Statens forurensningstilsyn
Norwegian Pollution Control Authority

Statlig program for forurensningsovervåking, rapportnr: 1060/ 2009

Screening of selected priority substances of the Water Framework Directive in marine samples 2004 - 2008

TA
2564
2009

NIVA
Norwegian Institute for Water Research

Norwegian Pollution Control Authority

SPFO-report: 1060/ 2009
TA-2564/ 2009
ISBN 978-82-577-5611-6

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

Screening of selected priority substances of the Water Framework Directive in marine samples 2004 - 2008

Rapport
1060/2009

Brominated flame retardents, perfluorinated organic compounds, dimethyltetrabrombisphenol A, isoproturon, cyclodienes and di(2-ethylhexyl)-phthalate, and selected organochlorines, phenols and metals in marine sediment, blue mussel and cod liver.

Authors: Norman W. Green (project leader), Kine Bæk, Alfhild Kringstad, Katherine Langford, Martine Muusse, Anders Ruus, Merete Schøyen, Marit Villø and Sigurd Øxnevad.

NIVA project no. O-29106, O-29333
NIVA report no. 5876-2009

Foreword

On behalf of the Norwegian Pollution Control Authority (SFT) the Norwegian Institute for Water Research (NIVA) has analysed selected metals and new organic contaminants. These compounds are silver, arsenic, chromium, nickel, brominated compounds including PBDEs and HBCDD, perfluorinated organic compounds including PFOS and PFOSA, organochlorines including trichloroethylene, endosulfan, trichlrorbenzene and HCBD, cyclodiene pesticides, selected phenols and chlorophenols, isoproturon and DEHP. Analyses were done on samples from sediment from the period 2004 - 2008, and blue mussel and cod from 2008 collected under the Coordinated Environmental Monitoring Programme (CEMP).

Thanks are due to all who have participated in this project and especially to:
Åse Gudmundson Rogne: sample preparation.
Merete Schøyen, Sigurd Øxnevad: sampling and sample preparation.
Alfhild Kringstad, Kine Bæk, Katherine Langford: organic analyses.
Marit Villø: metal analyses.
Katherine Langford, Martine Muusse: literature review.

Norwegian Pollution Control Authority (SFT)
Bård Nordbø: – project coordinator at SFT.

NIVA, Oslo, 11th December 2009

Norman W. Green
Research Scientist, Project leader

Contents

Extended summary **1**

Sammendrag **3**

1. Introduction **6**
1.1 Background and purpose 6
1.2 Elements and compounds 6
1.2.1 Brominated compounds 8
1.2.2 Perfluorinated organic compounds 10
1.2.3 Organochlorines 11
1.2.4 Cyclodienes 13
1.2.5 Pentachlorophenol, octylphenol and nonylphenol 13
1.2.6 Isoproturon 14
1.2.7 Di(2-ethylhexyl)phthalate (DEHP) 14
1.2.8 Silver 15
1.2.9 Arsenic 15
1.2.10 Chromium 16
1.2.11 Nickel 16

2. Materials and methods **17**
2.1 Description of sampling sites 17
2.2 Sampling and sample treatment 21
2.3 Chemical analyses 21
2.3.1 Brominated compounds 22
2.3.2 Perfluorinated organic compounds 23
2.3.3 Organochlorines 24
2.3.4 Cyclodienes 24
2.3.5 Phenols/ chlorophenols 24
2.3.6 Isoproturon 24
2.3.7 DEHP 24
2.3.8 Silver, arsenic, chromium and nickel 24
2.3.9 General remarks to chemical analyses 25

3. Results and discussion **26**
3.1 Brominated compounds 26
3.2 Perfluorinated organic compounds 35
3.3 Organochlorines 43
3.4 Cyclodienes 48
3.5 Phenols/ chlorophenols, isoproturon and DEHP 52
3.6 Silver, arsenic, chromium and nickel 57

4. Conclusions **61**

5. References **65**

Extended summary

On behalf of the Norwegian Pollution Control Authority (SFT) the Norwegian Institute for Water Research (NIVA) has monitored brominated compounds including PBDEs and HBCDD, perfluorinated organic compounds including PFOS and PFOSA, organochlorines including trichloroethylene, endosulfan, trichlororbenzene, HCBD, cyclodiene pesticides, selected phenols and chlorophenols, isoproturon and DEHP and the metals silver, arsenic, chromium and nickel. Analyses were done on ten samples of sediment from the period 2004 - 2008, and nine samples of blue mussel and 25 samples of cod liver from 2008 collected under the Coordinated Environmental Monitoring Programme (CEMP). Samples were collected in southern Norway (from Oslofjord to Lista), Lofoten and northern Norway (Varangerfjord); six sediment stations, nine blue mussel stations and five cod stations. The report should be a guideline in the planning of environmental monitoring where these substances are concerned.

The general lack of Predicted No Effect Concentrations (PNECs) or Environmental Quality Standard (EQS) for sediment or biota prevents an adequate means of assessing potential risk that the substances investigated in this study might have on the environment. The limit of detection (LOD) for many of these substances may not be sufficiently low to rule out potential risk. Furthermore, the moderate number and geographical distribution of the samples investigated warrant some concern for how representative these are. Considering these reasons and the anticipated development of quality criteria, further monitoring of these substances is advised but perhaps with different intensities with regard to selection of matrices and selection of distribution, sampling frequency and number of stations.

The main conclusions from the concentrations found and proposed intensity of monitoring follow relative to other substances.

Brominated compounds
The sum-PBDE in sediment ranged from 1.11-20.6 µg/kg d.w. and is well below the Predicted No Effect Concentration (PNEC). Concentrations of PBDEs in cod liver measured in this study were 2 - 3 times higher in inner Oslofjord and Sørfjord than elsewhere. A similar difference was not evident for concentrations in blue mussel.

Concentrations of HBCDD, TBBPA and the "new" brominated compound BTBPE in sediment, blue mussel and cod liver were below or close to limit of detection (LOD) in both presumed perturbed areas (i.e. inner Oslofjord, inner Sørfjord) and areas more remote from known sources of pollution.

A relative "high" intensity of monitoring is recommended.

Perfluorinated organic compounds
Perfluorinated organic compounds (PFCs) were not detected in sediment or blue mussel. The LODs for PFOS in sediment are well below PNEC. The concentrations of PFOS were found in cod liver from the open southern coast of Norway (outer Oslofjord and Lista) were roughly 2 - 3 times concentrations from other areas. For PFOSA, concentrations were higher in cod liver from the inner Oslofjord than elsewhere.

A relative "high" intensity of monitoring is recommended.

Organochlorines
Concentrations of trichloroethylene, alachlor, endosulfan, trichlorobenzenes hexachlorobutadien (HCBD) and dicofol in sediment, blue mussel and cod liver were not detected, with one minor exception.

A relative "moderate" intensity of monitoring is recommended, except for alachlor and dicofol where a relative "low" level is considered adequate.

Cyclodienes
Concentrations of the cyclodienes aldrin, dieldrin, endrin and isodrin were not detected.

A relative "low" intensity of monitoring is recommended.

Phenols/chlorophenols, isoproturon and DEHP
Pentachlorphenol, nonylphenol, isoproturon were not detected in sediment, blue mussel and cod liver. di(2-ethylhexyl)-phthalate (DEHP) was not detected in sediment and analytical interference hindered quantification in blue mussel and cod liver.

A relative "moderate" intensity of monitoring is recommended, except for DEHP where a relative "high" level is considered adequate.

Metals
Silver was detected in all blue mussel samples but there was no evident difference between presumed contaminated areas (inner Oslofjord, inner Sørfjord) and areas more remote.

That the average concentrations of **arsenic** (total) from more perturbed areas (inner Oslofjord and inner Sørfjord) was less than other areas remote from presumed contamination, could indicate the influence of pollution of the surface water from adjacent areas.

Chromium was only detected in the blue mussel with no evident difference between presumed contaminated and less contaminated areas.

For **nickel**, there was no evident difference between presumed contaminated and less contaminated areas.

A relative "high" intensity of monitoring is recommended for silver, whereas "moderate" intensity of monitoring is recommended for arsenic, chromium and nickel.

Sammendrag

Tittel: *Basisovervåking av utvalgte prioriterte stoffer i Vanndirektivet, marin kartlegging 2004 – 2008. Bromerte flammehemmere, perfluorerte organiske forbindelser, dimetyltetrabrombisfenol A, isoproturon, syklodiener, di(2-etylheksyl)-ftalat, og utvalgte klororganiske forbindelser, fenoler og metaller i marine sedimenter, blåskjell og torskelever.*

År: *2009.*

Forfattere: Norman Green (prosjektleder), Kine Bæk, Alhild Kringstad, Katherine Langford, Martine Muusse, Anders Ruus, Merete Schøyen, Marit Villø and Sigurd Øxnevad.

Kilde: Statens forurensningstilsyn, SFT SPFO rapport 1060/ 2009, TA-2564/ 2009. ISBN 978-82-577-5611-6.

På oppdrag for Statens forurensningstilsyn (SFT) har Norsk institutt for vannforskning (NIVA) analysert et utvalg metaller og "nye" organiske miljøgifter i sedimenter, blåskjell og torskelever. Hensikten med dette nasjonale overvåkingsprosjektet har vært å få et overblikk over forekomsten av utvalgte miljøgifter som er relevante for Vanndirektivet (2000/60/EC) og datterdirektivet 2008/105/EC, og å anbefale videre overvåkingsnivå for disse miljøgiftene. Fire metaller og 52 organiske forbindelser ble analysert i prosjektet: bromerte stoffer inkludert PBDEer og HBCDD, perfluorerte organiske forbindelser inkludert PFOS og PFOSA, klororganiske stoffer inkludert trikloretylen, endosulfan, triklorbenzen og HCBD, syklodien-pesticider, utvalgte fenoler og klorfenoler, isoproturon, DEHP, sølv, arsen, krom og nikkel. Analysene ble utført på 10 sedimentprøver fra perioden 2004 til 2008, ni blåskjellprøver fra 2008 og 25 prøver av torskelever fra 2008. Prøvene ble samlet inn til CEMP (Coordinated Environmental Monitoring Programme). Prøvene er tatt fra kysten av Østlandet, Sørlandet og Vestlandet, samt fra Lofoten og Varangerfjorden i Nord-Norge, og omfatter seks sedimentstasjoner, ni blåskjellstasjoner og fem stasjoner for torsk. Denne rapporten bør være retningsgivende for planlegging av miljøovervåking som angår stoffene i denne undersøkelsen.

Siden det ikke foreligger grenseverdier for økologisk risiko (PNEC) eller miljøkvalitetstandarder (EQS) for sediment og biota for stoffene i denne undersøkelsen, har vi ikke gode nok kunnskaper for å bestemme den potensielle risikoen disse stoffene har på miljøet. Selv om mange av stoffene ikke kunne detekteres, er det uvisst om deteksjonsgrensene er tilstrekkelig lave til å utelukke en potensiell risiko for miljøet. Videre kan det tenkes at det moderate antall prøver og den geografiske fordelingen av disse ikke er et godt nok representativt utvalg. På bakgrunn av disse betraktningene og forventet utvikling av kvalitetskriterier, gis det her råd om intensitet, valg av matriser, fordeling, prøvefrekvens og antall stasjoner for videre overvåking av disse prioriterte stoffene. Hovedkonklusjonene fra de observerte konsentrasjonene og foreslått overvåkingsintensitet gis for hver stoffgruppe.

Bromerte forbindelser
Konsentrasjonen av sumPBDE i sediment var på 1.11 til 20.6 µg/ kg t.v. som er godt under forventet grenseverdi for økologisk risiko. Konsentrasjonen for PBDEer i torskelever målt i dette studiet var 2 til 3 ganger høyere i indre Oslofjord og indre Sørfjord enn på de andre stasjonene. Den samme forskjellen ble ikke funnet for blåskjell. Konsentrasjonene av HBCDD, TBBPA og den "nye" bromerte flammehemmeren BTBPE i sediment, blåskjell og

torskelever var under eller nær deteksjonsgrensen (LOD) i både antatt forurensede områder (indre Oslofjord og indre Sørfjord) og i områder mer fjernt fra kjente forurensningskilder.

En relativt "høy" overvåkingsintensitet anbefales.

Perfluorerte organiske forbindelser
Perfluorerte organiske forbindelser var ikke sporbare i sediment- og blåskjellprøvene. Deteksjonsgrensen for PFOS i sediment var godt under PNEC. Konsentrasjonene av PFOS funnet i torskelever fra ytre Oslofjord og Lista var 2 til 3 ganger høyere enn på de andre stasjonene. Konsentrasjonen av PFOSA i torskelever var høyere i indre Oslofjord enn på de andre stasjonene.

En relativt "høy" overvåkingsintensitet anbefales.

Klororganiske stoffer
Konsentrasjoner av trikloretylen, alaklor, endosulfan, triklorbenzen, heksaklorbutadien (HCBD) og dicofol i sediment, blåskjell og torskelever kunne bare påvises for noen veldig få tilfeller.

En relativt "moderat" overvåkingsintensitet anbefales, bortsett fra for alaklor og dicofol hvor en relativt "lav" overvåkingsintensitet er tilstrekkelig.

Syklodiener
Syklodienene aldrin, dieldrin, endrin og isodrin kunne ikke detekteres.

En relativt "lav" overvåkingsintensitet anbefales.

Fenoler/ klorfenoler, isoproturon og DEHP
Pentaklorfenol, nonylfenol og isoproturon var ikke detekterbare i sediment, blåskjell og torskelever. Di(2-etylhexyl)-ftalat (DEHP) var ikke detekterbar i sediment, og analytisk interferens hindret kvantifisering i blåskjell og torskelever.

En relativt "moderat" overvåkingsintensitet anbefales, bortsett fra for DEHP hvor en relativt "høy" overvåkingsintensitet anbefales.

Metaller
***Sølv** ble påvist i alle blåskjellprøvene men det var ingen tydelig forskjell mellom antatte forurensede områder (indre Oslofjord og indre Sørfjord) og i områder mer fjernt fra kjente forurensningskilder.*

*Gjennomsnittkonsentrasjonen av **arsen** (total) fra antatte mer forurensede områder (indre Oslofjord og indre Sørfjord) var mindre enn for antatte referanseområder. Dette kan tyde på en forurensning av overflatevann fra tilstøtende områder.*

***Krom** ble bare påvist i blåskjell og det var ingen tydelig forskjell mellom antatte forurensede områder og antatte referanseområder.*

*For **nikkel** var det ingen tydelig forskjell mellom antatte forurensede områder og antatte referanseområder.*

En relativt "høy" overvåkingsintensitet anbefales for sølv, mens en "moderat" overvåkingsintensitet anbefales for arsen, krom og nikkel.

