. All chemical products containing more than 0,1 % PCP are prohibited. PCP is covered by the Rotterdam convention requiring each country to develop an information system for PCP.

4.4 Tensides

General
The compounds covered by the programme are DTDMAC, DSDMAC, DHTMAC[1] (see Table 1) which are cationic tensides. DHTDMAC is a mixture of quaternary ammonium compounds produced from hardened, i.e. hydrogenated natural fats, with bovine tallow as the most important raw fat in standard European products. The compounds are regarded to be not volatile, and little water soluble (but are dispersed).

Use and discharges
The cationic tensides are surface active substances at low concentration. The primary use within EU is as fabric softeners. They are also used in synthesis of organic clays, which are used as drilling muds in the oil industry, as additives in paints, lacquers, car washing agents, hair conditioners, shampoos, emulsifier in lotions, antistatic agents, corrosion inhibitors, foam depressants, flotation chemicals, asphalt and other petroleum products. Consumption within EU decreased from about 65,000 tons in 1990 to 408 tons in 1998.

Distribution and effects
In sewage or surface waters, the tensides are not really dissolved, but always adsorbed onto particles or included in vesicles together with other organics. The water solubility is not a limiting factor for emissions into the wastewater or for environmental pollution. These tensides are not readily biodegradable. Adaptation seems to be necessary for significant degradation to occur, but even then mineralisation is very slow. In river water tests with adapted inocula degradation is occurring with a half-life in the range of several weeks. It can be estimated that about 55% of the elimination in wastewater treatment plants is attributable

---

[1] Also known as DHTDMAC.

to adsorption. The available monitoring data reveal that biodegradation in environmental sediments is low. No abiotic degradation (e.g. hydrolysis, photolysis) under environmental conditions is expected.

Risk assessments indicate that production of tensides, the processing to and use in activated bentonites as well as in fabric softeners, car washing agents and hair conditioners do not represent a serious risk to the environment.

Remedial action
Norway has prohibited production, import, export, trading and use of chemicals and chemical mixtures that contain more than 0,1 weight % of PCP and PCP salts and esters. With the adoption and entry into force of EC Regulation 648/2004, detergents containing DTMAC, DSDMAC and DHTDMAC are prohibited from being placed on the market. PARCOM Recommendation 93/4 proposed to phase out the use of DTMAC, DSDMAC and DHTDMAC in fabric softeners, and this is close to being achieved.

4.5 Polyfluorinated organic compounds (PFC)

General
Polyfluoroalkyl compounds (PFC) are a group of compounds where the hydrogen in the alky-chain is exchanged completely by flouride. In addition, there is a polar aspect to the chemical structures that make them partly soluble, hence surface active. The group can be collectively termed perfluroalkyl sulphonates or perfluroralkyl acids (PFAS).Unique chemical properties of PFCs make them important ingredients in numerous industrial and consumer products. PFCs repel both water and oil, and are therefore ideal chemicals for surface treatment of for example textiles. Polytetrafluoroethylene (PTFE)-based membranes are often used due to their water resistance and ability to “breathe”.

Polyfluorinated compounds (PFCs) are acknowledged widespread environmental contaminants, due to their manufacture over a period of decades, and release into the environment after use and disposal. The different toxicological, chemical and physical behaviour of PFCs, some of which are used as technical mixtures (formulations) containing a number of individual compounds, makes it difficult to fully assess their impact on humans and the environment. Currently, worldwide research is mainly focused on the perfluorinated alkyl sulphonates and carboxylates/acids (PFS, PFCA), but sulphonates (FTS) and the more volatile compound groups, fluorotelomer alcohols (FTOH), are also studied (Table 2).

Table 2. Overview of polyfluorinated compounds (PFC) included in this study.

Parameter (abbreviation)	Type
FTOH: N-Me-FOSA, N-Et-FOSA, N-Me-FOSE,. N-Et-FOSE	Fluorotelomer alcohols
PFS (C4-C15): PFOSA, PFBS, PFHxS, PFOS, PFDcS	Perfluoro alkyl sulfonates and perfluoro alkyl sulfonamides
PFCA (C4-C15): PFHxA, PFHpA, PFOA, PFNA, PFDcA, PFUnA, PFDoA, PFTriA, PFTeA, PFPeDA	Perfluoro alkyl carboxylates or perfluoro alkyl carboxylic acids

Use and discharge

Pursuant to the SFT review material-flow (SFT 2004) there is no production of PFC in Norway. Therefore what is marketed nationally is imported, and this is in the form of chemical-technical products or components in manufactured goods.

Fire extinguishers (Aqueous Film Forming Foams, AFFF) and personal products like coated paper, carpets and furniture as well as all-weather clothing are the most important source of PFC in Norway. AFFF is used for extinguishing fires associated with petroleum-products (e.g., oil, petrol) or flammable water-soluble liquids (e.g. acetone, alcohol). It is used primarily in connection with offshore installations, airports, oil refineries, and tanker ships. PFC are also used to treat clothing and other textile products in order to enhance their dirt- and water repelling quality. Hence, PFCs can be imported or applied to these items. Treatments that involve PFCs are primarily connected to clothing that is water-tight or similar products with breathable fabrics (e.g. Gore-Tex) and to achieve dirt-repellent characteristics. For other imports, PFCs are mainly found in manufactured products. The quantity of PFC that is imported is uncertain. (Fjeld *et al.* 2005). A distinction is often made between the volatile PFCs (FTOH) and the rest.

PFS. PFOS is considered as the most important PFS because of its intentional industrial production and global distribution. PFOS and its homologues are used commercially for numerous applications. However, its potential toxicity, extreme persistence and accumulation potential have resulted in PFOS-containing products being prohibited for new use or importation by chemical regulatory authorities in the US and elsewhere. 3M, the major manufacturing company of PFOS, voluntarily began phase out of the PFOS chemistry in 2001 (3M, 2000; U.S. Environmental Protection Agency, 2001).

PFCA. Direct sources of PFCA compounds result from their manufacture and use. PFCA have been used as processing aids in the manufacture of fluoropolymers such as Teflon since the 1950s. Commercial PFCA products consist mainly of linear C8- and C9-PFCA. Homologues with a chain length between C4 and C13 can also be found.

Direct discharge of PFC is not considered relevant because there is no production of PFC in Norway (SFT 2004). There is some production of PFC-containing paint and varnish products as well as fire extinguisher, but this occurs in closed systems, and normally should not lead to direct emissions or discharge. Therefore the release of PFC to environment will be in the main related to where the PFC-containing products are used or disposed of.

The annual total discharge of PFC from Norway has been estimated to be (SFT 2004):

- 7-8 tons from the North Sea offshore industry
- 7-8 tons to water or groundwater from municipal pipelines, airports, industri, etc, of which <1 tonn can be attributed to refuse-sites.

Distribution and effects

Precursors PFCs such as FTOHs or perfluorosulfonamide (PFOSA) can transform (a)biotically to their stable end products like carboxylates and PFOS (Tomy et al. 2004).
A Nordic screening investigation (Kallenborn *et al.* 2004) has indicated the presence of PFC-compounds in all sample types with highest levels in marine mammals. The report concluded that significant concentrations of PFAS are found in the Nordic environment. In the SFT screening survey of 2004 and 2006 PFAS compounds were found both in freshwater and

marine ecosystems (Fjeld et al. 2005, Bakke et al. 2007). These compounds are environmentally stable and degrade slowly. PFAS, the dominating compound in most samples, is toxic to aquatic organisms, birds and insects.

Remedial action
Discharges of PFC-related compounds are to be reduced strongly in Norway within 2010 (Fjeld et al. 2005). SFT has proposed actions to reduce use and discharge of PFC, and PFOS is prohibited for use in flame retarding foams, fabric and impregnation products. OECD/EU is at present evaluating the risk from PFCs.

4.6 Polybrominated diphenyl ethers (PBDE)

General
PBDE comprises a large number of diphenyl ethers with 3 to 10 substituted bromine atoms. The present survey covers 19 PBDE compounds. Commercial PBDE products are supplied as three types of isomer mixtures (penta-BDE, octa-BDE and deca-BDE), but may contain other PBDEs as impurities. On average pentabrominated products contain 5 bromines, octabrominated products 8 bromines, and decabrominated products 10 bromines.

Use and discharges
PBDEs are a class of chemicals used as flame retardants in some plastics, fabrics and foams. A variety of consumer products may contain PBDE including computers, televisions, coated wires, upholstered furniture, mattresses, carpet padding and automobiles. Flame retardants are added to consumer products to reduce the likelihood that these materials will catch fire and to slow the rate that these materials burn. By 2004, penta-BDE and octa-BDE were phased out of production in North America and Europe because of concerns regarding the chemicals persistence, ability to bioaccumulate, and toxicity (EPA 2006). Deca-BDE remains in worldwide commercial use as a flame retardant, and is today one of the most widely used brominated flame retardants in consumer products.

Environmental releases of PBDEs can occur at recycling facilities, landfills and solid waste incineration plants.

Distribution and effects
Deca-BDE is considered to be persistent and has a low volatility and water solubility. Hence, it will bind strongly to particles that ultimately end up in depositional environments such as terrestrial soils and aquatic sediments. Studies have detected the presence of deca-BDE in household dust and biosolids from sewage sludge.

Current research indicates that deca-BDE may only have a low to moderate ability to bioaccumulate in people and wildlife. One explanation for this phenomenon is that the deca-BDE molecule is too large to move readily across cell membranes by passive diffusion. Despite its low to moderate ability to bioaccumulate, deca-BDE has been widely detected in biomonitoring studies of people and wildlife. Data are insufficient to determine if deca-BDE levels are increasing in people and wildlife.

There is a lack of information on the environmental fate and degradation of deca-BDE. Of concern is the possibility that the breakdown of deca-BDE may result in the formation of more bioaccumulative and toxic penta-BDE and octa-BDE products by the process of debromination (i.e., loss of bromine atoms from the parent compound). Octa-BDEs are classified as "hazardous substances" and subject to regulation. There is evidence indicating that degradation of deca-BDE by photolysis and anaerobic microorganisms in the laboratory can lead to the formation of octa-BDE. The extent to which this may occur in the environment is unknown.

New research suggests that deca-BDE may be an endocrine disruptor and developmental neurotoxin. The US EPA is currently in the process of updating the toxicological assessment for deca-BDE, and results should be released during 2008.

Remedial action

Norway has imposed regulation on production, import, export and trading of textiles, electrical and electronic products containing PBDEs. The aim is that the discharge of these compounds shall be reduced significantly within 2010. Solid waste containing more than 0,25 % of penta- octa- or deca-BDE shall be treated as special category waste. Use of deca-BDE in electrical articles is prohibited both in Norway and the EU.

4.7 Hexabromocyclododecane (HBCDD)

General

Hexabromocyclododecanes (HBCDDs) are brominated aliphatic cyclic hydrocarbons. Three isomers of HBCDD exist of which ά-HBCDD is predominant.

Use and discharges

Hexabromocyclododecane (HBCDD [2]) is used as flame retardants in thermal insulation building materials, upholstery textiles, and electronics. Its primary application is in extruded (XPS) and expanded (EPS) polystyrene foam. HBCDD is highly efficient in this application so that very low levels are required to reach the desired flame retardancy. Typical HBCDD levels in EPS are 0.7% and in XPS 2.5%. At present, HBCDD is the only suitable flame retardant for these applications. Any other flame retardant would likely need higher load levels in the polystyrene foam. Other uses are upholstered furniture, automobile interior textiles, car cushions and insulation blocks in trucks, packaging material, video cassette recorder housing and electric and electronical equipment. The industrial demand in Norway in 2001 was 20-25 tons and the demand in Europe is estimated to 9500 tons per year.

Distribution and effects

As a result of their widespread use and their physical and chemical properties, HBCDDs are now ubiquitous contaminants in the environment and humans. Its toxicity and harm to the environment are currently discussed. HBCDD can be found in environmental samples such as birds, mammals, fish and other aquatic organisms as well as soil and sediment. Generally, higher concentrations are measured near point sources and lower concentrations from locations with no obvious sources of HBCDD. High concentrations have been measured in top predators, such as marine mammals and birds of prey suggesting a biomagnification potential. Relatively low concentrations have reported in the few human studies conducted to date. HBCDD levels in biota are increasing slowly and seem to reflect the local market demand.

---

[2] The acronym HBCD is also often used for the same compound

Remedial action

HBCDD is in Norway regulated as one of the many brominated flame retardants. The aim is that the discharge of these compounds shall be reduced significantly within 2010. Solid waste containing more than 0,25 % HBCDD shall be treated as special category waste.

4.8 Tetrabromobisphenol A

General

TBBPA is a derivative of bisphenol A and is synthesized from this substance. Most commercial TBBPA products are of a relatively low purity, in fact containing a mixture of products brominated to varying extents. This is not generally considered to be a drawback, since in most applications of this substance (i.e. flame-retarding) it is the average % bromine that is of importance. The mixture resulting from the bromination of bisphenol A is therefore not purified, allowing a more efficient, lower cost product.

Use and discharges

TBBPA can be used as reactive and additive flame retardant. In the reactive application, TBBPA is bound chemically to the polymers. The main use is in epoxy resins of printed circuit boards and here TBBPA is covalently bound to the resin.. As an additive flame retardant it is used in TVs. The annual consumption worldwide has been estimated as 119,600 tons in 2001, of which 11,600 tons were used by the European industry. TBBPA is the primary flame retardant used in electronic circuit boards Decabromodiphenylether (deca-BDE) and TBBPA account for approximately 50% of the world's usage of brominated flame retardants.

Distribution and effects

Few studies report the presence of TBBPA in the environment. TBBPA has been reported in sludge collected from sewage treatment plants Elevated levels of TBBPA has been reported in river sediments downstream Swedish textile plants and a plastics industry applying these BFRs and less so upstream the discharge points. Being hydrophilic, TBBPA has been detected primarily in the dissolved phase of U.K. STW influents. TBBPA from different processes can be found in trace concentration the atmosphere, hydrosphere, soil, and sediments. It also occurs in sewage sludge and house-dust.

Remedial action

TBBPA is in Norway regulated as one of the many brominated flame retardants. The aim is that the discharge of these compounds shall be reduced significantly within 2010. Solid waste containing more than 0,25 % TBBPA shall be treated as special category waste and deposit systems for electrical and electronic waste containing TBBPA have been established in Norway.

4.9 Bisphenol A

General

Bisphenol A is a colourless white solid with a mol weight of 228.3 g and a mild phenolic odour.

Use and discharges

Bisphenol A current uses are numerous. It is a key monomer in production of polycarbonate plastic, epoxy resins. Otherwise it is used in the following polymer types: polyesters, polysulfones, and polyether ketones. Bisphenol A is also used in paint and building materials, as antioxidant in plasticisers and was earlier used as a polymerization agent in PVC production in Norway. It is also used to produce TBBPA. Bisphenol A is not produced in Norway, but the EU production is around 700 000 tons. Annual use in Norway is estimated to 60 tons.
The main source to the environment is from production, use of products and handling of solid waste. The degradation of TBBPA is also a likely source for Bisphenol A in the environment.

Distribution and effects

Bisphenol A is found both in sediments and aquatic organisms. It is readily degradable snd does not bioaccumulate to any extent. Tests show that Bisphenol A acts as an endocrine disruptor in mammals at low concentration, and it is unclear if it has the same effect on fish and gastropods. The effects are linked to reproduction disorder. Recent studies have confirmed that Bisphenol A exposure during development has carcinogenic effects and produce precursors of breast cancer. Bisphenol A may also cause skin irritation and possibly allergy.

Remedial action

Bisphenol A was included in the Norwegian priority list of chemicals in 2006, and products containing the compound shall be marked according to regulations.

4.10 Synthetic musk compounds

General

Musk compounds were in the past obtained from a gland of the male musk deer. Today all industrial musk compounds are made synthetically. Classes of synthetic musk substances are multicyclic musks, polycyclic musks (e.g. galaxolide and tonalide) and nitromusks (e.g. musk ambrette, musk xylene and musk ketone). Of the two compounds analysed here musk xylene is classified as damaging to the environment, and musk ketone is proposed for this classification.

Use and discharges

The main use of musk is as perfuming agents in consumer products, such as cosmetics, toiletries, detergents and soaps, as well as flavours in food industry and fish farming. The main discharge is from domestic waste water. The Norwegian discharge of musk xylene was reduced by 34 % from 1995 to 2003. Total Norwegian discharge in 2003 was 0,6 tons.

Distribution and effects

Nitro musk compounds have been detected in various biotic and abiotic samples, such as human breast milk, adipose tissue, and blood plasma. Human exposure is primarily through use of cosmetic products. Both musk ketone and musk xylene have been detected in fish, shellfish and river water. The levels in the marine environment seem lower than in freshwater. A Nordic screening survey form 2003 suggested higher environmental levels of polycyclic musk compounds than of nitromusks. On the other hand polycyclic musk seems to be less toxic than nitromusks. The acute toxicity of nitromusks is low, but they show a high bioaccumulation potential in aquatic organisms, and therefore cannot be neglected.

Remedial action
Musk compounds are included in the Norwegian priority list of chemicals, and products containing the compound shall be marked according to regulations. Three of the compounds are not allowed for use in cosmetics, for others concentration limits are in force.

4.11 Siloxanes (D4 and D5)

General
Siloxanes are chemical compounds composed of units of the form R_{2SiO}, where R is a hydrogen atom or a hydrocarbon group. A siloxane has a branched or unbranched backbone of alternating silicon and oxygen atoms -Si-O-Si-O-, with side chains R attached to the silicon atoms. The word *siloxane* is derived from the words silicon, oxygen, and alkane. Polymerized siloxanes with organic side chains are commonly known as silicones. The survey covers 3 compounds D4-, D5 and D6-siloxane.

Use and discharges
Siloxanes can be found in products such as cosmetics, water repelling windshield coating, food additives, soaps, fuel, car polish, cleaners, antifoam and car waxes. They occur in landfill gas and are being evaluated as alternatives to perchloroethylene for dry cleaning. The wide-spread and increasing use of siloxanes, their broad application as well as their high volatility has raised the environmental concern for these compounds. The Norwegian consumption of D4- and D5-siloxane was 42 tons in 2004.

Distribution and effects
Siloxanes are present as common pollutants in the Nordic environment and in many different matrices. They seem to be emitted through diffuse pathways. They seem to adsorb easily to particles in aquatic environments. Evaporation is also high, and measurements in arctic seagulls indicate significant long range transport. On the whole, biota data indicate that siloxanes may bioaccumulate. At present, the observed concentrations are not alarmingly high, and many background sites seem not to be contaminated. There is little information available on toxicity, but aquatic toxicity has been seen.

Remedial action
D5-siloxane was included in the Norwegian priority list of chemicals in 2006.

4.12 Phosphorous flame retardants (PFR)

General
The organic phosphate esters included in this report are in their pure state colourless viscous oils with low vapour pressure and water solubility making them excellent additives in *e.g.* plastic polymers. The general structure of organic phosphate esters is given in Figure 3. The organic substituents of the molecule are in some compounds chlorinated.

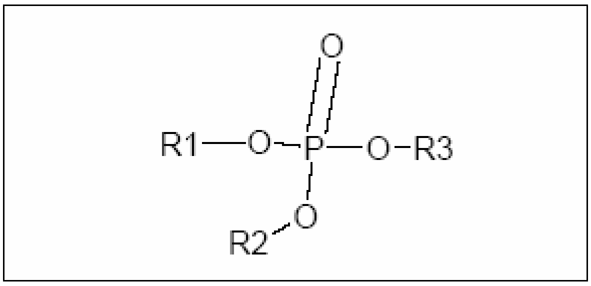


Figure 3. Molecular structure of organo-phosphate esters. R1, R2 and R3 are either similar or different organic substituents

Use and discharge
The world wide use of phosphorus based flame retardants was in 2001 186 000 tons. In recent years have the consumption in Western Europe rapidly increased from 53000 in 1998 to 83000 tons 2001 (Marklund *et al.* 2005b). The amount of organic phosphates esters imported in products of plastic is unknown.

Organophosphates esters (PFRs)are are used as alternatives to brominated flame retardants in polymeric materials such as polyphenyloxide (PPO), polyurethane foam (PUF) and polyvinylchloride (PVC). Organic phosphates are also used in plasticiser, paint, paper, surface treatment and as additive in different lubricant and transmission oils and hydraulic fluid in aircrafts (Marklund 2005a).

Arylphosphates are mostly used as flame retardants and plasticiser in PVC but also in polycarbonate, ABS (a copolymer made of acrylnitril, butadien and styrene) and other plastic polymers. Arylphosphates with short alkyl chain are used as flame retardant in different hydraulic oils and lubricants and phosphate esters with long carbon chain are more suitable in plastic as plasticiser.

Alkyl diarylphosphates have better properties compared to arylphosphates as plasticiser in PVC at low temperatures. On the other hand are these compounds less good as flame retardants.

Chlorinated trialkyl phosphates are mostly used in both flexible and rigid polyurethane foams, rubber and textile coatings.

The compounds in this study and their use are described below.

TIBP: Tris-iso-butylphosphate has a density slightly less than water. The use in Norway 2005 was 0.7 tonnes. The compound was used in 22 products. TIBP is used in the same products as TBP.

TBP: Tris-butylphosphate has a density slightly less than water. Use in Norway 2005 as 33.8 tonnes and was used in 28 products (SPIN[3]). Mixtures of TBD and tri-iso-butyl phosphate (TIBP) are used in aircraft hydraulic fluids wherein the amount of TIBP ranges from about 35

---

[3] A database of the use of chemical substances in the nordic countries.

to about 50 weight percent based on the total weight. Other applications are construction materials, paint, plaques, varnishes and different consumer preparartions (SPIN).

TCEP: Tri(2-chloroethyl)phosphate is currently replaced by other flame retardants, primarily TCPP, and is no longer produced in Europe. Use in Norway 2003 was 1286 tonnes mainly related to production of rubber and plastic products. TCEP may be emitted by sewage treatment plants since methodology removing PFR from effluents are missing (Andersen *et al*., 2004).

TCPP: Tri(1-chloro-2-propyl)phosphate is used mainly as an additive to polyurethane foams. Annual worldwide demand exceeds 40000 tonnes in 1997. 50 tonnes was used in Norway in 2001 for manufacture of chemicals, rubber and plastic. Traffic is assumed to be a general source for contamination of the outdoor environment by TCPP.

TDCP: Tri(1,3-dichloro-2-propyl)phosphate is used in a range of plastic foams, reins and latexes. The annual world-wide demand exceeded 8000 tonnes in 1997 and total EU production in 2000 was about 10000 tonnes. No data available for use in Norway. Since TDCP is applied as an additive it may be subject to volatilisation or leaching from the polymer matrix. An annual rate of release to air of 0.001% suggests that only 10% of TDCP is available for release (EU, 2006).

TBEP: Tri(2-butoxyethyl)phosphate. The use of trisbutoxyphosphate (TBEP) in Norway has decreased from 1.3-1.5 tonnes in 2003-2004 to 0.6 tonnes in 2005. The chemical was used in 12 different products 2005 (SPIN). Trisbutoxyphosphatec is for example applied in paint, lacquers and varnishes.

TPhP: Triphenylphosphate. The use of trisphenylphosphate (TPhP) in Norway has decreased from 55 ton 2004 to 6.7 ton in 2005, but TPhP is still used in the same numbers of products (29 products 2005; SPIN). TPhP is used as flame retardant in cellulose acetate, vinyl copolymers used in vacuum cleaner parts, Christmas tree lighting set (www.PAC-india.com).

EHDPP: 2-ethylhexyl-di-phenylphosphate. The use of EHDPP in Norway has increased from 2.8 tonnes year 2002 to 30.1 tonnes in 2005 but appears to level off from 2004-2005.

V6: Tetrekis(2-chlorethyl)dichloroisopentyldiphosphate. The main use of V6 is as a flame retardant in flexible polyurethane foam and has the potential for migration. One of the main impurities in V6 is TCEP (4.5 – 7.5%). Annual production in Europe was less than 5000 tonnes in 2000. No data available for use in Norway. Since V6 is applied as an additive it may be subject to volatilisation or leaching from the polymer matrix. An annual rate of release to air of 0.001% suggests that 10% of V6 is available for release (EU, 2006).

Distribution and effects

TCEP is considered as very stable both for oxidation and degradation by chlorine attack. It is considered as non biodegradable by EU (EU, 2005). TCEP has been detected in all precipitation samples collected in Ireland, Poland and Sweden in concentrations up to 20 ng/L. TCEP was present in 85% of a total of 983 domestic dust samples and results show that soft foam, paints and wallpapers contained TCEP. TCEP was one of the most frequent detected compounds in water samples from steams across USA in 1999 and 2002 (EU, 2005?). In Germany the levels in the river Oder showed mean values between 30 to 282 ng/l

(EU, 2005). The main source was effluents from sewage treatment plants. TCEP concentrations around 10 ml/l are suspected as a threshold level for trout and LC50: 170mg/l (EU, 2005).

EU has calculated a loss of TCPP to air of 0.75% from outdoor use articles suggesting that 40% of TCPP is available for release. This is much higher then for TDCP (EU, 2006). TCPP was found in 60 – 90% of 436 domestic dust samples with levels ranging from 0.1 to 375 mg/kg. In Sweden TCPP dominated in the snow samples with levels up to 170 ng/kg at 2 m from the road with levels decreasing with increasing distance from the road. TCPP is considered as very stable both for oxidation and degradation by chlorine attack. No degradation in sewage treatment plants is detected. It is considered to meet the screening criteria as persistent/ very persistent (EU, 2006).

The EU risk assessment 2006 states that it is unlikely for TCPP to exhibit a chronic toxicity to fish at <1 mg/l and suggest no classification for the compound. TCPP is found to be readily metabolised in fish (WHO, 1998) and due to lack of bioaccumulation of TCPP, the EU concluded that there were no risks for secondary poisoning of the marine environment. TCPP has been analysed in several rivers and sewage treatment plant effluents in Germany and the levels in the river Ruhr range from 20 to 200 ng/l TCPP. The sewage treatment plants effluents had concentrations up to 400 ng/l TCPP.

Up to 230 ng/kg TDCP has been found in snow samples along a road in northern Sweden indicating road traffic as point source for TDCP into the environment. TDCP is considered as very stable both for oxidation and degradation by chlorine attack. No degradation in sewage treatment plants is detected. A general lack of ready biodegradability was noted by the EU risk assessment (EU, 2006).

The aquatic toxicity of TDCP is approximately 1 mg/l for rainbow trout and 5 mg/l for *Daphnia magna* . The EU risk assessment confirms the classification N R51-53 – toxic to aquatic organisms and may cause long term effects in the aquatic environment. A bioconcentration factor of 45 l/kg for fish is suggested implying rapid metabolism (EU, 2006). TDCP has been analysed in several rivers and sewage treatment plants in Germany and the concentrations in River Ruhr were about 50 ng/l and a sewage treatment plant effluents have up to 120 ng/l TDCP. In Japan up to 5599 ng/l TDCP was detected in the leach ate from a landfill site.

V6 is considered as very stable both for oxidation and degradation by chlorine attack. No degradation in sewage treatment plants was detected. Biological degradation of 37% in 28 day has been reported (EU, 2006). On the other hand in the same report V6 was characterised as persistent in the marine environment (EU, 2006).

Measured V6 toxicity to fish and invertebrates is higher than for TCEP by a factor of 2 and 8, respectively. The EU risk assessment confirms the classification N R51-53 – toxic to aquatic organisms and may cause long term effects in the aquatic environment. No toxicity data is available for fish. No monitoring data is available.

Remedial action

The EU risk assessment 2006 suggests screening for TCPP in effluents and run-off from sewage treatment plants and landfills, marine and fresh water sediments close to potential source areas. TCPP is also recommended to be measured in drinking water sources situated near landfills and PUR applying plants. Broad screening is also suggested for TDCP and V6 in waste water and sediments from landfills and PUR production and application industries. TDCP analysis is also recommended for drinking water sources situated near landfills. EU has initiated an evaluation of human health risk from TCDP.

4.13 Diethyhexylphtalate (DEHP)

General

The potential biological effects of phtalates have been in focus in recent years, and since 1999 the use has been prohibited in toys and other products for children under the age of 3 years. DEHP is one of the most common of the phtalate compounds, with a mol weight of 388,26 g and structure as shown in Figure 4.

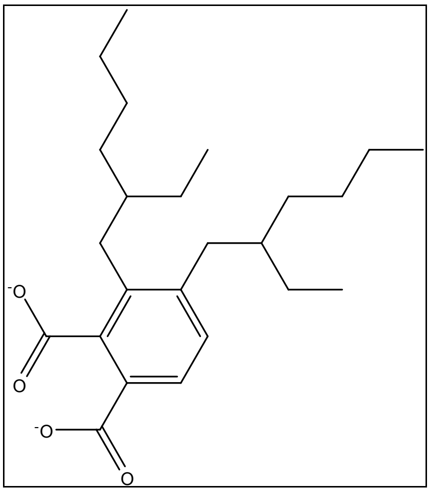


Figure 4. Chemical structure of DEHP.

Use and discharge

DEHP is a common constituent of PVC (polyvinyl chloride) products. In fact in some such products the content of DEHP is higher than that of PVC. Other products apply DEHP due to its surface active properties, as antifoam agent in the paper industry and as emulgator in cosmetics, perfumes, and pesticides. Other applications are in production of pain, varnish and ink. According to Økland et al. (2005) the use in Norway has declined strongly from 2300 tonnes in 1995 to 124 tonnes in 2002.

According to SFT the Norwegian discharges of DEHP have declined from over 28 tonnes/yr in 1995 to about 2 tonnes/yr in 2002. These figures represent discharges through public waste water systems, but according to a literature survey from SFT in 2005 probably only half of the input to the environment comes from this source.

Distribution and effects

Analysis of DEHP was done as part of the Norwegian screening survey in 2006. Surprisingly one of the highest concentrations found in freshwater sediments was from an alpine lake, Dargesjå, Hardangervidda, Norway, with only long range atmospheric input. Also trout from this lake had elevated DEHP. Leaving out the possibility of sample contamination one theory for this finding is cold air condensation and deposition. Xie et al. (2005) claim that DEHP is deposited in the North Sea in the winter and re-emitted to the atmosphere during summer. Hence DEHP enrichment can be expected with altitude or at higher latitudes as seen for several other persistent organic contaminants (Wania and Mackay 1993; Wania and Mackay 1996).

In the 2006 screening survey freshwater and marine sediments had concentrations much in the same range (75 – 350 µg/kg d.w). In the revised Norwegian environmental classification system for marine sediments (SFT TA-2229/2007) the upper limit of Class II, representing a chronic no-effects concentration (PNEC), is 215 µg/kg d.w.

Concentrations of DEHP in blue mussel and fish liver in the screening survey varied within 3 orders of magnitude, and the possibility of secondary contamination cannot be ruled out. Still the highest concentrations were a level reported from vegetable fat (11 000 µg/kg) and bakery products (25 000 µg/kg) by MAFF (1996) suggesting that the risk from eating such seafood should be moderate.

Phtalates seem to degrade reasonably rapidly in water, less so in sediments and soil. Phtalates may bioaccumulate and invertebrates have less ability than fish to metabolize phtalates (www.miljostatus.no). DEHP is classified as harmful to reproduction.

Remedial actions
DEHP is among the phtalates on the SFT Obs-list. With the formal classification “toxic”, chemical products with more than 0,5 % DEHP are not allowed to market to private persons.

4.14 Dioxins and furans (PCDD/PCDF)

General
Polychlorinated dibenzo-p-dioxins (PCDD) and dibenzofurans (PCDD) are commonly named dioxins. A total of 75 dioxins and 135 furans exist with different toxic properties. Incineration with chlorine and carbon present may produce dioxins (e.g. fires, incinerators, and thermal industrial processes).

Use and discharges
Dioxins are waste products with no specific usage. The total Norwegian discharges were reduced by 56 % between 1995 and 2003, but still legacy levels especially in soils and marine sediments represent a long term source to other parts of the environment.

Distribution and effects
Dioxins are present everywhere in low concentrations due to natural and manmade thermal processes. They are among the contaminants that have been most in focus in Norwegian and international environmental management. The wealth of information on sources, transport pathways, environmental levels and effects is enormous, and a treatise of this is beyond the scope of the present report.

Remedial action
Dioxins and furans are on the Norwegian list of priority chemicals, and is covered by the North Sea Declaration as well as the OSPAR list of priority pollutants. The most important action has been closing down of industrial plants producing dioxins.

4.15 Polychlorinated biphenyls (PCB)

General
There are 209 possible PCBs, from three monochlorinated isomers to the fully chlorinated decachlorobiphenyl isomer. Generally, the water solubility and vapour pressure decrease as the degree of substitution increases, and the lipid solubility increases with increasing chlorine substitution. The toxicology of PCBs is affected by the number and position of the chlorine atoms, as substitution in the ortho position hinders the rotation of the rings. PCBs without ortho substitution are generally referred to as coplanar and all others as non-coplanar. Coplanar PCBs bind, like dioxins and furans, to the cellular Ah-receptor and may thus exert dioxin-like effects, in addition to Ah-receptor independent effects which they share with non-coplanar PCBs. The present survey covers both types of PCBs, but different selections in the different subprojects.

Use and discharges
Polychlorinated biphenyls (PCBs) are mixtures of chlorinated hydrocarbons that have been used extensively since 1930 in a variety of industrial uses, including as dielectrics in transformers and large capacitors, as heat exchange fluids, as paint additives, in carbonless copy paper and in plastics. The value of PCBs for industrial applications is related to their chemical inertness, resistance to heat, non-flammability, low vapour pressure and high dielectric constant.

Distribution and effects
PCBs are among the contaminants that have been most in focus in Norwegian and international environmental management. The wealth of information on sources, transport pathways, environmental levels and effects is enormous, and a treatise of this is beyond the scope of the present report. In general the PCB-levels in the Norwegian environment is going down, but still there are restrictions on seafood consumption and marketing due to PCB in more than 10 fjord and coastal areas.

Remedial action
The authorities have made an action plan to phase out and remove all PCB containing products and waste. Use of new PCB in Norway was prohibited in 1980, and large transformers and capacitors were taken out of use within 1995. Removal of other PCB-containing articles in use was done within 2007.

4.16 Organohalogens (TCB, HCB)

General
Trichlorobenzene (TCB) is, like dioxins, produced as a by-product in thermal processes with chlorine and carbon present. Hexachlorobenzene (HCB) in pure form is a white powder. HCB is also a by-product of industrial processes and of waste incineration.

Use and discharges
TCB has no usage. It is discharged together with dioxins and HCB from waste incineration and various industrial processes. No sources of any significance have been registered in Norway, and total discharges were in 2003 estimated to 6 kg. HCB was used as a pesticide until 1965. The Norwegian discharges of HCB were reduced by 99 % from 1995 to 1 kg in 2003.

Distribution and effects
TCB is dispersed in air, water, and soil and long range transport is seen.
HCB is highly insoluble in water, and is soluble in organic solvents. It is quite volatile and can be expected to partition into the atmosphere as a result. High HCB level have been measured in the Arctic due to long range atmospheric transport. HCB is ubiquitous in the environment, and has been measured in foods of all types. It is very resistant to breakdown, and is known to bioconcentrate in the fat of living organisms. Lethal effects on man from ingestion of HCB-treated seed grains were reported from Turkey in the late 1950ies. HCB is, however, unlikely to cause direct toxic effects on aquatic animals at or below saturation concentrations in water.

Remedial action
TCB and HCB are on the Norwegian list of priority pollutants, and the aim is that the discharges are reduced significantly within 2010. The commitment to reduce the discharges is also covered by international agreements. Use of HCB is now prohibited.

4.17 Biocides (DDT, Toxaphene, Chlordane, HCH)

General
DDT occurs as odourless to slightly fragrant colourless crystals or white powder. The breakdown products of DDT, 1,1-dichloro-2,2-bis(4-chlorophenyl)ethane (DDD) and 1,1-dichloro-2,2bis(4-chlorophenyl)ethylene) (DDE), are also present virtually everywhere in the environment.

Toxaphene is a mixture of polychlorinated bicyclic terpenes (Figure 5) with chlorinated camphenes predominating. The toxaphenes are yellow, waxy solids with a chlorine/terpene-like odour. The survey covers 8 compounds.

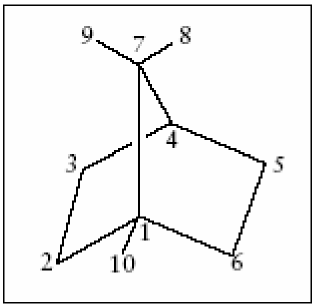


Figure 5. Basic structure of toxaphene molecules.

Chlordane is a colourless to yellowish-brown viscous liquid with an aromatic, pungent odour similar to chlorine.

Hexachlorocyclohexane (HCH) is a colourless, crystalline solid with either a faint or no smell. It is only slightly soluble in water, but soluble in organic liquids. HCH occurs in 3 isomers, a-, b- and g-HCH, the latter also known as lindane.

Use and discharges
DDT was widely used during the Second World War to protect the troops and civilians from the spread of malaria, typhus and other vector borne diseases. After the war, DDT was widely used on a variety of agricultural crops and for the control of disease vectors as well. It is still being produced and used for vector control. Growing concern about adverse environmental effects, especially on wild birds, led to severe restrictions and bans in many developed countries in the early 1970s. The largest agricultural use of DDT has been on cotton, which accounted for more than 80% of the US use before its ban there in 1972. DDT is still used to control mosquito vectors of malaria in numerous countries.

Toxaphene is a nonsystemic and contact insecticide that was used primarily on cotton, cereal grains fruits, nuts and vegetables. It has also been used to control ticks and mites in livestock. Toxaphene has been in use since 1949 and was the most widely used insecticide in the USA in 1975.

Chlordane is a broad spectrum contact insecticide that has been used on agricultural crops including vegetables, small grains, corn, other oilseeds, potatoes, sugarcane, sugar beets, fruits, nuts, cotton and jute. It has also been used extensively in the control of termites. Chlordane is highly insoluble in water, and soluble in organic solvents.

Lindane has been used as a broad-spectrum insecticide since the early 1950s for agricultural and nonagricultural purposes, which include treatment of seeds and soil, application on trees, timber and stored materials, treatment of animals against ectoparasites and in public health. In the third world, lindane is used for the control of a broad spectrum of plant-eating and soil-dwelling pests, public health pests and animal ectoparasites. It is relatively cheap, and its persistence is often seen as advantage in pest control rather than as an environmental hazard.