1. Introduction

1.1 Background and purpose

The purpose of this national screening survey is to obtain an overview of the occurrence of selected contaminants relevant to the Water Framework Directive 2000/60/EC as noted by the daughter directive Environmental Quality Standard Directive 2008/105/EC, and to assess whether any warrant inclusion in routine monitoring.

Relevant Environmental Quality Standards (EQSs) can be used to assess concentrations found, however these are under development where monitoring in sediment and biota is concerned[1]. EU's Chemical Monitoring Activity (CMA) is part of a common implementation strategy under the Water Framework activity. CMA deals with information on appropriate analytical methods including measurements in sediment and biota. In addition to this, CMA will focus on establishing EQS for substances listed in the EQSD (i.e. 2008/105/EC) in these matrices by 2010. However, it is not clear as to whether all substances will be dealt with or how this process might effect development of EQS by Member States of EU, which they are entitled to do under Article 3 of the EQSD.

Some compounds, such as PFCs, have also been included in national screening surveys carried out during the period 2002 - 2007. The report should be of value as a guide for establishment of national and regional environmental monitoring programmes on prioritized contaminants.

1.2 Elements and compounds

A total of 56 metals and organic compounds covered in the screening survey (***Table 1***). In the following a brief overview is given on these compounds with focus on their potential as environmental risk factors and occurrence in air, wastewater treatment facilities and natural recipients. The structure of some of these compounds is presented (Annex 1).

[1] Exceptions are for mercury, hexachlorbenzene (HCB) and hexachlorbutadiene (HCBD) where EQS are defined for "prey tissue" (2008/105/EC).

Table 1. Overview of the compounds and metals investigated with notation as to which are listed in Environmental Quality Standard Directive – EQSD (2008/105/EC) as either priority substances (PS), including priority hazardous substances (PHS)[2], or other substances (OS) for which Environmental Quality Standards are specified, or substances under review as to be included as a priority substance (RS).

Compound	Abbreviation	CAS-no.[3]	EQSD substance no.
Brominated compounds			
2,4,4'-tribromodiphenylether	BDE28	41318756	PHS
2,2',4,4'-tetrabromodiphenylether	BDE47	5436431	PHS
2,2',4,5'-tetrabromodiphenylether	BDE49	243982823	
2,3'4,4'-tetrabromodiphenylether	BDE66	187084615	
2,3',4',6-tetrabromodiphenylether	BDE71	189084626	
3,3',4,4'-tetrabromdiphenyleter	BDE77	93703481	
2,2',3,4,4'-pentabromodiphenylether	BDE85	182346210	
2,2',4,4',5-pentabromodiphenylether	BDE99	60348609	PHS
2,2',4,4',6-pentabromodiphenylether	BDE100	189084648	PHS
2,3',4,4',6-pentabromodiphenylether	BDE119	189084660	
2,2',3,4,4',5'-hexabromodiphenylether	BDE138	182677301	
2,2',4,4',5,5'-hexabromodiphenylether	BDE153	68631492	PHS
2,2',4,4',5,6'-hexabromodiphenylether	BDE154	207122154	PHS
2,2',3,4,4',5',6-heptabromdiphenyleter	BDE183	68928803	
2,2′,3,3′,4,4′,5,6′-octabromodiphenylether	BDE196	32536520	
2,2′,3,3′,4,4′,5,5′,6-nonabromodiphenylether	BDE206		
2,2′,3,3′,4,4′,5,5′,6,6′-decabromodiphenylether	BDE209	1163195	
α-, β-, and γ-hexabromcyclododecane	HBCDD	25637994	
bis-1,2(2,4,6-tribromphenoxy)ethane	BTBPE		
Dimethyltetrabrombisphenol A	TBBPA	79947	
Perfluorinated organic compounds			
perfluorobutane sulfonate	PFBS	29420493	
perflurorohеptanoic acid	PFHPA	375859	
perflurorohexanoic acid	PFHXA	307244	
Perfluorononanoic acid	PFNA	375951	
perfluoroctanoic acid (PFOA)	PFOA	335671	
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	4151502	
perfluorooctanyl sulphonic acid (perfluoroctanoic sulfonate, perfluorooctane sulfonate)	PFOS	1763231	RS
Organochlorines			
trichloroethylene (TRI)	TRI	79016	OS
Tetrachloroethylene (=perchloroethylene)	TET	127184	OS
Alachlor	ALA	15972608	PS
Endosulfan	ENDOA	115297	PHS

[2] The Water Framework Directive (2000/60/EC, article 1) requires progressive reduction of discharges, emissions and losses of Priority Substances (PS), whereas for Priority Hazardous Substances, the requirement is a cessation or phasing-out of discharges, emissions and losses, with the ultimate aim of achieving concentrations in the marine environment near background values for naturally occurring substances and close to zero for man-made synthetic substances.

[3] For some compounds CAS-no. were not available.

Compound	Abbreviation	CAS-no.[3]	EQSD substance no.
	ENDOB		
1,2,3-trichlorobenzene	TRCB0	87616	PS
1,2,4-trichlorobenzene	TRCB1	120821	PS
1,3,5-trichlorobenzene	TRCB2	108703	PS
Hexachlorobutadiene	HCBD	87683	PHS
4-chlor-a-(4-chlorphenyl)-a-(trichlormethyl)-benzenmethanol,	DICOFOL	3380345	RS
Cyclodienes			
Aldrin	ALD	309002	OS
Dieldrin	DIELD	60571	OS
Endrin	END	72208	OS
Isodrin*	ISOD	465736	OS
Phenols/ chlorophenols			
Pentachlorophenol (PCP)	PCP	87865	PS
octylphenol (4-(1.1,3,3-tetramethylbutyl)-phenol)	OCP	140669	PS
Nonylphenol (4-Nonylphenol)	NOP	104405	PHS
Isoproturon			
Isoproturon	ISO	34123596	PS
Phthalate			
Di(2-ethylhexyl)-phthalate	DEHP	117817	PS
Metals			
Silver	Ag	7440224, 7783906, 7785231, 7761888	
Arsenic	As		
Chromium	Cr		
Nickel	Ni	7440020	PS

[1] For some compounds CAS-no. were not available

1.2.1 Brominated compounds

Brominated flame retardants (BFR) comprise a diverse group consisting of about 70 brominated compounds. Some are no longer produced, such as the polybrominated biphenyls (PBBs). Of the currently used BFRs, those of importance are tetrabromobisphenol A (TBBPA, ***Figure 1***), decabrominated diphenyl ether (Deca-BDE; ***Table 1***) and hexabromocyclododecane (HBCDD). These compounds are used in plastics, textiles, electronic circuitry, insulation materials and other materials to increase fire safety.

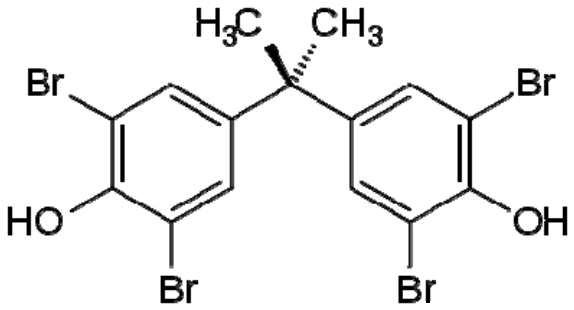

Figure 1. Dimethyltetrabrombisphenol A (TBBPA).

Polybrominated diphenylethers

Polybrominated diphenylethers (PBDEs) are a group of compounds that enter into the collective term "brominated flame retardants". Under strong heat influence, brome radicals are released from the PBDEs to stop the chain reaction in the combustion process. Common PBDEs are listed in ***Table 1***. The commercial available decaBDE product accounts for the bulk of the world market. The presence of PBDEs has been demonstrated in many environmental samples, including blubber of whales that preys in the deep sea, indicating this group of chemicals as global pollutants (de Boer *et al*. 1998; Lindström *et al*. 1999). Under anaerobic conditions DecaBDE can degrade to BDE congeners with fewer bromines (Gerecke *et al.* 2005).

Hexabromocyclododecane (HBCDD)

Hexabromocyclododecane has become one of the most used BFRs worldwide. It is the most used flameretardant both in Norway and globally (SFT 2009). This compound is primarily applied to expanded polystyrene (EPS) boards for thermal insulation of buildings and urban infrastructure. HBCDD is, however, also used in furniture, and electrical and electronic equipment. Most commercial HBCDD mixtures are dominated by the three diastereomers, α-, β- and γ-HBCDD (Becher, 2005). Other diastereomers isolated from the technical product have contributed to less than 1 % (Heeb *et al.* 2005; Law *et al.* 2005). Since HBCDD is an additive flame retardant, it is likely to leach out of the polymer product after incorporation. At present, HBCDD is known to be distributed over the entire northern hemisphere, where aquatic environments are the most heavily polluted (Law et al. 2006, 2008; Muir *et al.* 2006).

HBCDD is recalcitrant against degradation and has shown potential for biomagnification in marine food webs (Law *et al.* 2006). The importance of atmospheric long-range transport of HBCDD to the Arctic was confirmed by air concentrations over Svalbard that are only slightly lower than in southern Norway (OSPAR 2009). Recent studies in the Norwegian Arctic (OSPAR Region I) found HBCDD throughout the marine environment (OSPAR 2009).

The regulation of brominated flame retardants has not been uniform, with some substances more stringently regulated than others. Octa- and penta- BDEs have been banned and their release will more or less cease by 2020 (OSPAR 2009). However, others, such as decaBDE and HBCDD need more regulation, although voluntary action by industry has reduced releases from point sources to a significant extent. Over the period 2000 to 2005, PBDEs and

HBCDD were found in all components of the marine ecosystems in OSPAR Regions I, II, III and IV (OSPAR 2009).

In Norway penta-, octa- , and deca- PBDs are prohibited and HBCDD is regulated (SFT 2009). Penta- BDE is suggested as the most dangerous. It is very persistant, it bioaccumulates. Long exposure to penta-BDE has been classified as a risk to human health and the environment. Octa-BDE is classified as a risk to reproduction and prenatal development. Deca-BDE can cause neurological damage and it bioaccumulates. It can also degenerate to other toxic congeners, such as octa-BDE. Besides being persistant and bioaccumulative HBCDD is very toxic to aquatic organisms. TBBPA is classified as environmentally dangerous. Use of HBCDD and TBBPA has increased as a result of penta- and octa-BDEs regulation.

Bis-1,2(2,4,6-tribromphenoxy)ethane (BTBPE)

BTBPE is a common flame retardant used for plastics that require high manufacturing temperatures and UV light stability. The possibility exists that it could be leached from waste plastic and enter the environment, as has been observed with other flame retardants, although environmental levels have not been yet reported. The water solubility of BTBPE is very low, therefore, it would be expected to persist and be bioaccumulative (cf. Hakk *et al.* 2004).

1.2.2 Perfluorinated organic compounds

Perfluorinated organic compounds (PFC) are a group of compounds that contain a fully fluorinated alkyl chain and a group that render the compounds slightly water soluble. These compounds are neither lipophilic nor hydrophilic, but have an affinity for particle surfaces. The PFCs are used primarily for their surfactant properties and their water- and lipidrepellent properties. These compounds have been used in a number of applications, including surface treatment for carpets, leather and textiles and water repellents for paper. Specialised applications include polymers (e.g. Teflon™), fire extinguishers and oil well surfactants, while common household applications include polishers, dental cleaners, photographic film, shampoo, pesticides and adhesives. The most commonly used PFC is perfluoroctane sulfonic acid (PFOS), of which several thousand tons have been produced for surface treatment only (textile/carpet and paper). This chemical has been produced over the last 50 years. Common PFCs are listed in ***Table 1***.

Perfluorinated organic 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 (PFAS, PFCA), but sulphonates (FTS) and the more volatile compound groups, fluorotelomer alcohols (FTOH), are also studied.

Of the recent measures that OSPAR has promoted, the phase out of the main uses of perfluorooctane sulphonates as water and oil repellents in consumer products such as textiles and carpets and in fire fighting foams is included (OSPAR 2009). The phase-out of eleven individual priority chemicals is well underway in the OSPAR area. These chemicals include non-

ylphenol (below) and the two brominated flame retardants, penta- and octabrominated diphenyl ethers (BDEs; above; OSPAR 2009).

Pursuant to the SFT review material-flow (SFT 2004) there is no production of PFCs in Norway. Therefore what is marketed nationally is imported, and this is in the form of chemical-technical products or components in manufactured goods. The PFC PFOS degenerates very slowly and hence will persist in the environment once released. PFOS and related PCFs are known to accumulate up the food chain. PFOS is carcinogen and is toxic to aquatic organisms.

1.2.3 Organochlorines

Trichloroethylene and tetrachloroethylene

Trichloroethylene and tetrachloroethylene are chlorinated hydrocarbons commonly used as an industrial solvent for organic materials, particularly as a degreaser for metal parts. Both are clear non-flammable liquids and both have been used as dry cleaning solvents, although trichloroethylene was generally replaced in the 1950s by tetrachloroethylene (also known as perchloroethylene).

When inhaled, both substances produce central nervous system depression. Trichloroethylene has been used as a general anaesthesia. Higher concentrations of trichloroethylene result in tachypnea. Many types of cardiac arrhythmias can occur and are exacerbated by epinephrine (adrenaline). Cranial nerve dysfunction was not uncommon when trichloroehtylene anaesthesia was used. These nerve deficits could last for months. Occasionally facial numbness was permanent. Problems with hepatotoxicity have also been noted. Trichloroethylene was generally replaced by more potent anaesthetics in North America and Europe by the 1960s. Tetrachloroethylene has been classified by the International Agency for Research on Cancer as probably carcinogenic to humans (IARC 2007).

Concentrations of trichloroethylene are probably most influenced by local sources, but contamination due to atmospheric long-range transport can not be disregarded. The carcinogenic characteristics of this substance and its persistence in the environment are a danger to aquatic organisms (*Source: SFT 2009*).

Alachlor

Alachlor is an herbicide that is mainly used to control annual grasses and broadleaf weeds in corn (maize), soybeans, and peanuts. The United States Environmental Protection Agency classifies the herbicide as toxicity class III - slightly toxic. The EPA has described the following effects when exposed to levels above the maximum contaminant level (MCL): slight skin and eye irritation; at lifetime exposure to levels above the MCL: potential damage to liver, kidney, spleen; lining of nose and eyelids; cancer. Since 2006, use of alachlor as a herbicide is banned in the European Union.