Distribution and effects
DDT is highly insoluble in water and is soluble in most organic solvents. It is semi-volatile and can be expected to partition into the atmosphere as a result. Its presence is ubiquitous in the environment and residues have even been detected in the arctic. DDT and related compounds are very persistent in the environment, as much as 50% can remain in the soil 10-15 years after application. It is lipophilic and partitions readily into the fat of all living organisms and has been demonstrated to bioconcentrate and biomagnify. DDD and DDE are more persistent than the parent compound. DDT and its metabolites have been detected in food from all over the world and this route is likely the greatest source of exposure for the general population of DDT and its metabolites. Toxicity to humans, even after ingestion, seems to be small, but there is some evidence to suggest that DDT may be suppressive to the immune system.

Toxaphene is highly insoluble in water, and has a half life in soil of up to 12 years. It has been shown to bioconcentrate in aquatic organisms and is known to undergo atmospheric transport. Toxaphene is essentially non-toxic to terrestrial plants. In general, toxic effects have been observed only at levels much higher than the recommended usage level. Toxaphene is highly toxic to aquatic organisms

Chlordane is semi-volatile and can be expected to partition into the atmosphere which favours long range transport, and chlordane has been detected in arctic air, water and organisms. It binds readily to aquatic sediments and accumulates in the fat of organisms. Data suggest that chlordane is taken up directly from the water rather than from food. The acute toxicity of chlordane to aquatic organisms is quite variable.

Lindane undergoes rapid degradation (dechlorination) in the presence of ultra-violet irradiation, to form pentachlorocyclohexenes (PCCHs) and tetrachlorocyclohexenes (TCCHs). Lindane is strongly adsorbed on soils that contain a large amount of organic matter; furthermore, it can move downward through the soil with water from rainfall or artificial irrigation. Volatilization appears to be an important route of its dissipation especially under the high-temperature conditions of tropical regions. It is moderately toxic to aquatic invertebrates and fish. It is, however, directly toxic to wildlife and bioaccumulate.

Remedial action
The use of DDT has been banned in 34 countries and severely restricted in 34 other countries.

Use of toxaphene has been banned in 37 countries.

Action to ban the use of chlordane has been taken in the EU and in 9 countries outside, and its use is severely restricted or limited to non-agricultural uses in 15 countries.

Lindane has been banned for all uses in 7 countries and severely restricted in another four. A further 23 countries have prohibited its import. Lindane is one of the 27 pesticides on the Prior Informed Consent (PIC) list, an international procedure which requires exporters of certain particularly hazardous chemicals to inform the importing country of the chemical's legal status and its hazards.

4.18 Polycyclic aromatic hydrocarbons (PAH)

General
The PAHs constitute a large number of compounds where 3 or more benzene rings are coupled directly in covalent bonds. Alkylated derivatives are also included in this group, sometimes also the dicyclic aromatic compounds (naphtalenes). PAHs are formed during incomplete combustion of organic material, and some are biogenic as well. This is one of the oldest known contaminants of particular environmental and human health concern, especially since several compounds are carcinogenic. There is a very large knowledge on the environmental properties of PAHs and to summarise this is beyond the scope of the report.

Use and discharges
PAH occurs in most petroleum types and products in particular coal tar, other tars, creosote, and mineral oils. The largest sources to the environment are aluminium smelters and domestic firewood heating. Road and ship traffic are also significant contributors. Norwegian discharges of PAH were reduced by only 1 % between 1995 and 2003. The authorities expect another 10-30 % reduction within 2010, when diffuse entry is expected to dominate.

Distribution and effects
PAH is transported both in the atmosphere and ocean currents. The solubility in water is low, and most PAH of concern is associated with particulate matter. Degradation of PAH varies, and the compounds bioaccumulate. However, since PAH also occurs naturally several organisms, e.g. fish, have the ability to metabolise PAH. Several PAHs are toxic to aquatic organisms and may impact reproduction at long term exposure. The most damaging compound for human health is benzo(a)pyrene, due to its carcinogenic and mutagenic property.

Remedial action
PAH is on the Norwegian list of priority pollutants, and is also covered by the North Sea declarations, OSPAR, and the ECE protocol. The discharges from the aluminium smelters have been of particular concern in Norway and are strictly regulated. Emission from domestic fireplaces is also restricted.

4.19 Organotin compounds

General
The of the 6 organotin compounds covered by the survey tributyl-tin (TBT) and triphenyl-tin TPhT) are synthetic products. The others (mono- and di-butyl- and mono-and di-phenyl-tin) are breakdown products of these.

Use and discharges
Pure TBT and TPhT are not produced in Norway, but used in other production. TBT is primarily used as antifouling paint on ship hulls and in wood and fabric impregnation. TPhT was formerly used as a pesticide, but not any more. The breakdown products mentioned above are also used as additives in certain products. The main source of environmental TBT is leakage from ship hulls and waste from shipyards (primarily during sand blasting of hulls). The Norwegian discharges were reduced from 58 tons in 1995 to 8 tons in 2003. A further reduction to about 3 tons is expected within 2010.

Distribution and effects
The most elevated levels of TBT have been found in sediments and aquatic organisms near shipyards, harbours, marinas, and highly trafficked ship lanes. TBT has strong affinity to particles and may accumulate to very high levels in marine sediments. It is regarded as primarily a marine problem, although elevated levels have also been recorded in runoff from land. TBT is highly acute toxic to aquatic organisms, and have clear disrupting effect on genital development and reproduction in molluscs, especially gastropods.

Remedial action
Use of TBT at hulls smaller than 25 m in length and in fish net impregnation in Norway was prohibited in 1990. From 2003 use of TBT paint on larger boats is also prohibited and within 2008 all use of TBT on hulls shall have ceased. This regulation is also ratified by the international maritime organization UN IMO. Clean-up of several of the most TBT contaminated harbour areas in Norway shall be completed within 2010.

5. Stations, sampling, and sample treatment

Details on sampling stations, sampling and sample treatment in the survey are given in Figure 6 and Table 3 to Table 9.

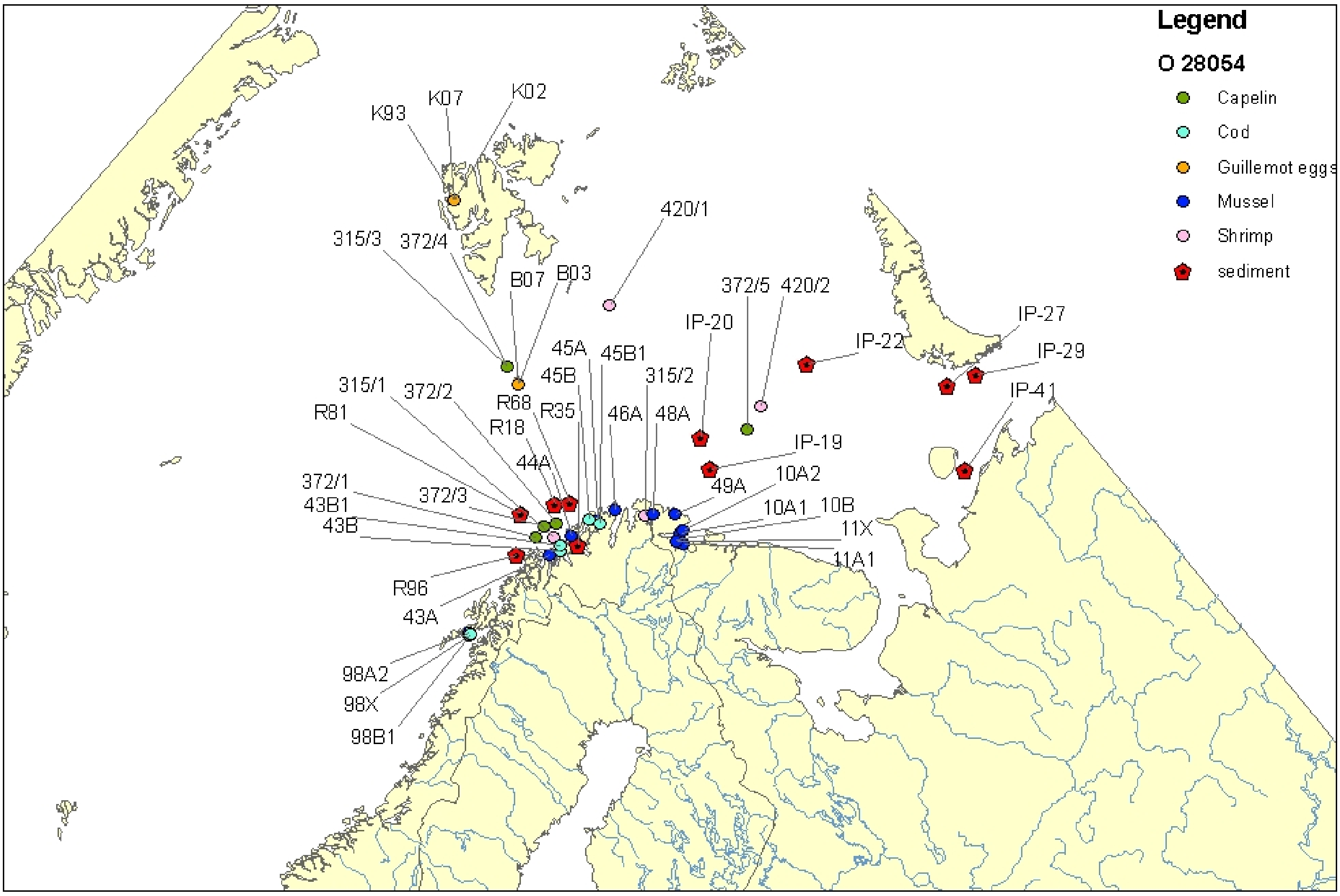


Figure 6. Map of sampling stations. Cf Table 3 for details on the stations.

Table 3. Overview of sample type and location as given in the subprojects. Coordinates transformed to decimal degrees.

Station	Category	Area	Area specification	Latitude	Longitude
IP-19	Sediment	Barents Sea	Kola Transect	71,3683	33,6283
IP-20	Sediment	Barents Sea	Kola Transect	72,1833	33,6317
IP-22	Sediment	Barents Sea	Shtokman structure	72,8667	44,0050
IP-27	Sediment	Barents Sea	Pechora Sea	70,5983	52,4067
IP-29	Sediment	Barents Sea	Pechora Sea	70,3817	54,5200
IP-41	Sediment	Barents Sea	Pechora Sea	68,6633	50,0900
R18	Sediment	Barents Sea	Tromsøflaket	71,3138	21,2783
R35	Sediment	Barents Sea	Stjernøysundet	70,2302	22,7132
R68	Sediment	Barents Sea	Tromsøflaket	71,3193	22,4955
R81	Sediment	Barents Sea	Tromsøflaket	71,1580	18,6517
R96	Sediment	Barents Sea	Troms II	70,1357	18,1493
315/1	Shrimp	Barents Sea	Barents-Sea-West_Feb.16-1	70,5167	20,9167
315/2	Shrimp	Barents Sea	Barents-Sea-East_Feb.16-2	70,6833	27,9000
315/3	Shrimp	Barents Sea	Barents-Sea-West_Feb.16-3	74,8167	18,1333
420/1	Shrimp	Barents Sea	Barents-Sea-Feb.13-4	75,9500	29,0000
420/2	Shrimp	Barents Sea	Barents-Sea-Feb.13-5	72,4167	39,0667
372/1	Capelin	Barents Sea	Barents-Sea-West_Feb.13-1	70,5500	19,6167
372/2	Capelin	Barents Sea	Barents-Sea-West_Feb.13-2	70,8333	21,2667
372/3	Capelin	Barents Sea	Barents-Sea-West_Feb.13-3	70,8167	20,3000
372/4	Capelin	Barents Sea	Barents-Sea-West_Feb.13-4	74,8167	18,1333
372/5	Capelin	Barents Sea	Barents-Sea-West_Feb.13-5	72,0000	37,3333
98X	Mussel	Barents Sea	Skrova harbour	68,1652	14,6588
98A2	Mussel	Barents Sea	Husvaagen area	68,2577	14,6638
43A	Mussel	Barents Sea	Lyngneset (Langfjord)	70,1005	20,5465
44A	Mussel	Barents Sea	Elenheimsundet	70,5162	22,2460
45A	Mussel	Barents Sea	Sauhamneset	70,7637	24,3200
46A	Mussel	Barents Sea	Smines (Altesula)	70,9728	25,8017
48A	Mussel	Barents Sea	Trollfjorden (Tanafjord)	70,6935	28,5547
49A	Mussel	Barents Sea	Nordfjorden (Syltefjord)	70,5502	30,0862
10A1	Mussel	Barents Sea	Skagodden	70,0688	30,1635
10A2	Mussel	Barents Sea	Skallneset	70,1383	30,3617
11A1	Mussel	Barents Sea	Sildkrokneset (south)	69,7837	30,1848
11X	Mussel	Barents Sea	Brashavn	69,8987	29,7442
98B1	Cod	Barents Sea	Bjørnerøya (east)	68,2073	14,8355
43B	Cod	Barents Sea	Kvænangen (Olderfjord)	70,1500	21,3667
43B1	Cod	Barents Sea	Leisundet	70,3020	21,4268
45B	Cod	Barents Sea	Hammerfest area	70,8333	23,7333
45B1	Cod	Barents Sea	Revsbotn	70,7000	24,4833
10B	Cod	Barents Sea	Varangerfjorden	69,9333	29,6667
K93	Guillemot eggs 1)	Barents Sea	Ossian Sars, Kongsfjorden	78,9405	12,4852
K02	Guillemot eggs	Barents Sea	Ossian Sars, Kongsfjorden	78,9405	12,4852
K07	Guillemot eggs	Barents Sea	Ossian Sars, Kongsfjorden	78,9405	12,4852
B03	Guillemot eggs	Barents Sea	Kapp Malmgren, Bjørnøya	74,3557	19,1510
B07	Guillemot eggs	Barents Sea	Evjebukta, Bjørnøya	74,3507	19,1010

1). Brünnich's guillemot (*Uria lomvia*)

5.1 Sediments

The Akvaplan-niva sediment samples, IP-19 til IP-41, were collected in June 2007 in the Russian region of the Barents Sea and in the Pechora sea during research cruise onboard RV “Ivan Petrov”. Samples for analysis were selected by SFT and the stations were situated along the Kola transect (stations IP-19 and IP-20), in the area of Shtockman field (station IP-22) and on the south-eastern part of the Barents Sea – the Pechora Sea area (stations IP-27, IP-29 and IP-41). Station locations were determined by using the Global Positioning System (GPS) which is accurate to ± 100 m. Details of the Akvaplan-niva programme are given in Annex 1.

Sediment samples were collected according OSPAR requirements (OSPAR, 1999) using box-corer. The upper sediment layer (0-1 cm) was sampled and frozen immediately. The amount of sedimentary material less than 63µm varied from 52 to 84%.

The Mareano samples, R18 – R96, were obtained from the Tromsøflaket region during surveys with RV ”Håkon Mosby” in May-June 2006 and with RV “G.O.Sars” from 24 March to 11 April and during 2 – 22 October 2007. The main sampling gear was a 12 core multicorer. The upper 3 cm of samples from the 100 mm diameter cores were selected for the present project and stored frozen wrapped in clean Al-foil. A boxcorer was used occasionally due to weather conditions or malfunction of the multicorer (station R81, Table 4).

Table 4. Overview of sediment samples. The IP samples are from Akvaplan-niva, the R samples from IMR-NILU. Note that the R81 samples were pooled before analysis, so also the R96 samples.

Station ID	Station name/no	Date	Depth m	Layer cm	Equipment, comment
IP-19	Kola Transect	20.06.2007	66	0-1	Box-corer
IP-20	Kola Transect	21.06.2007	262	0-1	Box-corer
IP-22	Shtokman structure	22.06.2007	275	0-1	Box-corer
IP-27	Pechora Sea	25.06.2007	62	0-1	Box-corer
IP-29	Pechora Sea	25.06.2007	188	0-1	Box-corer
IP-41	Pechora Sea	26.06.2007	53	0-1	Box-corer
R18	Tromsøflaket	02.06.2006	322	0-3	Multicorer
R35	Stjernøysundet	08.06.2006	475	0-3	Multicorer
R68	Tromsøflaket	19.06.2006	438	0-3	Multicorer
R81 BC2	Tromsøflaket	03.04.2007	166	0-3	Box-corer, 4 samples
R81 MC2	Tromsøflaket	03.04.2007	163	0-3	Multicorer, 1 sample
R81 MC3	Tromsøflaket	03.04.2007	282	0-3	Multicorer, 5 samples
R96 MC8	Troms II	10.04.2007	363	0-3	Multicorer, 1 sample
R96 MC9	Troms II	10.04.2007	362	0-3	Multicorer

The 3 subsamples from R81 were pooled before analysis, so also with the 2 subsamples from R96.

5.2 Blue mussel

The mussel samples have been collected as part of SFTs CEMP programme (Table 5). The present project covers 9 different coastal stations. Samples from the years 1994 and 2006 were included in the present analytical programme giving a total of 18 station/year combinations. Three replicate groups of mussels were collected from each station, and the soft tissues from the individuals in each group combined into one pooled sample. The replicate groups represented 3 different size classes. The 3 pooled samples from each station/year were analysed separately, and the results are presented as means of these.

Table 5. Overview of blue mussel (Mytilus edulis) samples.

Station ID	Station	Station no (CEMP)[4]	Sampling date	Number of mussels	Shell-size mm (min-max)
98X	Skrova harbour	98x	02.09.1994	20,20,20	40 - 49
98A2	Husvaagen area	98A2	28.08.2006	100,50,16	17 - 45[5]
43A	Lyngneset in Langfjord	43A	01.09.1994	50,50,50	30 - 39
43A	Lyngneset in Langfjord	43A	31.08.2006	86,50,49	22 - 49
44A	Elenheimsundet	44A	31.08.1994	20,20,20	40 - 49
44A	Elenheimsundet	44A	01.09.2006	100,50,50	20 - 49
45A	Sauhamnneset	45A	30.08.1994	50,50,50	30 - 39
45A	Sauhamnneset	45A	02.09.2006	99,50,50	20 - 49
46A	Smines (Altesula)	46A	30.08.1994	20,20,20	40 - 49
46A	Smines (Altesula)	46A	03.09.2006	100,50,50,	20 - 49
48A	Trollfjorden (Tanafjord)	48A	28.08.1994	3 x 50	30 - 39
48A	Trollfjorden (Tanafjord)	48A	04.09.2006	100,50,45	20 - 49
49A	Nordfjorden (Syltefjord)	49A	27.08.1994	100,100,100	20 - 29
49A	Nordfjorden (Syltefjord)	49A	05.09.2006	100,50,50	20 - 49
10A1	Skagodden	10A1	26.08.1994	100,100,100	20 - 29
10A2	Skallneset	10A2	06.10.2006	100,100,100	21 - 29
11A1	Sillkrokneset (south)	11A1	25.08.1994	40,40,40	30 - 39
11X	Brashavn	11X	06.10.2006	20, 20, 20	40 - 49

5.3 Shrimp

Five pooled samples of shrimps were secured during the winter research cruise done by the Institute of Marine Research, Bergen (Table 6). The samples were brought frozen to NIFES where they were boiled and peeled and only the edible part was made into a pooled sample.

Table 6. Overview of shrimp (Pandalus borealis) tail samples.

Station ID	NIFES Journal #	Station	Date	count	size
315/1	NIFES-1	Barents-Sea-West_Feb.16-1	24.02.2007	-	-
315/2	NIFES-2	Barents-Sea-East_Feb.16-2	02.03.2007	-	-
315/3	NIFES-3	Barents-Sea-West_Feb.16-3	16.02.2007	-	-
420/1	NIFES-4	Barents-Sea-Feb.13-4	18.02.2007	-	-
420/2	NIFES-5	Barents-Sea-Feb.13-5	13.02.2007	-	-

5.4 Capelin

Five pooled samples of whole capelin (25 individuals) were sampled during the winter research cruise done by the Institute of Marine Research, Bergen (Table 7). The samples were brought frozen to NIFES where the whole fish samples were freeze dried and homogenized and subsamples taken out for the various analyses.

---

[4] (CEMP: Coordinated Environmental Monitoring Programme, formerly named Joint Monitoring and Assessment Programme, JAMP)

[5] 3 size classes

Table 7. Overview of capelin (Mallotus villosus) samples.

Station ID	NIFES Journal #	Station	Date	Count	Length cm (min- max)	Weight g (min- max)
372/1	NIFES-1	Barents-Sea-West_Feb.13-1	13.02.2007	25	13,0 – 18,5	11,1 – 33,2
372/2	NIFES-2	Barents-Sea-West_Feb.13-2	13.02.2007	25	13,0 – 18,5	11,1 – 33,2
372/3	NIFES-3	Barents-Sea-West_Feb.13-3	13.02.2007	25	13,0 – 18,5	11,1 – 33,2
372/4	NIFES-4	Barents-Sea-West_Feb.13-4	13.02.2007	25	13,0 – 18,5	11,1 – 33,2
372/5	NIFES-5	Barents-Sea-West_Feb.13-5	13.02.2007	25	13,0 – 18,5	11,1 – 33,2

5.5 Atlantic cod

The present project covers analysis of individual samples of liver from Atlantic cod (*Gadus morhua*) sampled under the CEMP programme from 4 stations and 2-3 different years giving a total of 10 station/date combinations (Table 8). Liver samples from 10 – 25 replicate individuals were dissected out according to the OSPAR procedures applied in CEMP and analysed individually. The results are presented as means of the replicates.

Table 8. Overview of cod (Gadus morhua) samples. Note that some stations have been sampled several years.

Station ID	Station	Sample type	Station no. (JAMP)	Date	count	Fish length cm (min- max)	Fish weight g (min- max)
98B1	Bjørnerøya (east)	Liver	98B1	Nov.1994	25	490-600	1334-2625
98B1	Bjørnerøya (east)	Liver	98B1	28.02.2006	25	485-610	1242-2448
98B1	Bjørnerøya (east)	Liver	98B1	29.11.2006	25	510-670	1540-3950
43B	Kvænangen, Olderfjord	Liver	43B	Feb.1995	25	495-715	1167-3098
43B1	Leisundet	Liver	43B1	03.10.2006	25	515-800	1410-7050
45B	Hammerfest area	Liver	45B	16.02.1995	24	465-670	902-3101
45B1	Revsbotn	Liver	45B1	09.10.2006	25	454-635	850-2294
10B	Varangerfjorden	Liver	10B	30.11.1994	21	425-780	603-4663
10B	Varangerfjorden	Liver	10B	12.10.2005	25	325-540	318-1473
10B	Varangerfjorden	Liver	10B	25.11.2006	10	300-470	225-1020

5.6 Brünnich's guillemot eggs

The present project covers egg samples from 2 stations and 3 different years giving a total of 5 groups each with 5 replicate eggs that were analysed individually (Table 9).

Table 9. Overview of Brünnich's guillemot (Uria lomvia) egg samples.

Station ID	Station	Sample type	Date	Count	Mass (g)
B03	Bjørnøya	egg	25.06.2003	5	95 - 121
B07	Bjørnøya	egg	20.06.2007	5 1)	92 - 106
K93	Kongsfjorden	egg	1993	5	-
K02	Kongsfjorden	egg	03.07.2002	5	82 - 97
K07	Kongsfjorden	egg	21.06.2007	5	89 - 114

1) only 4 eggs for analysis of organotin compounds

6. Analytical details

Table 10 gives an overview of the analytical program for the various matrices, and the laboratories involved. Short descriptions of the analytical procedures are given in the following chapter.

Table 10. Overview of compounds, matrices and laboratories involved in the survey

Sample type Compound	Sediment	Blue mussel	Shrimp	Capelin	Cod	Brünnich's guillemot
Chlorinated paraffins	Tp/NILU					
AP and APE	NILU					
Tensides	NILU					
PFC	NILU		NIFES	NIFES	NIVA	SU
PBDE	Tp/NILU	NIVA	NIFES	NIFES	NIVA	NVH
HBCDD	NILU					NVH
Tetrabromobisphenol A	NILU					
Bisphenol A	NILU					
Synthetic musk compounds	NILU					
Siloxanes	NILU					
PFR	IVL					
DEHP	NILU					
PCDD/PCDF	Tp/NILU					
PCB	Tp/NILU					NVH
Organohalogens	Tp/NILU					NVH
Biocides 1)	NILU		NIFES	NIFES	NIVA	NVH
PAH	Tp	NIVA				Unilab
Trace metals	Tp					NTNU
Stable isotopes						IFE
Organotin						NIVA

1) Cf results chapters for range of biocides included in each subproject
Tp: Centre for Environmental Chemistry SPA "Typhoon", Obninsk, Russia
SU: Analytical Environmental Chemistry Unit at the Stockholm University
NVH: Laboratory of Environmental Toxicology at the Norwegian School of Veterinary Science
NTNU: Department of Chemistry, Norwegian University of Science and Technology
IFE: Institute for Energy Technology (Norway)
IVL: Swedish Environmental Research Institute

6.1 Chlorinated paraffins

NILU
See chapter 6.14.

NVH
See chapter 6.14.

6.2 Alkylphenolethoxilates

Octylphenol monoethoxilate (OPE_1O), octylphenol diethoxilate (OPE_2O), nonylphenol monoethoxilate (NPE_1O), and nonylphenol diethoxilate (NPE_2O) were analysed in sediment samples using solvent extraction, SPE clean-up and HPLC-HRMS..

Sample preparation
The sediment samples were freeze dried and extracted with acetone under sonication. The extracts were cleaned by anion exchange solid phase extraction.

Chemical analysis
The extracts were analysed by HPLC-HRMS. The column was a reversed phase Ace3 column from ACT, and the HPLC consisted of a 1525µ pump and a 2700 autosampler coupled to a QTOF micro mass spectrometer with positive atmospheric pressure chemical ionisation (all from Waters). The mobile phase was a gradient of water and acetonitrile. External calibration was used for quantification.

6.3 Phenolic compounds

BPA, TBBPA, PCP, octyl- nonyl- and dodecylphenol were analysed in the sediment samples using solvent extraction, SPE clean-up and LC-HRMS detection.

Sample preparation
Sediment samples were homogenised with a drying agent, added internal standards and extracted with methyl-tert-butyl ether. The extracts were cleaned by solid phase extraction using ion exchange and polymeric solid phase extraction columns.

Chemical analysis
The phenolic compounds were analysed by LC-HRMS. Reversed phase separation was performed on a Waters Acquity UPLC using acetonitrile and purified water as the mobile phase. The analytes were detected in high resolution on a Waters LCT Premier Time-of-Flight mass spectrometer using atmospheric pressure chemical ionisation in negative mode. Quantification was performed using ^{13}C-labelled internal standards.

6.4 Tensides (DTDMAC, DSDMAC, DHTMAC)

The tensides DODMAC/DSDMAC (dioctadecyl dimethyl ammonium chloride), DTDMAC (ditallow dimethyl ammonium chloride) and DHTDMAC (di-(hydrogenated tallow) dimethyl ammonium chloride) were analysed from sediment samples by liquid extraction, SPE clean-up and HPLC-HRMS.

Sample preparation
The sediment samples were freeze dried and extracted with ethanol under sonication. The extracts were cleaned by anion exchange solid phase extraction.

Chemical analysis
The extracts were analysed by HPLC-HRMS. The column was a reversed phase Ace3 column from ACT, and the HPLC consisted of a 1525µ pump and a 2700 autosampler coupled to a

QTOF micro mass spectrometer with positive atmospheric pressure chemical ionisation (all from Waters). The mobile phase was a gradient of water and acetonitrile. External calibration was used for quantification.

6.5 Polyfluorinated compounds (PFC)

NIFES - Sample preparation
The sample was weighed into a polypropylene vial, internal standard and methanol was added and the mixture extracted in a microwave bath. After centrifugation the supernatant was decanted into a plastic syringe with a 0.45 µm nylon syringe filter attached. The crude extract was filtered into a polypropylene vial and milliQ-water added and the solution was mixed on a swirl mixer. The aqueous solution was then transferred to two plastic tubes and rinsed on ASPEC using OASIS WAX SPE columns. The purified extract was then filtered through a 0.2 µm nylon syringe filter and transferred to the YM-3 filter for further purification. After centrifugation at >10.000 rpm for more than one hour the extract was transferred to a polypropylene LC-vial for analysis on the LC-MS/MS. Analysis was performed in MRM-mode with negative electron impact ionization and quantification was performed using internal standard calibration curve.

NIFES – Instrumentation

Centrifuge	Capable of > 10.000 rpm
ASPEC	ASPEC™ XL4, Gilson
LC	Waters Acquity UPLC™, Waters
MS/M	Waters Quattro Premier™ /XE, Waters

NILU - Sample preparation
An exact amount of the sediment was extracted by using a mixture of sodium hydroxide and methanol with subsequent extraction in acidified methanol. Further clean-up was done by centrifugation and mixing with acidified ENVI-Carb.

NILU - Chemical analysis
The chemical analysis was performed with high performance liquid chromatography (HPLC) combined with high-resolution mass spectrometry (HRMS). The analytical column was ACE-C18 and the compounds were gradient separated by a mobile phase made up of methanol and water in ammonium acetate buffer. The QuanLynx software from Waters was used to quantify the amount of analytes in the samples.

SU - Sample preparation
Samples were extracted twice from egg homogenates with acetonitrile in an ultrasonic bath. Concentrated extracts underwent clean-up on graphitised carbon and acetic acid. Clean extract was added to ammonium acetate and precipitation followed.

SU - Instrumentation
High performance liquid chromatography coupled to high resolution mass spectrometry (HPLC-HRMS, for sulfonates) or tandem mass spectrometry (MS-MS, for carboxylates) was applied. More details on the extraction procedure and quantification is given in Verreault et al. (2007).

6.6 Polybrominated diphenyl ethers (PBDE)

NIFES - Sample preparation
Samples were weighed into the extraction cell body containing hydromatrix and a 1:1 mixture of kiselgel and sulphuric acid before internal standard was added. The sample was extracted on ASE using a mixture of dichloromethane and hexane as the extraction solvent. The extract was then evaporated to approximately 1 ml using TurboVap, before the concentrated extract was added hexane. This solution was then washed with concentrated sulphuric acid in order to remove fat in the extract. The solvent was changed to nonane before GC-MS analysis. Analysis was performed in SIM-mode with negative chemical ionization and quantification was performed using internal standard calibration curve.

NIFES – Instrumentation

GC	ThermoQuest Trace GC 2000
MS	Trace DSQ
Autosampler	Autosampler AS 3000, ThermoQuest CE Instruments
ASE	ASE 300 ® (Accelerated Solvent Extractor). Dionex Corp
Turbo Vap	Turbo Vap II
Centrifuge	Eppendorf 5810 R.

NILU
See chapter 6.14.

Typhoon – Sample preparation
Before analysis samples were thawed and homogenized. Extraction of bottom sediments was carried out in Soxhlet apparatus using solvent mixture benzene-ethanol. Foe extraction control Sludge Reference Material IIS-01.02 was used. For extract clean up multilayer silica gel column was used, for serum removing active copper with following cleaning up on column with activated silica gel. PCB 209 was used as a recovery standard and laboratory blank – for each set of samples.

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

6.7 Hexabromocyclododecane (HBCDD)

See chapter 6.14.

6.8 Tetrabromobisphenol A and Bisphenol A

See chapter 6.3.

6.9 Synthetic musk compounds

See chapter 6.10.

6.10 Siloxanes, DEHP, TriCB, PeCB, HCBD and musk

Sample preparation
The cyclic polysiloxanes D4, D5 and D6, musk xylene, musk ketone, trichlorobenzenes, pentachlorobenzene, hexachlorobutadiene and DEHP were extracted from wet sediment samples using hexane. Isotope labelled analogs of some of the analytes was added prior to extraction. The extraction was performed by sonication. Just before quantification, the samples were spiked with a recovery control standard.

Chemical analysis – TriCB, PeCB, HCBD, DEHP, siloxanes
Separation was done using high resolution GC. The isomer identification was performed by high-resolution mass spectrometry (res>10000) in positive electron ionisation mode (EI+). Two masses were monitored for each analyte. The added ^{13}C-labelled/deuterated isomers were used as internal standards. Additionally, the recoveries of the added internal standard compounds were determined using a recovery control standard.

For siloxanes, no suitable internal standard is commercially available. Quantification was performed using external standards.

Chemical analysis – musk xylene, musk ketone
Analysis of musk xylene and musk ketone was performed by high resolution GC / low resolution mass spectrometry in positive electron ionisation mode. Two masses are monitored for each analyte. Quantification was performed using deuterated musk-xylene as internal standard. Additionally, the recoveries of the added internal standard compounds are determined.

6.11 Phosphorous flame retardants (PFR)

Sample preparation
Sediment samples were freeze dried before extraction. The dry sample was fortified with a recovery standard and mixed carefully. The sample was subsequently extracted with a mixture of methanol and MTBE. The extraction was repeated twice with MTBE. The pooled extract was extracted with water to remove the methanol. The organic extract was subjected to clean up on a PSA-column before GC-MS analysis.

Chemical analysis
All organic phosphate-esters but V6 were analysed on a 6890N gas chromatograph coupled to a 5973N mass selective detector (Agilent Technologies, Inc. Santa Clara , CA USA). The detector was used in selected ion monitoring mode (SIM) with electron ionisation. The analytes were identified by their characteristic retention times and one target ion used for quantification. In most cases two qualifier ions were recorded to increase specificity. Quantification was based on comparison of peak abundance to the known response of the

internal standard (biphenyl). The reported analyte concentrations were corrected according to the determined surrogate (TAP) standard losses.

The compound V6 was analysed on an Agilent 5890 II GC fitted with a short column connected to a Nitrogen-Phosphorous Detector (NPD). Helium was used as carrier gas.

6.12 Diethyhexylphtalate (DEHP)

See chapter 6.10.

6.13 PCDD/PCDF and non-ortho-PCBs

NILU - Sample preparation
PCDD/F and non-ortho PCB analysis was performed according to the method NILU-O-1. This method is according to the directives given by the European Commission for determination of dioxins for the official control of foodstuffs (2002/69/EC) and feedstuffs (2002/70/EC).

Sediment samples were dried, homogenised and sieved before spiking with ^{13}C-labelled 2,3,7,8-chloro substituted PCDD and PCDF congeners. The analytes were extracted from the sediment samples by Soxleth extraction using toluene as the solvent.

Most of the sample matrix was removed with multi column chromatography using different types of silica gel and activated charcoal. A final treatment was done using sulphuric acid coated silica and aluminium oxide. Prior to analysis, the samples were spiked with a recovery control standard.

NILU - Chemical analysis
Separation was done using high resolution GC. The isomer identification was performed by high-resolution mass spectrometry (res>10000) in positive electron ionisation mode. Two masses were monitored for each isomer group. The added ^{13}C-labelled isomers were used as internal standards. Additionally, the recoveries of the added internal standard compounds were determined using the recovery control standard.

The concentration of the toxic 2,3,7,8-chloro substituted congeners were determined. For all these congeners, the 2,3,7,8-TCDD toxicity equivalent (TE) was calculated. The TE is a measure for the total PCDD/PCDF toxicity of a sample, where the toxicity of all the 2,3,7,8-chloro congeners is compared to 2,3,7,8-TCDD.

Typhoon
See chapter 6.6.

6.14 Persistent Organic Pollutants

NILU - Sample preparation

A wide range of persistent organic pollutants was included in a common sample preparation according to the method NILU-O-2. NILU-O-2 is according to the directives given by the European Commission for determination of dioxin-like PCBs for the official control of foodstuffs (2002/69/EC) and feedstuffs (2002/70/EC). The method is also according to the guidelines given by the European Commission's for Residues Monitoring in the European Union (document no. SANCO/3103/2000). Sediment samples were spiked with ^{13}C-labelled analogs of the analytes and extracted by 8 h Soxleth extraction using cyclohexane as the solvent. Sample clean-up was performed by treatment with mercury, sulphuric acid and with silica columns. Just before quantification, the samples were spiked with a recovery control standard.

NILU - Chemical analysis – chlorinated paraffins

The chlorinated paraffins were analysed and reported as sum of short chain and sum of medium chain chlorinated paraffins. SCCP and MCCP were analysed using HRGC/HRMS in electron capture negative ion (ECNI) mode. Methane was used as the moderating gas at a pressure about 2×10^{-5} mbar. The $[M\text{-}Cl]^-$ ion of each formula group were monitored, and the pattern of the formula groups was used for quantification.

NILU - Chemical analysis – PCB, DDT, PBDE, HCH

High resolution GC was used for separation. The isomer identification was performed by high-resolution mass spectrometry (res>10000) in positive electron ionisation mode. Two masses were monitored for each isomer group. The added ^{13}C-labelled isomers were used as internal standard. Additionally, the recoveries of the added internal standard compounds were determined using the recovery control standard.

NILU - Chemical analysis – chlordanes and toxaphenes

Toxaphenes and chlordanes were analysed using high resolution GC- low resolution mass spectrometry. Ionisation was performed in electron capture negative ionisation (ECNI) mode. Methane was used as the moderating gas. Two masses were monitored for each component. ^{13}C-labelled analogs of trans-chlordane and trans-nonachlor were used as internal standards. The recoveries of the internal standards were determined using a recovery control standard.

NILU - Chemical analysis – HBCDD

Analysis of α-, β- and γ-HBCDD was performed by LC-MS. Reversed phase separation was achieved on a 15 cm C18 column, using methanol, acetonitrile and purified water as the mobile phase. The HBCDD isomers were ionised in negative electrospray mode, monitoring the $[M\text{-}H]^-$ ion. Deuterated α- and γ-HBCDD were used as internal standards. The recovery of the internal standards was determined using deuterated β-HBCDD as a recovery control standard.

NVH - Sample preparation

The procedure covers HBCDD, PCB, PBDE, and other organohalogens. Lipids were extracted twice from egg homogenate by acetone/cyclohexane extraction. Lipid content was determined gravimetrically. Extracts were treated twice with sulphuric acid for sample clean up. An aliquot for toxaphene analyses required further separation on silica columns.

NVH - Instrumentation
Contaminants were separated and quantified using high resolution gas chromatographs (GC) with mass spectrometer (MS) or electron capture detection (ECD). More details on the chromatographic separation and equipment is given in Murvoll et al. (2006) for organochlorines (OCs), in Andersen et al. (2006) for toxaphenes and in Sørmo et al. (2006) for BFRs.

The laboratory is accredited by Norwegian Accreditation (Kjeller, Norway) according to NS-EN ISO/IEC 17025, test 137, and the analytical quality of the laboratory has been approved in several intercalibration tests. As standard procedure recoveries of spiked samples, blanks and reference samples were analysed in each series and acceptable results were achieved.

6.15 PCB

NILU
See chapter 6.14.

NVH
See chapter 6.14.

Typhoon - Sample preparation
Before analysis samples were defrozen and homogenized. Extraction of bottom sediments was carried out in Soxhlet apparatus using solvent mixture benzene-ethanol for POPs and methylene chloride/acetone for PAHs determination during 16 hours. Schemes of clean-up for all types of analysis are presented on Fig. 1, 2, 3 and 4.