Endosulfan

Endosulfan is an organochlorine compound that is used as an insecticide and acaricide. This colourless solid has emerged as a highly controversial agrichemical due to its acute toxicity, potential for bioaccumulation, and role as an endocrine disruptor. Banned in more than 50 countries, including the European Union and several Asian and West African nations, it is still used extensively in many other countries including India, Brazil and Australia.

Endosulfan is one of the more toxic pesticides on the market today, responsible for many fatal pesticide poisoning incidents around the world. Endosulfan is also a xenoestrogen—a synthetic substance that imitates or enhances the effect of estrogens - and it can act as an endocrine disruptor, causing reproductive and developmental damage in both animals and humans. Whether endosulfan can cause cancer is debated.

Trichlorobenzene

Trichlorobenzenes are organic compounds used as solvents, and 1,2,4-Trichlorobenzene is one of the best known solvents used to dissolve fullerenes and pentacene (*Source: Wikipedia*). The substances are acutely toxic for aquatic organisms. The substance is persistent and bioaccumulates in the environment. No sources are known in Norway (*Source: SFT 2009*).

Hexachlorobutadiene (HCBD)

HCBD has niche applications but is most commonly used as a solvent for other chlorine-containing compounds (Rossberg et al. 2006, Marshall 2003).

Hexachlorobutadiene has been observed to produce systemic toxicity following exposure via oral, inhalation, and dermal routes. Effects may include fatty liver degeneration, epithelial necrotizing nephritis, central nervous system depression and cyanosis (ATSDR 1994).

The carcinogenicity of Hexachlorobutadiene has been classified by the United States Environmental Protection Agency (USEPA 1991) has classified hexachlorobutadiene as a group C Possible Human Carcinogen. The American Conference of Governmental and Industrial Hygienists has classified Hexachlorobutadiene as an A3 Confirmed Animal Carcinogen with Unknown Relevance to Humans (ACGIH 2001).

Dicofol

Dicofol is an organochlorine pesticide that is chemically related to DDT. Dicofol is a miticide that is very effective against red spider mite.

One of the intermediates used in its production is DDT. This has caused criticism by many environmentalists; however. The World Health Organization classifies dicofol as a Level III, or "slightly hazardous" pesticide. It is known to be harmful to aquatic animals, and can cause eggshell thinning in various species of birds.

It is classified by the World Health Organisation as a Class III, 'slightly hazardous' pesticide. The US EPA has classified dicofol as a Group C, possible human carcinogen.

1.2.4 Cyclodienes

Collectively, the pesticides derived from hexachlorocyclopentadiene are called the cyclodienes. The cyclodiene insecticides aldrin, endrin, dieldrin and isodrin are discussed here.

Aldrin is an organochlorine insecticide that was widely used until 1970s when it was banned in most countries. This colourless solid was heavily used as a pesticide to treat seed and soil. Aldrin and related "cyclodiene" pesticides became notorious as persistent organic pollutants.

Endrin is an organochloride that was primarily used as an insecticide. It is a colourless, odorless solid, although commercial samples are often off-white. It is also a rodenticide. This compound became infamous as persistent organic pollutant and for this reason is banned in many countries (Metcalf 2002).

Dieldrin is a chlorinated hydrocarbon originally developed in the 1940s as an alternative to DDT, dieldrin proved to be a highly effective insecticide and was very widely used during the 1950s to early 1970s. The molecule has a ring structure based on naphthalene. Endrin is a stereoisomer of dieldrin.

However, it is an extremely persistent organic pollutant, it does not easily break down. Furthermore it tends to biomagnify as it is passed along the food chain. Long-term exposure has proven toxic to a very wide range of animals including humans, far greater than to the original insect targets. For this reason it is now banned in most of the world.

It has been linked to health problems such as Parkinson's, Breast Cancer, and immune, reproductive, and nervous system damage. It can also adversely affect testicular descent in the fetus if a pregnant woman is exposed to dieldrin.

Isodrin is also an insecticide and can be found on a list of extremely hazardous substances in the United States[4].

1.2.5 Pentachlorophenol, octylphenol and nonylphenol

Many produced waters from oil production facilities contain high concentrations of phenol and alkyl phenols (Neff 2002). Sewage discharges are another source of alkylphenols. Furthermore, nonylphenol has been used for the production of nonionic surfactants (nonylphenol ethoxylates, NPE) and, to a lesser degree, for the synthesis of NP phosphates, which have been used as stabilisers and antioxidants in the rubber and plastic industries (Granmo *et al.* 1989). Nonylphenol ethoxylates are degraded to nonylphenol in waste water treatment plants. Surfactants containing nonylphenol have been synthetic organic chemicals used in high volumes in commercial detergent and household cleaning products (Lewis 1992). These have also been used as oil dispersants and adjuvants in pesticide formulations (Lewis 1991, 1992).

[4] As defined in Section 302 of the U.S. Emergency Planning and Community Right-to-Know Act (42 U.S.C. 11002). The list can be found as an appendix to 40 C.F.R. 355.

Pentachlorophenol (PCP) is an organochlorine compound. First produced in the 1930s and can be found in two forms: PCP itself or as the sodium salt of PCP, which dissolves easily in water. In the past, it has been used as a herbicide, insecticide, fungicide, algaecide, disinfectant and as an ingredient in antifouling paint (USEPA 2006). It is used as a wood preserver.

Short-term exposure to large amounts of PCP can cause harmful effects on the liver, kidneys, blood, lungs, nervous system (USEPA 2006), immune system, and gastrointestinal tract. Contact with PCP (particularly in the form of vapour) can irritate the skin, eyes and mouth. Long-term exposure to low levels such as those that occur in the workplace can cause damage to the liver, kidneys, blood and nervous system (USEPA 2006). Finally exposure to PCP is also associated with carcinogenic, renal and neurological effects. The U.S. Environmental Protection Agency Toxicity Class classifies PCP in group B2 (probable human carcinogen).

Pentachlorophenol is persistent and bioaccumulates in the environment. Also, atmospheric long-range transport of the substance can be a source of contamination in Norway (SFT 2009).

Octylphenols and **nonylphenols** are considered very toxic on aquatic organisms (SFT 2009). These and some other highly alkylated phenols have shown estrogenic properties (Neff, 2002 and references within). There is thus an environmental concern regarding the contamination of aquatic environments. Environmental estrogens are chemicals with biological activity that mimics the natural female hormone estrogen. These type of chemicals are usually divided into three groups, ‘estrogen mimics’, ‘androgen mimics’ and ‘anti-androgens’. Octylphenol and nonylphenol are characterized as ‘estrogen mimics’.

Binding of octylphenol or nonylphenol to the estrogen receptor in fish elicts several biochemical responses (octylphenols are 10 to 20-fold more potent than nonylphenols), including the synthesis of egg yolk protein in the liver of fish. The synthesis of vitellogenin is a process normally dependent on endogenous estrogens. Vitellogenin is taken up by growing oocytes and stored as yolk to serve as food for growing embryos.

1.2.6 Isoproturon

Isoproturon is an herbicide used to protect cereal production in Europe against annual grasses and broadleaves. It is moderately toxic. It does not accumulate in mammals, where it is totally metabolised and excreted within three days.

In Norway, it has been prohibited to use since 2006. The substance is very toxic for aquatic organisms and moderately persistent. Levels found in the Norwegian environment are low, but data is very limited (Økland *et al.* 2005).

1.2.7 Di(2-ethylhexyl)phthalate (DEHP)

Di(2-ethylhexyl)phthalate, commonly abbreviated DEHP, is an organic compound and the most important "phthalate," being the diester of phthalic acid and the branched-chain 2-ethylhexanol. This colourless viscous liquid is soluble in oil, but not in water. It possesses good plasticizing properties. It is known as an endrocrin disrupter.

DEHP is one of the most common phtahlates in use, it is teratogenic, a reproductive effector, it is on the list of endocrine disruptors and it is persistent. Phthalates have been banned in products for small children (Økland *et al.* 2005). It degrades relatively quickly in water but much slower in sediment and it bioaccumulates in organisms. DEHP degrades quicker in fish compared to crustaceans (SFT 2009).

1.2.8 Silver

Silver and silver salts have a wide range of applications. It does not corrode in air.

Silver is commonly used in electrical and electronic products, including batteries. It is also used in dental alloys, e.g. with mercury. Silver containing compounds are further used as a bacteriocide, e.g. in flamazin lotion used to prevent infections of complex burns. Recently this ability has been utilised in production of e.g. fridges, washing machines, cosmetics, and clothing to prevent bacterial growth. Earlier one of the most common use of silver salts was in photographic films and papers, but this use is declining.

The increased number of nanomaterial based consumer products raises concerns regarding their eventual impact on the environment. Nanowash washing machines are e.g. products that release silver nanoparticles.

Metallic silver and insoluble silver compounds appear to pose minimal risk to human health (WHO, 1977; Drake & Hazelwood, 2005). Silver in any form is not thought to be toxic to the immune, cardiovascular, nervous or reproductive systems, and there is no scientific evidence of silver to be carcinogenic (Drake & Hazelwood, 2005). The most prominent effect of prolonged ingestion, inhalation or dermal absorption of silver is discoloration of skin and eyes.

Silver in its ionic form is highly toxic to aquatic bacteria, animals and plants (WHO, 2002). Some acute toxicity data on mammals is available (WHO, 1977, WHO, 2002). Freshwater fish and amphibians are the most sensitive vertebrates to dissolved silver.

1.2.9 Arsenic

Arsenic and its compounds are used as pesticides, herbicides, insecticides and in various alloys. Although arsenic is sometimes found native in nature, but mainly in the mineral arsenopyrite and also found in arsenides of metals such as silver, cobalt, and nickel. In addition to the inorganic forms mentioned above, arsenic also occurs in various organic forms in the environment. Naturally occurring pathways of exposure include volcanic ash, weathering of the arsenic-containing mineral and ores as well as groundwater. It is also found in food, water, soil and air.

Inorganic arsenic and its compounds, upon entering the food chain, are progressively metabolised to less toxic forms of arsenic through a process of methylation. Some organic forms are found in some marine foods such as fish and algae.

Arsenobetaine (a naturally occurring arcenic species) has been detected in a range of marine animals and is considered as the major arsenic species in marine animals, including fish (Amlund et al. 2006 and references therein). It is a water-soluble compound and is generally regarded as non-toxic to vertebrates (Amlund et al. 2006 and references therein).

Atmospheric long-range transport of arsenic can be a source of contamination in Norway. It is very toxic to aquatic organisms (SFT 2009).

1.2.10 Chromium

Chromium was regarded with great interest because of its high corrosion resistance and hardness. A major development was the discovery that steel could be made highly resistant to corrosion and discoloration by adding chromium and nickel to form stainless steel. This application, along with chrome plating (electroplating with chromium) is currently the highest-volume uses of the metal.

Although trivalent chromium (Cr(III)) is required in trace amounts for sugar and lipid metabolism in humans and its deficiency may cause a disease called chromium deficiency, hexavalent chromium (Cr(VI)) is toxic and carcinogenic. As chromium compounds were used in dyes and paints and the tanning of leather, these compounds are often found in soil and groundwater at abandoned industrial sites, now needing environmental cleanup and remediation per the treatment of brownfield land. Primer paint containing hexavalent chromium is still widely used for aerospace and automobile refinishing applications.

1.2.11 Nickel

The metal is corrosion-resistant, finding many uses in alloys, as a plating, in the manufacture of coins, magnets and common household utensils, as a catalyst for hydrogenation, and in a variety of other applications. Enzymes of certain life-forms contain nickel as an active center making the metal essential for them. Nickel sulfide fume and dust is believed to be carcinogenic, and various other nickel compounds may be as well (Dunnick, 1995, Kasprzak, 2003).

The source of some background information on specific contaminants above (trichloroethylene, tetrachloroethylene, alachlor, endosulfan, HCBD, dicofol, cyclodienes, PCP, isoproturon, DEHP, As, Cr, Ni) was *Wikipedia*.

2. Materials and methods

2.1 Description of sampling sites

The screening survey covered 20 CEMP sites for sampling of sediment (6), blue mussel (9) and cod (5) (**Figure 2**, **Table 2**, **Table 3, Table 4** and **Table 5**). All the blue mussel and cod samples were collected in 2008 and the sediment samples were collected during the period 2004 - 2008). A wider description of the station selection is given in Chapter 2.1. Concentrations of PBDEs and PFCs were investigated in additional cod from stations 30B, 53B and 67B as routine of CEMP, but only some of these results are presented here.