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

6.16 Organohalogens (TriCB, PeCB, HCB, HCBD)

NILU
See chapter 6.16.

NVH
See chapter 6.14.

Typhoon
See chapter 6.15.

6.17 Biocides (DDT, Toxaphene, Chlordane, HCH)

NIFES (Toxaphene) - Sample preparation
Samples were weighed into the extraction cell body containing hydromatrix and a 1:1 mixture of silica gel and sulphuric acid before internal standard was added. The sample was extracted

on ASE using a mixture of dichloromethane and hexane as the extraction solvent. The extract was evaporated to approximately 1 ml using TurboVap, before the concentrated extract was added hexane. This solution was then washed with concentrated sulphuric acid in order to remove fat in the extract. The solvent was changed to nonane and recovery internal standard was added before GC-MS analysis. Analysis was performed in SIM-mode with negative chemical ionization and quantification was performed using internal standard calibration curve.

NIFES – Instrumentation

GC	Trace GC Ultra, Thermo.
MS	Trace DSQ II, single quadropole, Thermo
Autosampler	Triplus, Thermo
ASE	ASE 300 ® (Accelerated Solvent Extractor). Dionex Corp.
Turbo Vap	Turbo Vap II. Zymark.
Centrifuge	Eppendorf 5810 R.

NILU
See chapter 6.14.

NVH
See chapter 6.14.

6.18 Organotin compounds

Sample preparation
The sediment matter was homogenised and added internal standards. The analytes were extracted from the matrix by hydrochloric acid. The compounds were complexed by tropolone in a mixture of ethylacetate and hexane. The analytes were ethylated in an aqueous solution of pH 4 – 5 and were extracted into hexane. The hexane extract was cleaned on silica before analysis by GC/MS in SIM mode.

Chemical analysis
The GC was equipped with a 30 m column with a stationary phase of 5% phenyl polysiloxane (0,25 mm i.d. and 0,25 µm film thickness). The initial temperature was 50 °C, which was raised to 290 °C in steps during a 20 min period. The injection was pulsed splitless. Quantification of individual components was performed by using the internal standard method. Certified reference material was analysed together with the samples and was within ± 30 % of certified value.The concentrations of the different compounds in the standards were in the interval from 1,5 to 4500 pg/µl.

6.19 PAH

NIVA and Unilab - Sample preparation
Homogenised material was added methanol (100 ml) and potassium hydroxide (3 g) together with a solution containing 0.5 µg/ml of the following internal standards; naphthalene-d_8, biphenyl-d_{10}, anthracene-d_{10}, fenanthrene-d_{10}, pyrene-d_{10}, chrysene-d_{12} and perylene-d_{12}. The solution was left to reflux for 1.5 h, before extraction with pentane. The pentane extract was

concentrated using a rotavapor. Clean up of the extracts was performed on extraction columns with 500 mg silica. The petroleum components were eluted with pentane followed by dichloromethane. The extract was evaporated almost to dryness under nitrogen before clean up on GPC. A solvent change was performed before instrument analysis.

NIVA and Unilab - Instrumentation
The quantification of aromatic and bicyclic, aliphatic hydrocarbons was performed on GC-MS (Hewlett-Packard).

Typhoon
Sample preparation see chapter 6.15.

6.20 Trace metals

NTNU - Sample preparation
Freeze-dried homogenate samples were added 50% HNO_3, giving a final volume of 50 ml. The biological material was digested using an UltraClave (Milestone Inc., Bergamo, Italy) using a pre-set temperature profile.

NTNU - Instrumentation
The elements were quantified using high resolution inductive coupled plasma mass spectrometry (HR-ICP-MS; Element 2, Thermo Electronics). The measurements were verified against certified reference material.

Typhoon
The extraction of Cd, Cu, Pb, Cr was carried out by the full decomposition of the samples with HF (hydrofluoric), HNO_3 (nitric) and HCl (hydrochloric) acids mixture. Cd was measured by furnace technique on Perkin Elmer Z-3030 with Zeeman correction of background. Cu, Pb, Cr were measured by AAS method by flame procedure on Perkin Elmer B-3030. Hg was measured by method of “cold vapor” on MHC 15 after a decomposition of the samples by mixture of sulfuric and nitric acids. As was measured by borhydrid method on MHC 15 after decomposition of the samples by mixture of sulfuric and perchloric acids.

6.21 Stable isotopes

Freeze-dried homogenate samples were analysed for stable isotope ratios ($\delta^{15}N$ and $\delta^{13}C$). Lipids were removed by Soxhlet extraction with dichlormethane added 7 % methanolin. The sample was then dried at 80 °C before rinsing with 2 N HCl to remove traces of carbonates. Next, the sample was rinsed with distilled water and dried at 80 °C, before combustion with O_2 and Cr_2O_3 in a Carlo Erba NCS Elemental Analyser. Finally, the combustion products were separated on a Poraplot Q column and $\delta^{15}N$ and $\delta^{13}C$ were determined on a Micromass Optima mass spectrometer. International standards, Pee Dee Belemnite (PDB: USGS 24) for $\delta^{13}C$ and atmospheric air (IAEA-N-1 and 2) for $\delta^{15}N$, were generally run for each 10 samples. A detailed description of the method is given in Søreide et al. (2006).

6.22 General remarks on the chemical analyses

The Limit of Detection (LoD) of an analytical detection method varies with sample type and also within the same type of samples. The LoD is driven by the following factors:

1. Total sample amount extracted
2. Purity of the sample extract after sample clean-up
3. Proportion of the total sample extract injected into the analytical instrument
4. Chromatographic resolution and peak shape
5. Instrumental sensitivity

Factor (2), purity of the final sample extract, can vary due to differences in sample matrix and batch-to-batch variation of the clean-up system and often explains the difference in LoD of apparently identical samples. Due to the varying character of the samples with only a few spot check samples from each sampling site and type, e.g. NILU estimates the LoD individually for each single sample.

A thorough evaluation of the measurement uncertainty requires laboratory intercalibration exercises for each analytical method and all measured sample types/matrices. This is far beyond what is affordable in a screening study of this nature, and in many cases not possible at all. However, a rough estimate on the measurement uncertainty varies between 10 and 60 % (Table 11).

Table 11. A rough estimate on the analytical measurement uncertainty.

Compound group	Analytical measurement uncertainty in %
PFRs	20-40
PFCs (volatiles)	40-60
PFCs (ionics)	30-50
Nitro/oxy-PAH	40-60
Ag	10-30
Pt	30-50

In this report the concentration of an analysed compound (analyte) in a solid sample is defined as the mass of the analyte divided by the total sample mass and normally expressed as µg/kg or ng/kg. As the water content of soil, sediment and sewage sludge samples can vary quite heavily the concentration unit is normally given based on the dry weight of the analyzed sample (µg/kg d.w.). For biological material such as fish or mussel samples with a more stabile water content the concentration is normally given on a wet weight basis (µg/kg w.w.).

7. Analytical results and discussion

The results are presented compound by compound in tables and graphs with adjoined description. In the discussions attempts are made to assess the results relative to previous relevant information from the arctic region with emphasis on how the levels relate to known background concentrations and to limits of environmental effects. The main sources for these comparisons have been the contaminant assessments produced by AMAP (1998, 2004), the annual screening surveys for new contaminants made by SFT (Fjeld et al. 2005, Bakke et al. 2007 and Green et al 2008), and the revised classification system for contaminants in marine sediments (SFT TA-2229/2007). Furthermore specific scientific literature is used when relevant and available, but it has not been within the scope of the report to produce a complete literature survey of the various compounds and sample types.

7.1 Chlorinated paraffins

7.1.1 Sediments

Results

A total of 11 sediment samples were screened for short and medium chain chlorinated paraffins (Table 12, Figure 7). SCCP was quantifiable in all sediment samples, whereas MCCP could only be quantified in one sample from the coast outside Finnmark. The highest SCCP-level of 92 µg/kg d.w. was found at station IP-20, the northern station at the Kola transect, whereas the southern station of the same transect, IP-19 only had 12 µg/kg d.w.

Table 12. Content of chlorinated paraffins in sediment samples from the Barents Sea 2007 (µg/kg d.w.). Levels above LoD are shaded.

Station ID	SCCP (sum)	MCCP (sum)	Sum CP
IP-19	12	<0,2	12
IP-20	92	<0,3	92
IP-22	21	<0,1	21
IP-27	22	<0,2	22
IP-29	35	<0,1	35
IP-41	11	<0,1	11
R18	16	<0,1	16
R35	70	<0,1	70
R68	34	4,8	39
R81	15	<0,1	15
R96	8	<0,2	8

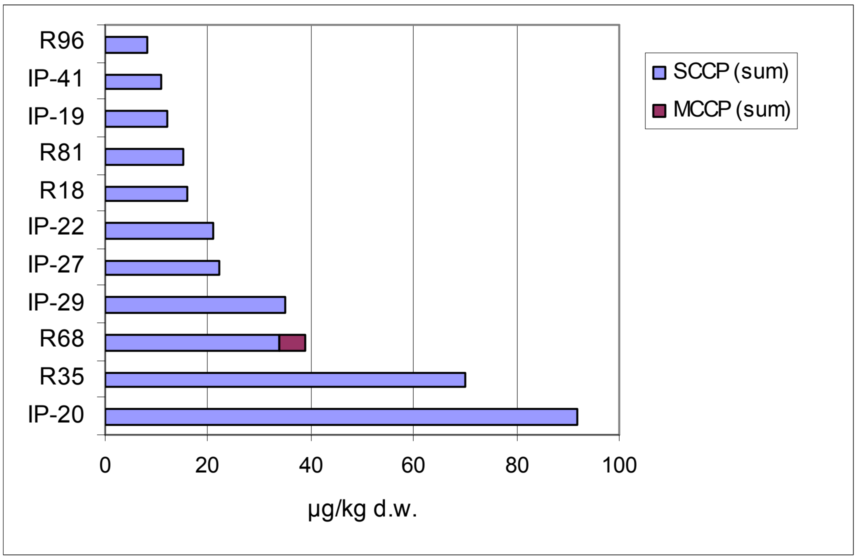


Figure 7. Chlorinated paraffins in sediment samples from the Barents Sea 2007.

Discussion
The highest SCCP concentration found is equal to the lowest level found in the Drammen harbour sediments (94 – 1300 µg/kg d.w., Fjeld et al. 2004). In Alaskan lakes remote from any civilisation AMAP reports of sediment levels around 2 – 18 µg/kg d.w. This is presumably due to long range atmospheric transport. Fjeld et al. (2004) reports of 16 – 26 µg/kg d.w. of SCCP from presumably uncontaminated Norwegian coastal sites, and 6 µg/kg d.w. from Tromsø harbour. These comparisons suggest that the present levels are above what should be expected as background for open sea sediments. They are still far less than the chronic exposure PNEC for SCCP set at 1000 µg/kg d.w. in the revised SFT classification system for marine sediments (SFT TA-2229/2007). Hence the recorded sediment levels should not cause environmental concern.

7.2 Alkyl phenols and AP ethoxylates

7.2.1 Sediments

Results
None of the samples had levels of alkyl phenols above the LoD. For the AP ethoxylates (APE) OPE1O and NPE1O dominated in the 3 samples having the highest sum of APEs (Figure 8), whereas NPE3O and NPE4O were quantifiable only in 3 of the 11 samples. The highest level of sum APEs was found in coastal sediments at station 35, but equally high levels were found at the open ocean stations IP-20 and R81, and an overall geographical trend was not found.

Table 13. Content of alkyl phenols and AP ethoxylates in sediment samples from the Barents Sea 2007 (µg/kg d.w.). Levels above LoD are shaded.

Station ID	**OPE1O**	**OPE2O**	**NPE1O**	**NPE2O**	**NPE3O**	**NPE4O**	**Octylphenol**	**Nonylphenol**	**Dodecyphenol**
IP-19	36,7	<4	14,7	<4	<1	<0,4	<0,84	<0,57	<0,43
IP-20	52,6	3,8	41,3	4,5	<1	<0,4	<1,05	<0,52	<0,46
IP-22	<10	20,6	<8	<4	<1	<0,4	<1,38	<0,72	<0,61
IP-27	<10	<4	<8	<4	<1	<0,4	<1,52	<0,95	<0,69
IP-29	12,4	12,4	8,3	5	1,1	1,1	<1,34	<1,28	<0,74
IP-41	<10	11,4	<8	6,6	<1	<0,4	<1,02	<0,57	<0,46
R18	<10	<4	<8	<4	<1	<0,4	<0,57	<0,35	<0,28
R35	86,9	4,9	13,6	<4	<1	<0,4	<1,14	<0,69	<0,61
R68	<10	4,2	14,1	9,9	1,2	0,5	<1,29	<0,80	<0,59
R81	35,6	4,8	35,6	20,6	2,4	1,2	<2,11	<1,10	<1,00
R96	<10	<4	<8	<4	<1	<0,4	<0,65	<0,45	<0,34

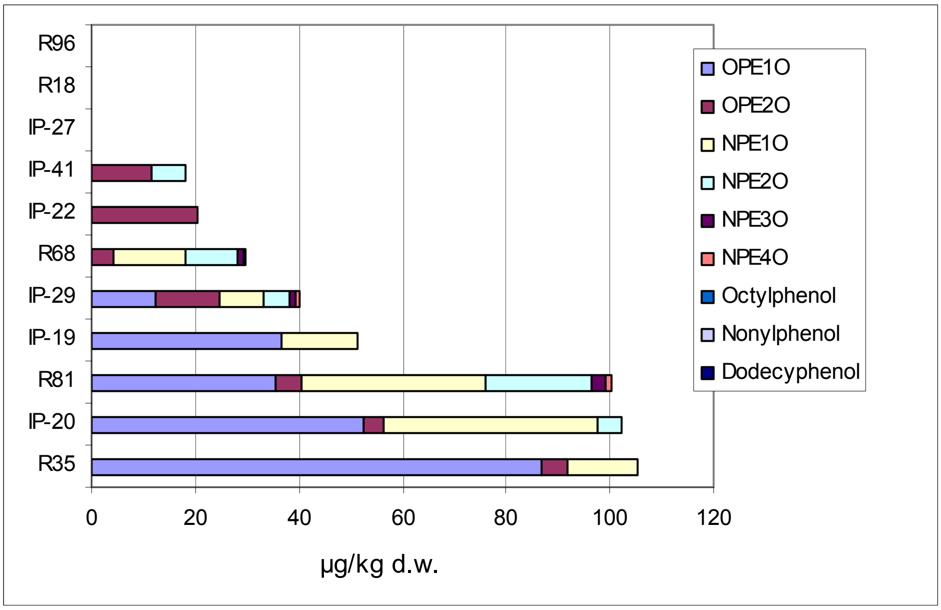


Figure 8. Alkyl phenol ethoxylates in sediment samples from the Barents Sea 2007

Discussion

The LoDs (0,6 – 1,5 µg/kg d.w. for octylphenol, 0,3 – 1,3 µg/kg d.w. for nonylphenol) are lower than the chronic PNECs for octyl- and nonylphenol in the Norwegian sediment classification system (octylphenol : 3,3 µg/kg d.w., nonylphenol 18 µg/kg d.w.; TA-2229/2007). In comparison nonylphenol levels in North Sea sediments (Bester et al. 2001) have been measured in the range <10 – 55 µg/kg d.w. and in populated coastal areas up to 1800 µg/kg d.w of octylphenol and up to 72 000 µg/kg for nonylphenol. In summary the results indicate no environmental risk from the alkyl phenols in the present sediments and being in the lower range of other studies found they may represent background conditions.

Corresponding PNECs for the ethoxylates have not been developed, but the range in NPE1O (<8 – 41,3 µg/kg d.w.) seems somewhat high compared to levels <10 µg/kg d.w found by Bester et al. (2001) in a range of North Sea sediments. Barents Sea sediment levels of APEs should therefore be monitored further to verify the trends

7.3 Tensides

7.3.1 Sediments

Results

Only DSDMAC had levels above the LOD, ranging from <0,1 µg/kg d.w. to 7,3 µg/kg d.w. (Table 14, Figure 9).

Table 14. Content of tensides in sediment samples from the Barents Sea 2007 (µg/kg d.w.). Levels above LoD are shaded.

Station ID	DSDMAC	DTDMAC	DHTDMAC
IP-19	1,7	<1	<1
IP-20	0,4	<1	<1
IP-22	7,0	<1	<1
IP-27	<0,1	<1	<1
IP-29	1,8	<1	<1
IP-41	6,6	<1	<1
R18	6,4	<1	<1
R35	<0,1	<1	<1
R68	0,2	<1	<1
R81	0,6	<1	<1
R96	7,3	<1	<1

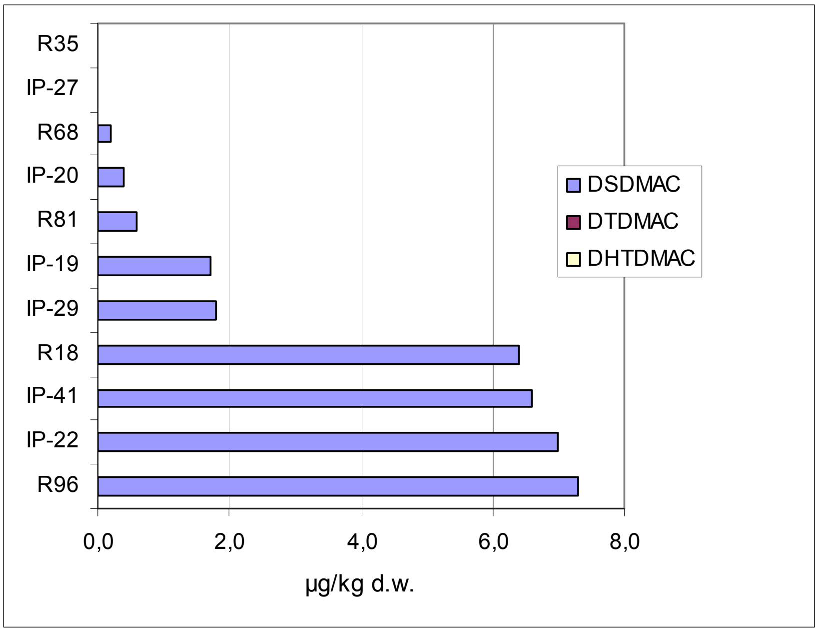


Figure 9. Tensides in sediment samples from the Barents Sea 2007

Discussion
The four stations having the highest levels, and clearly above the rest, are distributed all over the sampled region two near the coast outside Troms, one at the Shtokman region and one in the south Pechora Sea. No geographical trend in tenside distribution could be seen. We have not found any data against which to compare the DSDMAC levels, and background levels cannot be assessed.

7.4 Polyfluorinated compounds

7.4.1 Sediments

Results
The only PFC compound above the LoD was PFOS, which was quantifiable in 8 of the 11 samples and ranged from 0,11 to 0,44 µg/kg d.w. The two highest PFOS levels in the present survey, 0,41 and 0,44 µg/kg d.w were found at coastal stations outside Troms (Table 15, Figure 10).

Table 15. Polyfluorinated compounds PFC (µg/kg d.w.) in bottom sediments from the Barents Sea, 2007. Levels above LoD are shaded.

Station ID	N-Me-FOSA	N-Et-FOSA	N-Me-FOSE	N-Et-FOSE	PFOSA	PFOS	PFHxA	PFHpA	PFOA	PFNA	PFDcA	PFUnA	PFDoA
IP-19	<0,13	<0,11	<0,12	<0,15	<0,09	<0,08	<1,55	<1,29	<16,8	<1,49	<1,85	<3,77	<4,22
IP-20	<0,15	<0,13	<0,13	<0,16	<0,12	0,31	<1,67	<1,54	<10,2	<3,13	<3,14	<4,31	<4,61
IP-22	<0,18	<0,16	<0,18	<0,18	<0,15	0,23	<1,72	<1,71	<10,5	<2,65	<3,28	<3,60	<3,95
IP-27	<0,17	<0,15	<0,18	<0,21	<0,14	0,20	<1,97	<1,45	<11,5	<2,82	<3,23	<3,32	<4,04
IP-29	<0,14	<0,14	<0,14	<0,18	<0,11	<0,08	<2,07	<2,42	<13,8	<2,28	<2,38	<4,80	<5,38
IP-41	<0,17	<0,14	<0,16	<0,18	<0,12	0,11	<1,54	<1,25	<9,82	<2,13	<2,75	<2,42	<2,92
R18	<0,14	<0,12	<0,14	<0,14	<0,10	<0,08	<1,58	<1,32	<21,8	<1,83	<2,27	<4,63	<5,16
R35	<0,17	<0,16	<0,16	<0,18	<0,13	0,22	<1,72	<1,47	<14,9	<1,38	<2,10	<3,41	<3,68
R68	<0,13	<0,14	<0,14	<0,16	<0,11	0,44	<2,47	<1,82	<26,9	<1,42	<1,77	<3,93	<4,59
R81	<0,15	<0,17	<0,12	<0,14	<0,13	0,41	<3,10	<2,18	<26,1	<1,54	<1,89	<3,31	<3,53
R96	<0,12	<0,11	<0,13	<0,14	<0,10	0,19	<2,02	<2,19	<29,7	<1,72	<2,19	<2,52	<3,00

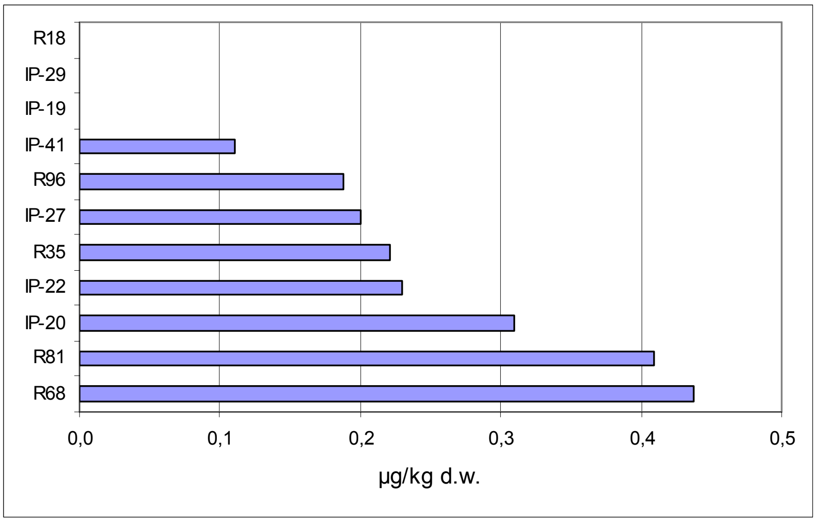


Figure 10. PFOS in bottom sediments from the Barents Sea, 2007

Discussion

In Norwegian coastal areas remote from any known point sources a sediment PFOS range of 0,2 – 0,5 µg/kg d.w. has been recorded, whereas a range of 0,2 – 6,7 has been found in populated areas and close to harbours (Bakke et al 2007; Green et al 2008). Data for PFOS in marine sediments are also available from 6 offshore installations at Haltenbanken in 2006 and the range here was similar: 0.2-1.8 µg/kg dry weight. The levels in Barents Sea sediments are on the lower side of these ranges, and may at present be regarded as background. In the Norwegian sediment classification system the chronic exposure PNEC for PFOS in sediments is as high as 220 µg/kg d.w., hence the environmental risk from the present Barents Sea levels should be insignificant.

7.4.2 Shrimp

Results

All six pooled samples of shrimp were screened for PFCs. Only PFOS (range 2,5 – 10,2 ng/g w.w.) and PFUnA (range 1,1 – 3,2 ng/g w.w.) were quantifiable in all samples, PFOA, PFNA, and PFDcA in 1-2 samples (Table 16). The highest levels of PFOS and PFUnA were found in the same samples (Figure 11).

Table 16. Polyfluorinated compounds PFC (µg/kg w.w.) in shrimp (Pandalus borealis) tails from the Barents Sea, 2007. Levels above LoD are shaded.

Sample ID	PFHxA	PFHpA	PFOA	PFNA	PFDcA	PFUnA	PFTeA	PFBS	PFOS	PFOSA
315/1	<9	<3	1,3	2,6	1,1	3,2	<1,5	<6	10,2	<3
315/2	<9	<3	<1	<1	<1	1,2	<1,5	<6	2,5	<3
315/3	<9	<3	<1	1,2	<1	2,8	<1,5	<6	9,8	<3
420/1	<9	<3	<1	<1	<1	1,1	<1,5	<6	3,0	<3
420/2	<9	<3	<1	<1	<1	1,2	<1,5	<6	3,1	<3

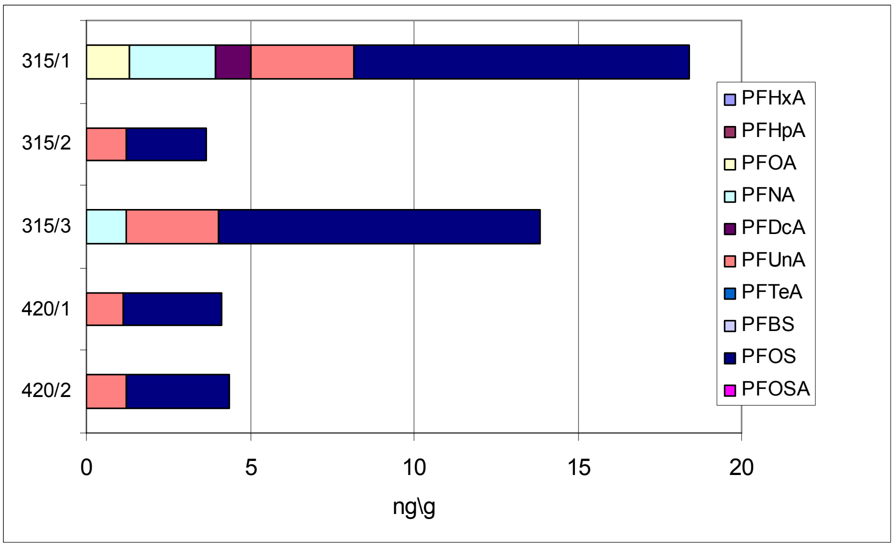


Figure 11. PFC in shrimp (Pandalus borealis) tails from the Barents Sea, 2007.

Discussion

Highest sum PFC was found at the two western stations 315/1 and 315/3, suggesting an input via the coastal current. These were also the only samples where PFOA, PFNA, and PFDcA were at quantifiable levels. No other data for PFC in shrimp has been found. The PFOS range found here, 3,0 – 10,2 µg/kg w.w. was clearly higher than seen in mussels both from open coastal and harbour areas by Bakke et al (2007): 0,1 – 0,6 µg/kg w.w., and by Green et al (2008): 0.4-2.9 µg/kg w.w. Although such comparison among different species is dubious, it could indicate elevated PFOS in arctic shrimp.

7.4.3 Capelin

Results

All five pooled samples of capelin were screened for PFC. As for shrimp only PFOS and PFUnA could be quantified in all samples (Table 17). The other PFC compounds were below the LoD. The range in sum PFC among the samples was small (3,1 – 6,9 µg/kg w.w.), and there was no geographical trend (Figure 12).

Table 17. Polyfluorinated compounds PFC (µg/kg w.w.) in whole capelin (Mallotus villosus) from the Barents Sea, 2007. Levels above LoD are shaded.

Sample ID	**PFHxA**	**PFHpA**	**PFOA**	**PFNA**	**PFDcA**	**PFUnA**	**PFTeA**	**PFBS**	**PFOS**	**PFOSA**
372/1	<9	<3	<1	<1	<1	4,2	<1,5	<6	2,7	<3
372/2	<9	<3	<1	<1	<1	2,9	<1,5	<6	2,2	<3
372/3	<9	<3	<1	<1	<1	2,5	<1,5	<6	2,4	<3
372/4	<9	<3	<1	<1	<1	1,1	<1,5	<6	2,0	<3
372/5	<9	<3	<1	<1	<1	1,9	<1,5	<6	3,5	<3

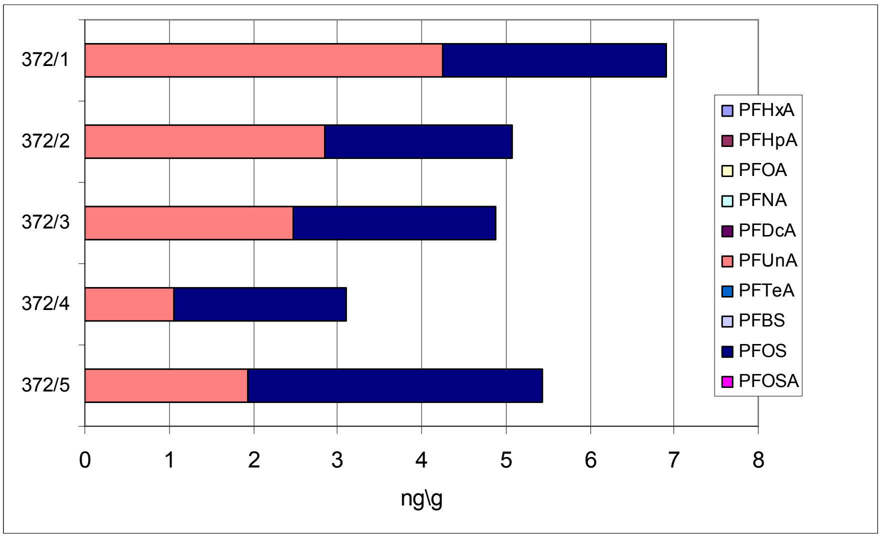


Figure 12. PFC compounds in whole capelin (Mallotus villosus) from the Barents Sea, 2007.

Discussion

No other data on PFC in capelin has been found, and background range is unknown. The levels of sum PFC were higher than seen in cod fillet from Kristiansandsfjorden (0,53 µg/kg w.w, Bakke et al, 2007), and fairly equal to the range seen in cod liver in the present survey (3-8 µg/kg w.w., chapter 7.4.4). Also PFOS (2,0 – 3,5 µg/kg w.w.) corresponded reasonably well with the range in polar cod liver (1.1–2.9 µg/kg w.w, Haukås et al. 2007). As the whole capelin was analysed it is not possible to conclude which organs that accumulate PFOS in this study, but it is worth noting that the whole capelin levels were similar to those in liver samples from other Barents Sea fish species, which might suggest that they accumulate PFCs more strongly.

7.4.4 Cod

Results

PFC was only measured in cod liver from 2 stations, 10B Varangerfjorden (2005: 12 replicate individuals and 2006: 2 individuals) and 98B1 Bjørnerøya, Lofoten (2005: 15 replicate individuals). The only PFC above LoD was PFOS in 5 of the replicates from station 98B1 Bjørnerøya in 2006. At this station quantifiable levels of PFOS were 3-8 µg/kg w.w. with an average of 4,8 µg/kg w.w.

Discussion

The levels found in the present survey were equal to that found in cod liver from a CEMP reference station at outer Bømlo in the SFT screening survey from 2007 (4,4 mg/kg w.w.; Green et al. 2008), from Lofoten in the 2006 SFT screening survey (2,59 µg/kg w.w.; Bakke et al. 2007) and far less than has been found in cod liver from the inner Oslofjord (19,8 – 62,2 µg/kg w.w.). The pattern suggest that coastal cod from the Barents Sea region have PFC levels similar to cod from diffusely contaminated coastal areas elsewhere in Norway and also in other Nordic countries (Kallenborn et al. 2004). No PNEC-data have been found for cod which would give an indication of possible toxic effects of these levels of PFC. This underlines the need for further research to establish useful environmental quality standards.

7.4.5 Brünnich’s guillemot

Results

Of the 15 analysed PFCs, 12 were detected in the Brünnich’s guillemot eggs in the present study (Table 18, Figure 13). PFUnA, PFTriA and PFOS were the most prevailing congeners with mean concentrations ranging (in the 5 different stations) from 1.9 – 20.1 ng/g w.w., 1.9 – 20.6 ng/g w.w. and 8.5 – 26.0 ng/g w.w., respectively.

Table 18. Polyfluorinated compounds (average ng/g w.w. ± 95 % CI) in Brünnich’s guillemot (Uria lomvia) eggs from Svalbard sampled in 1993, 2002, 2003 and 2007. Shaded areas indicate results above the detection limit. N indicates the number of individuals above the LoD.

	K93				**K02**				**K07**			
	Average	±	CI	N	Average	±	CI	N	Average	±	CI	N
PFHxA	<0,35	±	nd	0	<0,35	±	nd	0	<0,35	±	nd	0
PFHpA	<0,20	±	nd	0	<0,20	±	nd	0	<0,20	±	nd	0
PFOA	<1,2	±	nd	0	0,9	±	0,2	5	<0,50	±	nd	0
PFNA	0,5	±	0,1	4	0,7	±	0,1	5	0,6	±	0,3	3
PFDcA	0,5	±	0,1	5	1,1	±	0,3	5	1,0	±	0,3	5
PFUnA	1,9	±	0,3	5	6,3	±	1,2	5	5,5	±	1,4	5
PFDoA	0,6	±	0,1	5	2,0	±	0,4	5	1,5	±	0,4	5
PFTriA	1,9	±	0,7	5	6,1	±	1,2	5	4,6	±	1,0	5
PFTeA	<0,30	±	nd	0	0,5	±	0,1	5	0,4	±	nd	1
PFPeDA	<0,30	±	nd	0	0,7	±	0,1	5	0,5	±	0,1	3
PFOSA	0,2	±	0,1	5	0,04	±	0,0	5	0,03	±	nd	2
PFBS	<0,02	±	nd	0	<0,02	±	nd	0	<0,02	±	nd	0
PFHxS	0,1	±	0,1	5	0,1	±	0,0	5	0,1	±	0,0	4
PFOS	17,5	±	2,1	5	10,9	±	1,5	5	8,5	±	2,0	5
PFDcS	0,05	±	0	3	0,1	±	0,0	5	0,2	±	0,0	4

	B03				**B07**			
	Average	±	CI	N	Average	±	CI	N
PFHxA	<0,35	±	nd	0	<0,35	±	nd	0
PFHpA	<0,20	±	nd	0	<0,20	±	nd	0
PFOA	1,7	±	0,5	5	<0,50	±	nd	0
PFNA	1,3	±	0,4	5	1,2	±	0,3	5
PFDcA	1,0	±	0,3	5	2,6	±	0,8	5
PFUnA	5,4	±	1,6	5	20,1	±	5,6	5
PFDoA	1,8	±	0,4	5	5,8	±	1,3	5
PFTriA	7,2	±	1,2	5	20,6	±	4,8	5
PFTeA	0,4	±	0,1	5	1,4	±	0,3	5
PFPeDA	0,4	±	0,1	5	2,0	±	0,4	5
PFOSA	0,1	±	0,0	5	0,04	±	0,0	5
PFBS	<0,02	±	nd	0	<0,02	±	nd	0
PFHxS	0,1	±	0,1	5	0,04	±	0,0	5
PFOS	26,0	±	9,8	5	10,8	±	2,4	5
PFDcS	0,3	±	0,1	5	0,4	±	0,1	5

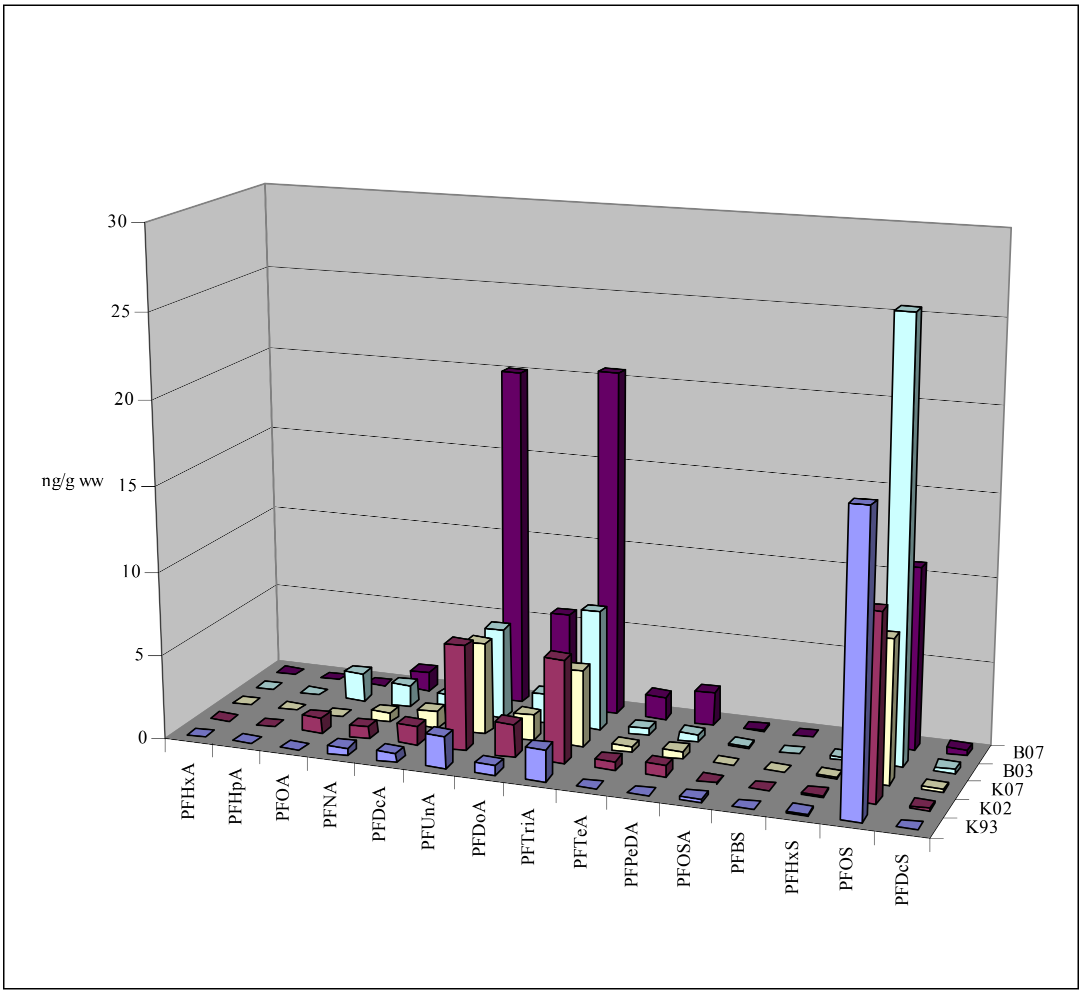


Figure 13. Polyfluorinated compounds (average ng/g w.w.) in Brünnich's guillemot (Uria lomvia) eggs from Svalbard sampled in 1993, 2002, 2003 and 2007.