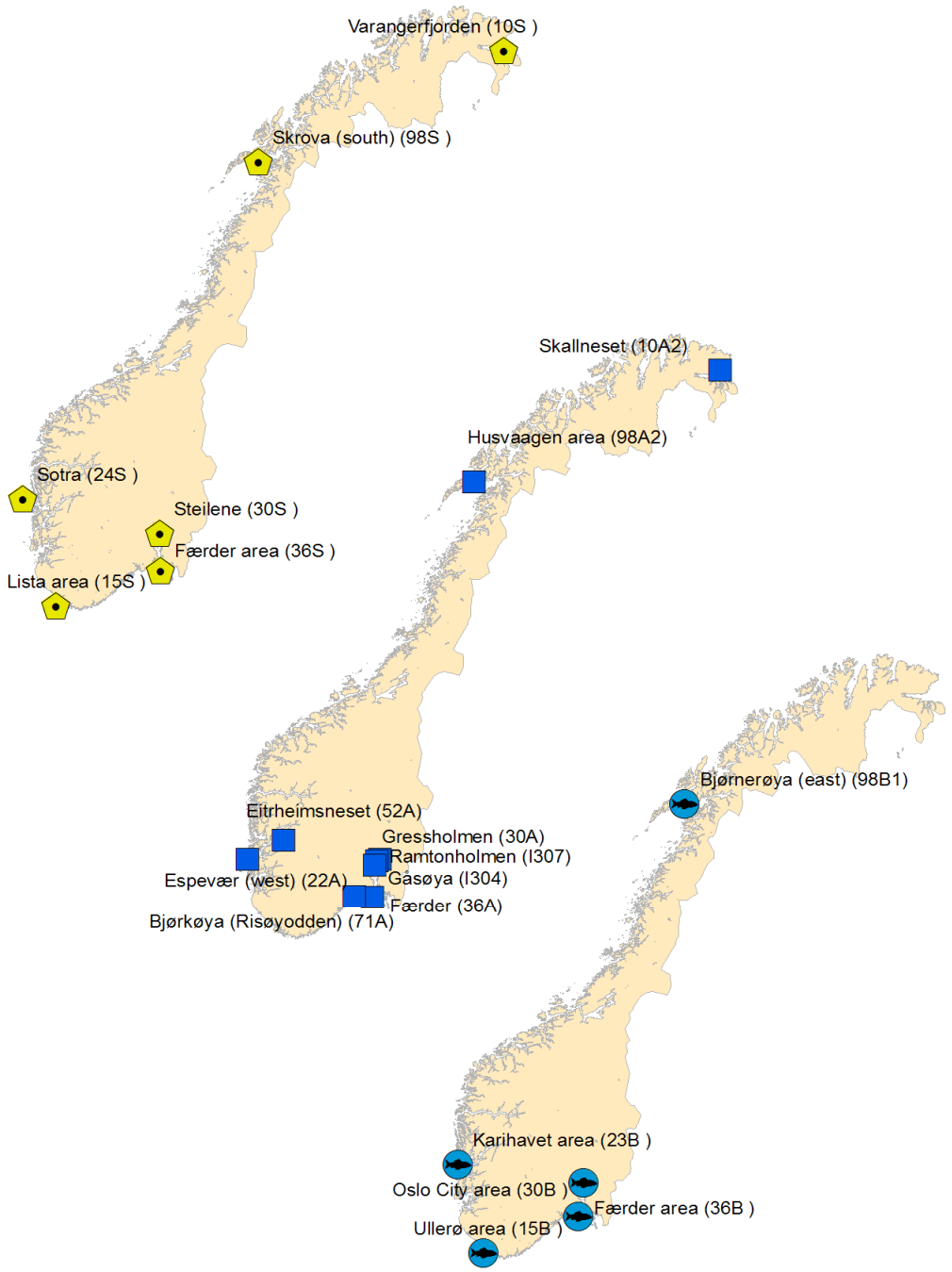

*Figure 2. Map of sampling sites for sediment (yellow pentagon), blue mussel (dark blue square), and cod (light blue circle) (see also **Table 2, Table 3, Table 4 and Table 5**).*

*Table 2. Overview of sample location, matrix and count (N) (see also **Figure 2**). Samples were collected in 2008 with noted exceptions.*

Site/Map ID	Area	Area specification	Latitude°	Longitude°	Matrix	N
30S	Inner Oslofjord	Steilene	59° 49.1	10° 33.8	Sediment	2
36S	Outer Oslofjord	Færder area	59° 0.4	10° 41.6	Sediment	1
15S	South Norway	Lista area	58° 1	6° 34.3	Sediment	2
24S	West Norway	Sotra	60° 15.1	4° 33.3	Sediment	1*
98S	Lofoten	Skrova (south)	68° 7	14° 41	Sediment	2*
10S	North Norway	Varangerfjorden	69° 56.07	30° 6.7	Sediment	2**
30A	Inner Oslofjord	Gressholmen	59° 52.89	10° 42.71	Blue mussel	1
I304	Inner Oslofjord	Gåsøya	59° 51.08	10° 35.34	Blue mussel	1
I307	Inner Oslofjord	Ramtonholmen	59° 44.67	10° 31.37	Blue mussel	1
36A	Outer Oslofjord	Færder	59° 1.63	10° 31.53	Blue mussel	1
71A	South Norway	Bjørkøya	59° 1.4	9° 45.22	Blue mussel	1
52A	Sørfjord	Eitrheimsneset	60° 5.8	6° 31.97	Blue mussel	1
22A	West Norway	Espevær (west)	59° 35.05	5° 8.63	Blue mussel	1
98A2	Lofoten	Husvaagen area	68° 15.46	14° 39.83	Blue mussel	1
10A2	Varangerfjord	Skallneset	70° 6.21	30° 15.75	Blue mussel	1
30B	Inner Oslofjord	Oslo City area	59° 47.96	10° 33.6	Cod	5
36B	Outer Oslofjord	Færder area	59° 2.43	10° 26.15	Cod	5
15B	South Norway	Ullerø area	58° 3	6° 43	Cod	5
23B	West Norway	Karihavet area	59° 54	5° 8	Cod	5
98B1	Lofoten	Bjørnerøya (east)	68° 14.8	14° 48.2	Cod	5

*) 2004.
**) 2006.

Most of the samples were taken in areas remote from known point source of pollution and can be considered reference stations. The exceptions were stations in the inner Oslofjord and in the inner Sørfjord (indicated in ***Table 2***).

Table 3. Marine sediments analysed, sample count (N), sampler used (Gemini twin corer – GC or Van Veen grab GS) and some supporting parameters.

Station	Date	Depth (m)	Layer (cm)	N	Instrument	Grain size <63µ (%)	Dry wt. (%)	Carbon content wt. (o/oo)
Sediment								
Inner Oslofjord	13.11.08	128	0-2	2	Gemini corer	95-96	34-36.4	26.6-27.3
Outer Oslofjord	13.11.08	133	0-2	1	Grab sampler	86	60.4	17.0
South Norway, Lista	13.11.08	367	0-2	2	Grab sampler	60-66	47.1-50.5	12.5
West Norway, Sotra	07.10.04	288	0-2	1	Grab sampler	34	51.3	9.2
Lofoten	24.08.04	325	0-2	2	Gemini corer	82-83	45.4-45.8	6.3-6.5
North Norway, Varangerfjord	07.09.06	414	0-2	2	Gemini corer	95-97	31-32	22.2-23.1

*Table 4. Blue mussel (*Mytilus edulis*) analysed, sample count (N) and some supporting parameters.*

Station	Station no. (CEMP)	Date	N	Number mussels in bulk	Shell-size (mm) (min-max)	Dry wt. (%)	Fat wt. (%)
Inner Oslofjord, Gressholmen	30A	01.10.08	1	50	40-49	16.0	1.1
Inner Oslofjord, Gåsøya	I304	01.10.08	1	20	32-49	15.0	1.6
Inner Oslofjord, Ramtonholmen	I307	01.10.08	1	20	35-48	13.0	1.2
Outer Oslofjord, Færder	36A	29.10.08	1	50	40-49	18.0	1.6
South Norway, Bjørkøya	71A	28.10.08	1	50	40-49	17.0	1.6
Sørfjord, Eitrheimsneset	52A	01.09.08	1	50	40-49	15.0	1.6
West Norway, Espevær (west)	22A	05.09.08	1	50	40-49	17.0	1.3
Lofoten. Husvaagen area	98A2	22.09.08	1	50	40-49	17.0	1.5
Varangerfjord, Skallneset	10A2	01.10.08	1	100	20-39	17.0	1.7

*Table 5. Atlantic cod (*Gadus morhua*) analysed, sample count (N), and some supporting parameters. Concentrations of PBDEs and PFCs were investigated in additional cod from stations 30B, 53B and 67B as routine of CEMP (statistics not shown below).*

Main area	Station no. (CEMP)	Date	Fish length (cm) (min- max)	Fish weight (g) (min- max)	N
Oslo City area	30B	24.10.06	50 - 68	1201 – 2769	5
Outer Oslofjord, Færder area	36B	24.10.06	50.5 – 86	1375 – 5200	5
South Norway, Ullerø area	15B	24.10.06	43.5 – 49	897 – 1338	5
West Norway, Karihavet area	23B	24.10.06	56 – 74	1891 – 3994	5
Lofoten, Bjørnerøya (east)	98B1	16.09.06	50 – 58	1376 – 2323	5

2.2 Sampling and sample treatment

All samples were derived from the Coordinated Environmental Monitoring Programme (CEMP), and OSPAR guidelines (1997) were used for collecting and pre-treating CEMP samples prior to analyses.

Surface sediment (0-2 cm) was collected either using a Gemini corer or Van Veen Grab. Blue mussel was collected and either frozen directly (stations I304 and I307) and later chucked or depurated and chucked before freezing. Cod was collected by local fishermen and liver samples were either collected from fresh specimens (station 30B) or from fish that had been frozen directly after catch. The samples were stored frozen prior til analysis.

2.3 Chemical analyses

Because of the limited materials available and limitations of chemical analysis (interference) not all samples were analysed for all elements/ compounds (***Table 6***).

Table 6. Overview of sample count for the element and compound groups analysed in the different sample matrix.

Analysis	Sediment	Blue mussel	Cod liver
Brominated compounds			
PBDE	10	9	24
Hexabromcyclododecane (HBCDD)	8	9	25
Bis-1,2(2,4,6-tribromphenoxy)ethane	8	9	25
Dimethyltetrabrombisphenol A (TBBPA)	10	9	14
Perfluorinated organic compounds	10	9	25
Organochlorines			
Trichloroethylene	0	9	25
Tetrachloroethylene	0	0	0
Alachlor, endosulfan	10	9	25
Trichlorobenzene	8	9	25
Hexachlorobutadiene (HCBD)	8	9	25
Dicofol	5	9	17
Cyclodienes	8	9	25
Phenols/ chlorophenols			
Pentachlorophenol	5	9	17
Octyphenol	0	0	0
Nonylphenol	5	9	15
Isoproturon	8	9	25
DEHP	8	0	0
Metals			
Silver, nickel	0	9	0
Arsenic, Chromium	0	9	25

2.3.1 Brominated compounds

Extraction

Cod liver
Approximately 0.5 g of homogenised liver was extracted with a mixture of isopropanol and pentane, and the pentane extract was divided in to two different fractions (1 and 2) for clean-up.

Blue mussel
Approximately 10 g of homogenised mussels was extracted with a mixture of isopropanol and pentane, and the pentane extract was divided in to two different fractions (1 and 2) for clean up.

Sediments
Depending on material available 1-20 g of homogenised sediment was extracted with a mixture of dichloromethane (DCM) and methanol. The dichloromethane was divided in to two different fractions (1 and 2) for clean up. BDE-compounds and bis-1,2(2,4,6-tribromphenoxy)ethane were extracted separately with DCM/cyclohexane.

Internal standards used
PCB 204, alachlor d13, endosulfan d4, dicofol d8, pentachlorphenol C_{13}, isoprutoron d3, 4-ter-octylphenol d2, 1,2,4-trichlorobenzene d3, bromotrichloromethane, BDE-30, BDE-181, α,β and γ-HBCDD C_{13}.

Clean-up and analysis

Cod and blue mussel
Fraction 1: The fraction was cleaned up several times with sulphuric acid. Trichloroethene and tetrachloroetene were analysed on a GC-ECD. BDE-compounds and bis-1,2(2,4,6-tribromphenoxy)ethane were analysed on a GC- MS -NICI.

Fraction 2: The fraction was cleaned up using gel permeation chromatography (GPC). This extract was again divided inn to two fractions (A and B). Fraction A went trough an extra clean-up using a silica column before the solvent was exchange to methanol:water and the extract was analysed on a LC-MS to determine α,β and γ-HBCDD (only bluemussel), TBBP-A and isoprutoron.

Fraction B was analysed using a GC-ToF-MS to determine endrine, dieldrine, isodrine, aldrine, alachlor, α -endosulfane, β-endosulphane, 1,2,3-trichlorobenzene, 1,2,4-trichlorobenzene, 1,3,5-trichlorobenzene and 1,3-hexachlorbutadiene.

The same extracts were afterwards derivatised with acetic anhydride before pentaklorfenol, tert-4-oktyl-fenol, 4-nonylfenol and dicofol were analysed on GC-MS-EI-SIM.

Sediment
Fraction 1 was cleaned up using gel permeation chromatography (GPC). This extract was divided into two fractions (A and B). In fraction A the solvent was changed to methanol; water and the extract was analysed on a LC-MS to determine α, β and γ-HBCDD, TBBP-A and isoprutoron.

Fraction B was analysed using a GC-MS-TOF to determine endrin, dieldrin, isodrin, aldrin, alachlor, α -endosulfan, β-endosulfan, 1,2,3-trichlorobenzene, 1,2,4-trichlorobenzene, 1,3,5-trichlorobenzene and 1,3-hexachlorobutadiene. Afterwards the same extract was derivatisated with acetic anhydride before pentachlorophenol, tert-4-octyl-phenol, 4-nonylphenol and dicofol were analysed on GC-MS-EI-SIM.

Fraction 2 was cleaned up using silica coloumn before DEHP was determined using a GC-ToF-MS. BDE-compounds and bis-1,2(2,4,6-tribromphenoxy)ethane were analysed on a GC/MSD–NICI after sulphuric acid treatment of the extract.

Instrumentation
LC-MS: liquid chromatography – tandem mass spectrometry (LC/MS/MS) (Waters Aquity UPLC coupled to a Waters Quattro Premier mass spectrometer). Separation used an Aquity UPLC BEH C18 column (1.7 µm, 1 x 50 mm) with a flow rate of 0.6 ml min^{-1} and a column temperature of 60 ^{o}C and a gradient of water-methanol.

GC-MS-EI-SIM: Gas chromatography-mass spectrometry (HP 6890 Series coupled to HP 5973 MS). The MS was operated in Single Ion Monitoring mode. Analytes were analysed on Rtx-1416, 30 m x 0,25 mm, 0,10 µm film thickness.

GC-MS-NCI: Gas chromatography-mass spectrometry (HP 6890 Series coupled to HP 5973 MS). The MS was operated in Negative Chemical Ionization Singe Ion Monitoring mode. BD-5MS column (J&W Scientific, Agilent) (30 m x 0.25 m id x 0.10 µm film thickness).

GC-ToF-MS: Gas chromatography-time of flight-mass spectrometry (GCT, Waters, coupled to 6890 GC, Agilent). Analytes were separated on a BD-5MS column (J&W Scientific, Agilent) (60 m x 0.25 m id x 0.25 µm film thickness). The mass spectrometer had a source temperature of 180 ^{o}C and an electron energy of 70 eV, and was operating with a resolution of 8500.

GC-ECD: Gas chromatography- Electron capture Detector (HP 6890 Series, Agilent). Analytes were separated on a DB-5MS column (J&W Scientific, Agilent) (60 m x 0.25 m id x 0.25 µm film thickness).

2.3.2 Perfluorinated organic compounds

Sample preparation

Extraction
Cod and blue mussel
Wet material was added internal standard and extracted with a mixture of water, Na_2CO_3 and TBA. The samples were extracted with diethyl ether at pH=2. The ether extracts were transferred to methanol before the LC/MS-analysis.

Sediment
Wet material was added internal standard and extracted with a mixture of methanol, acetic acid and water. The samples were cleaned up using C18 cartridges before they were analysed on a LC-MS.

Internal standard used
^{2}H-perfluorheptanoic acid and ^{13}C-perfluornonanoic acid.