Discussion

The levels of the most prevailing congener, i.e., PFOS, were generally low and much lower than that reported in liver of seabirds from more polluted and industrialised regions, such as the USA, Italy and Korea (concentrations up to 1780 ng/g ww) (Giesy and Kannan 2001; Kannan et al. 2001). There are few publications on PFOS concentrations in Arctic seabirds. PFOS levels in the Brünnich's guillemot eggs of the present study were, however, higher than that reported in northern fulmar livers (3.4 ng/g w.w.) (be aware of the different matrixes used; egg versus liver) (Knudsen et al. 2007). Generally, the levels of PFAS in the present study were lower than that reported in ivory gull (*Pagophila eburnea*) eggs from Svalbard and Russia (Miljeteig et al. 2007), but comparable to that reported in herring gull (*Larus argentatus*) eggs from Northern Norway (Verreault et al. 2006).

No significant temporal trend in SumPFAS concentrations was found in this study ($p > 0.05$). However, when considering the individual compounds (Figure 13), some changes become apparent. Concentrations of PFOS appear to be decreasing from 1993 to 2002/2003 and to 2007, whereas the majority of the other PFAS show increasing concentrations. The concentrations of both PFUnA and PFTriA are about two times as high as the concentration of PFOS in eggs from Bjørnøya in 2007. This differs from previous studies, where PFOS is the clearly dominating compound of the PFAS (Houde et al. 2006).

Furthermore, a significant spatial trend comparing SumPFAS concentrations were reported in the eggs from Bjørnøya and Kongsfjorden ($p < 0.05$). Generally, the levels of PFAS were highest at Bjørnøya.

It is important to keep in mind that contaminant levels and patterns might be influenced by the diet. Stable-nitrogen isotope analyses ($\delta^{15}N$) in the Brünnich's guillemot eggs of the present study indicated that the observed spatial trends in PFAS levels might be due to a shift in diet as $\delta^{15}N$ is statistically significantly different comparing eggs from Bjørnøya and Kongsfjorden ($p < 0.05$) (Table 39).

7.4.6 Comparison of PFOS in different species

Variation of PFOS levels among the species was small. The highest range in concentrations (8,5 – 26 µg/kg w.w.) was seen in the Brünnich guillemot eggs. Shrimp tails and individual cod livers followed next with 3 – 10 µg/kg w.w. and capelin with 2 – 3,5 µg/kg w.w. These ranges were clearly higher than found earlier in Norwegian blue mussel (0,03 – 0,6 µg/kg w.w., Fjeld et al. 2005, Bakke et al. 2007), but at level with PFOS in polar cod liver (1,1 – 2,9 µg/kg, Haukås et al. 2007) and coastal cod liver (0,5 – 10 µg/kg w.w., Fjeld et al. 2005, Bakke et al. 2007) and far less than in cod liver from inner Oslofjord (20 – 63 µg/kg w.w., Bakke et al. 2007, Green et al. 2008). One may at present assume that the lowest concentrations in the range for shrimp and fish represent background for these tissues.

7.5 Polybrominated diphenyl ethers

7.5.1 Sediments

Results

A total of 11 sediment samples were screened for PBDEs. Only BDE-100 could be quantified in all samples, but BDE-47, BDE-49+71 and BDE-99 could be quantified in most of the samples (
Table ***19***). Sum of all PBDEs ranged over 3 orders of magnitude from 1,5 to 1149,4 ng/kg d.w., with an average of 245,2 ng/kg d.w.. The two highest levels of sum PBDEs were found in coastal sediments outside Troms (Tromsøflaket and Troms II), and were manly due to high levels of BDE-209 (Figure 14). The lowest sum PBDEs was found in the south Pechora Sea (south of the Kolguyjev Island). Looking at sumPBDE$_7$ alone (cf footnote next page), the highest levels were found in the central and eastern Barents Sea.

Table 19. Polybrominated diphenyl ethers (ng/kg d.w.) in bottom sediments from the Barents Sea, 2007. Levels above LoD are shaded.

Station ID	IP-19	IP-20	IP-22	IP-27	IP-29	IP-41	R18	R35	R68	R81	R96
BDE-15	na	na	na	na	na	na	<0,09	<0,125	<0,13	<0,11	<0,10
BDE -17	<1,0	<1,0	<1,0	<1,0	<1,0	<1,0	na	na	na	na	na
BDE -28	<1,0	5,27	<1,0	1,90	4,45	<1,0	0,38	<0,19	<0,22	<0,18	<0,23
BDE -49+71	<1,1	9,46	4,12	3,51	4,58	<1,1	<0,05	0,34	0,38	0,39	0,32
BDE -47	12,08	82,06	30,78	47,28	33,40	<8,0	3,14	3,25	3,70	3,20	2,45
BDE-77	na	na	na	na	na	na	<0,06	<0,08	<0,08	<0,13	<0,07
BDE -66	<1,0	<1,0	<1,0	<1,0	<1,0	<1,0	1,19	1,22	1,03	1,33	0,94
BDE -100	2,45	68,12	62,49	41,65	23,23	1,51	0,39	0,62	0,48	0,53	0,47
BDE -99	1,55	39,73	24,87	4,82	6,62	<1,0	1,56	1,70	2,08	2,31	2,01
BDE-119	na	na	na	na	na	na	<0,10	<0,07	<0,161	0,82	0,72
BDE -85	<3,0	<3,0	<3,0	<3,0	<3,0	<3,0	<0,131	<0,10	<0,21	<0,19	<0,131
BDE -154	<3,0	69,37	33,17	9,56	<3,0	<3,0	<0,2	<0,25	0,45	<0,32	0,54
BDE-153	<3,0	20,61	5,67	<3,0	<3,0	<3,0	<0,30	<0,37	<0,32	<0,48	<0,31
BB-153	na	na	na	na	na	na	<0,22	<0,15	<0,23	<0,22	<0,15
BDE -138	<3,0	<3,0	<3,0	<3,0	<3,0	<3,0	<0,32	<0,39	<0,34	<0,51	<0,33
BDE -183	<5,0	12,53	<5,0	<5,0	<5,0	<5,0	<0,243	<0,24	<0,23	<0,34	<0,24
BDE -190	<5,0	<5,0	<5,0	<5,0	<5,0	<5,0	na	na	na	na	na
BDE -196	<5,0	<5,0	<5,0	<5,0	<5,0	<5,0	<1,10	<1,03	<1,21	<4,36	<1,23
BDE -208	<10,0	<10,0	<10,0	<10,0	<10,0	<10,0	na	na	na	na	na
BDE -207	<10,0	<10,0	<10,0	<10,0	<10,0	<10,0	na	na	na	na	na
BDE -206	<10,0	<10,0	<10,0	<10,0	<10,0	<10,0	6,29	6,12	<1,01	70,52	33,33
BDE -209	<10,0	<10,0	<10,0	<10,0	<10,0	<10,0	22,98	67,89	53,47	1070,33	639,63
Sum PBDE$_7$	**16,1**	**297,7**	**157,0**	**105,2**	**67,7**	**1,5**	**5,5**	**5,6**	**6,7**	**6,0**	**5,5**
Sum of PBDE	**16,08**	**316,61**	**165,21**	**112,23**	**76,86**	**1,51**	**35,93**	**81,14**	**61,58**	**1149,42**	**680,42**

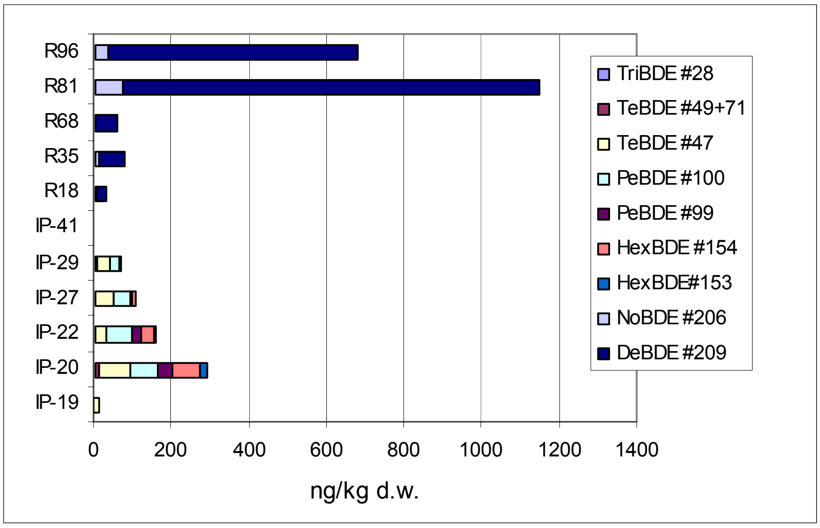


Figure 14. Polybrominated diphenyl ethers (ng/kg d.w.) in bottom sediments from the Barents Sea, 2007.

Discussion

Fjeld et al (2004) found levels of BDE-47 ranging from 0,17 – 0,24 µg/kg d.w in the Drammensfjord sediments and 0,01 – 0,06 µg/kg d.w in clean coastal sediments. The levels of BDE-57 in the present surveys were in the range <0,008 – 0,08 µg/kg d.w. 2,3 to 466,5 µg/kg d.w in more or less polluted harbour and fjord areas. The highest levels of sum BDE reported by Fjeld et al. (2005) were 248 – 466 µg/kg from Åsefjorden, Ålesund, one of the most PBDE polluted recipients in Norway. These levels were 200-400 times higher than the highest level found in the present survey. The comparisons might suggest that the levels found in the present survey would represent background conditions, but the relevant literature data on Arctic levels to compare with is fragmentary. The AMAP (20023) assessment only reports PBDEs in marine biota. The Norwegian sediment classification system sets the chronic PNEC for penta-BDE at 62 µg/kg d.w (62 000 ng/kg d,w,). The present sums of the penta-BDEs barely exceed 0,01 µg/kg d.w. The environmental risk from PBDEs in the Barents Sea sediments should therefore be insignificant.

An interesting, yet unexplained, feature is that the PBDE composition differed almost completely between the two sets of sediment samples. The Tromsøflaket (R-) samples were dominated completely by BDE-209 with some addition from BDE-206. These were not present in the samples from the Russian Barents and Pechora Sea (IP-) which had a reasonably even distribution of 3-4 other PBDE compounds. These were also found in the Tromsøflaket samples but at lower levels (e.g. BDE-47, Table 19). One cannot rule out that the difference is due to different laboratories handling the two sets of samples. One result is that the sum $PBDE_7$ [6] was far higher in the Russian Barents and Pechora Sea samples than in the Tromsøflaket samples (Table 19), except for one sample (station IP-41, south Pechora Sea). The results show a clear geographical separation of the two sets of samples, and if this is not due to laboratory differences, they may suggest that the two regions receive PBDE from different sources. We have, however, no information on likely regional PBDE sources.

7.5.2 Blue mussel

Results

A total of 13 pooled blue mussel samples were screened for PBDEs. Some of these represented different years from the same station (1994 and 2006). None of the PBDEs could be quantified in all samples (Table 20). In the sample from stations 43A-1994, Langfjord, Troms, and 11X-2006, Varangerfjorden, none of the PBDEs were above the LOD. The compounds that were quantified were BDE-47 (7 samples), BDE-100 (7 samples), BDE-49 (6 samples), and BDE-28, BDE-66, and BDE-99 (1 sample each). Highest sum $PBDE_7$, 1,19 µg/kg w.w., was found at station 98X, Skrova harbour, in 1994. BDE-47 accounted for 71 % of the sum $PBDE_7$ in this sample (Figure 15). Blue mussels from a nearby station, 98A2 in 2006 had only 0,14 µg/kg w.w., but this was still the second highest sum$PBDE_7$ level of these samples.

---

[6] Sum of the compounds of highest concern: BDE-28, BDE-47, BDE-99, BDE-100, BDE-153, BDE-154, and BDE-183. BDE-209 is sometimes also included among those of high concern, but is not in the sum $PBDE_7$.

Table 20. Polybrominated diphenyl ethers (µg/kg w.w., average of 3 pooled samples) in blue mussel (Mytilus edulis) from the Barents Sea, 1994 and 2006. Levels above LoD are shaded. Sum PBDE₇ is the sum of the compounds in bold.

Code	BDE-77	**BDE-28**	BDE-66	BDE-71	BDE-85	**BDE-99**	BDE-49	**BDE-100**	**BDE-47**	BDE-119	BDE-138	**BDE-153**	**BDE-154**	**BDE-183**	BDE-205	Sum $PBDE_7$
98X-94	<0,03	0,05	0,05	<0,02	<0,03	0,17	0,235	0,125	0,845	<0,06	<0,03	<0,03	<0,03	<0,06	<0,1	1,19
98A2-06	<0,02	<0,02	<0,02	<0,02	<0,03	<0,04	0,035	0,07	0,07	<0,06	<0,04	<0,04	<0,03	<0,1	<0,3	0,14
43A-94	<0,03	<0,02	<0,02	<0,02	<0,03	<0,05	<0,02	<0,05	<0,04	<0,06	<0,03	<0,03	<0,03	<0,06	<0,1	0,00
43A-06	<0,02	<0,02	<0,02	<0,02	<0,03	<0,04	0,04	0,06	<0,04	<0,06	<0,04	<0,04	<0,03	<0,1	<0,3	0,06
44A-06	<0,02	<0,02	<0,02	<0,02	<0,03	<0,04	0,04	0,075	<0,04	<0,06	<0,04	<0,04	<0,03	<0,1	<0,3	0,08
45A-06	<0,02	<0,02	<0,02	<0,02	<0,03	<0,04	0,035	0,07	<0,04	<0,06	<0,04	<0,04	<0,03	<0,1	<0,3	0,07
46A-94	<0,03	<0,02	<0,02	<0,02	<0,03	<0,05	<0,02	<0,05	0,04	<0,06	<0,03	<0,03	<0,03	<0,06	<0,1	0,04
46A-06	<0,02	<0,02	<0,02	<0,02	<0,03	<0,04	0,035	0,075	0,05	<0,06	<0,04	<0,04	<0,03	<0,1	<0,3	0,13
48A-06	<0,02	<0,02	<0,02	<0,02	<0,03	<0,04	<0,02	<0,04	<0,04	<0,06	<0,04	<0,04	<0,03	<0,1	<0,3	0,00
49A-06	0,035	<0,02	<0,02	<0,02	<0,03	<0,04	<0,02	<0,04	0,055	<0,06	<0,04	<0,04	<0,03	<0,1	<0,3	0,06
10A2-06	<0,02	<0,02	<0,02	<0,02	<0,03	<0,04	<0,02	0,095	0,045	<0,06	<0,04	<0,04	<0,03	<0,1	<0,3	0,14
11A1-94	<0,03	<0,02	<0,02	<0,02	<0,03	<0,05	<0,02	<0,05	0,04	<0,06	<0,03	<0,03	<0,03	<0,06	<0,1	0,04
11X-06	<0,02	<0,02	<0,02	<0,02	<0,03	<0,04	<0,02	<0,04	<0,04	<0,06	<0,04	<0,04	<0,03	<0,1	<0,3	0,00

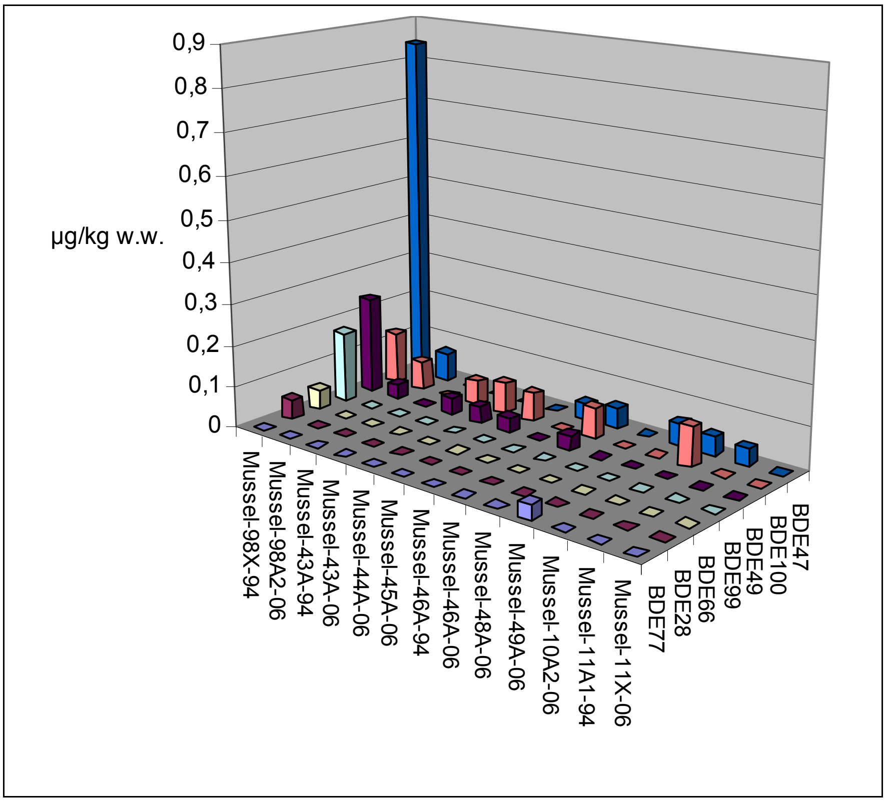


Figure 15. PBDE composition in blue mussel (Mytilus edulis) from the Barents Sea 1994 and 2006. Each bar is the average of 3 pooled samples.

Discussion

In 1994 Fjeld et al. (1995) found overall sum PBDE compounds (exclusive of BDE-183, but inclusive of BDE-209) similar to this survey ranging from 1,2 to 2,6 µg/kg w.w. in blue mussel from Åsefjorden at Ålesund, which is know to be contaminated by PBDEs, and 0,36 µg/kg w.w. in mussels from Espevær, a west coast reference site. The sum PBDE$_7$ in mussels from Åsefjorden was 0,9 – 1,9 µg/kg w.w, from Espevær 0,07 µg/kg w.w., and from the present mussels (leaving out 1994 Skrova harbour) 0,00 – 0,14 µg/kg w.w. This suggests that the PBDE levels in blue mussel from the present survey represent background levels for clean coastal areas, one exception being the mussels from Skrova harbour in 1994 that were contaminated.

7.5.3 Shrimp

Results

Peeled and boiled shrimp tails from the Barents Sea had a mean concentration of sum PBDE$_7$ of 8 ng/kg w.w. (Table 21). BDE-153 and BDE-47 had means of 5 and 3 ng/kg w.w., respectively, while most other congeners had concentrations below their limit of detection (LoD) of 1 ng/kg w.w. These were set to 0 when calculating the sum PBDE$_7$.

Table 21. Polybrominated diphenyl ethers PBDE and HBCDD (ng/kg w.w.) in pooled samples of shrimp (Pandalus borealis) tails from the Barents Sea, 2007. Levels above LoD are shaded.

Sample ID	**HBCDD**	**BDE-28**	**BDE-47**	**BDE-66**	**BDE-99**	**BDE-100**	**BDE-119**	**BDE-138**	**BDE-153**	**BDE-154**	**BDE-183**	**Sum PBDE$_7$**
315/1	<200	<1	5	4	<1	<1	3	<1	11	<1	<1	16
315/2	<200	<1	1	<1	<1	<1	<1	<1	<1	<1	<1	1
315/3	<200	<1	4	<1	<1	<1	<1	<1	13	<1	<1	17
420/1	<200	<1	4	<1	1	<1	<1	<1	<1	<1	<1	5
420/2	<200	<1	2	<1	<1	<1	<1	<1	<1	<1	<1	2

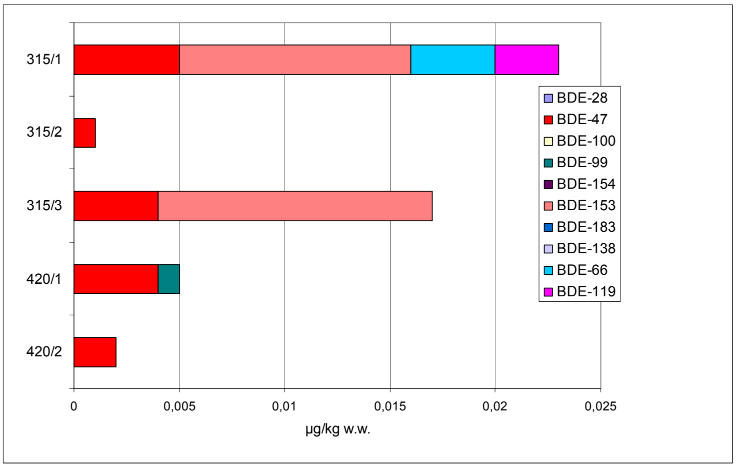


Figure 16. Total PBDE composition in shrimp (Pandalus borealis) tails from the Barents Sea, 2007.

Discussion

The PBDE concentrations found in shrimps were lower than those found for all fish species from the Barents Sea (unpublished data, NIFES), and also 2 orders of magnitude lower than levels in cod fillet from SW Greenland (AMAP 2004).

Low concentrations of fat soluble substances such as PBDEs in shrimps are not surprising, as shrimps have a fat content of only approximately 2%, according to our analyses. The fat content of shrimps is only slightly higher than in cod fillet, which is also generally low in PBDEs. However, only the edible parts, i.e. muscle tissue, of shrimps were analysed, and a quite different result might have been found if the whole animal had been analysed.

Comparing the concentrations of PBDEs in shrimps from the Barents Sea with shrimps from Skagerrak and the North Sea it appears that shrimps from the Barents Sea had much lower concentrations of BDE-47 and hence sum PBDE$_7$ than shrimps from the North Sea and the Skagerrak. In the North Sea and Skagerrak the mean concentrations of BDE-47 were almost ten times as high, with 0.026 and 0.027 µg/kg w.w., respectively (unpublished data, NIFES). This makes sense, since these areas are surrounded by much more populated and industrialised areas than the Barents Sea and therefore are expected to be more polluted.

There were also some differences between the Barents Sea stations, with the highest concentrations of sum PBDE$_7$ in the two stations to the west, stations 315-1 and 315-3 (Figure 6). BDE-153 contributed mainly to these differences (Figure 16). However, only one collective sample from each station does not allow for statistical comparisons of the different areas. The overall impression gives reason to believe that the levels represent background, but the basis for stating this is still too low.

7.5.4 Capelin

Results

Capelin from the Barents Sea (Table 22, Figure 17) had a mean concentration of sum PBDE$_7$ of 0.13 µg/kg w.w. When calculating sum PBDE$_7$, concentrations of single congeners below the limit of detection of 0.002 µg/kg w.w. were set to 0. BDE-47 was the dominating congener, with a mean concentration of 0.11 µg/kg w.w.

Table 22. Polybrominated diphenyl ethers PBDE and HBCDD (ng/kg w.w.) in pooled samples of whole capelin (Mallotus villosus) from the Barents Sea, 2007. Levels above LoD are shaded.

Sample ID	HBCDD	BDE-28	BDE-47	BDE-66	BDE-99	BDE-100	BDE-119	BDE-138	BDE-153	BDE-154	BDE-183	Sum PBDE$_7$
372/1	<250	8	143	<2	14	<2	<2	<2	<2	8	<2	172
372/2	<250	4	120	<2	11	<2	<2	<2	<2	6	<2	141
372/3	<250	6	152	<2	13	<2	<2	<2	<2	8	<2	180
372/4	<250	<2	42	0,07	5	<2	<2	<2	<2	<2	<2	47
372/5	<250	3	74	<2	9	<2	<2	<2	<2	3	<2	88

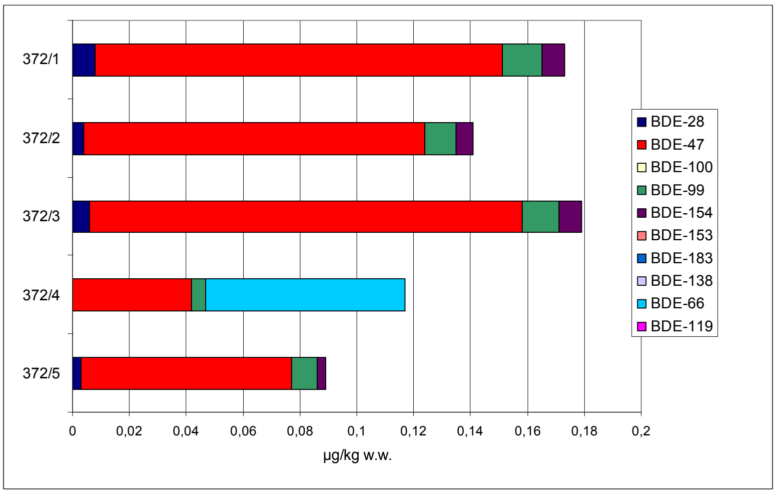


Figure 17. PBDE composition in whole capelin (Mallotus villosus) from the Barents Sea, 2007.

Discussion
Comparing the values with other fish caught in the Barents Sea, the concentrations of sum $PBDE_7$ in the pooled samples of whole capelin were similar to fillets of plaice (*Pleuronectes platessa*; 0.14 µg/kg w.w.) and lower than fillets of redfish (*Sebastes marinus*; 0.28 µg/kg w.w.). The PBDE concentrations were higher than found in fillets of lean fish species such as cod (*Gadus morhua*) and saithe (*Pollachius virens*), which had mean concentrations of $sumPBDE_7$ of 0.041 and 0.044 µg/kg w.w., respectively (unpublished data, NIFES). On the other hand the coastal cod liver samples in the present investigation had sum $PBDE_7$ level as high as 3,4 - 29 µg/kg w.w. (Table 23), which again is at level with cod fillet from SW Greenland (AMAP 2004).

Capelin is the only species from the Barents Sea that has been analysed as whole fish, so direct comparisons with other fish species from the Barents Sea are problematic. Fish from more southerly Norwegian fishery areas which have been analysed whole for PBDEs are blue whiting (*Micromesistius potassou*) and sandeel (family Ammodytidae). Both species have much higher concentrations of PBDEs than capelin from the Barents Sea, with mean $sumPBDE_7$ concentrations of 1.1 and 1.2 µg/kg w.w. (Sjømatdata, www.nifes.no). Also fillets of fat rich species such as herring (*Clupea harengus*), maquerel (*Scomber scombrus*) and horse maquerel (*Trachurus trachurus*) from the North Sea and Norwegian Sea have considerably higher PBDE concentrations than Barents Sea capelin, with mean sum $PBDE_7$ concentrations from 0.95 to 4.0 µg/kg w.w. (Sjømatdata, www.nifes.no).

Capelin in the Barents Sea rarely exceeds 4-5 years of age (Gjøsæter, 2007). Relatively low concentrations of PBDEs may be a result of the combination of short life span and a position at a low trophic level. Comparing capelin from the different stations in the Barents Sea, the measured concentrations of BDE-47 were higher at stations 372/1, 372/2 and 372/3 than at stations 372/4 and 372/5 (Figure 17). This may reflect a greater influence from pollution closer to the coast and in the western part of the Barents Sea than in the open sea areas to the north and east. However, a much larger number of samples would be needed to confirm this pattern. It is also too early to suggest that the lowest levels found represent a real background situation.

7.5.5 Cod

Results

Individual cod liver samples from 1994 and 2005/2006 from 4 stations were screened for PBDEs. The average concentrations are given in Table 23. Sum PBDE$_7$ ranged from 3,4 to 29,0 µg/kg w.w. BDE-47 accounted for 61 – 79 % of the sum PBDE$_7$ (Figure 18).

Table 23. Mean levels of polybrominated diphenyl ethers PBDE (µg/kg w.w.) in individual cod (Gadus morhua) liver from the Barents Sea 1994, 2005, and 2006. Levels above LoD are shaded.

Code	BDE-71	BDE-138	BDE-183	BDE-205	BDE-153	BDE-85	BDE-119	BDE-77	BDE-66	BDE-154	BDE-99	BDE-28	BDE-49	BDE-100	BDE-47	Sum BDE$_7$
98B1-94	<0,1	<0,1	<0,2	<0,8	0,2	0,1	<0,2	0,2	0,4	0,3	0,5	0,7	1,8	1,2	7,9	10,7
98B1-06	<0,18	<0,5	<0,8	<2	0,1	0,3	0,6	0,2	0,2	0,4	1,2	0,3	1,2	1,4	5,5	9,0
43B-94	<0,09	<0,1	<0,3	<1,3	<0,1	0,1	0,2	0,2	0,3	0,5	0,3	1,1	1,6	2,5	14,7	19,1
43B1-06	<0,03	<0,07	<0,13	<0,5	<0,05	<0,05	0,4	0,1	0,1	0,2	0,1	0,2	0,5	0,6	2,3	3,4
45B-94	<0,01	<0,1	<0,2	<0,8	0,1	0,2	<0,3	0,1	0,3	0,3	0,3	0,9	1,5	1,6	10,4	13,6
45B1-06	<0,08	<0,2	<0,2	<0,8	0,1	0,2	0,2	0,1	0,1	0,4	0,3	0,2	0,8	0,8	2,6	4,3
10B-94	<0,1	<0,2	<0,3	<0,8	0,2	0,2	<0,2	0,3	0,4	0,6	0,8	1,2	1,7	3,3	23,0	29,0
10B-05	<0,08	<0,2	<0,2	<0,7	<0,09	0,1	0,4	0,1	0,1	0,2	0,2	0,2	0,6	0,7	3,4	4,7

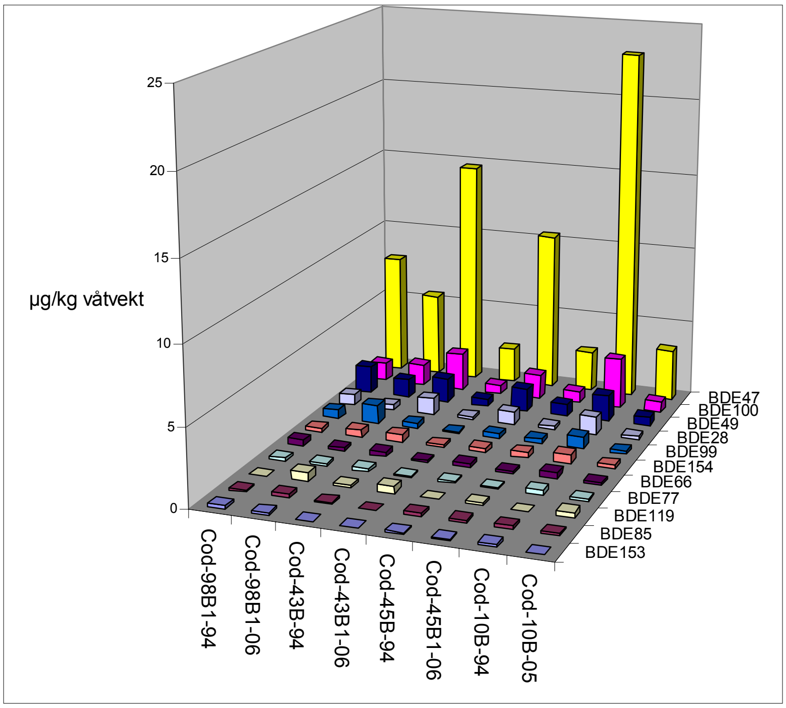


Figure 18. PBDE compounds in cod (Gadus morhua) liver from the Barents Sea 1994, 2005, and 2006

Discussion

The samples were selected so as to enable changes in concentrations of sum $PBDE_7$ in cod liver from 1994 til 2005/2005 to be assessed. At all stations the mean levels had decreased strongly since 1994, on an average by 63 %. The reduction was least at station 98B, the Svolvær region (16 %), most at station 10B Varangerfjorden (84%). As can be seen from Figure 14 the relative composition of the PBDEs did not vary much from the Lofoten area to Varangerfjorden, which is different from what was seen in the sediment samples.

In 2004 Fjeld.et al. (2005) reported levels of sum $PBDE_7$ in the range 6,8 – 17,2 µg/kg w.w. in cod liver from open coastal areas, which again were comparable with earlier analyses in cod from Greenland and the North Sea. The 2006 levels in the present survey are at the lower end of this range (3,4 – 9,0 µg/kg w.w.). The levels of BDE-47 alone in 2006 were 2,3 – 5,5 µg/kg w.w. which is below coastal levels of the same compound (15 – 48 µg/kg w.w., AMAP 2004), but higher than reported by AMAP (2004) in cod liver from Greenland (1,8 ± 20 µg/kg w.w.). These comparisons suggest that the PBDE contamination level in the 2006 cod liver samples was low and could represent background condition. In the inner Oslofjord Fjeld et al. (2005) measured far higher levels of sum $PBDE_7$ (100,7 and 104,4 µg/kg w.w).

7.5.6 Brünnich's guillemot eggs

Results

Average sum of all PBDEs ranged from 16,7 ± 5,1(CI) µg/kg lipid weight to 86,7 ± 47,4 µg/kg l.w. (Table 24). Details on the concentrations of the different congeners are shown in Figure 19.

Table 24. Fat % and sum of PBDEs (average ng/g l.w. ± 95 % CI) in Brünnich's guillemot (Uria lomvia) eggs from Svalbard sampled in 1993, 2002, 2003 and 2007.

Station ID	**Fat %**			**Sum PBDEs**		
	Average	±	CI	Average	±	CI
K93	12,4	±	12,6	86,7	±	47,4
K02	13,5	±	11,0	47,9	±	26,9
K07	13,5	±	13,7	16,7	±	5,1
B03	15,6	±	11,8	26,9	±	16,3
B07	13,7	±	12,7	17,2	±	3,4

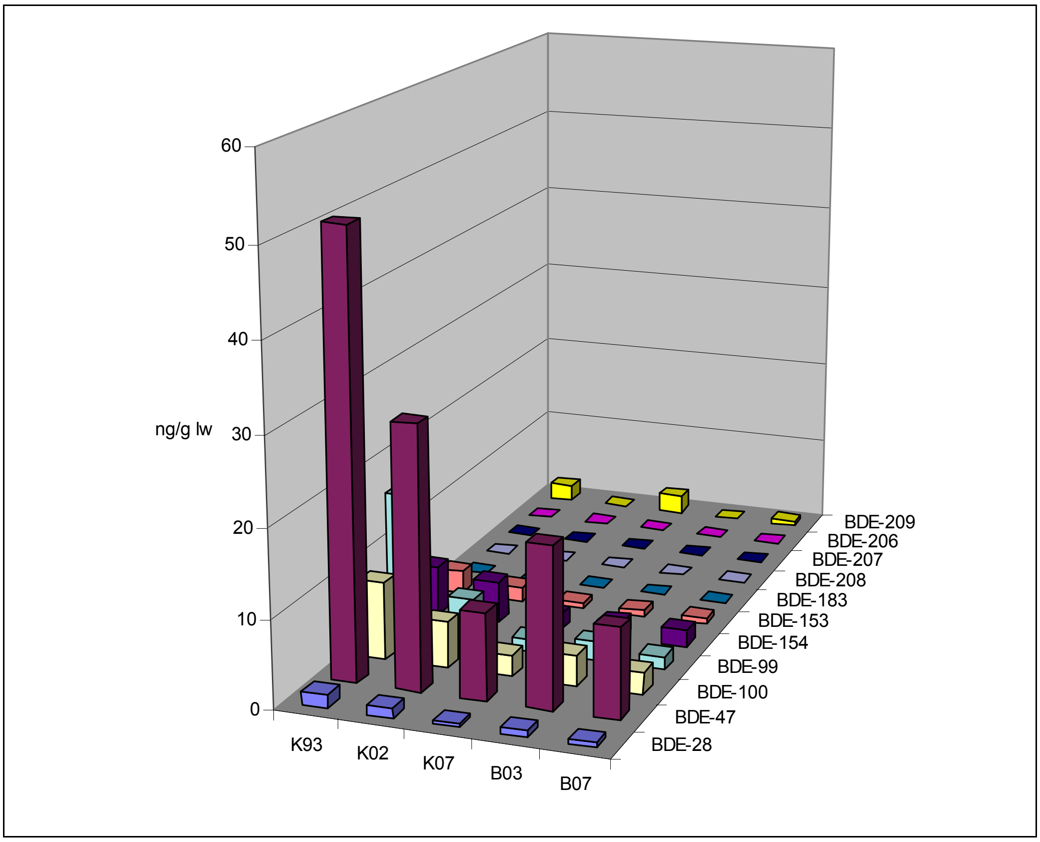


Figure 19. Average PBDE congener levels (ng/g l.w.) in Brünnich's guillemot (Uria lomvia) eggs from Svalbard sampled in 1993, 2002, 2003 and 2007.

Discussion

Levels of PBDEs in eggs of Brünnich's guillemots of the present study were lower than that reported for peregrine falcon (*Falco peregrinus*) eggs from Norway (Herzke et al. 2005), South Greenland (Vorkamp et al. 2005) and Sweden (Lindberg et al. 2004). The levels were also much lower than that reported in glaucous gull (*Larus hyperboreus*) eggs from Bjørnøya (Verreault et al. 2004), herring gull eggs from the Great Lakes (USA, Canada) (Norstrom et al. 2002) and ivory gull eggs from Svalbard and Russia (Miljeteig et al. 2007). Generally, the PBDE concentrations in the Brünnich's guillemot eggs of the present study were lower than that reported in eggs of black-legged kittiwakes (*Rissa tridactyla*), Atlantic puffins (*Fratercula arctica*) and herring gulls from Northern Norway (Knudsen et al. 2005).

In the Brünnich's guillemot eggs of the present study BDE-47 was the most prevailing PBDE congener, constituting from 40 to 70 % of the sum of all PBDEs. Higher proportions of BDE-47 compared to other PBDE congeners have been found in previous studies, e.g., in common guillemot (*Uria aalge*) eggs (Sellström et al. 2003) and in black guillemots (*Cepphus grylle*) (Vorkamp et al. 2004).

There was no statistical significant temporal trend of the sums of all PBDEs in the present study ($p > 0.05$). However, a clear trend of lower concentrations of PBDEs in 2007 compared to that found in 1993, 2002 and 2003 can be seen from Figure 19. The indications of lower levels of PBDEs in 2007 compared to that found in 1993, 2002 and 2003 support findings in a temporal trend study (1969 to 2001) of tetra- and penta-BDEs in eggs of common guillemots from the Baltic Sea. In this study the levels of PBDEs increased from the 1970s to the 1980s, followed by a rapid decrease in concentrations until 2001 (Sellström et al. 2003). In Canada and Greenland PBDE concentrations have increased in the biota up until today (Norstrom et al. 2002; Vorkamp et al. 2005).

No clear spatial trend of PBDEs was apparent in the dataset ($p > 0.05$).

7.5.7 Comparison among species

Comparison among the 4 marine species included show that cod liver had sum $PBDE_7$ and BDE-47 levels around 3 orders of magnitude higher than in the other species. Lowest range was found in shrimp tails (1-17 ng/kg w.w. of sum $PBDE_7$), whereas mussels and capelin were higher (around 40 – 150 ng/kg w.w. leaving out one high value for mussels from Skrova). These differences are probably to some extent linked to differences in lipid content in these types of samples, and do not necessarily suggest differences in exposure to PBDE. Although no data are available from the present samples, one can expect that the lipid content of cod liver is far higher than in whole capelin which again is far higher than in shrimp tails. Typical lipid levels in corresponding tissue types from the Grenland fjords in Norway are 25-50 % in cod liver, 1-10 % in fat fish fillet and 0,5 % in shrimp tails. A quick normalisation on basis of these typical lipid levels suggested that the lowest normalised BDE-47 occurred in shrimp and capelin. Lipid-normalised levels in blue mussel and guillemot eggs were 5-10 times higher and cod liver about 50 times higher than these. Information to assess this in more detail is not available.

7.6 Other bromoorganic compounds

This group comprises tetrabromobisphenol A (TBBPA) and the isomers of hexabromocyclododecane (HBCDD).

7.6.1 Sediments

Results

A total of 11 sediment samples were screened for these compounds. TBBPA was not above the LoD in any of the samples (Table 25). All 3 isomers of HBCDD could be quantified in all but two samples. One of these, from station IP-41 in the south Pechora Sea, has an artificially high LOD, due to matrix problems during analysis. Several attempts of repeated analysis were made without improving the resolution. For the quantifiable samples the sum HBCDD ranged from 38 to 191 ng/kg d.w. with the sample from station IP-29 south of Novaja Zemlja clearly above the others. Apart from this, only small differences were found among the samples, and no clear geographical trend.

Table 25. HBCDD (ng/kg d.w.) and tetrabromobisphenol A (TBBPA) (µg/kg d.w.) in bottom sediments from the Barents Sea 2007. Levels above LoD are shaded.

Station ID	a-HBCDD	b-HBCDD	g-HBCDD	Sum HBCDD	TBBPA
IP-19	11	25,1	38,2	74	<0,31
IP-20	<3,65	<2,48	<3,01	0	<0,36
IP-22	10,7	14,7	19,5	45	<0,51
IP-27	14,9	15,4	7,47	38	<0,54
IP-29	17,2	15,3	158	191	<0,54
IP-41	<400	<1503	<1883	0	<0,21
R18	10,0	9,38	6,94	26	<0,15
R35	16,2	14,7	27,9	59	<0,36
R68	15,8	31,6	7,14	55	<0,38
R81	14,5	20,1	26,2	61	<0,62
R96	15,7	22,7	30,8	69	<0,20

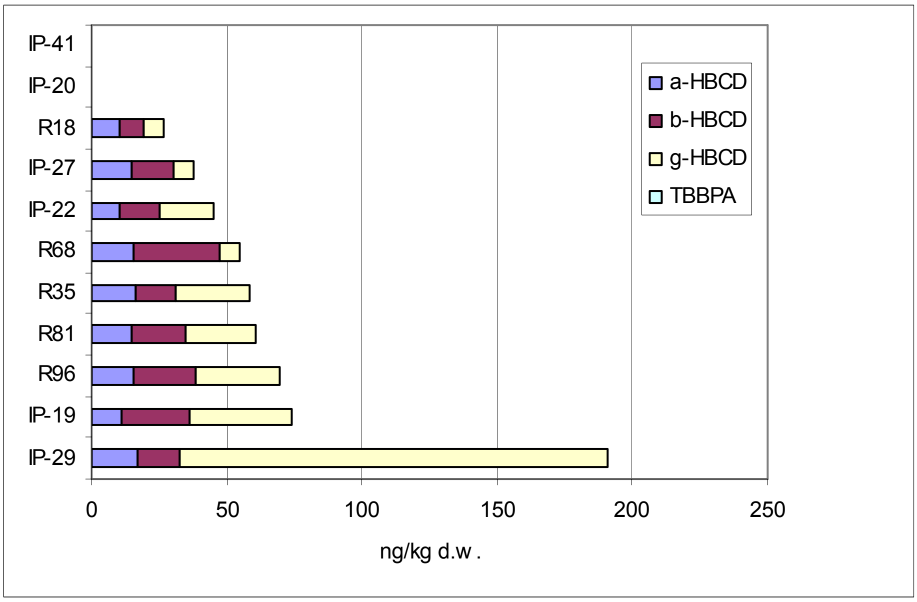


Figure 20. HBCDD and tetrabromobisphenol A in bottom sediments from the Barents Sea 2007.

Discussion

The elevated level of sum HBCDD at station IP-41 was due to elevated level of g-HBCDD. A predominance of this isomer has also been found earlier in marine sediments (Fjeld et al. 2005). However, leaving out station IP-41 there was no particular predominance of any of the HBCDD isomers. Fjeld et al. (2005) reported sum HBCDD in the range 280 – 21 000 ng/kg d.w. in Norwegian coastal areas, whereas the contaminated sediments in Åsefjorden, Ålesund had concentrations as high as 24 000 to 8 482 000 ng/kg w.w. Fjeld et al. (2005) suggested that levels below 3 µg/kg d.w (3 000 ng/kg d.w.) should be considered typical for sites without any point source influence. This is not exceeded in any of the present samples. The chronic PNEC level in the Norwegian sediment classification system is 86 000 ng/kg d.w., showing that the levels found in the Barents Sea sediments should be regarded as an insignificant environmental risk.

TBBPA levels did not exceed an LoD of 0, 6 µg/kg d.w in any of the samples, and were therefore at least 100 times less than the PNEC in the sediment classification system. This suggests that the LoDs in the present survey are sufficiently low for any practical purpose.

7.6.2 Shrimp and capelin

Results

TBBPA was not analysed in shrimp and capelin. Sum HBCDD was included in the analysis of PBDE and are presented in Table 21 for shrimp and Table 22 for capelin. None of the samples had HBCDD levels above the LoD (<200 and <250 ng/kg w.w. respectively).A basis for assessing these levels or the adequacy of the LoDs is lacking.

7.6.3 Brünnich's guillemot eggs

Results

The isomer-specific concentrations of HBCDD were not analysed in the present study, only the total sum HBCDD. The mean levels ranged from 1,5 µg/kg w.w. at Kongsfjord 2007 to 3,2 µg/kg w.w. at Kongsfjord 2002 (Table 26, cf. Figure 21 for corresponding levels on lipid basis).

Table 26. HBCDD (average ng/g w.w. and 95 % CI) in Brünnich's guillemot (Uria lomvia) eggs from Svalbard sampled in 1993, 2002, 2003 and 2007.

Station ID	Mean	95 % CI
B03	3,04	1,43
B07	2,29	0,53
K93	2,45	1,00
K02	3,23	1,02
K07	1,50	0,23

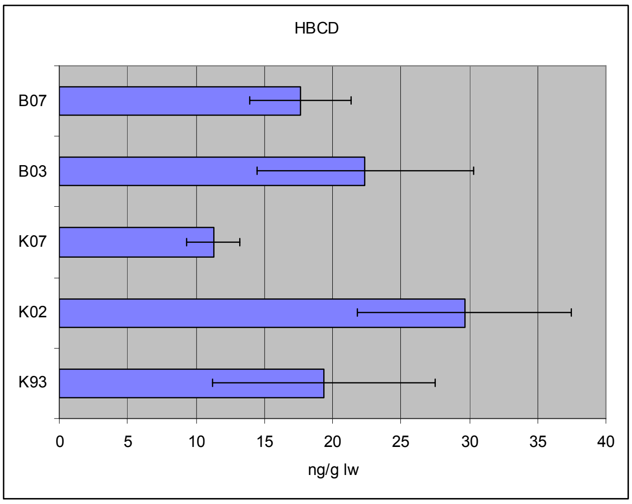


Figure 21. HBCDD (average ng/g lw ± 95 % CI) in Brünnich's guillemot (Uria lomvia) eggs from Svalbard sampled in 1993, 2002, 2003 and 2007.

Discussion

Sum HBCDD in Brünnich's guillemot eggs (Figure 21) were comparable to the levels found in peregrine falcon eggs from Greenland (Vorkamp et al. 2005). In contrast to this, the levels of HCBD in the Brünnich's guillemot eggs of the present study were somewhat lower than that reported in glaucous gull eggs from Bjørnøya (Verreault et al. 2004), peregrine falcon eggs from Sweden (Lindberg et al. 2004), ivory gull eggs from Svalbard and Russia (Miljeteig et al. 2007), and black-legged kittiwake eggs, herring gull eggs and Atlantic puffin eggs from Northern Norway (Knudsen et al. 2005).

The levels of HBCDD were higher in 2002/2003 compared to the levels reported in 2007 ($p < 0.05$). This is in concert with the findings in a recent temporal trend study (1983 to 2003) from Northern Norway investigating the temporal trends of HBCDD in eggs of black-legged kittiwakes, herring gulls and Atlantic puffins the levels of HBCDD were increasing from 1983 to 2003 (Knudsen et al. 2006). In Greenland, a decrease in total HBCDD was reported in peregrine falcon eggs between 1986 and 2003 (Vorkamp et al. 2005). Furthermore, no significant temporal trend of HBCDD was reported between 1981 and 2001 in eggs of common guillemots in the Baltic (Sellström et al. 2003).

As already mentioned, contaminant levels and patterns might be influenced by a shift in the diet, e.g. to fish with a higher or lower fat content, or at a higher or lower trophic level. Stable-nitrogen isotope analyses ($\delta^{15}N$) in the Brünnich's guillemot eggs of the present study indicated that the observed temporal trends in HBCDD levels might be due to a shift in diet as $\delta^{15}N$ is statistically significantly different in eggs sampled in 2002/2003 and in 2007 ($p < 0.05$). No spatial trend of HBCDD was found in the present study ($p > 0.05$).

7.7 Bisphenol A

7.7.1 Sediments

Results

BPA could be quantified in all the 11 sediment samples screened (Table 27). The concentrations varied from 2,32 to 10,20 µg/kg d.w. Highest level was found at station R81, and lowest at station R18, both stations at Tromsøflaket (Figure 22).

Table 27. Bisphenol A, synthetic musk compounds, siloxanes (µg/kg d.w.), and DEHP (mg/kg d.w.) in bottom sediments from the Barents Sea 2007. Levels above LoD are shaded.

Station ID	BPA	Muskxylene	Muskketone	D4-siloxane	D5-siloxane	D6-siloxane	DEHP
IP-19	8,27	2,82	<0,36	<17	<10	<38	7,76
IP-20	5,80	<0,13	<0,16	40	11	<41	1,16
IP-22	6,67	<0,92	<1,20	<21	<13	<49	1,40
IP-27	9,50	3,10	<0,13	<18	<11	<41	1,62
IP-29	5,84	<0,19	<0,24	<21	13	<49	17,60
IP-41	5,99	<0,15	<0,19	<17	<10	<39	5,85
R18	2,32	<0,27	<0,33	<13	<8	<30	4,19
R35	3,54	4,18	<0,20	<20	<12	<45	7,77
R68	4,82	<0,49	<0,61	<21	<13	<49	57,69
R81	10,20	<1,20	<1,60	<16	<10	<37	12,96
R96	4,39	<0,32	<0,41	<26	<15	<59	2,36

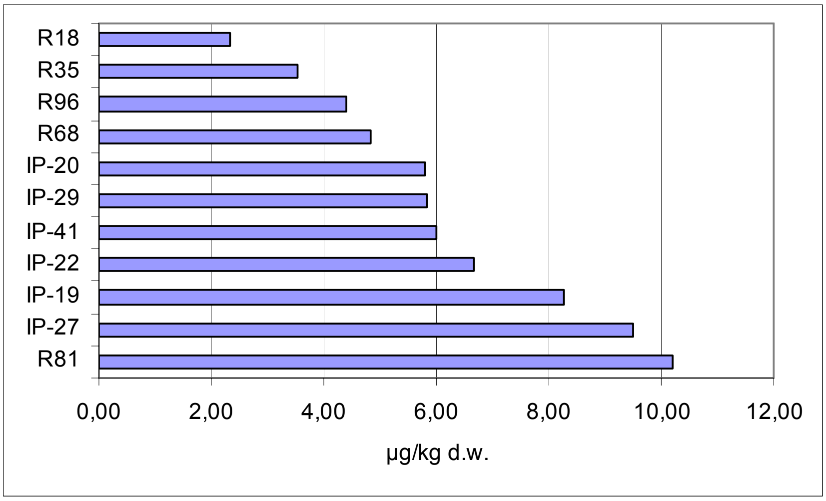


Figure 22. Bisphenol A in bottom sediments from the Barents Sea 2007.

Discussion

Fjeld et al. (2005) found levels of BPA ranging from 0,01 til 7,4 µg/kg d.w. in sediments from presumably uncontaminated sites, 120 – 304 µg/kg d.w. in harbour sediments from Trondheim and Drammen, and 58 µg/kg d.w. in the Tromsø harbour. The levels found in the present sediments were at level with the lowest range reported by Fjeld et al. (2005), far less than in the harbour sediments, and slightly below the chronic PNEC of 11 µg/kg d.w. for BPA in the Norwegian sediment classification system, suggesting that the levels in the Barents Sea sediments could represent background, and that the environmental risk from the sediments is acceptable.

7.8 Synthetic musk compounds

7.8.1 Sediments

Results

Musk ketones were below the LoD in all sediment samples (Table 27) and musk xylenes could be quantified in only 3 of the 11 samples (Figure 23). The levels of musk xylenes did not differ to any extent (2,8 – 4,2 µg/kg d.w.).

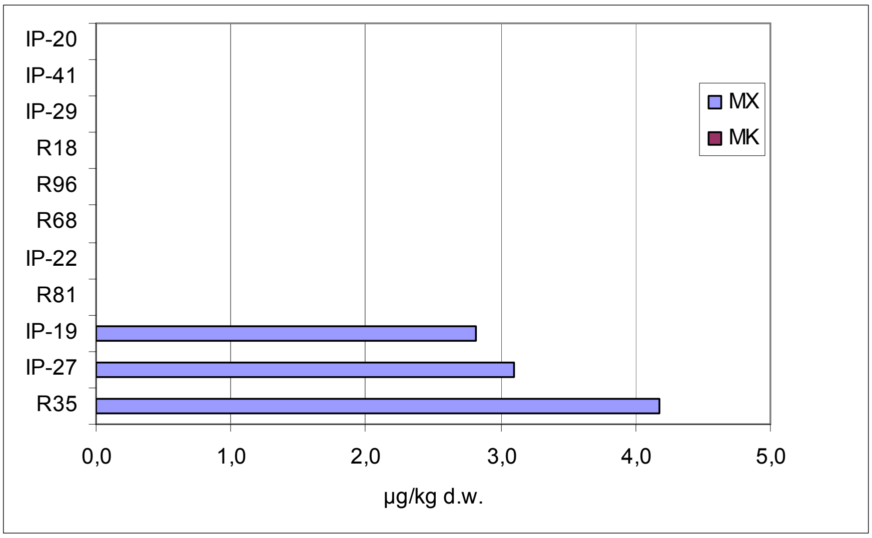


Figure 23. Synthetic musk xylenes (MX) and musk ketones (MK) in bottom sediments from the Barents Sea 2007.

Discussion
In a Nordic screening study of musk compound in various media (Mogensen et al. 2004) results from 2 sediment survey are presented giving levels of musk xylene in the range 2,2 – 5,2 µg/kg d.w. Musk ketones were below the LoD. We have no detailed information on the sites referred to, but the levels are equal to those that were quantifiable in the present project. Hence the available information is too fragmentary to assess if the samples in which musk xylenes could be quantified, are at background. These samples, however, were all over the region and indicated no geographical trend.

7.9 Siloxanes

7.9.1 Sediments

Results
The sediment levels of D4-, D5-, and D6-siloxane are shown in Table 27. Station IP-20 contained levels of D4- and D5-siloxane above LoD (40 and 11 µg/kg d.w. respectively), and at station IP-29 south of Novaja Semlja only D5-siloxane could be quantified (13 µg/kg d.w.). All other samples were below LOD.

Discussion
In 6 sediment samples from the inner Oslofjord Schlabach et al. (2007) found levels of D5-siloxane in the range 93 – 920 µg/kg d.w. and D6-siloxane in the range <17 – 100 µg/kg d.w. D4-siloxane was below the LoD (<4 - <38 µg/kg d.w.). In the Stockholm and Helsinki harbour sediments levels of D5-siloxane of 77 – 130 µg/kg d.w. have been found. The Barents Sea sediment levels of D5-siloxane of less than15 µg/kg d.w. are clearly below these ranges, but whether they represent background or not cannot be assessed.

7.10 Phosphorous flame retardants

7.10.1 Sediments

Results

A total of 11 sediment samples were screened for 10 different PFRs. None of the samples had levels above the LoD for any of the compounds (Table 28). The highest LoD was 20 µg/kg d.w. for V6.

Table 28. Phosphorous flame retardants (µg/kg d.w.) in bottom sediments from the Barents Sea 2007. Levels above LoD are shaded. Levels found in sediments from Arendal and Lista in 2007 (Green et al 2008) are included for comparison.

Station ID	**TIBP**	**TBP**	**TCEP**	**TCPP1**	**TCPP2**	**TDCP**	**TBEP**	**TPhP**	**EHDPP**	**V6**
IP-19	<5	<7	<5	<4	<4	<5	<5	<5	<8	<20
IP-20	<5	<7	<5	<4	<4	<5	<5	<5	<8	<20
IP-22	<5	<7	<5	<4	<4	<5	<5	<5	<8	<20
IP-27	<5	<7	<5	<4	<4	<5	<5	<5	<8	<20
IP-29	<5	<7	<5	<4	<4	<5	<5	<5	<8	<20
IP-41	<5	<7	<5	<4	<4	<5	<5	<5	<8	<20
R18	<5	<7	<5	<4	<4	<5	<5	<5	<8	<20
R35	<5	<7	<5	<4	<4	<5	<5	<5	<8	<20
R68	<5	<7	<5	<4	<4	<5	<5	<5	<8	<20
R81	<5	<7	<5	<4	<4	<5	<5	<5	<8	<20
R96	<5	<7	<5	<4	<4	<5	<5	<5	<8	<20
Arendal (sediment)	*4,7*	*4,8*	*8,1*	*7,5*	*-*	*8,7*			*5,6*	*<20*
Lista_(reference, sediment)	*8,0*	*8,8*	*<5*	*5,0*	*-*	*5,0*			*12,0*	*<20*

Discussion

The results are in contrast to the results from the SFT screening survey 2007 (Green et al. 2008) showing clearly higher concentrations of most of the PFRs in marine sediments harbour from South Norway. On the other hand the levels at two open coast stations, Arendal and Lista, were only slightly higher than the LoDs in the present survey (Table 28). Hence one cannot exclude that the Barents Sea levels may be similar to those of coastal sediments elsewhere in Norway. Green et al (2008) also refer to other studies giving concentration ranges of TCEP alone of 13 – 28 ng/kg d.w. (unit is uncertain) and 10 – 70 000 µg/kg d.w., and of TCDP of 10 – 17 µg/kg d.w. in marine sediments from Japan. In comparison to these the Barents Sea levels for TCEP and TCDP were low. To be able to assess the real PFR levels and determine relevant background concentrations the LoDs have to be lowered.

7.11 Diethyhexylphtalate

7.11.1 Sediments

Results
A total of 11 sediment samples were screened for DEHP. All concentrations were above the LoD (Table 27) and ranged from 1,16 mg/kg d.w to 57,69 mg/kg d.w. Lowest level was found at station IP-20 in the open Barents Sea (the Kola transect) and the highest at station R68 at Tromsøflaket.

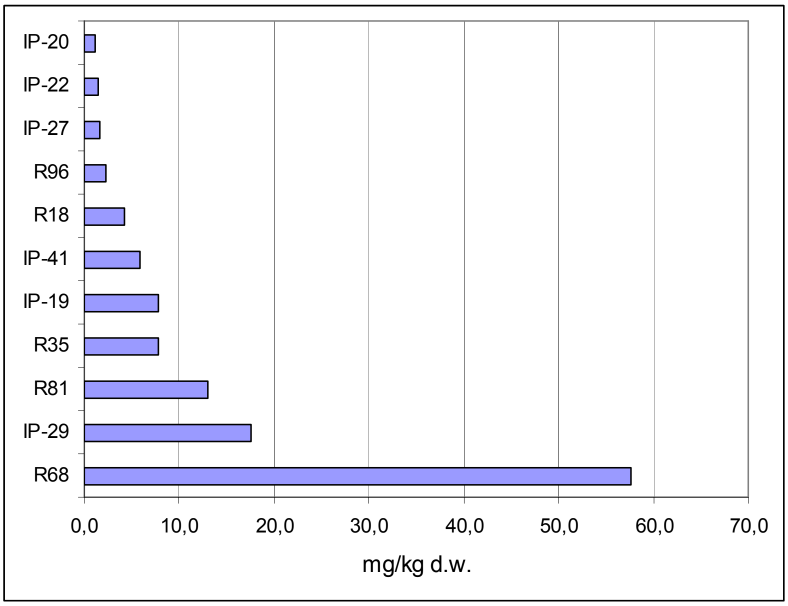


Figure 24. DEHP in bottom sediments from the Barents Sea 2007.

Discussion
In the SFT screening survey in 2006 (Bakke et al. 2007) the DEHP levels in marine sediments in Norwegian harbour and coastal areas were far less than this, and varied within a range of from 0,07 to 0,3 mg/kg. It is unlikely that the DEHP levels in open Barents Sea sediments should be 2-3 orders of magnitude higher than in sediments from contaminated fjords such as inner Oslofjord, Frierfjorden, and Kristiansandsfjorden. The possibility that the notation may be wrong in one of the data sets has been eliminated through cross checking. On the other hand, secondary contamination could be a reason since special care must be taken during sampling, transportation, storage and analysis for DEHP to avoid this. Increased levels may originate from equipment or packaging materials used for the samples. DEHP can also migrate into the samples if they are not transported and stored in air-tight containers. At present the results on DEHP levels in the Barents Sea sediments are deemed inconclusive and new analyses should be made.

7.12 Dioxins and furans

7.12.1 Sediments

Results

All 11 sediment samples were screened for dioxins (PCDD/PCDF). The concentrations of sumPCDD/PCDF, given as toxicity equivalents (TEQ) varied from 0,01 ngTEQ/kg d.w. at the open ocean station IP-19 of the Kola transect to 2,22 ngTEQ/kg d.w. at the inshore station R35 in Stjernøysund (Table 29). At most stations the PCDFs gave higher contribution to the total sum TEQ than the PCDDs (Figure 25).

Table 29. PCDD and PCDF (ngTEQ/kg d.w.) in bottom sediments from the Barents Sea 2007. Levels above LoD are shaded. TEQ is calculaTEQd according to WHO (1998)

Compound\Station ID	IP-19	IP-20	IP-22	IP-27	IP-29	IP-41	R18	R35	R68	R81	R96
Dioxins											
2378-TCDD	<1,0	<1,0	<1,0	<1,0	<1,0	<1,0	0,024	0,386	0,030	0,030	0,050
12378-PeCDD	<0,2	<0,2	<0,2	<0,2	<0,2	<0,2	0,042	0,599	0,172	0,282	0,409
123478-HxCDD	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	0,009	0,053	0,008	0,022	0,031
123678-HxCDD	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	0,006	0,071	0,010	0,017	0,025
123789-HxCDD	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	0,002	0,065	0,010	0,041	0,059
1234678-HpCDD	0,002	0,023	0,019	0,023	0,014	0,002	0,005	0,036	0,008	0,048	0,064
OCDD	0,000	0,001	0,001	0,001	0,001	0,000	0,000	0,002	0,000	0,002	0,004
SUM PCDD	**0,00**	**0,02**	**0,02**	**0,02**	**0,02**	**0,00**	**0,09**	**1,21**	**0,24**	**0,44**	**0,64**
Furans											
2378-TCDF	0,003	0,023	0,014	0,033	0,010	0,010	0,008	0,087	0,031	0,041	0,050
12378/12348-PeCDF	<0,2	0,016	0,016	0,017	0,006	0,003	0,002	0,034	0,010	0,017	0,025
23478-PeCDF	<0,2	0,220	0,171	0,211	0,053	0,050	0,052	0,486	0,148	0,328	0,389
123478/123479-HxCDF	<0,1	0,062	0,047	0,068	0,018	0,007	0,013	0,105	0,028	0,086	0,106
123678-HxCDF	<0,1	0,041	0,035	0,044	0,013	0,008	0,006	0,076	0,015	0,037	0,067
123789-HxCDF	<0,1	0,011	<0,1	<0,1	<0,1	<0,1	0,005	0,059	0,009	0,026	0,027
234678-HxCDF	<0,1	0,047	0,036	0,045	0,007	0,009	0,012	0,114	0,017	0,090	0,105
1234678-HpCDF	0,00058	0,024	0,018	0,024	0,005	0,003	0,005	0,037	0,007	0,048	0,052
1234789-HpCDF	<0,1	0,002	0,002	0,003	<0,1	<0,1	0,001	0,008	0,001	0,005	0,005
OCDF	0,00001	0,00019	0,00016	0,00018	0,00006	0,00003	0,00007	0,00058	0,00009	0,00062	0,00069
SUM PCDF	**0,00**	**0,44**	**0,34**	**0,44**	**0,11**	**0,09**	**0,10**	**1,01**	**0,27**	**0,68**	**0,83**
SUM PCDD/PCDF	**0,01**	**0,47**	**0,36**	**0,47**	**0,13**	**0,09**	**0,19**	**2,22**	**0,50**	**1,12**	**1,47**

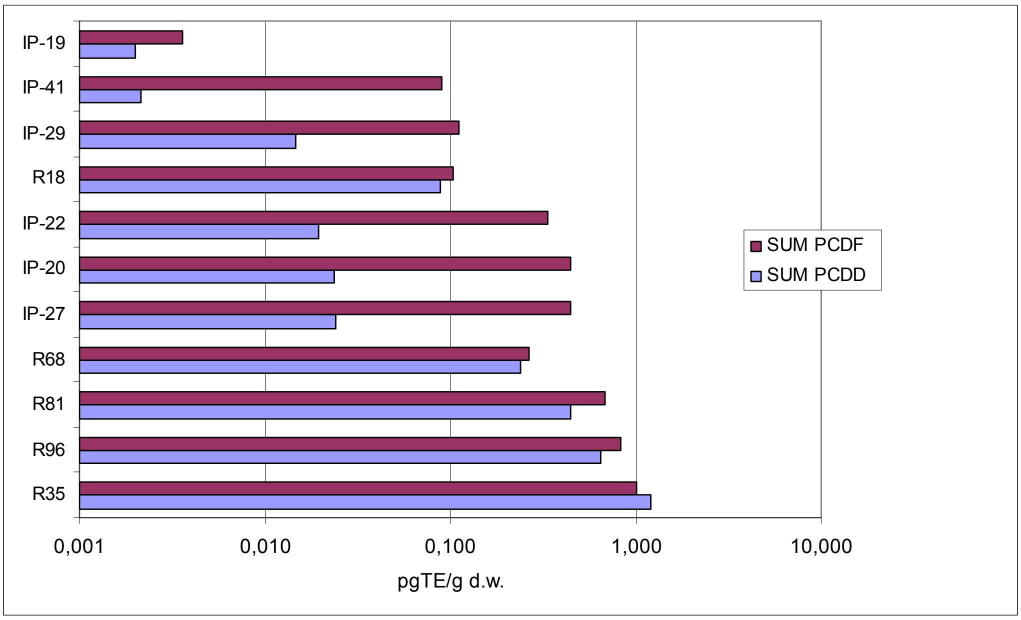


Figure 25. PCDD and PCDF in bottom sediments from the Barents Sea 2007. Note logarithmic scale.

Discussion
It may look as if the Tromsøflaket (R-) stations had slightly higher PCDD/PCDF levels than the Russian Barents and Pechora Sea (IP-) samples taken further east, but this may also be a difference between the laboratories. Table 29 shows that the LoD for the russian samples were at least one order of magnitude higher than those for the Tromsøflaket samples, causing zero values in the summation of the former even though the real concentrations may have been higher than those for the Tromsøflaket samples.

In a review of POP levels by AMAP (1998) the TEQ for PCDD/PCDF for Arctic coastal sediments lay in the range 0,1 – 2,8 ngTEQ/kg d.w., with a dominance of PCDFs, which corresponds reasonably well with the present results. AMAP (1998) also states that Barents Sea sediments had TEQ levels of TCDD 10-20 times less than the 5,5 – 17,2 ngTEQ/kg d.w. found in the northern North Sea (presumably in the range 0,25 – 1,7 ngTEQ/kg d.w.). At a reference site outside Varangerfjorden 0,1 ngTEQ/kg d.w. was found. In the present survey the TCDD at Tromsøflaket was in the range 0,02 – 0,36 ngTEQ/kg d.w. These comparisons suggest that the present dioxin levels represent background concentrations.

As a contrast to the results from this survey one could mention that the levels recorded in sediments from the most dioxin contaminated fjord in Norway, the Grenland fjords, were between 1400 and 458 000 ngTEQ/kg d.w. in 1997, the latest survey (Næs 1999). Also in these samples the PCDFs dominated over the PCDDs. In the Norwegian sediment classification system the chronic PNEC for sumPCDD/PCDF is 30 ngTEQ/kg d.w. These comparisons show that the PCDD/PCDF levels in the Barents Sea sediments are low and pose no significant environmental risk.

7.13 Polychlorinated biphenyls (PCB)

7.13.1 Sediments

Results

All 11 sediment samples were screened for PCB, but the set of congeners included differed between the Tromsøflaket and the Russian Barents and Pechora Sea samples (Table 30). Hence, the two data sets are only weakly comparable. Only PCB-105 and PCB-118 could be quantified in all samples. These were also the only congeners above the LoD in the Russian

Table 30. PCB levels (ng/kg d.w.) in bottom sediments from the Barents Sea 2007. Levels above LoD are shaded.

Station Congener	IP-19	IP-20	IP-22	IP-27	IP-29	IP-41	R18	R35	R68	R81	R96
HCB	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	9,96	16,82	28,18	14,63	15,01
PCB-18	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	9,03	12,23	8,76	6,53	5,21
PCB-28	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	13,18	21,89	14,30	10,83	7,32
PCB-31	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	11,51	17,94	11,36	10,15	5,75
PCB-33	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	8,95	13,28	9,44	6,75	4,49
PCB-37	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	4,04	5,76	3,82	1,86	1,83
PCB-47	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	7,36	11,09	7,39	5,41	4,68
PCB-52	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	14,61	30,37	19,64	11,64	10,96
PCB-66	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	10,62	19,93	12,91	10,24	8,49
PCB-74	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	5,97	12,43	6,60	5,65	4,49
PCB-99	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	10,36	21,95	10,41	11,31	12,54
PCB-101	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	32,22	75,96	48,15	22,70	24,73
PCB-105	63,08	83,06	224,47	100,56	106,29	97,18	5,40	14,54	9,26	8,54	8,35
PCB-114	<10	<10	<10	114,99	<10	<10	<0,295	1,55	<0,535	<0,495	<0,501
PCB-118	107,92	188,35	569,01	173,51	170,29	193,22	18,53	40,37	28,09	23,44	22,19
PCB-122	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	<0,299	<0,444	<0,544	<0,503	<0,509
PCB-123	<10	<10	<10	<10	<10	<10	0,41	0,76	<0,552	<0,505	<0,514
PCB-128	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	3,26	13,16	6,64	7,84	7,25
PCB-138	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	26,24	70,73	46,99	35,63	36,11
PCB-141	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	6,99	13,64	11,22	5,21	3,62
PCB-149	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	30,03	68,52	47,96	20,63	24,64
PCB-153	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	38,49	94,49	58,94	42,22	47,24
PCB-156	<10	<10	<10	<10	<10	<10	1,68	5,03	2,82	3,83	2,50
PCB-157	<20	<20	<20	<20	<20	<20	0,93	1,69	1,07	1,24	1,05
PCB-167	<20	<20	<20	<20	<20	<20	1,15	2,72	1,45	1,95	1,78
PCB-170	<10	<10	<10	<10	<10	<10	3,57	9,66	9,23	10,87	7,55
PCB-180	<10	<10	<10	<10	<10	<10	7,80	26,94	20,32	20,60	14,33
PCB-183	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	2,51	6,82	4,59	3,84	3,09
PCB-187	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	5,74	22,38	11,76	12,39	13,48
PCB-189	<10	<10	<10	<10	<10	<10	<0,332	0,80	<0,56	<0,499	<0,547
PCB-194	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	<0,443	4,07	<0,841	4,72	3,55
PCB-206	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	<0,565	4,05	2,90	4,59	3,98
PCB-209	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	2,55	12,50	7,98	20,70	14,73
PCB-81	<10	<10	<10	<10	<10	<10	n.a.	n.a.	n.a.	n.a.	n.a.
PCB-77	<10	10,84	<10	<10	<10	<10	n.a.	n.a.	n.a.	n.a.	n.a.
PCB-126	<10	<10	<10	<10	<10	<10	n.a.	n.a.	n.a.	n.a.	n.a.
PCB-169	<10	<10	<10	<10	<10	<10	n.a.	n.a.	n.a.	n.a.	n.a.
Sum PCB	30,99	152,26	653,48	259,06	136,58	150,39	445,61	1002,89	630,13	467,58	422,35
Sum PCB$_7$	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	151,07	360,74	236,43	167,06	162,88

region. For both PCB-105 and PCB-118 the Russian region results were 10-20 times higher than the Tromsøflaket results. Since the LoD for the Russian region analyses also was 1-2 orders of magnitude higher than those for the Tromsøflaket analyses it is uncertain to conclude if this difference is real or not. The sum PCB_7 could only be determined in the Tromsøflaket samples (Figure 26), and ranged from 0,15 µg/kg d.w. at the open sea station R18 to 0,36 µg/kg at the coastal station R35 Stjernøysundet.

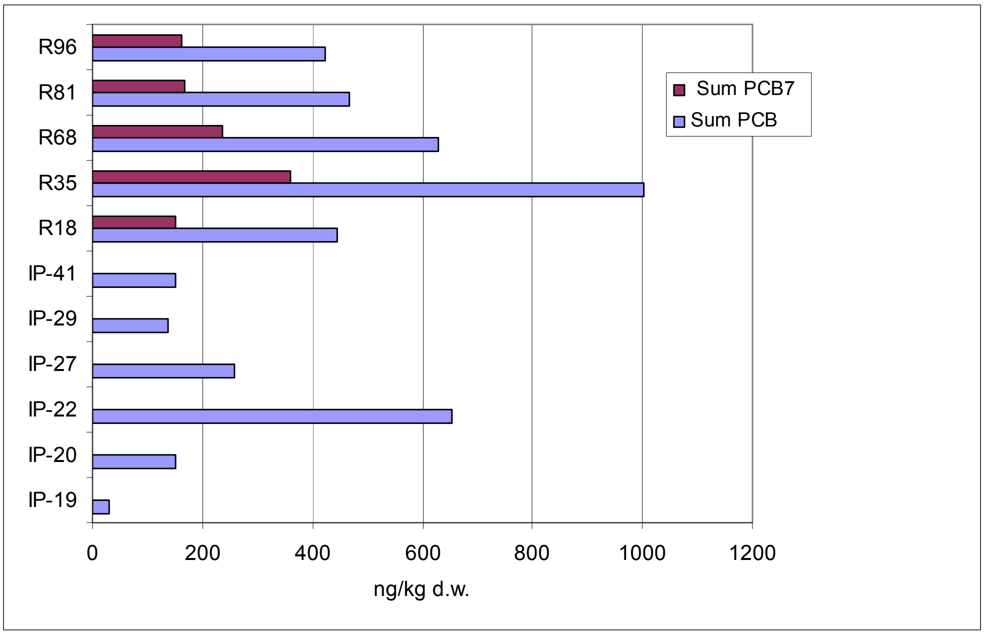


Figure 26. PCB in bottom sediments from the Barents Sea 2007. Sum PCB_7 could not be calculated for the IP stations (only 2 of the 7 congeners were analysed).

Discussion

AMAP (1998, 2004) gives a typical range in background levels of sum PCBs (13 – 60 congeners) in arctic sediments of 0,1-3 µg/kg d.w. The revised Norwegian sediment classification system gives a background level for sum PCB_7 in marine coastal sediments of 5 µg/kg d.w. and a chronic PNEC of 17 µg/kg d.w. This suggests that the PCB levels in the present Barents Sea sediments (sums of all congeners was less than 1 µg/kg d.w. and sum PCB_7 in the range 0,15 – 0,36 µg/kg d.w.) are low and essentially represent background conditions.

7.13.2 Brünnich's guillemot eggs

Results

Mean sum of concentrations of all PCB congeners included in the analysis ranged from 1000 to 3500 ng/g l.w. among the 5 stations. The highest levels were reported in eggs collected in Kongsfjorden in 1993. The PCB profile in all sample stations was dominated by penta-, hexa- and hepta-PCBs (Figure 27, Table 31). The levels of mono-ortho PCBs (cf. Table 1) ranged from 200 to 700 ng/g l.w. As for sum PCBs, the highest levels were found in the eggs sampled in Kongsfjorden in 1993.

Discussion

The levels are similar to that found in eggs of black-legged kittiwakes, herring gulls, common guillemots and Atlantic puffins (Helgason et al. 2007). The highest sum PCBs concentration (3500 ng/g l.w.) in the present study was higher than concentrations of sum PCBs found in eggs of Brünnich's guillemots from Canada and Bjørnøya (AMAP 2004). Levels of sum PCBs reported in eggs of black guillemots (*Cepphus grylle*), black-legged kittiwakes and northern fulmars (*Fulmarus glacialis*) from the Canadian and Norwegian Arctic (Braune et al. 2001; Evenset et al. 2002; Gabrielsen et al. 1997) were, however, in the same range as the highest levels reported in the present study. The levels of PCBs found in eggs of glaucous gull (Verreault et al. 2004) and ivory gull (Miljeteig et al. 2007) sampled on Svalbard were much higher.

Table 31. Lipid normalised tri- to nona-PCB levels (average ng/g l.w. ± 95 % CI) in Brünnich's guillemot (Uria lomvia) eggs from Svalbard sampled in 1993, 2002, 2003 and 2007.