Analytical determination

Analysis of perfluorinated compounds were performed by LC coupled to mass spectrometry (LC/MS/MS). Separation on an Aquity UPLC BEH C18 column (1.7 µm, 2.1 mm id, 50 mm) with a C18 security column (4 x 2.0 mm) with a flow rate of 0.2 ml min^{-1} and a column temperature of 60°C. The mass spectrometer was operated in electro-spray-injector (ESI) negative mode using multiple reaction monitoring.

2.3.3 Organochlorines

See chapter 2.3.1.

2.3.4 Cyclodienes

See chapter 2.3.1.

2.3.5 Phenols/ chlorophenols

See chapter 2.3.1.

2.3.6 Isoproturon

See chapter 2.3.1.

2.3.7 DEHP

See chapter 2.3.1.

2.3.8 Silver, arsenic, chromium and nickel

Sample preparation

Blue mussel and cod liver samples were homogenized with a Silverson 4R Homogeniser was used.

Extraction

Extracts are made from 0.5 - 1.5 g wet sample in nitric acid in a Milestone MLS 1200 microwave oven.

Analytical determination

Determination of silver, arsenic, and nickel was performed by Inductively Coupled Plasma Mass Spectrometry (ICP-MS). An aerosol of sample is passed into a plasma of very high temperature. The resulting ions are extracted into a vacuum system via a pair of "cones". Electrostatic lenses focus the stream of ions into a chamber where the mass spectrometer and detector are housed. The masses are separated by a quadropole mass analyser and detected by an electron multiplier detector. The determination is done by using internal standards. Instrument: Perkin Elmer Elan 6000. The detection limit is largely determined by the purity of the blank-samples, and to a lesser degree by the amount of material weighed in.

Determination of chromium is by Inductively Coupled Atomic Emission Spectroscopy (ICP-AES). An aerosol of sample is passed into a plasma of very high temperature. The resulting atoms and ions are emitting radiation which is separated into their different wavelengths in a spectrometer. The light is detected using a Charged-Coupled Device (CCD) and converted into concentration. The determination is done by using internal standards and a Perkin Elmer 4300DV.

2.3.9 General remarks to chemical analyses

The Limit of Detection (LOD) of an analytical detection method is driven by the following factors:

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

In this study the amount of sample available was probably the most important limiting factor. All of the factors vary from matrix to matrix and also within the same matrix of samples. They may also enhance *interference (co-elution)*; where a peak on a chromatogram can not be sufficiently distinguished to quantify the substances they represent. A thorough evaluation of the measurement uncertainty requires laboratory intercalibration exercises for each analytical method and all measured sample 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 7***).

Table 7. A rough estimate on the analytical measurement uncertainty.

Compound group	Analytical measurement uncertainty in %
PBDEs	30
PFCs (ionics)	40
Organochlorines	40
Trichloroethylene	40
Tetrachloroethylene	-
Alachlor	50
Trichlorobenzene	30
HCBD	30
DICOFOL	30
Cyclodienes	-
Phenols/ chlorophenols	50
Isoproturon	60
DEHP	40
Ag	20
As	20
Cr	20
Ni	20

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 sediment can vary quite heavily the concentration unit is normally given based on the dry weight of the analysed sample (µg/kg d.w.). For biological material as fish or mussel samples with a more stabile water content the concentration is normally given on a wet weight base (µg/kg w.w.).

3. Results and discussion

3.1 Brominated compounds

Brominated compounds included 9 polybrominated diphenyl ethers (PBDE), 3 isomers of HBCDD, TBBPA and a so called "new" brominated compound bis-1,2(2,4,6-tribromphenoxy)ethane (BTBPE) were investigated in 8-10 sediment samples, 9 blue mussel samples and 14-25 cod liver samples (***Table 6***, ***Table 8***).

Of the 799 analyses of polybrominated diphenyl ethers (PBDE) 206 (26 %) were above the detection limit. The most dominant compounds in sediment were BDE congeners (in decreasing order of concentration): 209, 205, 47, and 183 (***Figure 3***). Whereas BDE99 was the most dominant in blue mussel. In cod liver samples the most dominant congeners were, in decreasing order: 47, 100, 49 and 154 (***Figure 4***). Dimethyltetrabrombisphenol A (TBBPA) was not detected in sediment samples and found in only one blue mussel sample. However, it was detected in nine of the 25 cod liver samples, and ranged from 5.8-70.9 µg/kg w.w. The range of these nine values was low judging from the limit of detection (LOD) for the other livers samples which ranged from 10 to 60 µg/kg w.w. HBCDD was not dectected in sediment and blue mussel, and was only detected in one sample of cod liver. Bis-1,2(2,4,6-tribromphenoxy)ethane (BTBPE) was not detected except for two sediment samples.

Table 8. Concentrations of brominated compounds in sediment (µg/kg d.w.), blue mussel and cod liver (µg/kg w.w.). Values above the detection limit are shaded. Samples that could not be quantified because of interference (F) are indicated. Limit of detection not included in sum of PBDE.

matrix	station	BDE28	BDE 47	BDE49	BDE66	BDE71	BDE77	BDE85	BDE99
sediment	Inner Oslofjord, core 1	<0.04	0.21	<0.04	<0.05	<0.05	<0.05	<0.08	0.2
sediment	Inner Oslofjord, core 3	<0.4	0.13	<0.04	<0.05	<0.04	<0.06	<0.05	0.13
sediment	Outer Oslofjord, core 7	<0.04	0.06	<0.04	<0.04	<0.04	<0.05	0.06	0.06
sediment	South Norway, Lista, core 14	<0.04	0.08	<0.04	<0.04	<0.04	<0.05	0.05	0.07
sediment	South Norway, Lista, core 15	<0.04	0.07	<0.04	<0.04	<0.04	<0.05	<0.04	<0.05
sediment	West Norway, Sotra, core 4	<0.04	<0.04	<0.04	<0.04	<0.04	<0.05	<0.04	<0.04
sediment	Lofoten, core 22	<0.04	<0.04	<0.04	<0.04	<0.04	<0.05	<0.04	<0.04
sediment	Lofoten, core 24	<0.04	<0.04	<0.04	<0.04	<0.04	<0.05	<0.04	<0.04
sediment	Varangerfjorden, core 28	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
sediment	Varangerfjorden, core 30	<0.2	0.29	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
blue mussel	Inner Oslofjord, Gresholmen	<0.03	0.25	<0.19	<0.03	F	<0.03	0.07	0.29
blue mussel	Inner Oslofjord, Gåsøya	<0.03	0.22	<0.08	<0.03	F	<0.03	<0.03	0.15
blue mussel	Inner Oslofjord, Ramtonholmen	<0.03	<0.03	<0.04	<0.04	F	<0.03	<0.03	0.04
blue mussel	Outer Oslofjord, Færder	<0.03	0.10	<0.16	<0.04	F	<0.03	0.04	0.13
blue mussel	South Norway, Bjørkøya	<0.03	0.19	<0.09	<0.03	F	<0.03	<0.03	0.16
blue mussel	Sørfjord, Eitrheimsneset	<0.04	0.37	<0.09	<0.03	F	<0.05	0.04	0.22
blue mussel	West Norway, Espevær (west)	<0.03	0.46	<0.08	<0.07	F	<0.09	0.06	0.14
blue mussel	Lofoten	<0.03	0.15	<0.09	<0.03	F	<0.03	<0.03	0.11
blue mussel	Varangerfjord	<0.03	0.03	<0.06	<0.03	F	<0.03	<0.03	0.03
cod liver	Inner Oslofjord, ind.no.7	1.6	99	5.0	0.91	<0.05	<0.1	<0.07	0.27
cod liver	Inner Oslofjord, ind.no.9	1.7	86	5.2	0.52	<0.1	<0.1	<0.08	0.76
cod liver	Inner Oslofjord, ind.no.10	0.64	47	2.5	0.26	<0.1	<0.1	0.23	2.3
cod liver	Inner Oslofjord, ind.no.13	1.1	88	6.6	1.6	<0.13	<0.15	<0.07	1.7
cod liver	Inner Oslofjord, ind.no.23	4.7	100	4.4	3.3	<0.2	<0.2	1.7	25
cod liver	Outer Oslofjord, ind.no.19	-	-	-	-	-	-	-	-
cod liver	Outer Oslofjord, ind.no.21	0.07	2.2	0.16	<0.05	<0.03	<0.05	<0.05	0.07
cod liver	Outer Oslofjord, ind.no.23	0.11	6	0.52	0.07	<0.04	<0.05	<0.05	0.09
cod liver	Outer Oslofjord, ind.no.24	0.11	7	0.31	0.06	<0.04	<0.05	<0.05	0.08
cod liver	Outer Oslofjord, ind.no.25	0.14	8	0.43	<0.05	<0.05	<0.05	<0.05	<0.05
cod liver	South Norway, Lista, ind.no.1	0.12	4.2	0.65	0.1	<0.04	<0.05	<0.05	0.23
cod liver	South Norway, Lista, ind.no.10	0.39	12	2.9	0.34	<0.09	<0.07	<0.06	0.22
cod liver	South Norway, Lista, ind.no.15	0.31	9.7	3	0.26	<0.09	<0.06	<0.05	0.23
cod liver	South Norway, Lista, ind.no.16	0.37	10	2	0.25	<0.08	<0.06	<0.05	0.12
cod liver	South Norway, Lista, ind.no.23	0.31	14	3.9	0.46	<0.16	<0.12	<0.06	0.39
cod liver	West Norway, Karihav, ind.no.9	0.21	3.8	1.1	<0.13	<0.09	<0.08	<0.09	0.20
cod liver	West Norway, Karihav, ind.no.12	0.15	3.6	0.58	<0.21	<0.1	<0.12	<0.11	0.16
cod liver	West Norway, Karihav, ind.no.14	0.14	2.1	0.44	<0.17	<0.08	<0.12	<0.09	0.18
cod liver	West Norway, Karihav, ind.no.15	0.07	1.4	0.13	<0.12	<0.05	<0.12	<0.07	0.1
cod liver	West Norway, Karihav, ind.no.17	0.45	10	1.7	0.24	<0.14	<0.17	<0.14	0.42
cod liver	Lofoten, ind.no.3	0.14	3.4	0.9	0.09	<0.07	<0.08	<0.06	0.1
cod liver	Lofoten, ind.no.10	0.12	3.7	1	0.12	<0.21	<0.14	<0.09	0.26
cod liver	Lofoten, ind.no.14	0.16	3.5	0.92	0.09	<0.05	<0.07	<0.05	0.17
cod liver	Lofoten, ind.no.17	0.1	1.9	0.47	<0.05	<0.04	<0.05	<0.05	0.07
cod liver	Lofoten, ind.no.22	0.1	2.6	0.69	0.07	<0.04	<0.08	<0.05	0.29

Table 8 cont.

matrix	station	BDE100	BDE 119	BDE138	BDE153	BDE154	BDE183	BDE196	BDE205
sediment	Inner Oslofjord, core 1	0.19	<0.13	<0.1	<0.05	<0.04	<0.1	<0.1	<0.1
sediment	Inner Oslofjord, core 3	0.09	<0.1	<0.1	<0.1	<0.04	0.21	<0.1	<0.1
sediment	Outer Oslofjord, core 7	<0.04	<0.1	<0.1	<0.04	<0.04	<0.1	<0.1	<0.1
sediment	South Norway, Lista, core 14	0.1	<0.1	<0.1	<0.04	<0.04	<0.1	<0.1	<0.1
sediment	South Norway, Lista, core 15	<0.06	<0.1	<0.1	<0.04	<0.04	<0.1	<0.1	<0.1
sediment	West Norway, Sotra, core 4	<0.04	<0.1	<0.1	<0.04	<0.04	<0.1	<0.1	<0.1
sediment	Lofoten, core 22	<0.04	<0.1	<0.1	<0.04	<0.04	<0.1	<0.1	<0.1
sediment	Lofoten, core 24	0.04	<0.1	<0.1	<0.04	<0.04	<0.1	<0.1	<0.1
sediment	Varangerfjorden, core 28	<0.1	<0.15	<0.1	<0.1	<0.1	<0.2	<0.2	<0.2
sediment	Varangerfjorden, core 30	<0.2	<0.3	<0.3	<0.2	<0.2	<0.3	<0.3	0.33
blue mussel	Inner Oslofjord, Gressholmen	0.15	<0.07	<0.06	<0.1	<0.03	<0.05	<0.05	<0.05
blue mussel	Inner Oslofjord, Gåsøya	0.05	<0.04	<0.06	<0.06	<0.03	<0.04	<0.05	<0.05
blue mussel	Inner Oslofjord, Ramtonholmen	<0.03	<0.05	<0.05	<0.03	<0.03	<0.04	<0.05	<0.05
blue mussel	Outer Oslofjord, Færder	0.07	<0.07	<0.06	<0.13	<0.05	<0.04	<0.05	<0.05
blue mussel	South Norway, Bjørkøya	0.09	<0.04	<0.03	<0.06	<0.03	<0.04	<0.05	<0.05
blue mussel	Sørfjord, Eitrheimsneset	0.14	<0.06	<0.06	<0.10	<0.04	<0.04	<0.05	<0.05
blue mussel	West Norway, Espevær (west)	0.14	<0.11	<0.06	<0.05	<0.03	<0.04	<0.05	<0.05
blue mussel	Lofoten	0.06	<0.04	<0.03	<0.03	<0.04	<0.04	<0.05	<0.05
blue mussel	Varangerfjord	0.09	<0.04	<0.03	<0.08	<0.04	<0.04	<0.05	<0.05
cod liver	Inner Oslofjord, ind.no.7	37	0.20	<0.08	<0.06	5.2	<0.2	<0.1	<0.2
cod liver	Inner Oslofjord, ind.no.9	39	0.20	<0.1	<0.07	5.2	<0.15	<0.1	<0.2
cod liver	Inner Oslofjord, ind.no.10	40	0.22	<0.1	0.55	4.6	<0.2	<0.1	<0.2
cod liver	Inner Oslofjord, ind.no.13	25	<0.15	<0.14	<0.09	3.4	<0.2	<0.1	<0.2
cod liver	Inner Oslofjord, ind.no.23	20	<0.15	0.53	4.1	4.5	<0.2	<0.1	<0.2
cod liver	Outer Oslofjord, ind.no.19	F	F	F	F	F	F	F	F
cod liver	Outer Oslofjord, ind.no.21	0.45	<0.05	<0.10	0.06	0.15	<0.15	<0.15	<0.15
cod liver	Outer Oslofjord, ind.no.23	1.9	0.09	<0.12	<0.03	0.5	<0.15	<0.15	<0.15
cod liver	Outer Oslofjord, ind.no.24	1.7	0.07	<0.11	0.04	0.25	<0.15	<0.15	<0.15
cod liver	Outer Oslofjord, ind.no.25	2.3	0.12	F	<0.03	0.52	<0.15	<0.15	<0.15
cod liver	South Norway, Lista, ind.no.1	1.2	0.09	<0.12	<0.04	0.51	<0.15	<0.15	<0.15
cod liver	South Norway, Lista, ind.no.10	3	0.23	<0.16	0.05	0.8	<0.15	<0.15	<0.15
cod liver	South Norway, Lista, ind.no.15	4.1	0.21	<0.13	0.08	0.99	<0.15	<0.15	<0.15
cod liver	South Norway, Lista, ind.no.16	2.8	0.2	F	0.05	0.83	<0.15	<0.15	<0.15
cod liver	South Norway, Lista, ind.no.23	3.9	0.29	<0.16	0.08	0.96	<0.15	<0.15	<0.15
cod liver	West Norway, Karihav, ind.no.9	0.82	<0.1	<0.16	<0.10	0.25	<0.1	<0.2	<0.2
cod liver	West Norway, Karihav, ind.no.12	0.65	<0.15	<0.18	<0.09	0.17	<0.1	<0.2	<0.2
cod liver	West Norway, Karihav, ind.no.14	0.41	<0.15	<0.15	<0.13	0.13	<0.1	<0.2	<0.2
cod liver	West Norway, Karihav, ind.no.15	0.24	<0.15	<0.15	<0.11	0.12	<0.1	<0.2	<0.2
cod liver	West Norway, Karihav, ind.no.17	1.1	<0.17	<0.21	<0.13	0.66	<0.1	<0.2	<0.2
cod liver	Lofoten, ind.no.3	0.68	<0.1	<0.12	<0.06	0.22	<0.15	<0.15	<0.15
cod liver	Lofoten, ind.no.10	0.61	0.21	<0.13	<0.07	0.87	<0.15	<0.15	<0.15
cod liver	Lofoten, ind.no.14	0.99	0.11	<0.14	<0.04	0.52	<0.15	<0.15	<0.15
cod liver	Lofoten, ind.no.17	0.41	0.07	<0.12	<0.04	0.2	<0.15	<0.15	<0.15
cod liver	Lofoten, ind.no.22	0.48	0.09	<0.10	<0.03	0.16	<0.15	<0.15	<0.15