	TriPCB			**TetraPCB**			**PentaPCB**			**HexaPCB**		
	Average	±	CI	Average	±	CI	Average	±	CI	Average	±	CI
K93	55,3	±	10,8	276,9	±	66,2	828,9	±	235,6	1690,4	±	828,1
K02	37,6	±	8,8	167,0	±	34,0	504,8	±	84,4	977,0	±	244,9
K07	23,3	±	2,0	93,5	±	11,2	266,5	±	41,8	514,8	±	113,7
B03	28,4	±	7,3	120,2	±	35,5	356,8	±	149,9	670,0	±	324,5
B07	30,9	±	1,4	97,3	±	4,3	264,6	±	8,5	462,8	±	23,4

	HeptaPCB			**OctaPCB**			**NonaPCB**		
	Average	±	CI	Average	±	CI	Average	±	CI
K93	615,7	±	361,5	47,5	±	24,3	15,4	±	6,2
K02	332,9	±	85,7	22,6	±	4,4	9,7	±	1,8
K07	173,4	±	41,6	13,9	±	2,0	8,1	±	0,5
B03	199,2	±	77,6	16,7	±	2,5	8,9	±	1,3
B07	145,7	±	10,1	13,7	±	1,7	7,7	±	1,1

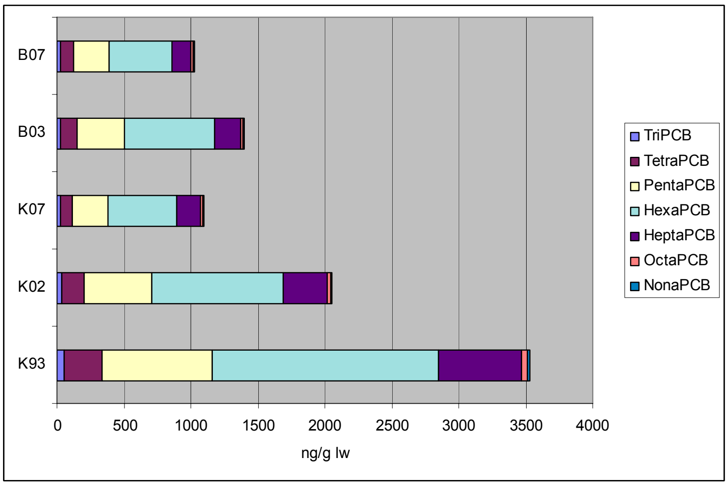


Figure 27. Lipid normalised tri- to nona-PCBs (ng/g l.w.) in Brünnich's guillemot (Uria lomvia) eggs from Svalbard sampled in 1993, 2002, 2003 and 2007.

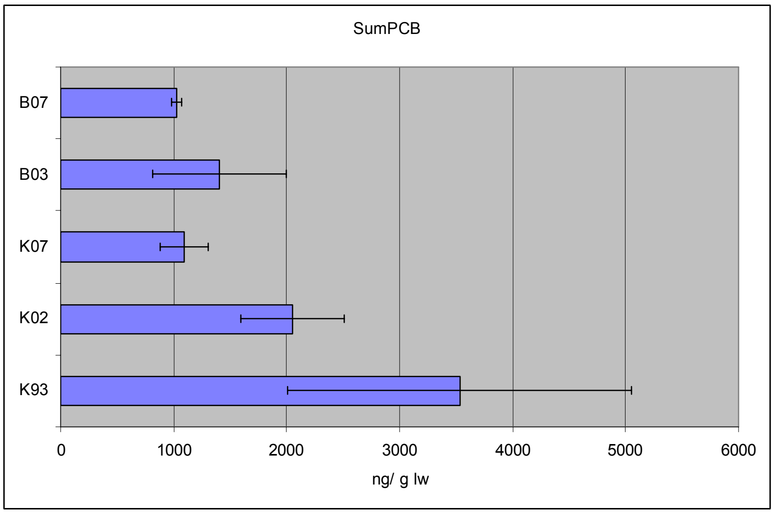


Figure 28. Lipid normalised sum PCB (average ng/g l.w. ± 95 % CI) in Brünnich's guillemot (<u>Uria lomvia</u>) eggs from Svalbard sampled in 1993, 2002, 2003 and 2007.

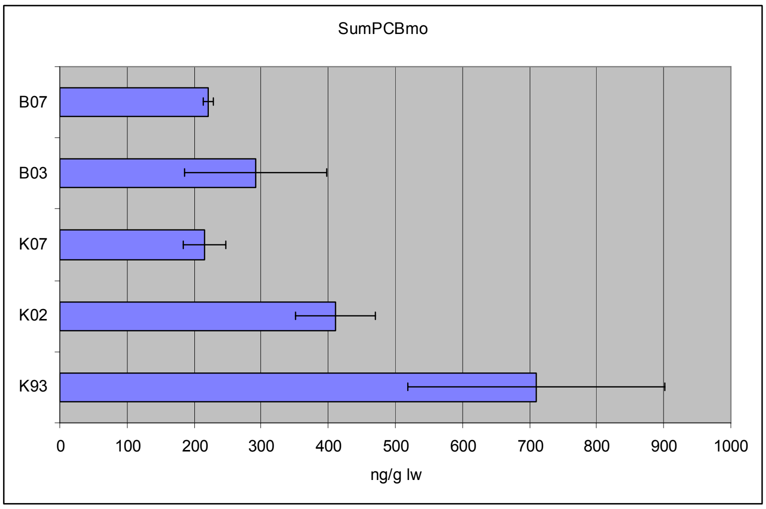


Figure 29. Lipid normalised sum mono-ortho PCBs (average ng/g l.w. ± 95 % CI) in Brünnich's guillemot (<u>Uria lomvia</u>) eggs from Svalbard sampled in 1993, 2002, 2003 and 2007.

The levels of tetra- to octaPCBs were higher in 2002/2003 compared to the levels reported in the eggs collected in 2007 ($p < 0.05$). Also the levels of sum PCBs and sum mono-*ortho* PCB were significantly different, i.e., the levels were highest in the eggs collected in 2002/2003 ($p < 0.05$). The decrease in PCB concentrations from 2002/2003 to 2007 in Brünnich's guillemot eggs followed the trends demonstrated for other seabird eggs, i.e., Helgason et al. (2007), suggesting reduced exposure. See comment on shift in diet (chapter 7.6.3).

7.14 Organohalogens

7.14.1 Sediments

Results

A total of 11 sediment samples were screened for a range of chlorinated compounds: TCB, PeCB, HCB, PCP and HCBD. PCP was below the LoD in all samples (Table 32). TCB was the dominating compound (Figure 30), and sum TCBs varied from 0,27 µg/kg d.w at station R18, Tromsøflaket, to 1,20 µg/kg d.w. at station IP-27 south of Novaja Zemlja. The levels of PeCB varied moderately from 0,17 µg/kg d.w. at station R18 Tromsøflaket to 0,43 µg/kg d.w. at station IP-22 the Shtokman region. HCB could only be quantified in 3 samples spread all over the eastern Barents and Pechora Seas and with a range of 0,05 – 0,29 µg/kg d.w. HCBD could be quantified in 6 of the 11 samples with a range of 0,05 – 0,16 µg/kg d.w.

Table 32. Various organohalogen compounds (µg/kg d.w.) in bottom sediments from the Barents Sea 2007. Levels above LoD are shaded.

Station ID	**1,3,5-TCB**	**1,2,4-TCB**	**1,2,3-TCB**	**sumTCB**	**PeCB**	**HCB**	**PCP**	**HCBD**
IP-19	<0,01	0,41	<0,01	0,41	0,24	<0,03	<0,27	<0,01
IP-20	<0,01	0,57	0,10	0,67	0,35	0,12	<0,30	0,15
IP-22	<0,01	0,94	0,09	1,03	0,43	<0,03	<0,41	0,16
IP-27	<0,01	1,08	0,12	1,20	0,32	0,29	<0,38	0,10
IP-29	0,08	0,75	0,11	0,94	0,20	<0,03	<0,36	0,08
IP-41	0,09	0,46	0,09	0,64	0,27	0,05	<0,22	0,10
R18	<0,01	0,27	<0,01	0,27	0,17	n.a.	<0,12	0,05
R35	<0,01	0,39	<0,01	0,39	0,18	n.a.	<0,32	<0,01
R68	<0,01	0,49	<0,01	0,49	0,26	n.a.	<0,33	<0,01
R81	<0,01	0,45	<0,01	0,45	<0,01	n.a.	<0,57	<0,01
R96	<0,01	0,34	<0,01	0,34	<0,01	n.a.	<0,17	<0,01

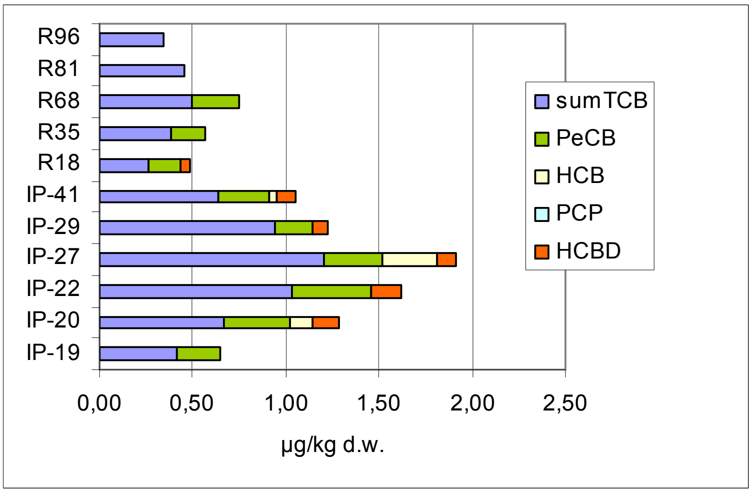


Figure 30. Various organohalogen compounds in bottom sediments from the Barents Sea 2007.

Discussion
In the SFT screening survey 2006 (Bakke et al. 2007) a corresponding range in sum TCBs as in the present survey was found in coastal and fjord sediments (0,02 – 1,35 µg/kg d.w.). The revised Norwegian sediment classification system gives a chronic PNEC of 56 µg/kg d.w. for TCB which suggests that the Barents Sea sediment levels should give no reason for concern.

The PeCB concentrations were at level with the 2006 screening survey (Bakke et al. 2007) and well below the chronic PNEC of 400 µg/kg in the revised sediment classification system.

For HCB AMAP (1998, 2004) gives a typical background range of <10 µg/kg d.w. in arctic sediments, and the levels found are safely within this range. HCB levels in sediments of the polluted Grenland fjords, south Norway, were between 1 and 188 µg/kg d.w. (Næs 1999). The chronic PNEC for HCB in the sediment classification system is 17µg/kg d.w.

The sediment classification system gives a chronic PNEC for HCBD of 49 µg/kg d.w., which is 300 times above the highest level found in the present survey.

These comparisons show that the recorded organohalogen levels in the Barents Sea sediments should not represent an environmental risk, and with respect to HCB at background.

7.14.2 Brünnich's guillemot eggs

Results
The analysis in the present study covered only HCB. Mean lipid normalised HCB concentrations varied slightly from approximately 300 to 400 ng/g l.w. (Figure 31).

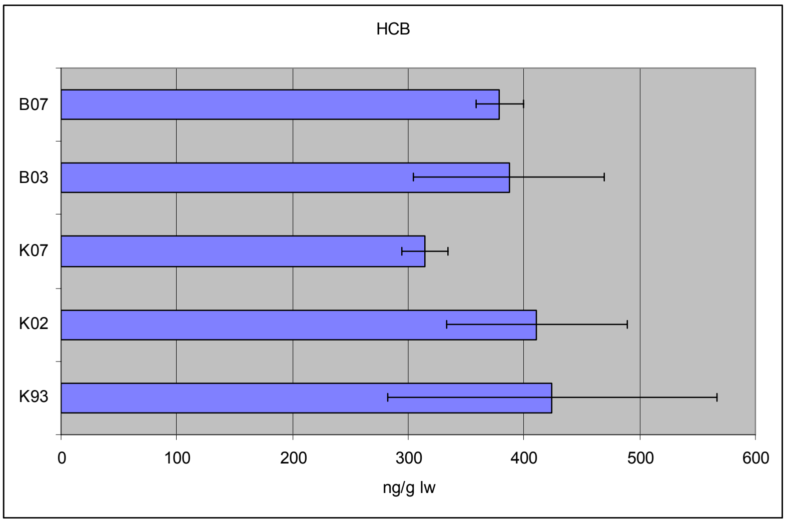


Figure 31. Lipid normalised HCB (average ng/g l.w. ± 95 % CI) in Brünnich's guillemot eggs (Uria lomvia) from Svalbard and Bjørnøya sampled in 1993, 2002, 2003 and 2007.

Discussion
The concentrations were somewhat lower than that reported in Brünnich's guillemot eggs from the Canadian arctic (AMAP 2004), eggs of herring gulls, black-legged kittiwakes and Atlantic puffins from Northern Norway (Helgason et al. 2007), and ivory gull eggs from Svalbard and Russia (Miljeteig et al. 2007). The levels of HCB in the present study were comparable to the concentrations of HCB reported in Brünnich's guillemot eggs (mean levels 400 ng/g l.w.) and black guillemot eggs from Bjørnøya (mean levels 300 ng/g l.w.) (AMAP 2004).

There were no spatial or temporal trends in HCB concentrations comparing the levels of HCB in eggs collected at Bjørnøya and Kongsfjorden in 2002/2003 and 2007. This is in concert with the findings in a similar egg study from Norway, i.e., no spatial trend of HCB concentrations was found in eggs of herring gulls, black-legged kittiwakes and Atlantic puffins from Northern Norway (Helgason et al. 2007). Interestingly, the same study did not find any temporal trend in HCB concentrations comparing eggs collected in 1993 and 2003. Nevertheless, they found a statistical significant difference in HCB levels comparing eggs collected in 1983 and 2003 (highest levels in 1983), indicating that the levels of HCB were levelling off in the biota (Helgason et al. 2007).

7.15 Biocides

5.15.0. Sediments

Results
Analysis of selected biocides was only done on the Tromsøflaket sediment samples (Table 33, Figure 32). The toxaphenes were below the LoD in all samples. Sum HCHs ranged from 17,1 ng/kg d.w. at station R96 Troms II to 44,8 ng/kg d.w. at station R35 Stjernøysundet. Sum DDTs ranged from 64,4 ng/kg d.w. at station R81 Tromsøflaket to 121 ng/kg d.w. at station R35. The chlordanes could not be quantified at station R18. At the other stations sum chlordanes ranged from 9,37 ng/kg d.w. at station R81 to 34,4 ng/kg d.w. at station R35.

Table 33. Concentration of biocides (ng/kg d.w.) in bottom sediments from the Barents Sea 2007. Levels above LoD are shaded.

Compound\Station	**R18**	**R35**	**R68**	**R81**	**R96**
a-HCH	7,23	9,91	6,34	5,28	6,1
b-HCH	2,95	4,58	4,65	3,46	2,6
g-HCH	23,4	30,3	15,7	10,4	8,4
sum HCHs	**33,6**	**44,8**	**26,7**	**19,1**	**17,1**
o,p'-DDE	<2,75	5,23	5,22	<3,10	7,1
p,p'-DDE	27,5	72,4	41,1	32,6	53,4
o,p'-DDD	2,42	15,0	5,94	2,60	11,7
p,p'-DDD	6,43	13,7	13,2	4,13	13,4
o,p'-DDT	6,45	7,43	11,1	7,98	5,0
p,p'-DDT	4,00	6,80	18,8	14,1	<5,2
Sum DDT	**49,5**	**121**	**95,3**	**64,4**	**95,6**
trans-Chlordane	<2,49	5,21	<3,00	<2,61	<2,4
cis-Chlordane	<4,74	10,3	<5,72	<4,96	<4,5
trans-Nonachlor	<2,99	12,5	7,82	7,19	7,0
cis-Nonachlor	<2,04	6,36	3,30	2,18	3,6
sum chlordanes	**0,00**	**34,4**	**11,1**	**9,37**	**10,6**
CHB26	<10,9	<12,7	<12,7	<11,3	<10,3
CHB32	<7,42	<8,66	<8,70	<7,72	<7,02
CHB40 + CHB41	<4,50	<5,25	<5,27	<4,68	<4,25
CHB42a	<3,26	<3,80	<3,82	<3,39	<3,08
CHB44	<8,86	<10,4	<10,4	<9,22	<8,39
CHB50	<6,45	<7,52	<7,55	<6,71	<6,1
CHB62	<39,8	<46,4	<46,6	<41,4	<37,6
Sum toxaphenes	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**

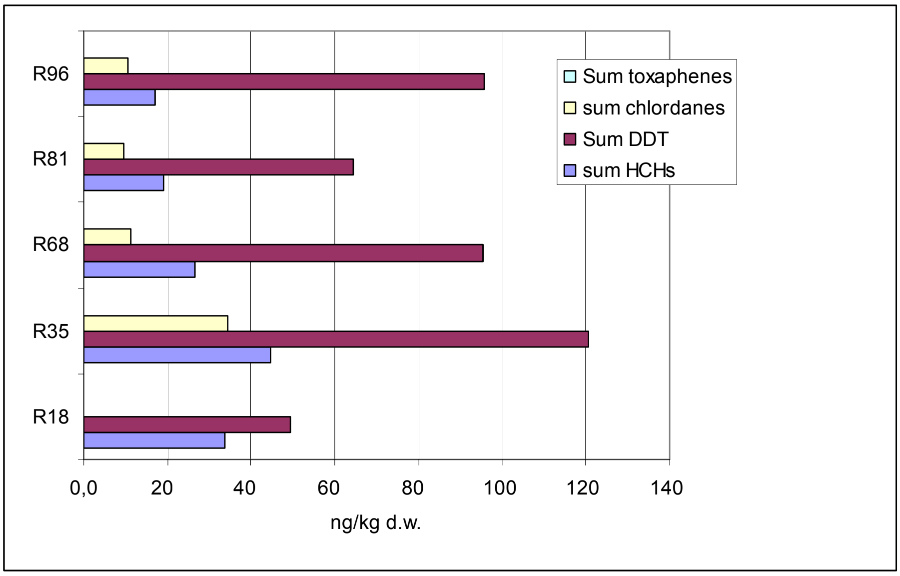


Figure 32. Sums of biocides (toxaphenes, chlordanes, DDTs, and HCHs) in bottom sediments from the Barents Sea 2007.

Discussion
Highest levels of all the quantifiable biocides were found at station R35, Stjernøysundet, Troms (Figure 32). This is the only near-shore station among those sampled. In the revised Norwegian sediment classification system a chronic PNEC for lindane (g-HCH), which was the dominating HCH compound in the samples, is 100 ng/kg d.w., and none of the samples exceeded this. Typically sum HCHs in Arctic sediments are below 10 µg/kg d.w. (AMAP 2004). The range found in the present sediments (0,02 – 0,05 µg/kg d.w.) are at the lower end of the ranges (0,01 – 5 µg/kg d.w.) reported by AMAP (2004) and probably represent background.

The chronic PNEC for sum DDTs is 20 µg/kg d.w, and Arctic sediments away from cities are normally in the range 0,01 -10 µg/kg d.w. according to AMAP (2004). The sum DDT levels in the present samples are at the lower end of this range and also within the the background levels of 500 ng/kg d.w or less in Norwegian coastal sediments. Neither HCH nor DDT in the sediments included should therefore represent any environmental risk. Corresponding limits for chlordanes have not been developed. The LoDs for toxaphenes show that all levels were <0,5 µg/kg d.w. which corresponds with the lowest levels reported by AMAP (2004): <1,0 µg/kg d.w. The LoDs are therefore are judged to be acceptable, and it is reasonable to assume that the toxaphene levels represent background conditions.

7.15.1 Shrimp

Results
The 5 pooled shrimp tail samples were screened for 7 toxaphene compounds (Table 34). Only 3 of the compounds could be quantified. Lowest total concentration of these toxaphenes (sum CHB) of 0,03 µg/kg w.w. was found at stations 315/1 and 315/2 at the Troms and Finnmark coast, and highest concentration of 0,19 µg/kg w.w. at station 420/1 in the open sea SE of Svalbard.

Discussion
AMAP (1998, 2004) reports of toxaphenes in arctic marine invertebrates in the range 50 – 1300 µg/kg w.w. in amphipods from Barrow Strait, Canada, and 0,3 – 1400 µg/kg w.w. in various zooplankton from several sites. In this context the present shrimp levels must be considered to be very low, and probably represents background.

Table 34. Toxaphenes (µg/kg w.w.) in pooled samples of shrimp (Pandalus borealis) tails from the Barents Sea, 2007. Levels above LoD are shaded.

Sample ID	CHB26	CHB32	CHB40+41	CHB42a	CHB44	CHB50	CHB62	Sum CHB
315/1	0,018	<0,20	0,013	<0,01	<0,5	0,003	<0,2	0,03
315/2	0,013	<0,20	0,009	<0,01	<0,5	0,007	<0,2	0,03
315/3	0,024	<0,20	0,015	<0,01	<0,5	0,005	<0,2	0,04
420/1	0,08	<0,20	0,046	<0,01	<0,5	0,06	<0,2	0,19
420/2	0,04	<0,20	0,026	<0,01	<0,5	0,03	<0,2	0,09

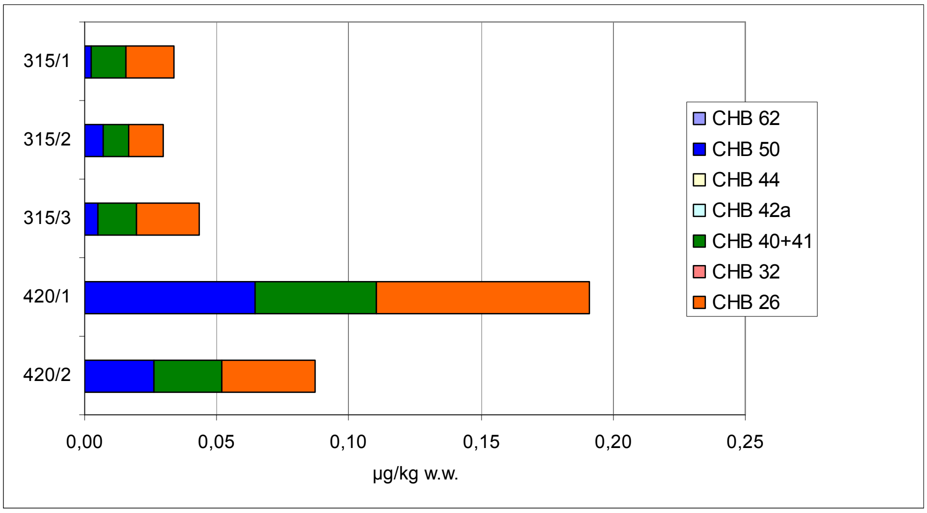


Figure 33. Toxaphene composition in shrimp (Pandalus borealis) tails from the Barents Sea, 2007.

7.15.2 Capelin

Results

The 5 pooled whole capelin samples were screened for 7 toxaphene compounds (Table 35). Five of the compounds could be quantified in all samples. Variation in total concentration of these toxaphenes (sum TX) among the samples was small (Figure 34). Lowest level, 3,37 µg/kg w.w., was found at station 372/4 close to Bjørnøya, and highest concentration of 5,10 µg/kg w.w. at station 420/1 at the coast in Troms.

Table 35. Toxaphenes (µg/kg w.w.) in pooled samples of whole capelin (Mallotus villosus) from the Barents Sea, 2007. Levels above LoD are shaded.

Sample ID	CHB26	CHB32	CHB40+41	CHB42a	CHB44	CHB50	CHB62	Sum CHB
372/1	0,86	<0,20	1,2	0,63	<0,5	1,56	0,83	5,10
372/2	0,78	<0,20	1,2	0,66	<0,5	1,48	0,72	4,88
372/3	0,84	<0,20	1,2	0,63	<0,5	1,48	0,73	4,86
372/4	0,50	<0,20	0,9	0,45	<0,5	0,96	0,57	3,37
372/5	0,60	<0,20	1,0	0,52	<0,5	1,11	0,55	3,76

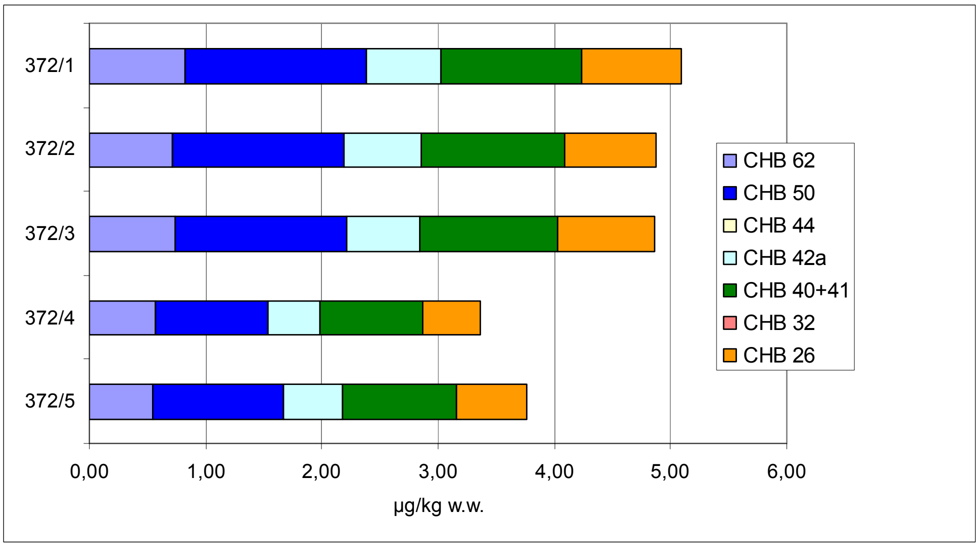


Figure 34. Toxaphene composition in whole capelin (Mallotus villosus) from the Barents Sea, 2007.

Discussion

AMAP (1998) reports of toxaphenes in whole polar cod (*Boreogadus saida*) of 39 ± 11 ng/g lipid (equivalent to 5,3 µg/kg w.w.) from Lancaster Sound, Canada, and similar levels from the open mid-Arctic ocean (10,0 – 11,6µg/kg w.w.). AMAP (2004) also report levels in salmonid fillet from assumed non-contaminated areas around 2 – 11 µg/kg w.w. The present toxaphene concentrations in capelin fillet are at level with these, and, hence, most likely representing background. On the other hand far higher toxaphene level, 14 - 45 µg/kg w.w., has been found in turbot (*Reinhardtius hippoglossoides*) fillet and liver from Baffin Island, Canada (AMAP 1998).

7.15.3 Cod

Results

Individual cod livers from 2 coastal stations, 98B1 (15 individuals) at Lofoten and 10B (13 individuals) at Varangerfjorden were screened for the biocides toxaphene and chlordane. The sum of toxaphenes varied slightly from 53,9 to 63,4 µg/kg w.w (Table 36, Figure 35). The corresponding sum of chlordane levels were 27,9 and 37,1 µg/kg w.w. The highest levels were found in Varangerfjorden for both biocides.

Table 36. Mean toxaphene and chlordane levels (µg/kg w.w.) inindividual cod (Gadus morhua) livers from the Barents Sea, 2005 and 2006. Levels above LoD are shaded.

Station ID	**CHB42A**	**CHB32**	**CHB62**	**CHB40-41**	**CHB26**	**CHB50**	**CHB44**	**Sum CHBs**	**TCDAN**	**CNONXC**	**CCDAN**	**TNONC**	**Sum chordanes**
98B1-06	0,3	0,4	3,5	5,2	9,5	15,5	19,5	**53,9**	0,8	5,8	7,2	14,1	**27,9**
10B-05	0,4	0,3	3,7	5,2	10,4	19,2	24,2	**63,4**	1,2	8,2	9,0	18,7	**37,1**

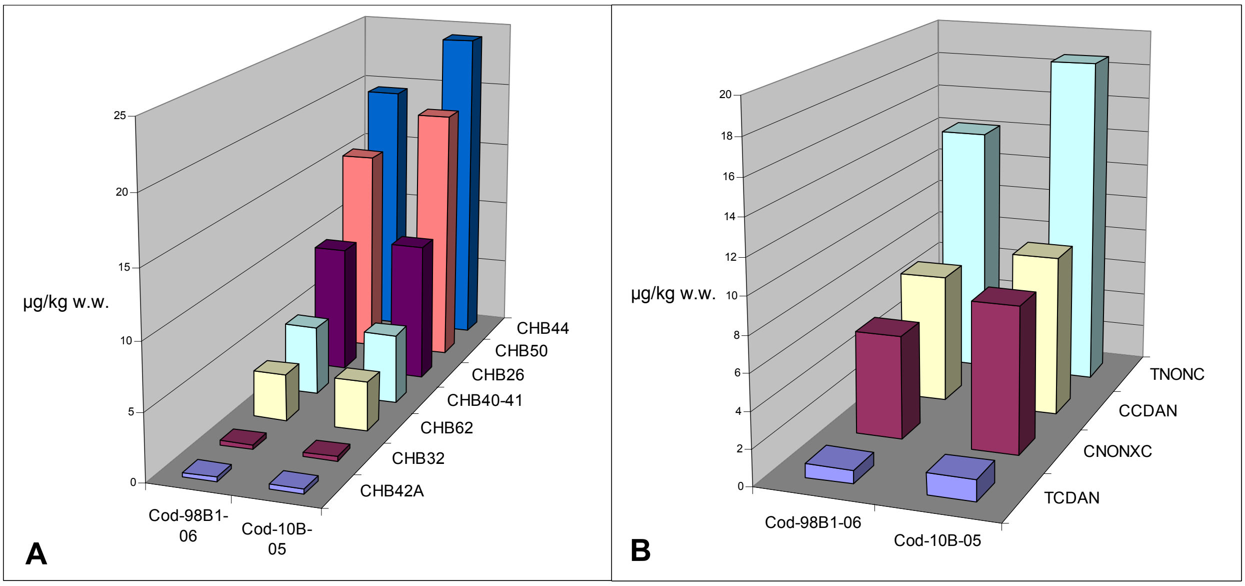


Figure 35. Toxaphene (A) and Chlordane (B) composition in cod liver (Gadus morhua) from the Barents Sea, 2005 and 2006. Each bar shows the mean of 13-15 individuals.

Discussion

AMAP (1998) reports a similar level of toxaphenes of 28 – 69 µg/kg w.w. in cod liver from Greenland and Iceland, and 81 µg/kg w.w. in liver of turbot (*Reinhardtius hippoglossoides*) from Baffin Island, Canada. The found levels seem typical for north Atlantic marine fish, but one cannot conclude if they represent background or not. We have found no comparable data on chlordanes.

7.15.4 Brünnich's guillemot eggs

Results

Mean lipid normalised sum HCHs concentrations in the eggs of Brünnich's guillemots ranged from 20 to 50 ng/g l.w. (Table 37, Figure 37). The HCH profile in all species was dominated by the b-HCH (Figure 37). Mean concentrations of sum chlordanes (Figure 36), Mirex, DDTs and sum toxaphenes (Figure 38) in the eggs of Brünnich's guillemots were in the range 80 - 280 ng/g l.w., 10 - 40 ng/g lw, 20 - 50 ng/g lw, 800 - 2000 ng/g l.w., and 90 - 400 ng/g lw, respectively. TBT was not found above the detection limit in any samples. Of the chlordanes analysed only oxychlordane and trans-chlordane were found and reported (Figure 36). Of these two oxychlordane was the prevailing congener.

Table 37. Fat % and lipid normalised levels of biocides (sum HCHs (a-, b-, g-HCH), sum Chlordanes (oxychlordane, cis-chlordane, trans-chlordane, trans-nonachlor, cis-nonachlor), Mirex, pp-DDE, pp-DDT, sum Toxaphenes (CHB-26, 40, 41, 44, 50, 62) and tributyltin (TBT)) (average ng/g l.w. ± 95 % CI) in Brünnich's guillemot (<u>Uria lomvia</u>) eggs from Svalbard sampled in 1993, 2002, 2003 and 2007.

	Fat %			**Sum HCHs**			**SumChlordanes**			**Mirex**		
	Average	±	CI	Average	±	CI	Average	±	CI	Average	±	CI
K93	12,4	±	12,6	54,2	±	15,46	282,6	±	106	36,7	±	20,5
K02	13,5	±	11,0	42,1	±	11,67	182,1	±	58,2	27,3	±	8,8
K07	13,5	±	13,7	22,1	±	4,258	84,6	±	20,8	12,2	±	4,2
B03	15,6	±	11,8	26,4	±	7,942	129,8	±	50	16,5	±	3,7
B07	13,7	±	12,7	23,3	±	4,217	88,6	±	11,2	10,2	±	1,1

	pp-DDE			**pp-DDT**			**SumTox**			**TBT-B**
	Average	±	CI	Average	±	CI	Average	±	CI	
K93	1788,0	±	789,6	135,0	±	65,36	421,8	±	206	na
K02	1237,1	±	370	80,2	±	30,68	235,5	±	80,1	<5
K07	831,8	±	106,3	24,9	±	8,825	87,8	±	26	<5
B03	991,2	±	91,45	47,3	±	18,87	165,8	±	63,8	<5
B07	798,7	±	53,63	36,1	±	6,265	114,5	±	21,7	<5

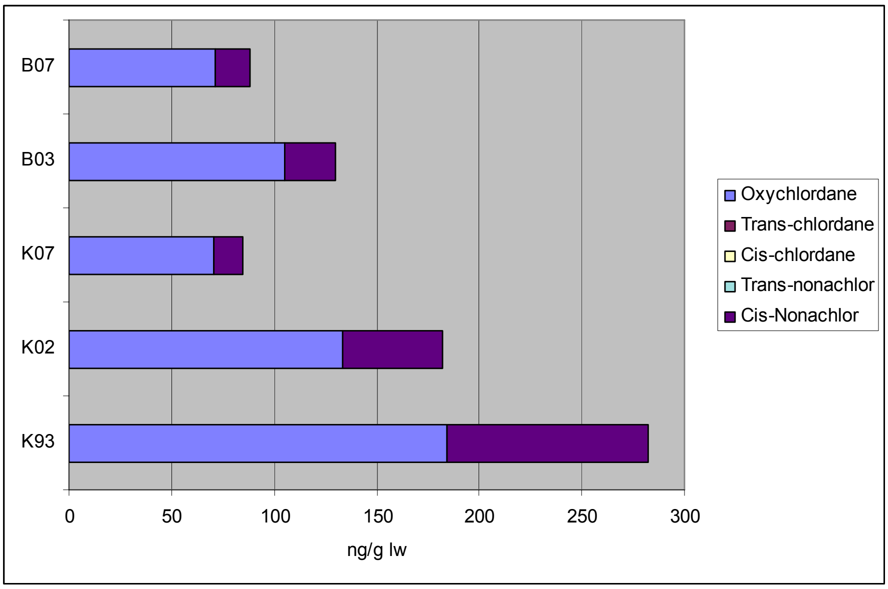


Figure 36. Lipid normalised chlordanes (oxychlordane, trans-chlordane, trans-nonachlor, cis-nonachlor) (average ng/g l.w.) in Brünnich's guillemot (<u>Uria lomvia</u>) eggs from Svalbard sampled in 1993, 2002, 2003 and 2007.

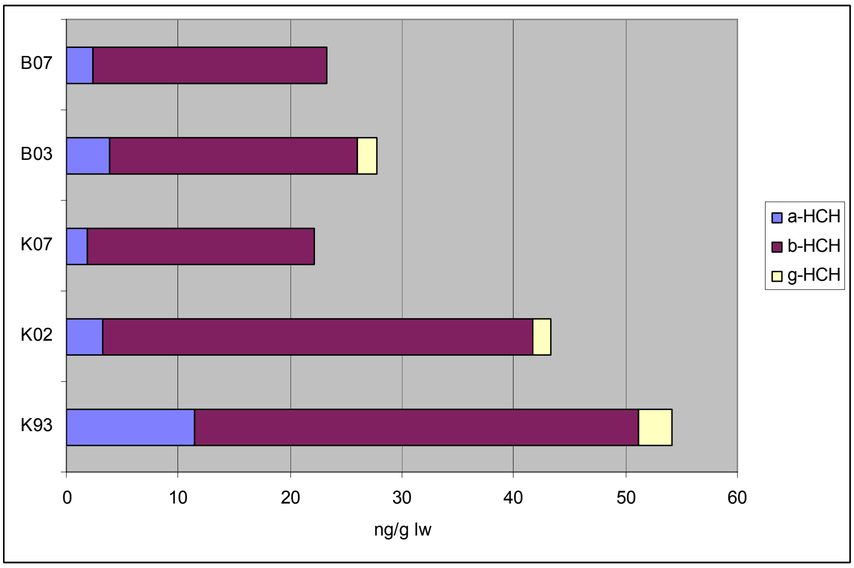


Figure 37. Lipid normalised HCH (a-, b-, g-HCH) (ng/g l.w.) in Brünnich's guillemot (Uria lomvia) eggs from Svalbard sampled in 1993, 2002, 2003 and 2007.

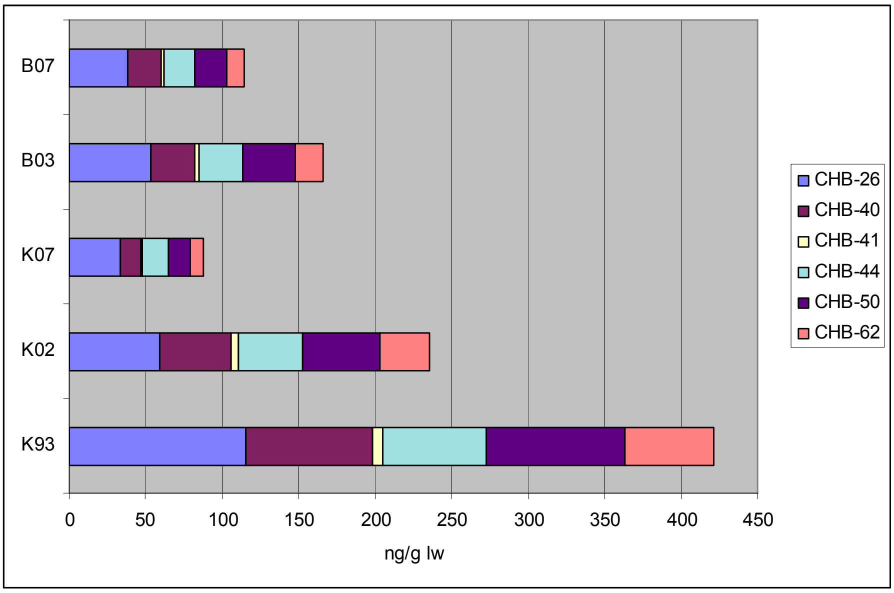


Figure 38. Lipid normalised toxaphene (ng/g l.w.) in Brünnich's guillemot (Uria lomvia) eggs from Svalbard sampled in 1993, 2002, 2003 and 2007.