Table 8 cont.

matrix	station	BDE209	Sum PBDE$_5$	α-HBCDD	B-HBCDD	γ-HBCDD	TBBP-A	BTBPE
sediment	Inner Oslofjord, core 1	2	2.6	<4	<4	<8	<4	<0.08
sediment	Inner Oslofjord, core 3	2.4	2.96	<3	<3	<10	<3	1.9
sediment	Outer Oslofjord, core 7	<1	0.18	<3	<3	<5	<3	<0.03
sediment	South Norway, Lista, core 14	<1	0.3	<2	<2	<4	<2	<0.05
sediment	South Norway, Lista, core 15	1.7	1.77	<2	<2	<4	<2	0.03
sediment	West Norway, Sotra, core 4	<0.5	0	<2	<2	<4	<2	<0.04
sediment	Lofoten, core 22	<0.5	0	<9	<9	<10	<20	<0.03
sediment	Lofoten, core 24	<0.2	0.04	<2	<2	<7	<10	<0.03
sediment	Varangerfjorden, core 28	3.3	3.3	-	-	-	-	<0.14
sediment	Varangerfjorden, core 30	<17	0.62	-	-	-	-	<0.3
blue mussel	Inner Oslofjord, Gressholmen	<0.15	0.76	<1	<1	<2	<1	<0.05
blue mussel	Inner Oslofjord, Gåsøya	<0.15	0.42	<1	<1	<2	<10	<0.05
blue mussel	Inner Oslofjord, Ramtonholmen	<0.1	0.04	<1	<1	<2	<1	<0.05
blue mussel	Outer Oslofjord, Færder	<0.15	0.34	<1	<1	<2	0.7	<0.05
blue mussel	South Norway, Bjørkøya	<0.15	0.44	<1	<1	<2	<1	<0.05
blue mussel	Sørfjord, Eitrheimsneset	<0.16	0.77	<1	<1	<2	<2	<0.05
blue mussel	West Norway, Espevær (west)	<0.15	0.8	<1	<1	<2	<10	<0.05
blue mussel	Lofoten	<0.3	0.32	<1	<1	<1	<1	<0.05
blue mussel	Varangerfjord	<0.15	0.15	<1	<1	<2	<10	<0.05
cod liver	Inner Oslofjord, ind.no.7	<2	149.18	<50	<50	<100	<30	-
cod liver	Inner Oslofjord, ind.no.9	<2	138.58	<50	<50	<50	10.9	-
cod liver	Inner Oslofjord, ind.no.10	<2	98.3	<50	<50	<50	5.8	-
cod liver	Inner Oslofjord, ind.no.13	<2	127.4	<50	<50	<80	<30	-
cod liver	Inner Oslofjord, ind.no.23	<2	168.23	<50	<50	<80	10.7	-
cod liver	Outer Oslofjord, ind.no.19	-	-	<50	<50	<100	<10	-
cod liver	Outer Oslofjord, ind.no.21	<6	3.16	<50	<50	<25	<12	<0.07
cod liver	Outer Oslofjord, ind.no.23	<3	9.28	<50	<50	<50	70.9	<0.04
cod liver	Outer Oslofjord, ind.no.24	<4	9.62	<50	<50	<25	<10	<0.08
cod liver	Outer Oslofjord, ind.no.25	<0.5	11.51	<50	<50	<25	7.5	<0.06
cod liver	South Norway, Lista, ind.no.1	<3	7.1	<50	<50	<25	12.4	<0.1
cod liver	South Norway, Lista, ind.no.10	<3	19.93	<50	<50	<50	<40	<0.17
cod liver	South Norway, Lista, ind.no.15	<2	18.88	66	<50	<60	<30	<0.08
cod liver	South Norway, Lista, ind.no.16	<1	16.62	<50	<50	<50	55.6	<0.07
cod liver	South Norway, Lista, ind.no.23	<1	24.29	<50	<50	<75	<40	<0.1
cod liver	West Norway, Karihav, ind.no.9	<8	5.36	<50	<50	<80	<10	-
cod liver	West Norway, Karihav, ind.no.12	<7	6.38	<50	<50	<50	9.6	-
cod liver	West Norway, Karihav, ind.no.14	<10	5.31	<50	<50	<50	<10	-
cod liver	West Norway, Karihav, ind.no.15	<6	3.4	<50	<50	<80	<10	-
cod liver	West Norway, Karihav, ind.no.17	<15	2.06	<50	<50	<100	<20	-
cod liver	Lofoten, ind.no.3	<2	4.57	<50	<50	<60	<30	<0.11
cod liver	Lofoten, ind.no.10	<1	9.44	<50	<50	<200	<60	<0.12
cod liver	Lofoten, ind.no.14	<1	7.26	<50	<50	<60	49.3	<0.04
cod liver	Lofoten, ind.no.17	<1	5.53	<50	<50	<200	<30	<0.05
cod liver	Lofoten, ind.no.22	<1	5.36	<50	<50	<160	<50	<0.08

[5] Limit of detection not included in sum of PBDE.

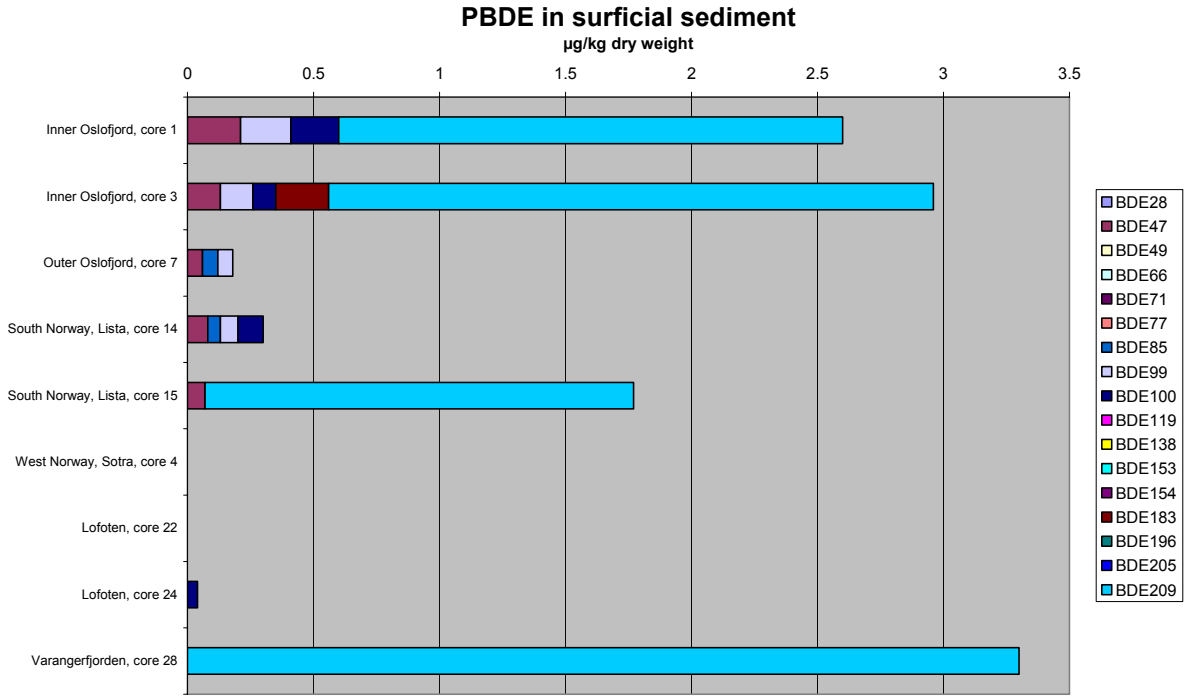

Figure 3. Brominated diphenyl ethers (BDE) in surficial sediment (µg/kg dry weight). LOD not included. Core 30 from Varanger is excluded because of unusually high LOD.

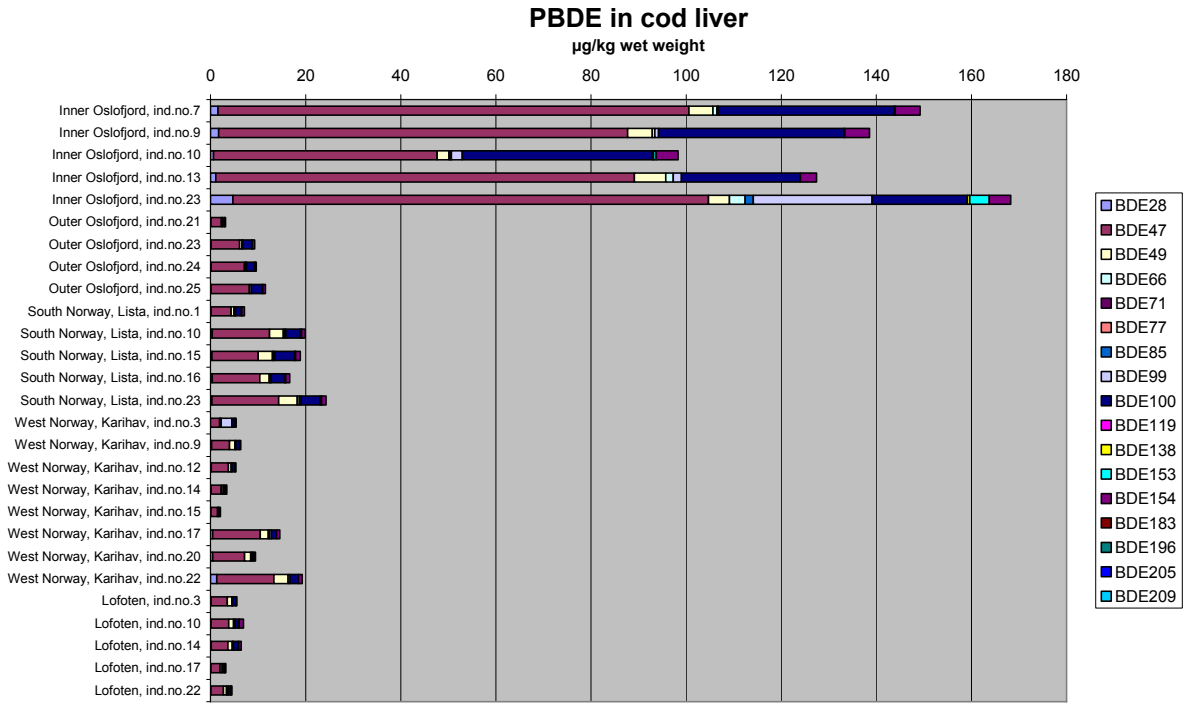

Figure 4. Brominated diphenyl ethers (BDE) in cod liver (µg/kg wet weight). LOD not included.

Discussion, brominated compounds

The sum-PBDE (counting values below LOD as the LOD) in sediment[6], blue mussel and cod liver was in the order of magnitude found in earlier investigations (***Table 9***). The highest values were found in the inner Oslofjord, except for sediment from Varangerfjord.

The sum-PBDE[7] in sediment in this study ranged from 0.04 to 3.3 µg/kg d.w. and is well below the predicted no effect concentration (PNEC) of 62 µg/ kg for PBDE in marine sediments in the revised SFT risk assessment tool (SFT 2007) and should therefore pose no risk to the environment.

Concentrations of PBDEs in other cod livers from 2008 and under the CEMP show that the highest values were found in the inner Oslofjord with and average of 97.8 µg/ kg w.w. compared to 35.5 µg/ kg w.w. from the inner Sørfjord (***Table 10***). The lowest average was 7.4 µg/kg w.w. found in Lofoten.

The high concentrations of PBDEs found indicate that these substances are a source of concern even though some restrictions on use have been implemented[8]. No PNEC-data were found for blue mussel and cod which would give an indication of possible toxic effects these compounds might have on the environment at this level of detection. Furthermore, some PBDEs[9] are on the list of priority substances under EU's Water Framework Directive, of which BDE congener 47 is particularly relevant in this case. This emphasises the need for further research to establish useful environmental quality standards and should be sufficient reasons to continue investigating the levels and trends of these substances.

[6] Excluding core 30 from the Varangerfjord with particularly high LOD for BDE 209 of 17 µg/kg d.w. compared to 0.2-1 µg/kg d.w. for the other sediment samples.
[7] Limit of detection not included in sum of PBDE.
[8] Pentabromdiphenylether (PeBDE or BDE congeners: 85, 99, 100, 119) have been banned from 2004 (Økland *et al.* 2005).
[9] BDE congeners 28, 47, 99, 100, 153, and 154.