Discussion

The HCH levels in the present study were similar to the levels reported in eggs of herring gulls, black-legged kittiwakes and Atlantic puffins from Northern Norway (Helgason et al. 2007), and northern fulmar eggs (Gabrielsen et al. 1997) from Jan Mayen, but in the lower range of values reported for kittiwake eggs collected in the Canadian Arctic (Braune et al. 2001). Higher concentrations of HCHs in the Canadian Arctic compared to the European Arctic biota have been suggested to be caused by the closer proximity to Asia were HCHs have been in use until recently (AMAP 2004). The levels of sum chlordanes, DDTs and

Mirex were generally lower than that found in other seabird egg studies, e.g., black-legged kittiwakes, herring gulls, Atlantic puffins, glaucous gulls, ivory gulls, northern fulmars and black guillemots (Braune et al. 2001; Evenset et al. 2002; Gabrielsen et al. 1997; Helgason et al. 2007; Miljeteig et al. 2007; Verreault et al. 2004). Of the toxaphenes CHB-26 was the prevailing compound, followed by CHB-50 = CHB-40 = CHB-44 > CHB-62 > CHB-44. There have been few reports of toxaphenes in seabird eggs. However, the toxaphene levels of the present study were generally lower than that reported in ivory gull eggs from Svalbard and Russia (Miljeteig et al. 2007) and glaucous gull eggs from Bjørnøya (Verreault et al. 2004).

The levels of sum HCHs, sum chlordanes, Mirex, p,p-DDE, p,p-DDT and sum toxaphenes were all higher in 2002/2003 compared to the levels reported in the eggs collected in 2007 ($p < 0.05$). The decrease in the biocide concentrations from 2002/2003 to 2007 presented in the present study follow the general trends reported in most biota samples, and recently published on seabird eggs from Northern Norway (Helgason et al. 2007). See comment on shift in diet (chapter 7.6.3).

7.15.5 Comparison of species

A illustrated by the results above toxaphene levels in cod liver were about one order of magnitude larger than in whole capelin, which again were about one order of magnitude higher than in shrimp tails. These differences are probably to some extent linked to differences in lipid content in these types of samples, and do not necessarily suggest differences in exposure to toxaphenes. Although no data are available from the present samples, one can expect that the lipid content of cod liver is far higher than in whole capelin which again is far higher than in shrimp tails. Typical lipid levels in corresponding tissue types from the Grenland fjords in Norway are 25-50 % in cod liver, 1-10 % in fat fish fillet and 0,5 % in shrimp tails. A quick normalisation against these lipid levels suggests that shrimp tails and capelin have corresponding lipid-normalised toxaphenes levels, which are equal to the lipid normalised levels of toxaphenes in guillemot eggs, and that the normalised levels in cod liver are about 2-3 times higher.

7.16 Polycyclic aromatic hydrocarbons (PAH)

7.16.1 Sediments

Results

The 6 sediment samples from the Russian Barents and Pechora Sea s were analysed for a total of 40 bi- and polycyclic PAH compounds (Table 38). Only 4 of these could be quantified in all samples. The total sum PAHs varied from 11.3 µg/kg d.w. at station IP-19 at the Kola transect to 237,1 µg/kg d.w. at station IP-22 the Shtokman region. The sum PAH_{16} varied from 0,68 at station IP-19 to 96,07 µg/kg at station IP-22.

Table 38. PAH compounds and sumPAH (µg/kg d.w.) in Barents Sea sediments 2007.

Station ID **Compound**	**IP-19**	**IP-20**	**IP-22**	**IP-27**	**IP-29**	**IP-41**
Naphthalene	<10	<10	<10	<10	10,1	<10
1-Methylnaphtalene	<5	11,3	6,49	7,47	12,1	5,44
2-Methylnaphtalene	<5	5,69	5,05	7,77	12,6	<5
C2-Naphtalenes	<5	7,86	8,79	18,5	21,4	<5
C3-Naphtalenes	<10	<10	14,1	12,0	<10	<10
C4-Naphtalenes	<10	<10	<10	<10	<10	<10
Acenaphthylene	<0.3	0,61	0,58	0,69	<0.3	<0.3
Acenaphthene	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3
Fluorene	<0.3	1,50	0,84	3,97	2,43	1,07
C1-Fluorenes	0,66	2,10	3,36	8,06	3,90	1,11
C2-Fluorenes	<0.5	<0.5	<0.5	3,08	<0.5	2,82
C3-Fluorenes	<0.7	<0.7	<0.7	<0.7	<0.7	<0.7
Phenanthrene	<1.0	1,57	2,31	6,77	7,92	1,77
Anthracene	<0.5	<0.5	<0.5	0,58	0,69	<0.5
C1-Phenanthrene/Antracene	1,52	3,11	4,81	16,5	16,5	5,81
C2-Phenanthrene/Antracene	<0.7	2,72	6,70	6,26	3,96	2,12
C3-Phenanthrene/Antracene	<0.7	2,46	10,1	3,80	<0.7	<0.7
C4-Phenanthrene/Antracene	1,61	3,12	9,74	2,30	n.d.	n.d.
Dibenzothiophene	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3
C1-Dibenzothiophenes	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
C2-Dibenzothiophenes	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
C3-Dibenzothiophenes	<0.7	<0.7	<0.7	<0.7	<0.7	<0.7
Fluoranthene	0,68	4,32	10,1	14,8	6,81	9,00
Pyrene	<0.5	2,74	4,85	4,10	3,39	3,20
C1-Flanths/Pyrs	<0.6	6,06	9,11	6,11	<0.6	2,35
C2-Flanths/Pyrs	<0.6	5,15	7,08	1,90	<0.6	<0.6
C3-Flanths/Pyrs	<0.8	0,80	1,48	<0.8	<0.8	<0.8
Benzo(a)anthracene	<0,5	1,60	4,43	3,31	4,02	5,15
Chrysene	<0,5	10,1	15,5	17,7	6,68	7,72
C1-Chrysenes	<0,7	<0,7	<0,7	10,3	<0,7	<0,7
C2-Chrysenes	<0,7	<0,7	<0,7	<0,7	<0,7	<0,7
C3-Chrysenes	<1,0	<1,0	<1,0	<1,0	<1,0	<1,0
Benzo(b+j)fluoranthene	<1,0	13,1	23,8	17,6	5,00	7,44
Benzo(k)fluoranthene	<1,0	6,43	10,4	7,60	2,57	3,80
Benzo(e)pyrene	<1,0	8,31	16,1	13,0	6,90	6,93
Benzo(a)pyrene	<1,0	2,16	5,53	4,40	<1,0	2,47
Perylene	6,86	28,6	38,1	26,0	39,0	44,32
Indeno(1,2,3-c,d)pyrene	<1,5	6,44	10,8	6,46	<1,5	5,63
Dibenz(a,h)antracene	<1,5	<1,5	<1,5	<1,5	<1,5	<1,5
Benzo(g,h,i)perylene	<1,5	4,58	7,02	6,08	<1,5	5,77
Sum PAH	11,3	142,5	237,1	237,0	165,9	123,9
sum PAH16	0,68	55,18	96,07	93,46	48,95	53,02

Discussion

The sum PAH_{16} at station IP-19 was 2 orders of magnitude lower than at any of the other stations, whereas station IP-20 to the north on the same Kola transect had the same level as the rest of the stations. Still the sum PAH_{16} concentrations are within the background levels for coastal regions (< 300 µg/kg d.w.) according to the revised Norwegian sediment classification, and far below the chronic PNEC of 2000 µg/kg d.w. The PAHs in these sediments do therefore not represent an environmental risk.

7.16.2 Blue mussel

Results

Pooled blue mussel samples from 4 stations in 2006 were screened for 37 PAH compounds, out of which 22 compounds were quantifiable (Table 39). The highest level of sumPAH$_{16}$, 67,1 µg/kg w.w., was found at station 46A close to the city of Honningsvåg. The other samples, even station 98A2 close to the city of Svolvær, had far lower levels: 1,9 – 2,6 µg/kg w.w. The levels of sum NPD [7] varied from 78 µg/kg w.w. at station 11X in Varangerfjorden to 791 µg/kg w.w. at station 46A close to Honningsvåg.

Table 39. PAH (average of 2 replicate pooled samples, µg/kg w.w.) in blue mussel (Mytilus edulis) from the Barents Sea 2006. Levels above LoD are shaded.

Station ID	BAP	ICDP	DBA3A	BAA	BBJF	ACNLE	BKF	CHR	ANT	ACNE	PYR	FLU	PA
46A-06	<0,5	<0,5	<0,5	1,35	0,955	<0,5	<0,5	2,3	2,8	3,15	13,5	16	27
43A-06	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	0,945	<0,5	<0,5	1,7
98A2-06	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	0,51	<0,5	<0,5	1,6
11X-06	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	1,9

	PER	BGHIP	BEP	FLE	DBT	DBTC1	DBTC2	DBTC3	PAC1	PAC2	PAC3	NAP	NAPC1
46A-06	<0,5	<0,5	1,1	7,35	2,25	10,5	36,5	44,5	76	170	72,5	31	62
43A-06	<0,5	<0,5	<0,5	2,9	<0,5	<2	<2	<2	2,75	2,4	4,1	43,5	115
98A2-06	<0,5	<0,5	0,61	1,195	<0,5	<2	2,8	3,45	3,45	7,25	6,65	24	40
11X-06	<0,5	<0,5	<0,5	0,79	<0,5	<2	<2	<2	4,4	4,1	4,55	13	16

	NAPC2	NAPC3	DI_S	P_S	PK_S	PAHSS	PK7PP	PK7_P	BAPPP	BAP_P	BPK_P	SUM-PAH16	SUM-KPAH
46A-06	65,5	190	348,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	67,1	2,305
43A-06	66	52,5	277	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	2,6	0
98A2-06	28	32	124	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	2,1	0
11X-06	11,5	22,5	63	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	<0,5	1,9	0

Discussion

There is wealth of information on the levels of PAHs in blue mussels from many monitoring programmes, in Norway in particular the CEMP programme from which the present samples have been extracted. According to the Norwegian classification system for contaminants in marine organisms (SFT TA-1467/1997), the blue mussel sample from station 46A at Honningsvåg was moderately polluted (Class II), and the others were in Class I (background; < 50 µg/kg w.w.). The correspondingly elevated level of NPDs at station 46A suggests a petroleum derived source.

---

[7] Sum of naphtalene, phenanthrene/anthracene, dibenzothiophene and their C1 – C3 substituted homologues; indicative of petrogenic PAHs.

7.16.3 Brünnich's guillemot eggs

Results

Sum of all quantifiable PAHs ranged from 0.2 to 7.5 ng/g w.w. (Table 40). Naphtalene was the prevailing compound. The levels of naphtalene were generally higher in 2002/2003 compared to the levels found in 2007. No corresponding analyses for Arctic seabird eggs have been found, thus these levels cannot be evaluated.

Table 40. Arithmetic mean concentrations (µg/kg ± CI) of PAHs in Brünnich's guillemot (Uria lomvia) eggs from Bjørnøya (2003 and 2007) and Kongsfjorden (2002 and 2007). Shaded areas indicate results above the detection limit.

	Naphtalene			Phenanthrene			Antracene			Acenaphtylene		
	Average	±	CI	Average	±	CI	Average	±	CI	Average	±	CI
B07	0,03	±	0,08	<0,171			<0,048			<0,111		
B03	4,5	±	1,7	0,5	±	0,3	0,04	±	0,05	0,0	±	0,1
K07	0,03	±	0,1	<0,171			<0,048			<0,111		
K02	2,8	±	0,6	<0,171			<0,048			<0,111		

	Acenaphtene			Fluorene			Fluoroanthene			Pyrene			Benzo[a]antracene		
	Average	±	CI	Average	±	CI	Average	±	CI	Average	±	CI	Average	±	CI
B07	0,1	±	0,1	0,02	±	0,05	0,1	±	0,1	<0,115			<0,044		
B03	0,2	±	0,3	<0,110			0,4	±	0,4	0,2	±	0,2	0,3	±	0,3
K07	<0,113			<0,110			0,1	±	0,1	0,1	±	0,2	<0,044		
K02	0,1	±	0,2	0,04	±	0,1	0,1	±	0,1	<0,115			0,3	±	0,6

	Chrysene			Benzo[b]fl-uorantene			Benzo[k]fl-uorantene			Benzo[a]pyrene		
	Average	±	CI	Average	±	CI	Average	±	CI	Average	±	CI
B07	<0,056			<0,051			<0,051			<0,038		
B03	0,4	±	0,3	0,5	±	0,5	0,4	±	0,3	0,1	±	0,1
K07	<0,056			<0,051			<0,051			<0,038		
K02	0,3	±	0,6	0,1	±	0,2	0,1	±	0,3	<0,038		

	Indeno[1,2,3-cd]-pyrene			Benzo[ghi]-perylene			Dibenzo[a,h]-antracene			Sum PAHs		
	Average	±	CI	Average	±	CI	Average	±	CI	Average	±	CI
B07	<0,036			<0,034			<0,067			0,2	±	0,2
B03	0,01	±	0,02	0,1	±	0,2	<0,067			7,5	±	3,2
K07	<0,036			<0,034			<0,067			0,2	±	0,2
K02	<0,036			<0,034			<0,067			3,8	±	2,1

7.17 Trace metals

7.17.1 Sediments

Results

The 6 Akvaplan-niva sediment samples were screened for 7 trace metals (Table 41, Figure 39). The Cu levels did not vary much: 10,2 – 14,9 mg/kg d.w. Cd levels varied from 0,033 to 0,111 mg/kg d.w., Pb from 9,35 to 18,30 mg/kg d.w., Hg from 0,016 to 0,028 mg/kg d.w., Cr from 59 to 102 mg/kg d.w., As from 11,1 to 52,2 mg/kg d.w., and Ba from 151 to 239 mg/kg d.w.

Table 41. Trace metals (mg/kg d.w.) in sediments from the Barents Sea 2007. Levels above LoD are shaded

Station ID	Cu	Cd	Pb	Hg	Cr	Ba	As
IP-19	14,9	0,0330	9,35	0,016	71,90	209	11,6
IP-20	13,9	0,0475	18,30	0,021	61,65	207	19,4
IP-22	13,9	0,0640	16,40	0,017	61,90	189	52,2
IP-27	15,9	0,0440	14,40	0,021	77,70	144	36,4
IP-29	17,6	0,1110	15,90	0,028	102,00	151	17,4
IP-41	10,2	0,0190	12,50	0,027	59,00	239	11,1

Figure 39. Trace metals in sediments from the Barents Sea 2007.

Discussion

The Cu levels were all at background for Norwegian coastal areas and far below the chronic PNEC of 51 mg/kg d.w. in the revised sediment classification system. The levels of Cd, Pb, and Hg were also at background and well below their PNEC values in the revised sediment classification system. The levels of Cr were just at the border of background (< 70 mg/kg d.w), but still well below the chronic PNEC of 560 mg/kg d.w. As exceeded the coastal background range of <20 mg/kg d.w. in 2 of the samples, and the chronic PNEC of 52 mg/kg d.w. for As was slightly exceeded at one station, IP-22 in the Shtokman region.

Ba is not included in the coastal classification system, but has been analysed extensively in offshore petroleum related monitoring. In a pre-drilling baseline sediment survey at the Snøhetta field in the Barents Sea in 2003 Ba levels in the range 68 – 133 mg/kg were found, and one year later a similar range from 111 to 144 mg/kg d.w. In offshore Area C, also in the SW Barents Sea, the Ba range in 2003 was slightly lower: 89 – 96 mg/kg d.w. The Ba levels in the present survey are on the high side of these ranges. The highest levels were found in the eastern Barents Sea, and one might speculate if this is connected to drilling activites of the Russian offshore petroleum exploration. Still the sediment sample from the Shtokman region, station IP-22, did not stand out in any way regarding Ba level.

Of the trace metals analysed in this survey only As from one open ocean station is formally considered to represent a possible environmental risk, according to the Norwegian sediment classification system. All other concentrations were either at expected background or safely below the chronic PNECs in the classification system. With respect to As there seems to be a general tendency in the north-eastern Barents Sea that natural As levels are elevated (e.g. Loring et al 1995). Since the PNEC also was only slightly exceeded and in only one sample we conclude that the environmental risk from the present AS levels is insignificant.

Only Cu and Cr correlated positively across the samples. The others did not correlate significantly, which also supports the impression of lack of any geographical trends in the trace metal distribution.

7.17.2 Brünnich’s guillemot eggs

Results

The analysis covered four sets (station/year) of 5 replicate egg samples each and 10 metal elements (Figure 40). The sum of average concentrations of all metals varied only little among the samples.

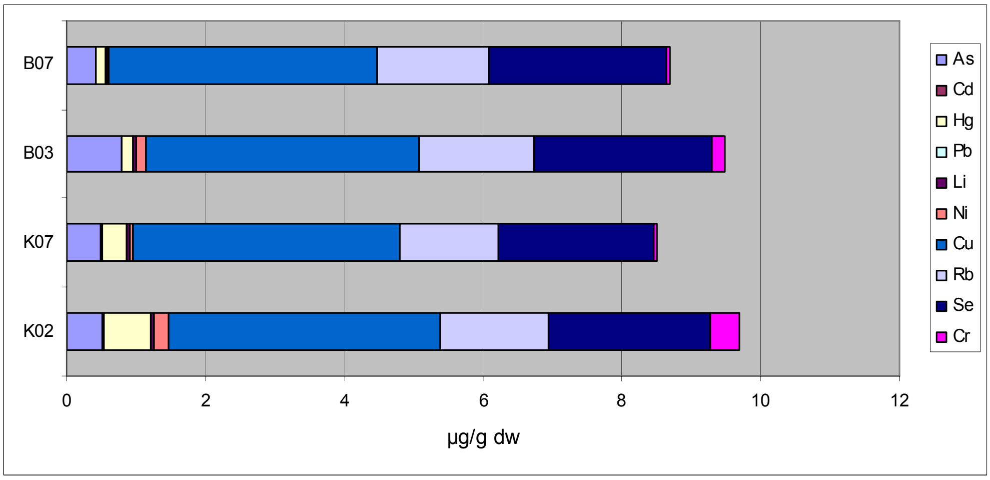


Figure 40. Arithmetic mean concentrations (µg/g d.w.) of trace metal elements analysed in Brünnich’s guillemot (Uria lomvia) eggs from Kongsfjorden (2002 and 2007) and Bjørnøya (2003 and 2007).

Discussion
The mean concentration of Hg in eggs from Kongsfjorden in 2007 was approximately half of the levels found in 2002, but twice as high as in eggs from Bear Island (2003 and 2007). All four mean concentrations of Hg in the present egg samples were lower than in northern fulmar, Brünnich's guillemot and black-legged kittiwake eggs from Canada (Braune and Simon 2004).

The concentrations of Cu were similar to concentrations found in eggs from northern fulmars, Brünnich's guillemots and black-legged kittiwakes from Canada, whereas the concentrations of Se were similar to the concentrations found in Canadian Brünnich's guillemots, but lower than in northern fulmars and black-legged kittiwakes (Braune and Simon 2004). The concentrations of Cd in the present study were comparable to concentrations found in black guillemot eggs from Greenland (AMAP 2005). Generally, the Pb levels were similar to or lower than that found in other aquatic birds (AMAP 2005).

7.18 Organotin compounds

7.18.1 Sediments

Results
Organotin compounds were analysed in the sediment samples from the Russian Barents and Pechora Sea (Table 42). All levels were below the LoDs of 3 µg/kg d.w. For TBT the LoD was slightly above the Norwegian coastal background (1 µg/kg d.w or less) but less than the PNEC of 5 µg/kg d.w. in the sediment classification system.

Table 42. Levels (µg/kg d.w.) of organotin compounds in sediments from the Barents Sea 2007. Levels above LoD are shaded.

Compound	unit	IP-19	IP-20	IP-22	IP-27	IP-29	IP-41
Monobutyltin	µg/kg d.w.	<3	<3	<3	<3	<3	<3
Dibutyltin	µg/kg d.w.	<3	<3	<3	<3	<3	<3
Tributyltin	µg/kg d.w.	<3	<3	<3	<3	<3	<3
Monophenyltin	µg/kg d.w.	<3	<3	<3	<3	<3	<3
Diphenyltin	µg/kg d.w.	<3	<3	<3	<3	<3	<3
Triphenyltin	µg/kg d.w.	<3	<3	<3	<3	<3	<3

Discussion
For tributyltin (TBT) the present LoD is within Class II (good) in the revised Norwegian sediment classification system (SFT TA-2230/2007), which suggests that the risk from the TBT levels in these sediments should be acceptable.

7.18.2 Brünnich's guillemot eggs

All organotin compounds were below the detection limit in all samples analysed.

7.19 Stable isotopes

7.19.1 Brünnich's guillemot eggs

Results

The levels of stable isotopes of carbon and nitrogen are shown in Table 43. Mean levels of $\delta^{13}C$ were almost identical in all four egg groups. The mean levels of $\delta^{15}N$ did also vary little, from 11,6 to 12,6.

Table 43. Stable isotopes ($\delta^{13}C$, $\delta^{15}N$) in Brünnich's guillemot eggs (Uria lomvia) from Kongsfjorden (2002 and 2007) and Bjørnøya (2003 and 2007).

	$\delta^{13}C$			**$\delta^{15}N$**		
Station ID	Average	±	CI	Average	±	CI
K02	-19,9	±	0,2	12,6	±	0,1
K07	-19,9	±	0,2	12,0	±	0,3
B03	-19,8	±	0,2	12,1	±	0,2
B07	-19,9	±	0,1	11,6	±	0,1

Discussion

There was no statistical significant relationship between $\delta^{13}C$ and any of the contaminants. There were, however, statistical significant relationships between several of the contaminant groups (HBCDD, sum toxaphenes, sum HCH, sum chlordanes, Mirex, p,p-DDE, p,p-DDT, tetra- to nonaPCBs, sumPCBs and sum PCB_{MO}) and $\delta^{15}N$ ($p < 0.05$) (example in Figure 41). These relationships, in addition to the statistically significant difference in $\delta^{15}N$ in eggs sampled in 2002/2003 and 2007 ($p < 0.05$), might confound the interpretations of temporal trends in the present study.

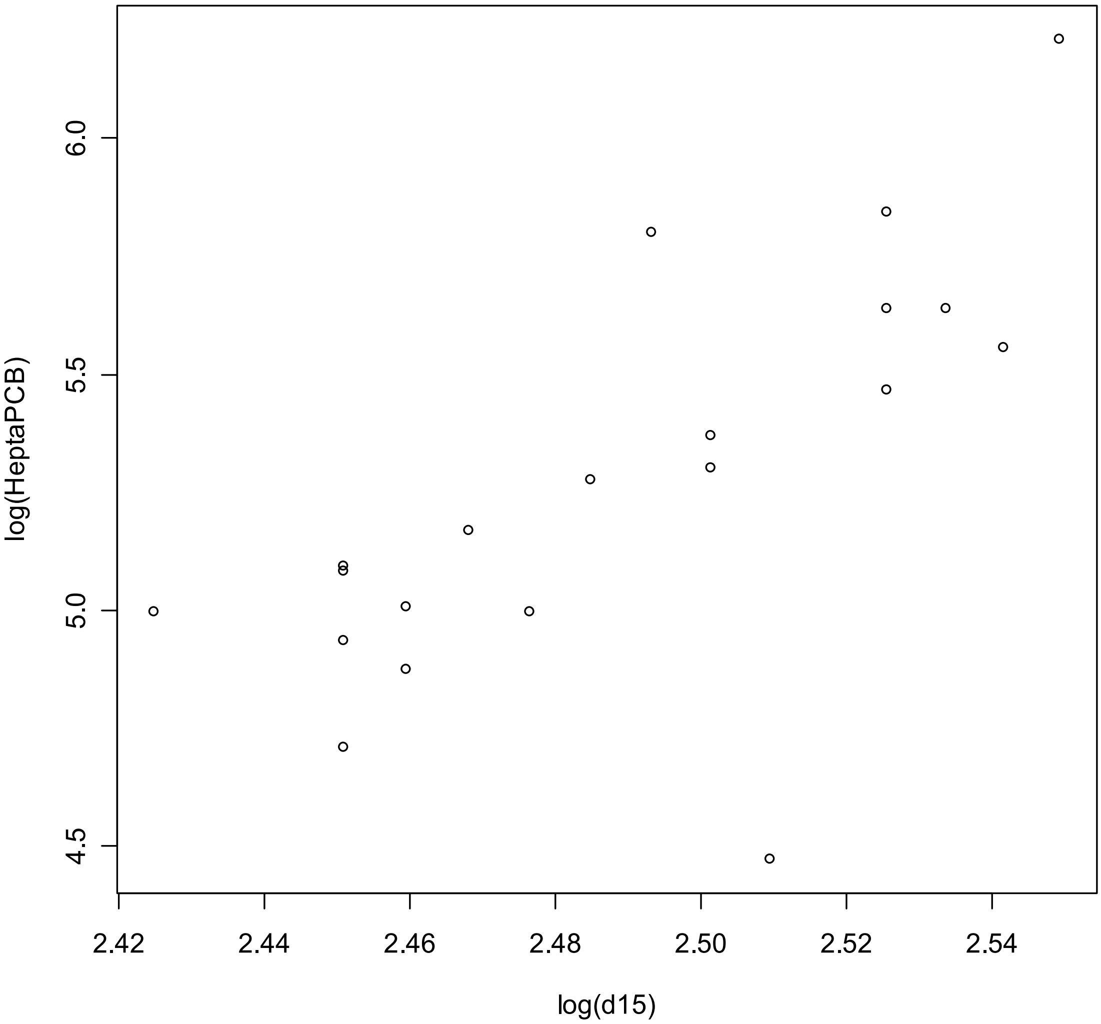


Figure 41. Relationship between HeptaPCBs and $\delta^{15}N$ in Brünnich's guillemot eggs (Uria lomvia) from Kongsfjorden (2002 and 2007) and Bjørnøya (2003 and 2007).

8. Overall status for the various media

In the sediments the SCCP levels were above what should be expected as background. APE levels were also elevated relative to North Sea levels and should be monitored further. For tensides, siloxanes, and chlordanes the levels relative to background cannot be assessed. The DEHP results are deemed inconclusive and new analyses should be made. For all the other contaminants the sediment levels were at assumed background.

PAH in blue mussel were at background except outside Honningsvåg. Also present levels of PBDE were at assumed background.

In shrimp and whole capelin the lowest levels of PFOS represented background. The other contaminants analysed were also at assumed background.

Toxaphene in cod liver was at level with other Arctic fish, but status with respect to background cannot be assessed. The other contaminants analysed in cod liver were at assumed background.

In Brünnich's guillemot eggs all contaminants were within the range found earlier in other Arctic seabird eggs, some at the low side of this range. Basis for assessing levels relative to background is lacking. For most contaminants a decrease with time was observed. TBT in eggs was not above the detection limit.

9. References

AMAP, 1998. AMAP Assessment Report: Arctic Pollution Issues. Arctic Monitoring and Assessment Programme (AMAP), Oslo, Norway. xii+859 pp.

AMAP 2005. AMAP Assessment 2002: Heavy Metals in the Arctic. Arctic Monitoring and Assessment Programme (AMAP) Oslo, Norway, pp 1-265.

AMAP 2004. AMAP Assessment 2002: Persistent Organic Pollutants in the Arctic. Arctic Monitoring and Assessment Programme (AMAP), Oslo, Norway, pp 1-309.

Andersen G, Føreid S, Skaare JU, Jenssen BM, Lydersen C, Kovacs KM, 2006. Levels of toxaphene congeners in white whales (*Delphinapterus leucas*) from Svalbard, Norway. Science of the Total Environment 357:128-137.

Bakke, T., Fjeld, E., Skaare, B., Berge. J.A., Green, N., Ruus, A., Schlabach, M., and Botnen, H., 2007. kartlegging av metaller og utvalgte nye organiske miljøgifter 2006. Krom, arsen, perfluoralkylstoffer, dikloretan, klorbenzener, pentaklorfenol, HCBD og DEHP. SFT TA2284/2007. NIVA report 5464-2007. 105s.

Bester, K. Theobald N. and Schröder, H.Fr. 2001. Nonylphenols, nonylphenol-ethoxylates, linear alkylbenzenesulfonates (LAS) and bis(4-chlorophenyl)-sulfone in the German Bight of the North Sea, Chemosphere 45 (2001), pp. 817–826.

Braune BM, and Simon M, 2004. Trace elements and halogenated organic compounds in Canadian Arctic seabirds. Marine Pollution Bulletin 48:986-992.

Braune BM, Donaldson GM, Hobson KA. 2001. Contaminant residues in seabird eggs from the Canadian Arctic. Part I. Temporal trends 1975-1998. Environmental Pollution 114: 39-54.

Evenset, A., Christensen, G., Kallenborn, R., Skotvold, T. 2002. The “Bjørnøya case”. Akvaplan-Niva report. Tromsø, Norway. 33 pp.

Fjeld, E, Schlabach, M, Berge JA, Green, N, Eggen, T, Snilsberg, P, Vogelsang, C, Rognerud, S, Kjellberg, G, Enge, EK, Dye, CA, Gundersen, H., 2005. Kartlegging av utvalgte nye organiske miljøgifter 2004. Bromerte flammehemmere, perfluoralkylstoffer, irgarol, diuron, BHT og dicofol, NIVA rapport nr 5011-2005.

Gabrielsen, G.W., Alsos, I.G., Brekke, B. 1997. Undersøkelser av PCB i jord, fisk og sjøfugl i områdene rundt avfallsfyllingen på Jan Mayen (FBT lokalitet 1805001). Rapportserie Norsk Polarinstitutt 104, 4-31.

Giesy JP, Kannan K. 2001. Global distribution of perfluorooctane sulfonate in wildlife. Environmental Science & Technology 35: 1339-1342.

Green, N, Schlabach, M, Bakke, T, Brevik,EM, Dye, C, Remberger, M, Herzke, D, Huber, S, Plosz , B, Schøyen, M, Uggerud, HT, and Vogelsang, C, 2008. Screening of selected metals and new organic contaminants 2007. Phosphorus flame retardants, polyfluorinated organic compounds, nitro-PAHs, silver, platinum and sucralose in air, wastewater treatment falcilities, and freshwater and marine recipients. SFT report TA-2367/2008.

Helgason LB, Barrett R, Lie E, Polder A, Skaare JU, Gabrielsen GW. 2007. Levels and temporal trends (1983e2003) of persistent organic pollutants (POPs) and mercury (Hg) in seabird eggs from Northern Norway. Environmental Pollution, xx (in press): 1-9.

Herzke D, Berger U, Kallenborg R, Nygård T, Vetter W. 2005. Brominated flame retardants and other organobromines in Norwegian predatory bird eggs. Chemosphere 61: 441-449.

Houde M, Martin JW, Letcher RJ, Solomon KR, Muir DCG. 2006. Biological monitoring of polyfluoroalkyl substances: a review. Environmental Science & Technology 40: 3463-3473.

Kallenborn, R., Berger, U., Järnberg, U, 2004. Perfluorinated alkylated substances (PFAS) in the nordic environment. TemaNord 2004:552. Nordic Council of Ministers, Copenhagen.

Kannan K, Franson JC, Bowerman WW, Hansen KJ, Jones PD, Giesy JP. 2001. Perfluorooctane sulfonate in fish-eating water birds including bald eagles and albatrosses. Environmental Science & Technology 35: 3065-3070.

Knudsen, L.B., Borgå, K., Jørgensen, E.H., van Bavel, B., Schlabach, M., Verreault, J., Gabrielsen, G.W. 2007. Halogenated organic contaminants and mercury in northern fulmars (*Fulmarus glacialis*): Levels, relationships to dietary descriptors and blood to liver comparison. Environmental Pollution 146: 25-33.

Knudsen LB, Gabrielsen GW, Verreault J, Barrett R, Skåre JU, Polder A, Lie E. 2005. Temporal trends of brominated flame retardants, cyclododeca-1,5,9-triene and mercury in eggs of four seabird species from Northern Norway and Svalbard. SFT SPFO-report942/2005, The Norwegian Pollution Control Authority, Oslo, Norway. pp. 1-43.

Lindberg P, Sellström U, Häggberg L, de Wit CA. 2004. Higher brominated diphenyl ethers and hexabromocyclododecane found in eggs of peregrine falcons (*Falco peregrinus*) breeding in Sweeden. Environmental Science & Technology 38: 93-96.

Loring D.H., K. Næs, S. Dahle, G.G. Matishov & G. Illin, 1995. Arsenic, trace metals, and organic micro contaminants in sediments from the Pechora sea, Russia. *Mar. Geol.* 128: 153-157.

Miljeteig C, Strøm H, Gavrilo M, Skåre, JU, Jenssen BM, Gabrielsen GW. 2007. Organohalogens and mercury in ivory gull eggs. SFT SPFO-rapport 1006/2007, The Norwegian Pollution Control Authority, Oslo, Norway. pp. 1-33.

Murvoll KM, Skaare JU, Anderssen E, Jenssen BM, 2006. Exposure and effects of persistent organic pollutants in European shag (Phalacrocorax aristotelis) hatchlings from the coast of Norway. Environmental Toxicology and Chemistry 25:190-198.

Norstrom RJ, Simon M, Moisey J, Wakeford B, Weseloh DVC. 2002. Geographical distribution and temporal trends (1981-2000) of brominated diphenyl ethers in Great Lakes herring gull eggs. Environmental Science & Technology 36: 4783-4789.

OSPAR, 1999. JAMP [Joint Assessment and Monitoring Programme] Guidelines for Monitoring Contaminants in Sediment . Oslo and Paris Commissions. Ref. No: 1999-01, 45 pp.Sakshaug, E., Bjørge, A., Gulliksen, B., Loeng, H., Mehlum, F. (eds.) 1992. Økosystem Barentshavet. Pro Mare. Trondheim, 304 p.

Sellstrom U, Bignert A, Kierkegaard A, Haggberg L, de Wit CA, Olsson M, Jansson B. 2003. Temporal trend studies on tetra- and pentabrominated diphenyl ethers and hexabromocyclododecane in guillemot egg from the Baltic Sea. Environmental Science & Technology 37:5496-501.

Søreide JE, Hop H, Carroll ML, Falk-Petersen S, Hegseth EN, 2006. Seasonal food web structures and sympagic-pelagic coupling in the European Arctic revealed by stable isotopes and a two-source food web model. Progress in Oceanography 71:59-87.

Sørmo EG, Salmer MP, Jenssen BM, Hop H, Bæk K, Kovacs KM, Lydersen C, Falk-Petersen S, Gabrielsen GW, Lie E, Skaare JU, 2006. Biomagnification of polybrominated diphenyl ether and hexabromocyclododecane flame retardants in the polar bear food chain in Svalbard, Norway. Environmental Toxicology and Chemistry 25:2502-2511.

Tomy, G.T.. Tittlemier, S.A Palace, V.P. Budakowski, W.R. Braekevelt, E. Brinkworth L. and Friesen, K. Environ. Sci. Technol. 38 (2004), p. 758.

Verreault J, Berger U, Gabrielsen GW, 2007. Trends of Perfluorinated Alkyl Substances in Herring Gull Eggs from Two Coastal Colonies in Northern Norway: 1983-2003. Environmental Science and Technology 41:6671-6677.

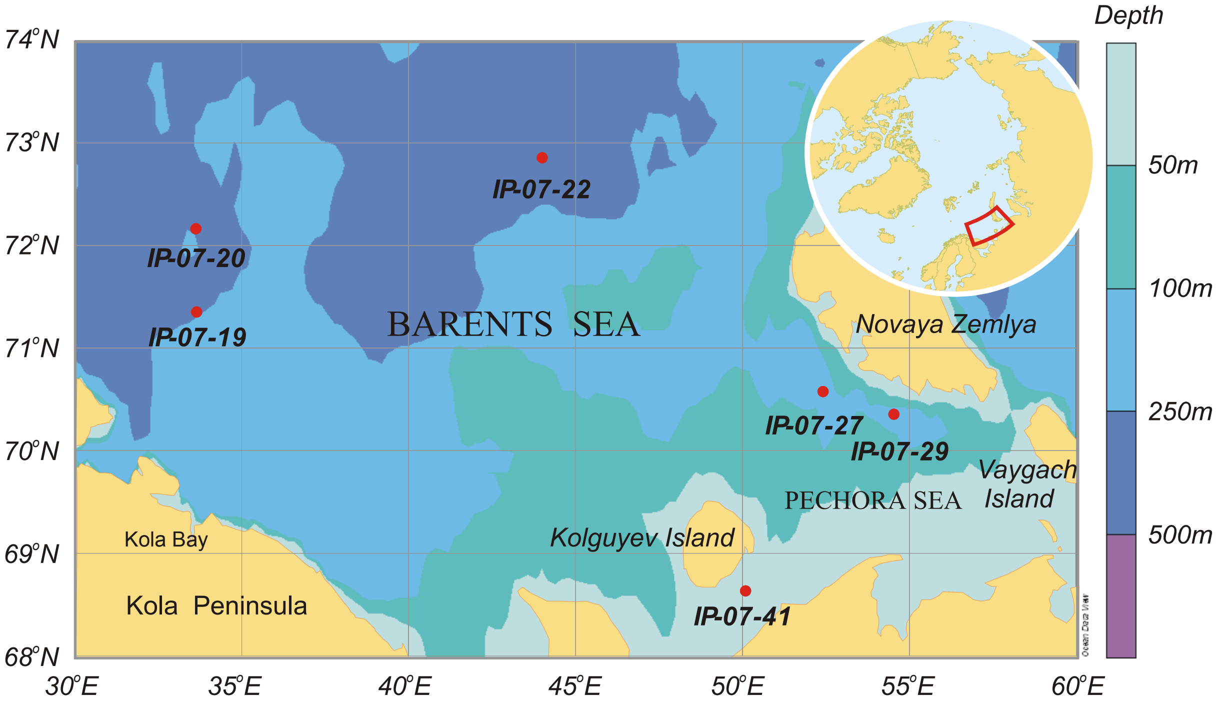
Verreault J, Gabrielsen GW, Berger U. 2006. Perfluorinated alkyl substances in eggs of herring gulls from Northern Norway: Spatial and temporal trends. SFT SPFO-report 971/2006, The Norwegian Pollution Control Authority, Oslo, Norway. pp. 2-21.