Table 9. Comparison to previous measurements of PBDE in recipient; µg/kg dry weight for sediment and µg/kg wet weight for blue mussel and cod liver. Unless otherwise specified, the highest detection limit and highest concentration quantified is indicated.

Matrix	Study area	Value	Reference
sediment	Norway	0.17-1.04	Fjeld *et al.* 2005
sediment	Norway	<0.06-3.73	Bakke *et al.* 2007
sediment	Western Scheldt (NL)	0.002	de Voogt 2006 [2]
sediment	North Sea	0.22-1.78	DnV 2007
sediment	Barents Sea	0.001-1.150	Bakke *et al.* 2008
sediment	*Norway, coast*	*0.04-3.3*[10]	*This study*
blue mussel	Norway	0.034-0.165	Fjeld *et al.* 2005
blue mussel	Norway	<0.06-0.56	Bakke *et al.* 2007
blue mussel	Barents Sea	<0.06-1.19	Bakke *et al.* 2008
blue mussel	*Norway, coast*	*0.04-0.77*[11]	*This study*
polar cod liver	Barents Sea	1.07–2.85	Haukås, *et al.* 2007
cod liver	Sweden	5-61 [3]	Berger *et al.* 2004
cod liver	Norway	0.45-6.26	Fjeld *et al.* 2005
cod liver	Norway, inner Oslofjord	37-63	Bakke *et al.* 2007
cod liver	Norway, remote sites [1]	2-10	Bakke *et al.* 2007
cod liver	Barents Sea	<3.4-29.0	Bakke *et al.* 2008
cod liver	*Norway, coast*	*3.16-1.68*[12]	*This study*

1) Ålesund, Gangstøvika, Lofoten, Tromsø, Varangerfjord; except for Ålesund assumed to be areas of low exposure.
2) As cited by Bakke *et al.* 2007.
3) Estimated from Figure 3 in Berger *et al.* 2004.

Table 10. Summary statistics for concentrations of sum-PBDE in cod liver from eight CEMP stations cod liver (µg/kg w.w.) sampled in 2008. "<" or "<<" indicates that less than 25 % or more than 25 % of the values, respectively, were below the detection limit. "~" indicates that values below the detection limit were included. The highest limit of detection is included in the sum PBDE.

Station	Mean	Minimum	Maximum	St.Dev	Count
Inner Oslofjord (st.30)	<<97.83	<31.85	<176.64	~41.64	20
Outer Oslofjord(st.36)	<<12.51	<9.94	<14.32	~1.84	4
South Norway (st.15)	<<20.15	<10.85	<26.24	~5.97	5
Inner Sørfjord (st.53)	<<35.45	<25.39	<50.09	~9.36	7
West Norway (st.23)	<<15.44	<0.20	<34.26	~8.57	23
Mid Norway (st.92)	<<15.03	<4.22	<26.28	~7.49	25
Lofoten (st.98)	<<7.39	<5.02	<8.98	~1.69	5
North Norway (st.43)	<<14.85	<11.03	<21.41	~2.73	20

That concentrations of HBCDD, TBBPA and the "new" brominated compound BTBPE in sediment, blue mussel and cod liver were below to or close to LOD in both presumed perturbed areas (i.e. inner Oslofjord, inner Sørfjord) and areas more remote from known sources of pollution is an indication that these substances are not a matter of concern. However, the LOD for HBCDD and TBBPA was roughly a factor of 10 higher than some other studies (***Table 11***, ***Table 12***). Though high, the maximum LOD for HBCDD (10 µg/kg d.w.) was in the range found in some other studies. Further investigations should not be disregarded.

[10] Limit of detection not included in sum of PBDE.
[11] Limit of detection not included in sum of PBDE.
[12] Limit of detection not included in sum of PBDE.

Table 11. Comparison to previous measurements of HBCDD in recipient; µg/kg dry weight for sediment and µg/kg wet weight for blue mussel and cod liver. Unless otherwise specified, the highest detection limit and highest concentration quantified is indicated.

Matrix	Study area	Value	Reference
sediment	Norway, other than Ålesund	0.28-21.08	Fjeld *et al.* 2005
sediment	Norway, Ålesund	24.4-8483	Fjeld *et al.* 2005
sediment	Norway, Ålesund	12-932	Berge *et al.* 2006
sediment	*Norway, coast*	*<10*	*This study*
blue mussel	Norway, other than Ålesund	0.22-2.3	Fjeld *et al.* 2005
blue mussel	Norway, Ålesund	55.4-329.3	Fjeld *et al.* 2005
blue mussel	*Norway, coast*	*<1 - <2*	*This study*
cod liver	Norway	2.46 - -22.67	Fjeld *et al.* 2005
cod liver	Norway, Ålesund	15.4 – 44.2	Berge *et al.* 2006
cod liver	*Norway, coast*	*<50 - (66) - <200*	*This study*

1) Values in Ålesund ranged from 24.4-8483µg/kg d.w.

The ranges of HBCDD and TBBPA in sediment in this study are <2 - <10 and <2 - <20 µg/kg d.w., respectively, and are well below the predicted no effect concentration (PNECs) of 86 and 63 µg/kg for HBCDD and TBBPA, respectively, in marine sediments in the revised SFT risk assessment tool (SFT 2007) and should therefore pose no risk to the environment. However, no PNEC-data were found for blue mussel and cod which would give an indication of possible toxic effects these compounds might have on the environment at this level of detection. This emphasises the need for further research to establish useful environmental quality standards and should be sufficient reasons to continue investigating the levels and trends of these substances.

Table 12. Review of limit of detection (LOD) for HBCDD and TBBBPA. "nd" indicates not detected. Values from this study are marked in gray; approximate conversion of other basis in parentheses assuming 40, 16 and 66 % dry weight for sediment, blue mussel and cod liver, respectively.

Compound	Matrix	Study area	Concentration (µg/kg d.w.)	LOD (µg/kg d.w.)	Reference
HBCDD	sediment	Scheldt Basin	nd-950	0.2	Morris *et al.* 2004
HBCDD	sediment	Western Schedlt	nd-99	0.6	Morris *et al.* 2004
HBCDD	sediment	German North Sea	nd-0.03-0.37		Lepom *et al.* 2007
HBCDD	*sediment*	*Norway, coast*	*Nd*	*2-10*	*This study*
HBCDD	mussel	Scheldt Basin	nd-950	0.2	Morris *et al.* 2004
HBCDD	mussel	Western Schedlt	nd-99	0.6	Morris *et al.* 2004
HBCDD	mussel	German North Sea	nd-0.03-0.37		Lepom *et al.* 2007
HBCDD	*blue mussel*	*Norway, coast*	*Nd*	*1-2 w.w. (6-12 d.w.)*	*This study*
HBCDD	cod liver	North Sea	nd-50	0.7	Morris *et al.* 2004
HBCDD	*cod liver*	*Norway, coast*	*Nd-66*	*50-60 w.w. (75-90 d.w.)*	*This study*
TBBPA	sediment	Svalbard	nd	0.17-0.62	Evenset *et al.* 2009
TBBPA	sediment	Scheldt Basin	nd-67	0.1	Morris *et al.* 2004
TBBPA	sediment	Western Schedlt	nd-3.2	0.1	Morris *et al.* 2004
TBBPA	*sediment*	*Norway, coast*	*Nd*	*2-20*	*This study*
TBBPA	mussel	Svalbard	nd	0.17-0.62	Evenset *et al.* 2009
TBBPA	mussel	Scheldt Basin	nd-67	0.1	Morris *et al.* 2004
TBBPA	mussel	Western Schedlt	nd-3.2	0.1	Morris *et al.* 2004
TBBPA	*blue mussel*	*Norway, coast*	*Nd-0.7*	*1-10 w.w. (6-60 d.w.)*	*This study*
TBBPA	cod liver	Svalbard	nd	0.19-3.3	Evenset *et al.* 2009
TBBPA	cod liver	North Sea	nd-1.8	0.3	Morris *et al.* 2004
TBBPA	*cod liver*	*Norway, coast*	*Nd-70.9*	*10-60 w.w. (15-90 d.w.)*	*This study*

3.2 Perfluorinated organic compounds

Seven perfluorinated organic compounds were investigated in 10 sediment samples, 9 blue mussel samples and only 25 cod liver samples (***Table 15***). PFHpA, PFHxA, PFNA and PFOA were not detected in any matrix. Furthermore, only PFBS, PFOSA and PFOS were not detected in sediment or blue mussel; only in cod liver with a ranges of 5-8, 1.9-50 and 1-570 µg/kg w.w., respectively. The highest concentrations of PFOS were found in the outer Oslofjord with an average of 306 µg/kg w.w. The average was over twice the next highest average, which was found in South Norway (***Table 13***, ***Figure 5***). This was not the case for PFOSA where higher concentrations were found in cod from the inner Oslofjord (***Table 14***). Slight concentrations of PFBS were also detected in two cod liver samples.

Table 13. Summary statistics for concentrations of PFOS in cod liver from eight CEMP stations cod liver (µg/kg w.w.). "<" or "<<" indicates that less than 25 % or more than 25 % of the values, respectively, were below the detection limit. "~" indicates that values below the detection limit were included.

Station	Mean	Minimum	Maximum	St.Dev	Count
Inner Oslofjord (st.30)	79.00	14.00	410.00	99.55	23
Outer Oslofjord(st.36)	306.00	64.00	570.00	227.27	5
South Norway (st.15)	126.00	31.00	220.00	79.78	5
Inner Sørfjord (st.53)	19.00	8.00	40.00	14.35	5
West Norway (st.23)	<8.75	2.30	27.00	~6.20	21
Mid Norway (st.92)	<24.40	<1.00	170.00	~35.43	23
Lofoten (st.98)	<<15.40	1.00	49.00	~20.94	5
North Norway (st.43)	<44.78	<1.00	160.00	~45.43	20

Table 14. Summary statistics for concentrations of PFOSA in cod liver from eight CEMP stations cod liver (µg/kg w.w.) sampled in 2008. "<" or "<<" indicates that less than 25 % or more than 25 % of the values, respectively, were below the detection limit. "~" indicates that values below the detection limit were included.

Station	Mean	Minimum	Maximum	St.Dev	Count
Inner Oslofjord (st.30)	14.09	7.00	50.00	9.01	23
Outer Oslofjord(st.36)	<5.25	<2.00	6.00	~2.99	5
South Norway (st.15)	<<4.0	<2.00	5.00	~1.41	5
Inner Sørfjord (st.53)	<<5.2	<5.00	6.00	~0.45	5
West Norway (st.23)	<<3.70	1.9	<10.00	~1.95	21
Mid Norway (st.92)	1.47	0.70	2.90	0.57	23
Lofoten (st.98)	<<2.20	<2.00	<3.00	~0.44	5
North Norway (st.43)	<3.35	<1.00	<8.00	~2.31	20

Table 15. Concentrations of perfluorinated organic compounds in sediment (µg/kg d.w.), blue mussel and cod liver (µg/kg w.w.). Values above the detection limit are shaded.

matrix	station	PFBS	PFHpA	PFHxA	PFNA	PFOA	PFOSA	PFOS
sediment	Inner Oslofjord, core 1	<1	<1	<1	<1.5	<2.5	<1	<1
sediment	Inner Oslofjord, core 3	<1	<1	<1	<1.5	<2.5	<1	<1
sediment	Outer Oslofjord, core 7	<1	<1	<1	<1.5	<2.5	<1	<1
sediment	South Norway, Lista, core 14	<1	<1	<1	<1.5	<2.5	<1	<1
sediment	South Norway, Lista, core 15	<1	<1	<1	<1.5	<2.5	<1	<1
sediment	West Norway, Sotra, core 4	<1	<1	<1	<1.5	<2.5	<1	<1
sediment	Lofoten, core 22	<1	<1	<1	<1.5	<2.5	<1	<1
sediment	Lofoten, core 24	<1	<1	<1	<1.5	<2.5	<1	<1
sediment	Varangerfjorden, core 28	<1	<1	<1	<1.5	<2.5	<1	<1
sediment	Varangerfjorden, core 30	<1	<1	<1	<1.5	<2.5	<1	<1
blue mussel	Inner Oslofjord, Gresholmen	<10	<20	<10	<10	<10	<5	<10
blue mussel	Inner Oslofjord, Gåsøya	<10	<20	<10	<10	<10	<5	<10
blue mussel	Inner Oslofjord, Ramtonholmen	<10	<20	<10	<10	<10	<5	<10
blue mussel	Outer Oslofjord, Færder	<10	<20	<10	<10	<10	<5	<10
blue mussel	South Norway, Bjørkøya	<10	<20	<10	<10	<10	<5	<10
blue mussel	Sørfjord, Eitrheimsneset	<10	<20	<10	<10	<10	<5	<10
blue mussel	West Norway, Espevær (west)	<10	<20	<10	<10	<10	<5	<10
blue mussel	Lofoten	<10	<20	<10	<10	<10	<5	<10
blue mussel	Varangerfjord	<10	<20	<10	<10	<10	<5	<10
cod liver	Inner Oslofjord, ind.no.7	<35	<6	<5	<19	<40	50	38
cod liver	Inner Oslofjord, ind.no.9	<35	<6	<5	<7	<25	19	53
cod liver	Inner Oslofjord, ind.no.10	<35	<6	<4	<5	<25	8	16
cod liver	Inner Oslofjord, ind.no.13	<10	<5	<4	<8	<10	13	26
cod liver	Inner Oslofjord, ind.no.23	<5	<5	<3	<4	<10	24	40
cod liver	Outer Oslofjord, ind.no.19	<5	<1	<15	<3	<6	2	32
cod liver	Outer Oslofjord, ind.no.21	<5	<1	<15	<3	<6	6	180
cod liver	Outer Oslofjord, ind.no.23	5.3	<1	<15	<3	<6	<2	410
cod liver	Outer Oslofjord, ind.no.24	<5	<1	<15	<3	<6	4	570
cod liver	Outer Oslofjord, ind.no.25	<5	<1	<15	<3	<6	9	64
cod liver	South Norway, Lista, ind.no.1	<5	<1	<15	<3	<6	<2	59
cod liver	South Norway, Lista, ind.no.10	<5	<1	<15	<3	<6	<2	31
cod liver	South Norway, Lista, ind.no.15	<12	<1	<15	<3	<6	<2	180
cod liver	South Norway, Lista, ind.no.16	<5	<1	<15	<3	<6	3	220
cod liver	South Norway, Lista, ind.no.23	<5	<1	<15	<3	<6	5	140
cod liver	West Norway, Karihav, ind.no.9	<5	<4	<3	<1	<1	3	9.3
cod liver	West Norway, Karihav, ind.no.12	<5	<4	<3	<1	<3	6.1	8.4
cod liver	West Norway, Karihav, ind.no.14	<5	<3	<3	<1	<1	1.9	3.9
cod liver	West Norway, Karihav, ind.no.15	<6	<3	<4	<1	<2	4.9	8.5
cod liver	West Norway, Karihav, ind.no.17	<12	<3	<5	<1	<20	<10	<6
cod liver	Lofoten, ind.no.3	<5	<1	<15	<3	<6	<3	49
cod liver	Lofoten, ind.no.10	<5	<1	<15	<3	<6	<2	<2
cod liver	Lofoten, ind.no.14	<8	<1	<15	<3	<6	<2	<2
cod liver	Lofoten, ind.no.17	8	<1	<15	<3	<6	<2	1
cod liver	Lofoten, ind.no.22	<5	<1	<15	<3	<6	<2	23