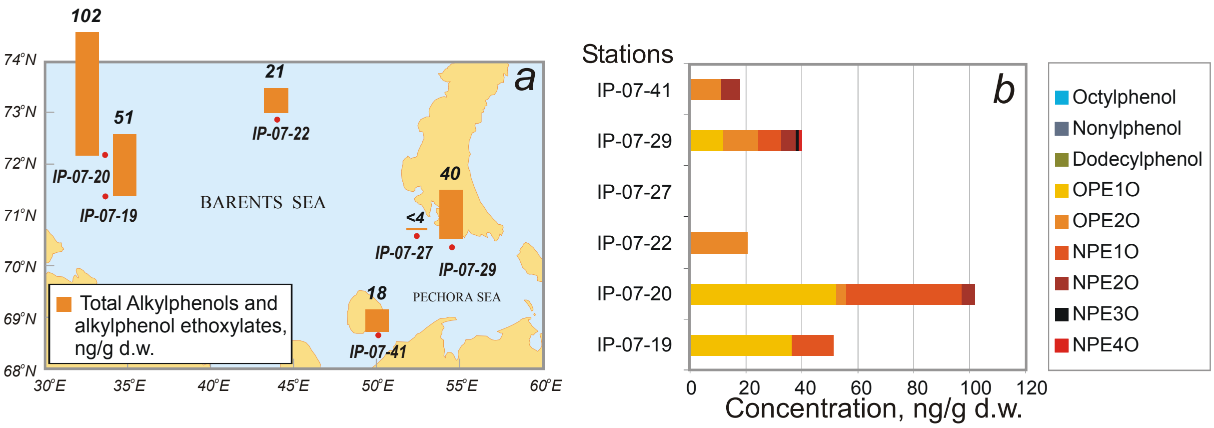
Verreault J, Gabrielsen GW, Letcher RJ, Muir DCG, Chu S. 2004. New and established organohalogen contaminants and their metabolites in plasma and eggs of glaucous gull from Bear Island. SFT rapport prosjektnummer 6003089, The Norwegian Pollution Control Authority, Oslo, Norway. pp. 2-19.

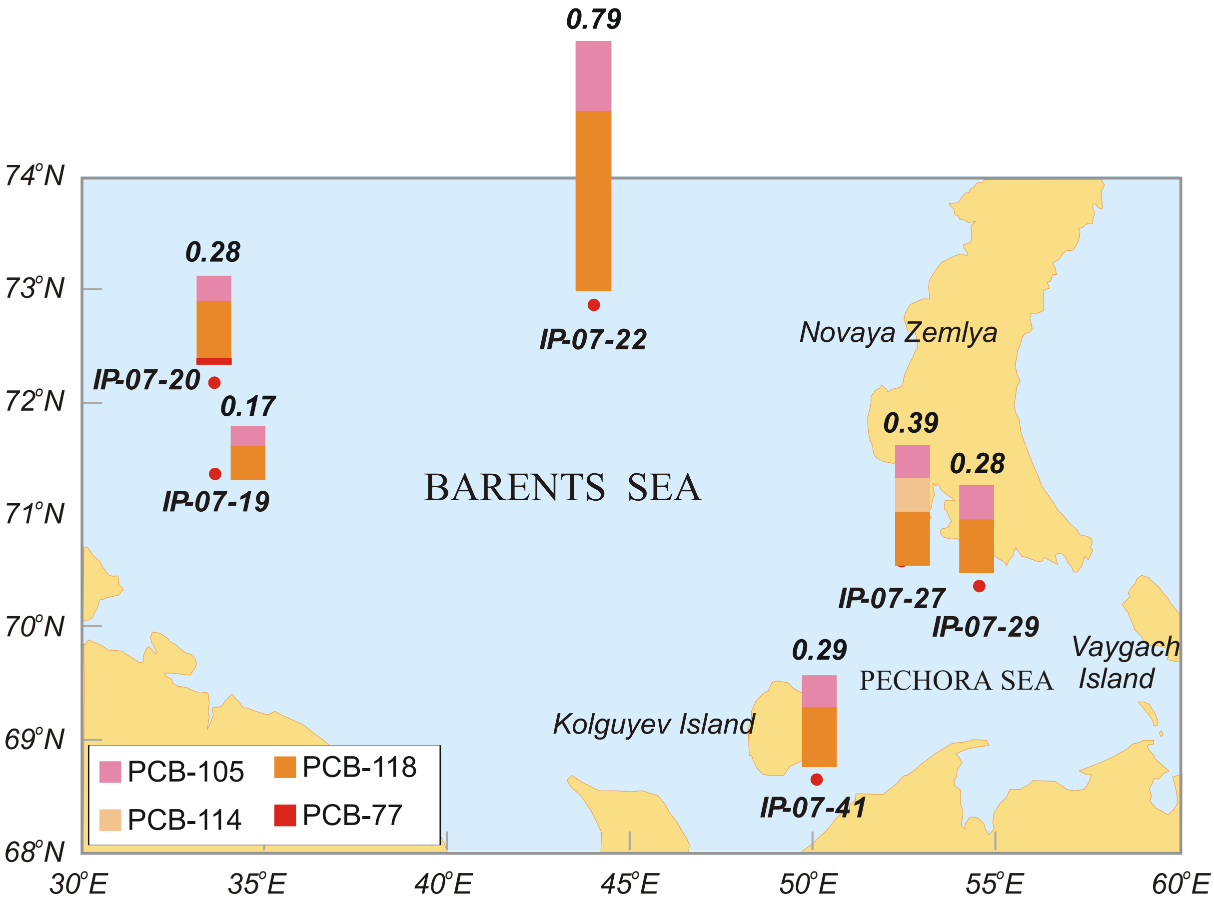
Vorkamp K, Christensen JH, Glasius M, Riget FF. 2004. Persistent halogenated compounds in black-guillemots (*Cepphus grylle*) from Greenland – levels, pattern, and spatial trends. Marine Pollution Bulletin 48: 111-121.

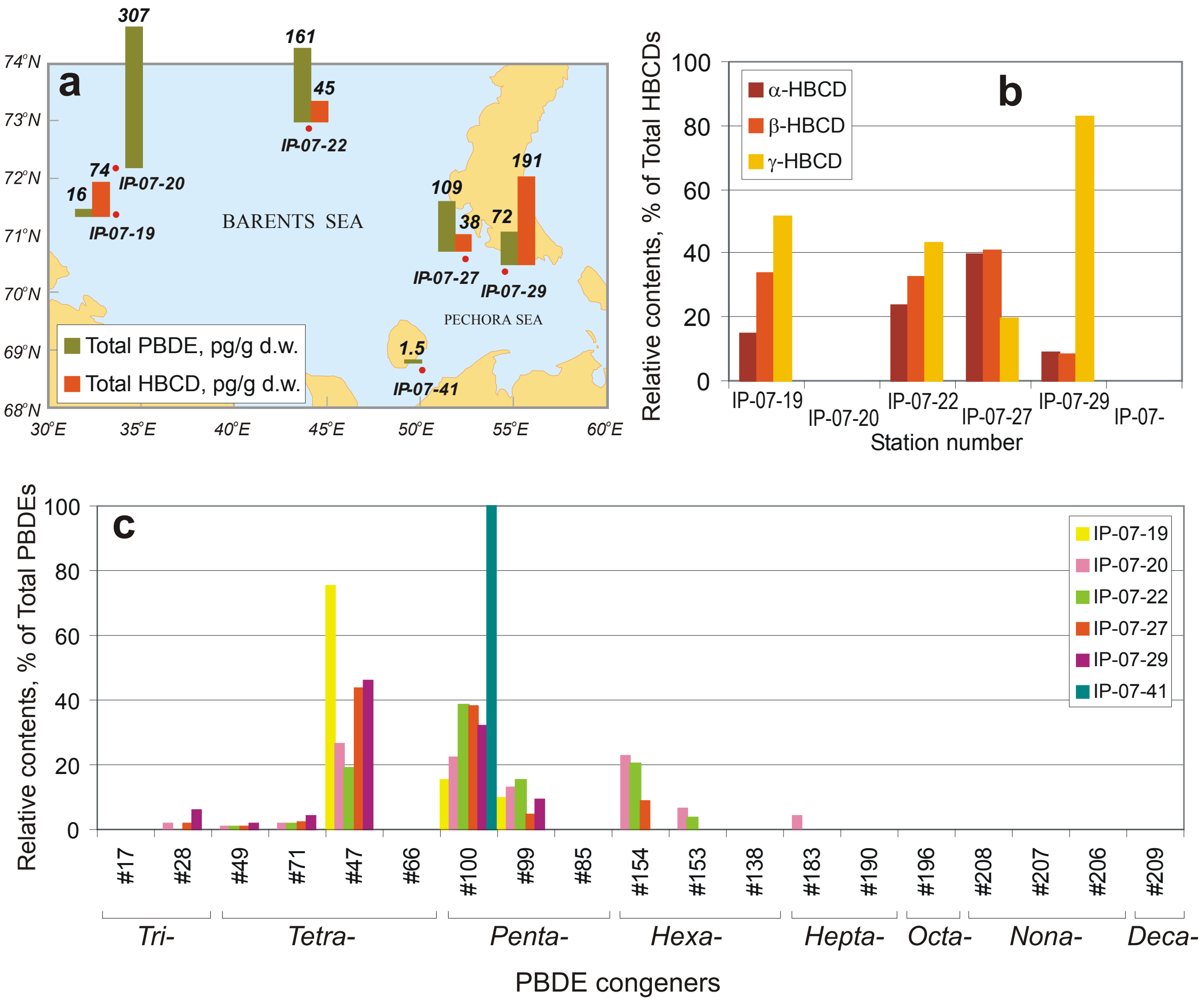
Vorkamp K, Thomson M, Falk K, Leslie H, Møller S, Sørensen PB. 2005. Temporal development of brominated flame retardants in peregrine falcon (*Falco peregrinus*) eggs from South Greenland (1986-2003). Environmental Science & Technology 39: 8199-8206.

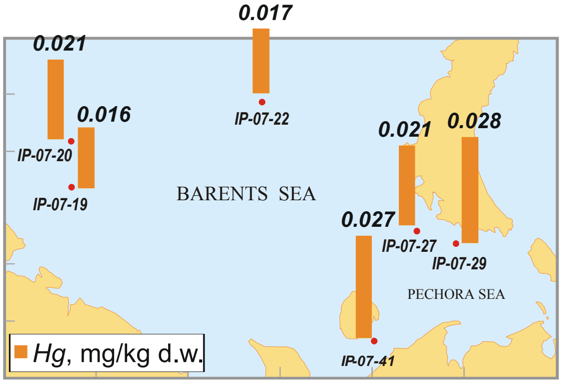
10. Annex I – Detailed maps Akvaplan-niva

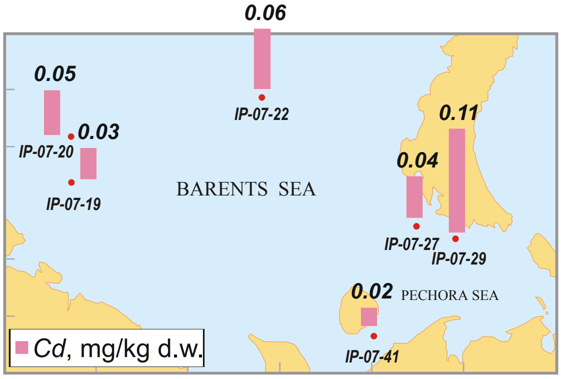


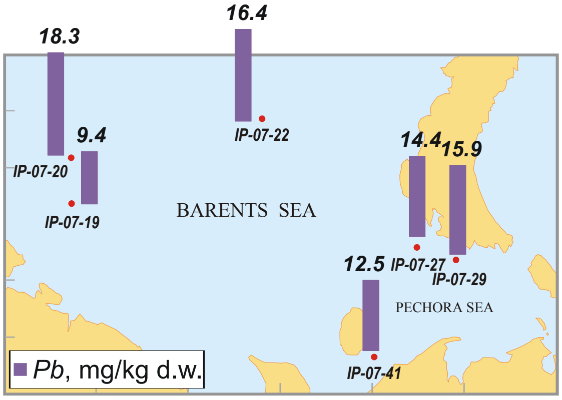


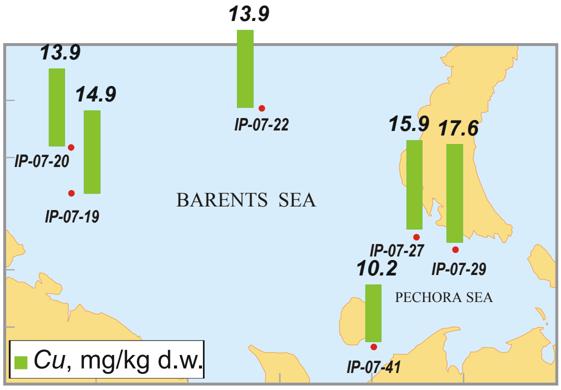

0.79
74°N
0.28
73°N
IP-07-22
Novaya Zemlya
IP-07-20
72°N
0.17
0.39
0.28
BARENTS SEA
IP-07-19
71°N
IP-07-27
IP-07-29
70°N
0.29
Vaygach Island
PECHORA SEA
Kolguyev Island
69°N
PCB-105
PCB-118
PCB-114
PCB-77
IP-07-41
68°N
30°E
35°E
40°E
45°E
50°E
55°E
60°E

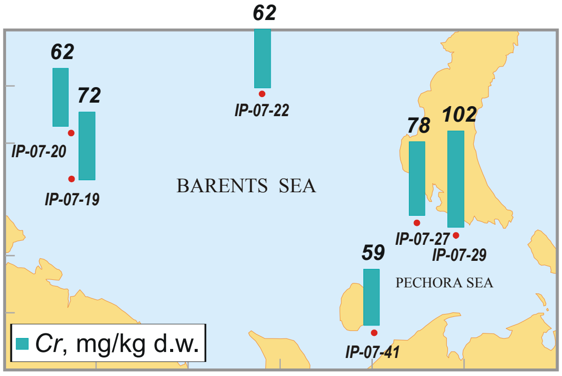

a
307
161
45
74
16
IP-07-20
IP-07-19
IP-07-22
BARENTS SEA
109
38
72
191
IP-07-27
IP-07-29
PECHORA SEA
1.5
IP-07-41
74°N
73°N
72°N
71°N
70°N
69°N
68°N
30°E
35°E
40°E
45°E
50°E
55°E
60°E
Total PBDE, pg/g d.w.
Total HBCD, pg/g d.w.
b
Relative contents, % of Total HBCDs
100
80
60
40
20
0
α-HBCD
β-HBCD
γ-HBCD
IP-07-19
IP-07-20
IP-07-22
IP-07-27
IP-07-29
IP-07-
Station number
c
Relative contents, % of Total PBDEs
IP-07-19
IP-07-20
IP-07-22
IP-07-27
IP-07-29
IP-07-41
#17
#28
#49
#71
#47
#66
#100
#99
#85
#154
#153
#138
#183
#190
#196
#208
#207
#206
#209
Tri-
Tetra-
Penta-
Hexa-
Hepta-
Octa-
Nona-
Deca-
PBDE congeners

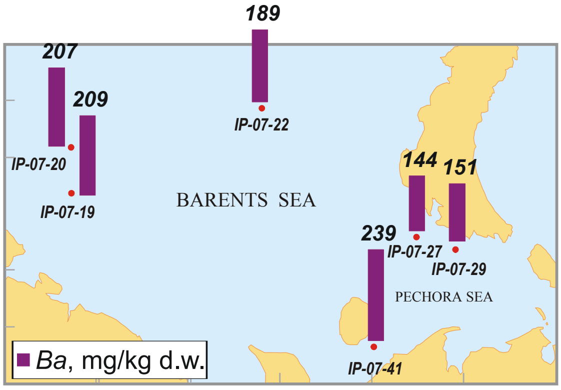

0.021
0.017
0.016
IP-07-20
IP-07-22
IP-07-19
BARENTS SEA
0.021
0.028
0.027
IP-07-27
IP-07-29
PECHORA SEA
IP-07-41
Hg, mg/kg d.w.

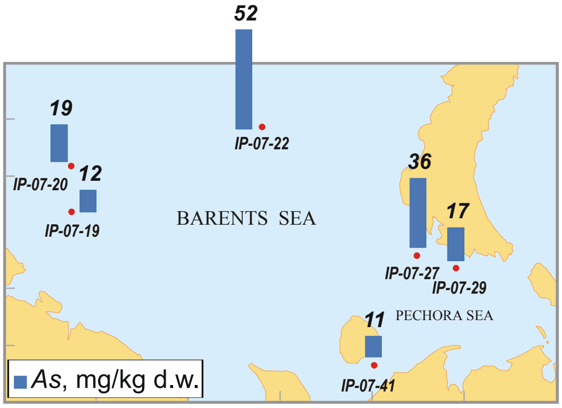

0.06
0.05
0.03
IP-07-20
IP-07-22
IP-07-19
BARENTS SEA
0.11
0.04
IP-07-27
IP-07-29
0.02
PECHORA SEA
IP-07-41
Cd, mg/kg d.w.

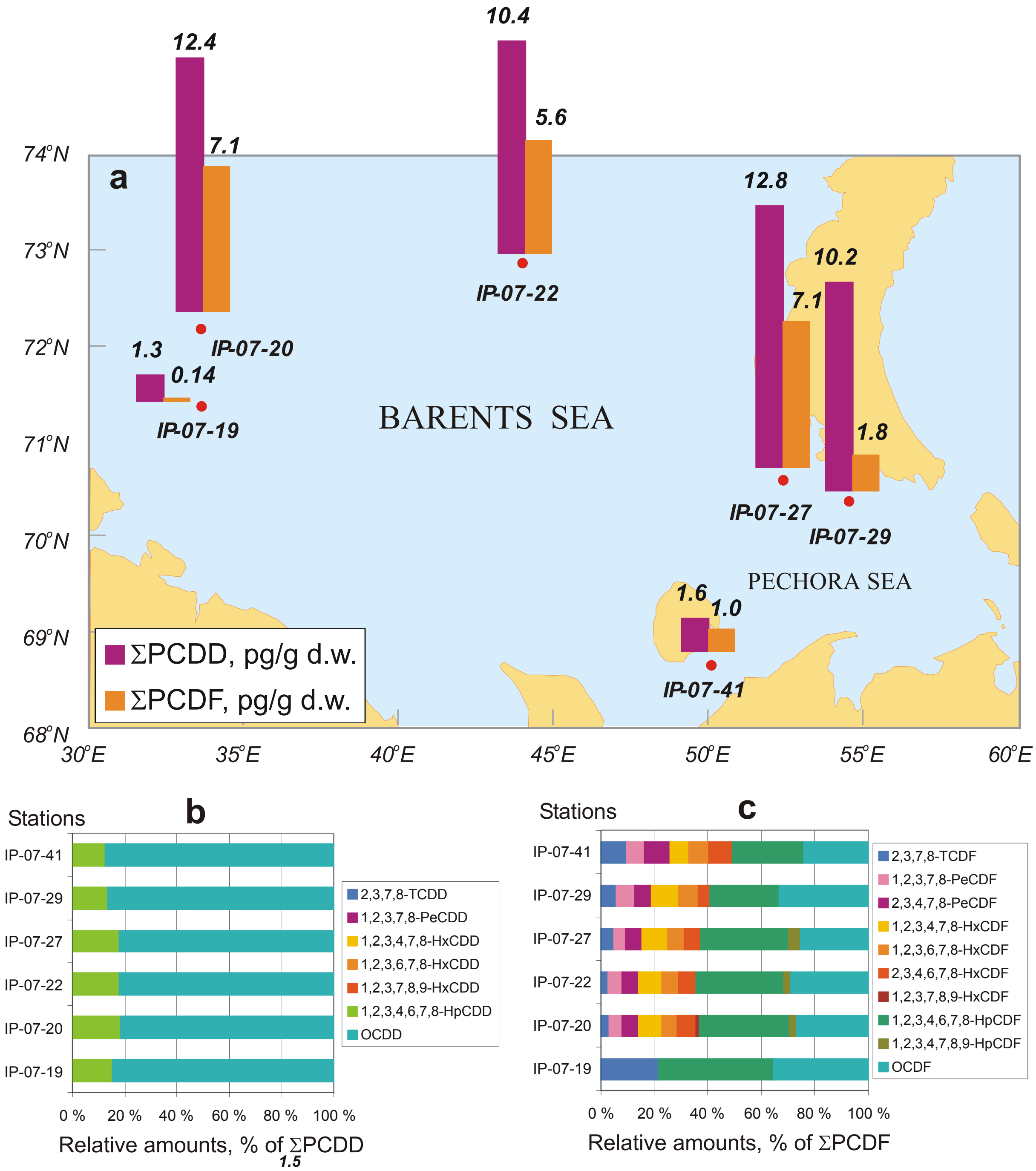

16.4
18.3
9.4
IP-07-20
IP-07-22
IP-07-19
BARENTS SEA
14.4
15.9
12.5
IP-07-27
IP-07-29
PECHORA SEA
IP-07-41
Pb, mg/kg d.w.

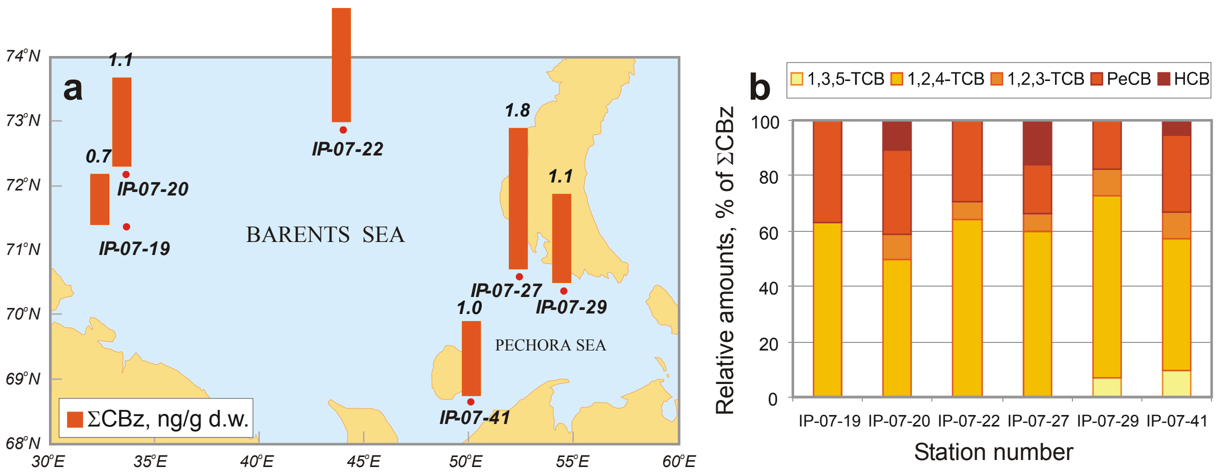

13.9
13.9
14.9
IP-07-20
IP-07-22
IP-07-19
BARENTS SEA
15.9
17.6
IP-07-27
IP-07-29
10.2
PECHORA SEA
IP-07-41
Cu, mg/kg d.w.

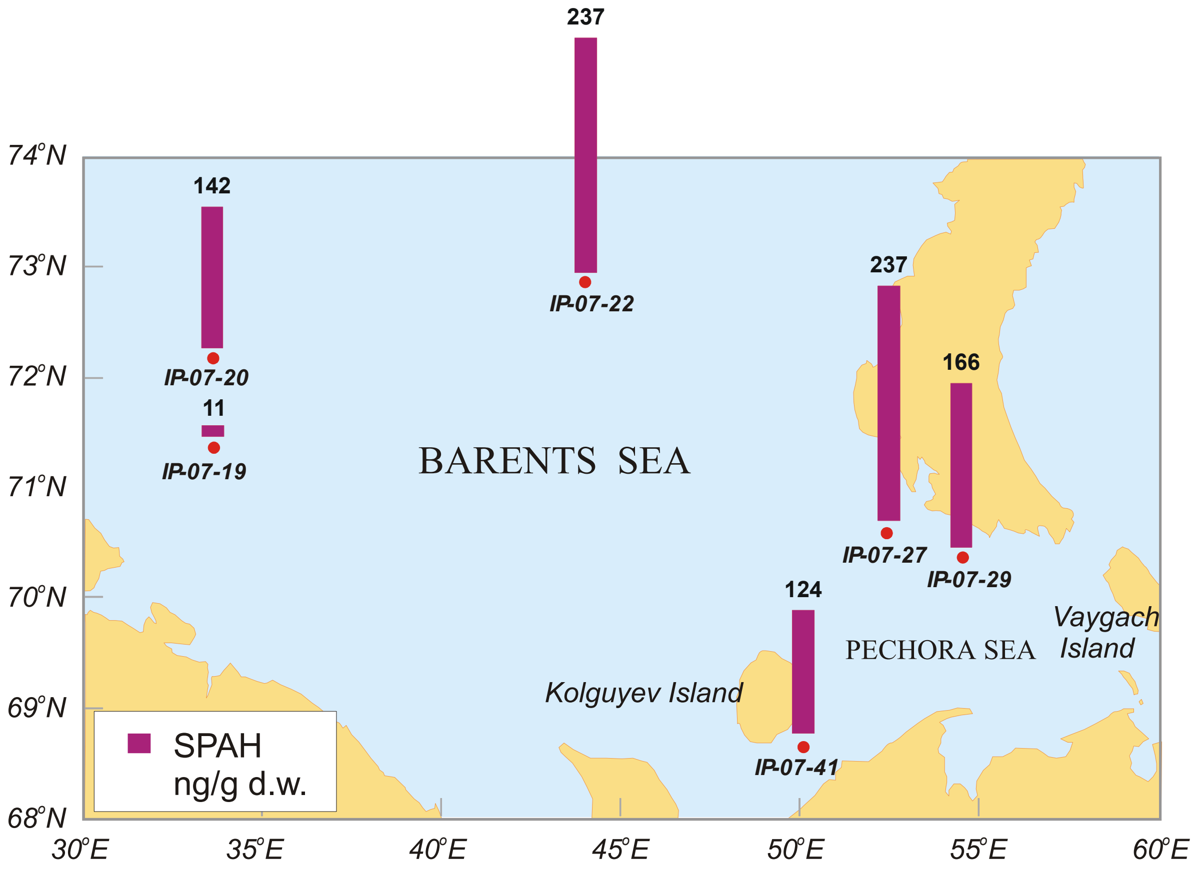

62
62
72
IP-07-20
IP-07-22
IP-07-19
BARENTS SEA
78
102
IP-07-27
IP-07-29
59
PECHORA SEA
IP-07-41
Cr, mg/kg d.w.

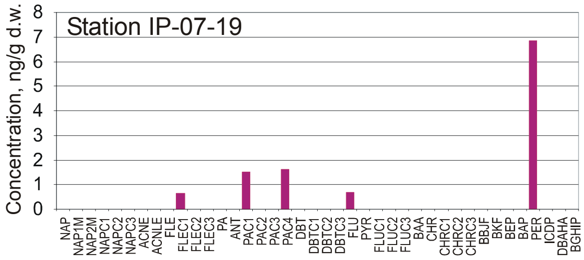

189
207
209
IP-07-20
IP-07-22
IP-07-19
BARENTS SEA
144
151
239
IP-07-27
IP-07-29
PECHORA SEA
IP-07-41
Ba, mg/kg d.w.

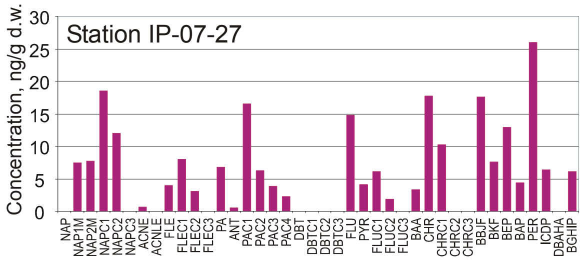

52
19
12
IP-07-20
IP-07-22
IP-07-19
BARENTS SEA
36
17
IP-07-27
IP-07-29
11
PECHORA SEA
IP-07-41
As, mg/kg d.w.

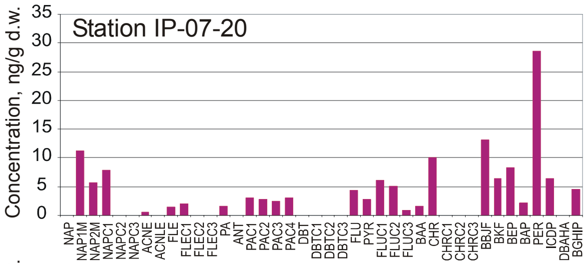

a
12.4
7.1
10.4
5.6
12.8
10.2
7.1
1.8
1.3
0.14
1.6
1.0
IP-07-19
IP-07-20
IP-07-22
IP-07-27
IP-07-29
IP-07-41
BARENTS SEA
PECHORA SEA
74°N
73°N
72°N
71°N
70°N
69°N
68°N
30°E
35°E
40°E
45°E
50°E
55°E
60°E
🟪 ΣPCDD, pg/g d.w.
🟧 ΣPCDF, pg/g d.w.
b
Stations
IP-07-41
IP-07-29
IP-07-27
IP-07-22
IP-07-20
IP-07-19
0 %
20 %
40 %
60 %
80 %
100 %
Relative amounts, % of ΣPCDD
2,3,7,8-TCDD
1,2,3,7,8-PeCDD
1,2,3,4,7,8-HxCDD
1,2,3,6,7,8-HxCDD
1,2,3,7,8,9-HxCDD
1,2,3,4,6,7,8-HpCDD
OCDD
c
Stations
IP-07-41
IP-07-29
IP-07-27
IP-07-22
IP-07-20
IP-07-19
0 %
20 %
40 %
60 %
80 %
100 %
Relative amounts, % of ΣPCDF
2,3,7,8-TCDF
1,2,3,7,8-PeCDF
2,3,4,7,8-PeCDF
1,2,3,4,7,8-HxCDF
1,2,3,6,7,8-HxCDF
2,3,4,6,7,8-HxCDF
1,2,3,7,8,9-HxCDF
1,2,3,4,6,7,8-HpCDF
1,2,3,4,7,8,9-HpCDF
OCDF

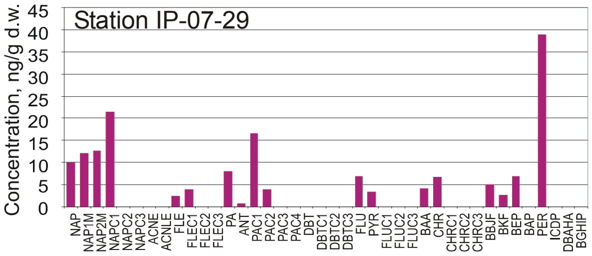

a
1.5
1.1
0.7
1.8
1.1
1.0
IP-07-19
IP-07-20
IP-07-22
IP-07-27
IP-07-29
IP-07-41
BARENTS SEA
PECHORA SEA
74°N
73°N
72°N
71°N
70°N
69°N
68°N
30°E
35°E
40°E
45°E
50°E
55°E
60°E
🟧 ΣCBz, ng/g d.w.
b
1,3,5-TCB
1,2,4-TCB
1,2,3-TCB
PeCB
HCB
Relative amounts, % of ΣCBz
100
80
60
40
20
0
IP-07-19
IP-07-20
IP-07-22
IP-07-27
IP-07-29
IP-07-41
Station number

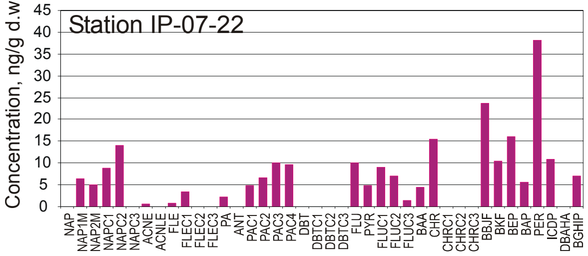

237
142
IP-07-20
11
IP-07-19
IP-07-22
237
166
IP-07-27
IP-07-29
124
IP-07-41
BARENTS SEA
PECHORA SEA
Kolguyev Island
Vaygach Island
SPAH ng/g d.w.
74°N
73°N
72°N
71°N
70°N
69°N
68°N
30°E
35°E
40°E
45°E
50°E
55°E
60°E

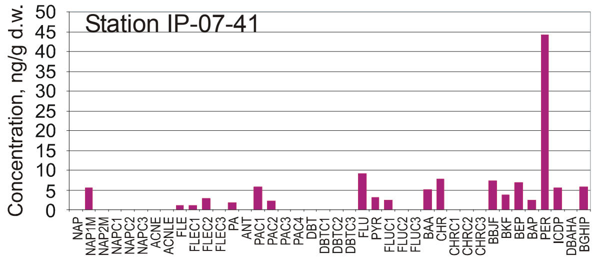

Station IP-07-19
Concentration, ng/g d.w.
0 1 2 3 4 5 6 7 8
NAP NAP1M NAP2M NAPC1 NAPC2 NAPC3 ACNE ACNLE FLE FLEC1 FLEC2 FLEC3 PA ANT PAC1 PAC2 PAC3 PAC4 DBT DBTC1 DBTC2 DBTC3 FLU PYR FLUC1 FLUC2 FLUC3 BAA CHR CHRC1 CHRC2 CHRC3 BBJF BKF BEP BAP PER ICDP DBAHA BGHIP


Station IP-07-27
Concentration, ng/g d.w.
0 5 10 15 20 25 30
NAP NAP1M NAP2M NAPC1 NAPC2 NAPC3 ACNE ACNLE FLE FLEC1 FLEC2 FLEC3 PA ANT PAC1 PAC2 PAC3 PAC4 DBT DBTC1 DBTC2 DBTC3 FLU PYR FLUC1 FLUC2 FLUC3 BAA CHR CHRC1 CHRC2 CHRC3 BBJF BKF BEP BAP PER ICDP DBAHA BGHIP


Station IP-07-20
Concentration, ng/g d.w.
0 5 10 15 20 25 30 35
NAP NAP1M NAP2M NAPC1 NAPC2 NAPC3 ACNE ACNLE FLE FLEC1 FLEC2 FLEC3 PA ANT PAC1 PAC2 PAC3 PAC4 DBT DBTC1 DBTC2 DBTC3 FLU PYR FLUC1 FLUC2 FLUC3 BAA CHR CHRC1 CHRC2 CHRC3 BBJF BKF BEP BAP PER ICDP DBAHA BGHIP


Station IP-07-29
Concentration, ng/g d.w.
0 5 10 15 20 25 30 35 40 45
NAP NAP1M NAP2M NAPC1 NAPC2 NAPC3 ACNE ACNLE FLE FLEC1 FLEC2 FLEC3 PA ANT PAC1 PAC2 PAC3 PAC4 DBT DBTC1 DBTC2 DBTC3 FLU PYR FLUC1 FLUC2 FLUC3 BAA CHR CHRC1 CHRC2 CHRC3 BBJF BKF BEP BAP PER ICDP DBAHA BGHIP


Station IP-07-22
Concentration, ng/g d.w.
0 5 10 15 20 25 30 35 40 45
NAP NAP1M NAP2M NAPC1 NAPC2 NAPC3 ACNE ACNLE FLE FLEC1 FLEC2 FLEC3 PA ANT PAC1 PAC2 PAC3 PAC4 DBT DBTC1 DBTC2 DBTC3 FLU PYR FLUC1 FLUC2 FLUC3 BAA CHR CHRC1 CHRC2 CHRC3 BBJF BKF BEP BAP PER ICDP DBAHA BGHIP


Station IP-07-41
Concentration, ng/g d.w.
0 5 10 15 20 25 30 35 40 45 50
NAP NAP1M NAP2M NAPC1 NAPC2 NAPC3 ACNE ACNLE FLE FLEC1 FLEC2 FLEC3 PA ANT PAC1 PAC2 PAC3 PAC4 DBT DBTC1 DBTC2 DBTC3 FLU PYR FLUC1 FLUC2 FLUC3 BAA CHR CHRC1 CHRC2 CHRC3 BBJF BKF BEP BAP PER ICDP DBAHA BGHIP

Statlig program for forurensningsovervåking

Statens forurensningstilsyn (SFT)
Postboks 8100 Dep, 0032 Oslo - Besøksadresse: Strømsveien 96
Telefon: 22 57 34 00 - Telefaks: 22 67 67 06
E-post: postmottak@sft.no - Internett: www.sft.no

Utførende institusjon Norwegian Institute for Water Research	ISBN-nummer 978-82-577-5324-5

Oppdragstakers prosjektansvarlig Torgeir Bakke	Kontaktperson SFT Christine Daae Olseng	TA-nummer 2400/2008

	År 2008	Sidetall 117	SFTs kontraktnummer 5008011

Utgiver Norsk Institutt for vannforskning NIVA-rapport nr 5589-2008	Prosjektet er finansiert av Statens forurensningstilsyn

Forfatter(e)

Torgeir Bakke (NIVA)	Norman Green (NIVA)	Cecilie Miljeteig (NP)	Martin Schlabach (NILU)
Stepan Boitsov (HI)	Lisa B. Helgason (NP)	Amund Måge (NIFES)	Bent B Skaare (NIVA)
Einar M. Brevik (NIVA)	Jarle Klungsøyr (HI)	Britt E Rolfsnes (NIFES)	Stig Valdersnes (NIFES)
Geir W. Gabrielsen (NP)	Henriette Leknes (NILU)	Tatiana Savinova (Akvaplan-niva)	

Title:
Mapping selected organic contaminants in the Barents Sea 2007.
Tittel:
Kartlegging av utvalgte organiske miljøgifter fra Barentshavet 2007.

Sammendrag – summary

The report covers five investigations on chlorinated paraffins, alkyl phenols and alkyl phenol etoxilates, pentachlorophenol, tensides, polyfluorinated compounds, polybrominated diphenylethers, hexabromocyclododecane, tetrabromobisphenol A, bisphenol A, synthetic musk compounds, siloxanes, phosphorus flame retardants, diethylhexylphtalate, dioxins and furans, PCBs, organohalogens, biocides (toxaphenes, DDT, chlordanes, HCH, TBT), PAHs, trace metals and stable isotopes of C and N in samples of sediment, blue mussel, shrimp, capelin, cod and Brünnich’s guillemot eggs from the Barents Sea region. The report is a contribution to closing an information gap pointed out in the Governmental White Paper (St.mld. 8, 2005/2006, Management Plan Barents).

4 emneord	4 subject words
Forvaltningsplan Barents	Barents Sea Management Plan
Organiske mikroforurensninger	Organic contaminants
Sedimenter	Sediments
Marin fauna	Marine fauna

Statens forurensningstilsyn
Postboks 8100 Dep,
0032 Oslo
Besøksadresse: Strømsveien 96

Telefon: 22 57 34 00
Telefaks: 22 67 67 06
E-post: postmottak@sft.no
www.sft.no

Statlig program for forurensningsovervåking omfatter overvåking av forurensningsforholdene i luft og nedbør, skog, vassdrag, fjorder og havområder. Overvåkningsprogrammet dekker langsiktige undersøkelser av:

- overgjødsling
- forsuring (sur nedbør)
- ozon (ved bakken og i stratosfæren)
- klimagasser
- miljøgifter

Overvåkningsprogrammmet skal gi informasjon om tilstanden og utviklingen av forurensningssituasjonen, og påvise eventuell uheldig utvikling på et tidlig tidspunkt. Programmet skal dekke myndighetenes informasjonsbehov om forurensningsforholdene, registrere virkningen av iverksatte tiltak for å redusere forurensningen, og danne grunnlag for vurdering av nye tiltak. SFT er ansvarlig for gjennomføringen av overvåkningsprogrammet

TA-2400/2008
ISBN 978-82-577-5324-5