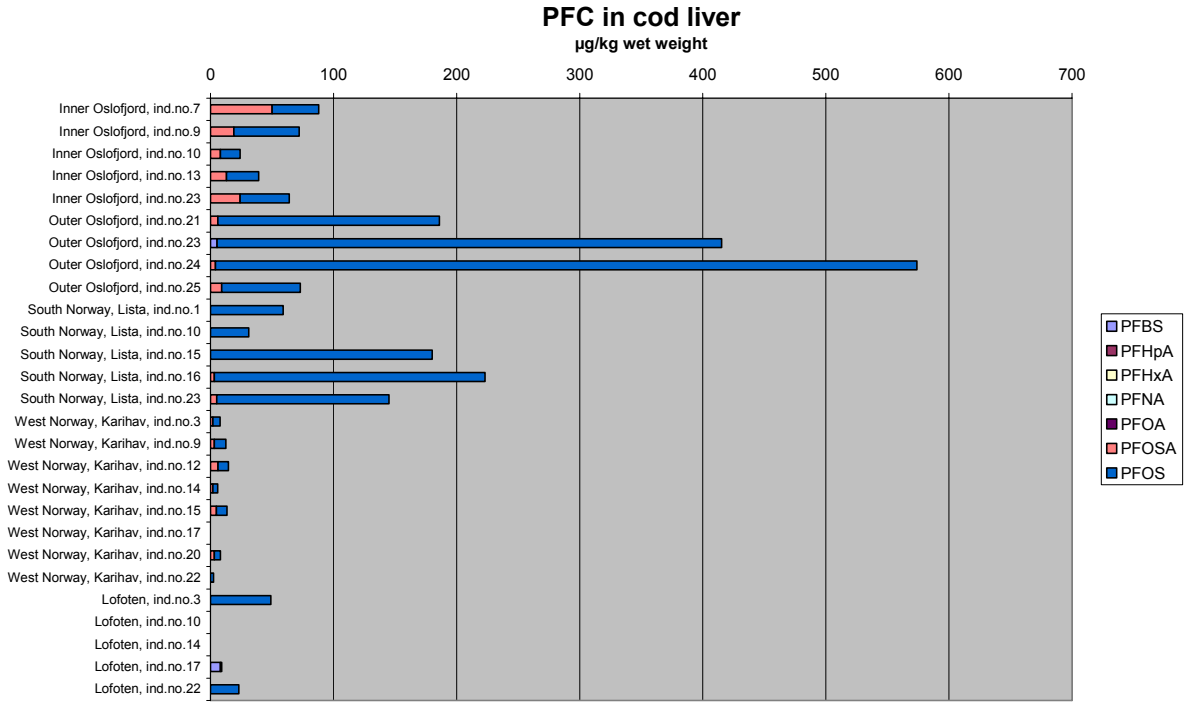

Figure 5. Perfluorinated organic compounds (PFC) in cod liver (µg/kg wet weight).

Discussion, perfluorinated organic compounds

The LOD for PFOS concentrations in sediment was 1 µg/kg d.w. and reasonably comparable to LOD from previous investigations (***Table 16***, ***Table 18***). All concentrations in sediment in this study are well below the predicted no effect concentration (PNECs) of 220 µg/ kg for PFOS in marine sediments in the revised SFT risk assessment tool (SFT 2007) and should therefore pose no risk to the environment.

Though not detected, the LODs for PFOS and PFOSA in mussels was roughly ten times higher than found in previous studies (***Table 16***, ***Table 17***, ***Table 18***) and might be an argument for continued monitoring of PFCs in blue mussel. The amount of sample material available was probably the main reason for the high LOD (see also chapter 2.3.9).

The LODs for PFOS and PFOSA in cod liver were comparable to previous studies (***Table 16***, ***Table 17***, respectively, ***Table 18***). High concentrations of PFOSA were found in cod from the inner Oslofjord compared to cod from the outer Oslofjord. In contrast high concentrations of PFOS were found in open coastal areas of southern Norway (outer Oslofjord and Lista), higher than in previous studies. This could indicate an influence from the Glomma river or from the Kattegat or southern Skagerrak.

No PNEC-data were found for blue mussel and cod which would give an indication of possible toxic effects these compounds might have on the environment at this level of detection. This emphasises the need for further research to establish useful environmental quality standards.

For these reasons and the fact that PFOS is on review as a possible priority substance under the Water Framework Directive, should be an adequate argument to continue investigating the levels and trends of this substance.

Table 16. Comparison to previous measurements of PFOS in recipient; µg/kg dry weight for sediment and µg/kg wet weight for blue mussel and cod liver. Unless otherwise specified, the highest detection limit and highest concentration quantified is indicated.

Matrix	Study area	Value	Reference
sediment	Norway	0.17-1.04	Fjeld *et al.* 2005
sediment	Norway	<0.06-3.73	Bakke *et al.* 2007
sediment	Western Scheldt (NL)	0.002	De Voogt 2006 [2]
sediment	North Sea	0.22-1.78	DnV 2007
sediment	Barents Sea	<0.08-0.44	Bakke *et al.* 2008
sediment	Norway, inner Oslofjord	3.48-6.66	Green *et al.* 2008
sediment	Norway, reference	0.34	Green *et al.* 2008
sediment	*Norway, coast*	*<1*	*This study*
blue mussel	Norway	0.034-0.165	Fjeld *et al.* 2005
blue mussel	Norway	<0.06-0.56	Bakke *et al.* 2007
blue mussel	Norway	0.24-1.89	Green *et al.* 2008
blue mussel	*Norway, coast*	*<10*	*This study*
polar cod liver	Barents Sea	1.07–2.85	Haukås, *et al.* 2007
cod liver	Sweden	5-61 [3]	Berger *et al.* 2004
cod liver	Norway	0.45-6.26	Fjeld *et al.* 2005
cod liver	Norway, inner Oslofjord	37-63	Bakke *et al.* 2007
cod liver	Norway, remote sites [1]	2-10	Bakke *et al.* 2007
cod liver	Barents Sea	3-8	Bakke *et al.* 2008
cod liver	Norway	4.41-27.95	Green *et al.* 2008
cod liver	*Norway, coast*	*<2-570*	*This study*

1) Ålesund, Gangstøvika, Lofoten, Tromsø, Varangerfjord; except for Ålesund assumed to be areas of low exposure.
2) As cited by Bakke *et al.* 2007.
3) Estimated from Figure 3 in Berger *et al.* 2004.

Table 17. Comparison to previous measurements of PFOSA in recipient; µg/kg dry weight for sediment and µg/kg wet weight for blue mussel and cod liver. Unless otherwise specified, the highest detection limit and highest concentration quantified is indicated.

Matrix	Study area	Value	Reference
sediment	Norway	<0.010-237 [2]	Fjeld *et al.* 2005
sediment	Norway	<0.12	Bakke *et al.* 2007
sediment	North Sea	<0.04	DnV 2006
sediment	Barents Sea	<0.15	Bakke *et al.* 2008
sediment	Norway, inner Oslofjord	<0.28	Green *et al.* 2008
sediment	Norway, reference	<0.13	Green *et al.* 2008
sediment	*Norway, coast*	*<1*	*This study*
blue mussel	Norway	<0.008-0.16	Fjeld *et al.* 2005
blue mussel	Norway	<0.11-1.77	Bakke *et al.* 2007
blue mussel	Norway	<0.36-2.56	Green *et al.* 2008
blue mussel	*Norway, coast*	*<5*	*This study*
cod liver	Sweden	1-5 [3]	Berger *et al.* 2004
cod liver	Norway	<0.004-0.056	Fjeld *et al.* 2005
cod liver	Norway, inner Oslofjord	20-22	Bakke *et al.* 2007
cod liver	Norway, remote sites [1]	<2	Bakke *et al.* 2007
cod liver	Norway	<1.56-11.26	Green *et al.* 2008
cod liver	*Norway, coast*	*<2-50*	*This study*

1) Ålesund, Gangstøvika, Lofoten, Tromsø, Varangerfjord; except for Ålesund assumed to be areas of low exposure.
2) Hvaler, near mouth of the Glomma river. Only value above the detection limit.
3) Estimated from Figure 3 in Berger *et al.* 2004.

Table 18. Review of limit of detection (LOD) for perfluorated organic compounds. "Nd" indicates not detected. Values from this study marked in gray; approximate conversion of other basis in parentheses assuming 40, 16 and 66 % dry weight for sediment, blue mussel and cod liver, respectively.

Compound	Matrix	Study area	Concentration (µg/kg d.w.)	LOD (µg/kg d.w.)*	Reference
PFBS	sediment	Japan	Nd -<1.1	0.7	Senthilkumar *et al.* 2007
PFBS	*sediment*	*Norway, coast*	*Nd*	*1*	*This study*
PFBS	mussel	Japan	Nd -<1.1	0.7	Senthilkumar *et al.* 2007
PFBS	*blue mussel*	*Norway, coast*	*Nd*	*10 w.w. (60 d.w.)*	*This study*
PFHpA	whole cod	Canadian western artic	Nd	0.3	Powley *et al.* 2008
PFHpA	*cod liver*	*Norway, coast*	*Nd*	*1 w.w. (1.5 d.w.)*	*This study*
PFHxA	cod liver	Barents sea	0.64-5.38	0.22	Haukås *et al.* 2007
PFHxA	whole cod	Canadian western artic	Nd	0.3	Powley *et al.* 2008
PFHxA	*cod liver*	*Norway, coast*	*Nd*	*1 w.w. (1.5 d.w.)*	*This study*
PFNA	cod liver	Barents sea	Nd-.03	0.24	Haukås *et al.* 2007
PFNA	whole cod	Canadian western artic	Nd	0.4	Powley *et al.* 2008
PFNA	*cod liver*	*Norway, coast*	*Nd*	*1 w.w. (1.5 d.w.)*	*This study*
PFOA	sediment	Japan	Nd -2.3	0.26	Senthilkumar *et al.* 2007
PFOA	sediment	Norway, Hamar	0.278 (wet wt)	0.4 (w.w.)	Kallenborn *et al.* 2004
PFOA	sediment	Norway, Gålås	0.312 (wet wt)	0.4 (w.w.)	Kallenborn *et al.* 2004
PFOA	sediment	Farao Islands, Torshavn	Nd	0.4 (w.w.)	Kallenborn *et al.* 2004
PFOA	sediment	Finland, porvoo	Nd	0.4 (w.w.)	Kallenborn *et al.* 2004
PFOA	sediment	Sweden, Kristianstad	Nd	0.4 (w.w.)	Kallenborn *et al.* 2004
PFOA	sediment	Iceland, Gufunes Bay	Nd	0.4 (w.w.)	Kallenborn *et al.* 2004
PFOA	*sediment*	*Norway, coast*	*Nd*	*2.5 d.w. (1 w.w.)*	*This study*
PFOA	mussel	Japan	nd -2.3	0.26	Senthilkumar *et al.* 2007
PFOA	mussel	Norway, Hamar	0.278 (wet wt)	0.4 (w.w.)	Kallenborn *et al.* 2004
PFOA	mussel	Norway, Gålås	0.312 (wet wt)	0.4 (w.w.)	Kallenborn *et al.* 2004
PFOA	mussel	Farao Islands, Torshavn	Nd	0.4 (w.w.)	Kallenborn *et al.* 2004
PFOA	mussel	Finland, porvoo	Nd	0.4 (w.w.)	Kallenborn *et al.* 2004
PFOA	mussel	Sweden, Kristianstad	Nd	0.4 (w.w.)	Kallenborn 2004
PFOA	mussel	Iceland, Gufunes Bay	Nd	0.4 (w.w.)	Kallenborn *et al.* 2004
PFOA	*blue mussel*	*Norway, coast*	*Nd*	*10 w.w. (60 d.w.)*	*This study*
PFOA	cod liver	Barents sea	Nd-1.88	1.25	Haukås *et al.* 2007
PFOA	whole cod	Canadian western artic	Nd	0.2	Powley *et al.* 2008

Compound	Matrix	Study area	Concentration (µg/kg d.w.)	LOD (µg/kg d.w.)*	Reference
PFOA	*cod liver*	*Norway, coast*	*Nd*	*1-40 w.w. (1.5-60 d.w.)*	*This study*
PFOS	sediment	Japan	Nd – 11	0.8	Senthilkumar *et al.* 2007
PFOS	sediment	Norway, Hamar	0.394 (wet wt)	0.5 (w.w.)	Kallenborn *et al.* 2004
PFOS	sediment	Norway, Gålås	0.217 (wet wt)	0.5 (w.w.)	Kallenborn *et al.* 2004
PFOS	sediment	Farao Islands, Tor-shavn	0.054 -0.111 (wet wt)	0.5 (w.w.)	Kallenborn 2004
PFOS	sediment	Finland, Porvoo	0.222-0.290 (wet wt)	0.5 (w.w.)	Kallenborn *et al.* 2004
PFOS	sediment	Sweden, Kristian-stad	Nd-0.069 (wet wt)	0.5 (w.w.)	Kallenborn 2004
PFOS	sediment	Iceland, Gufunes bay	Nd	0.5 (w.w.)	Kallenborn *et al.* 2004
PFOS	*sediment*	*Norway, coast*	*Nd*	*1 d.w. (0.4 w.w.)*	*This study*
PFOS	mussel	Japan	Nd – 11	0.8	Senthilkumar *et al.* 2007
PFOS	mussel	Norway, Hamar	0.394 (wet wt)	0.5 (w.w.)	Kallenborn *et al.* 2004
PFOS	mussel	Norway, Gålås	0.217 (wet wt)	0.5 (w.w.)	Kallenborn *et al.* 2004
PFOS	mussel	Farao Islands, Tor-shavn	0.054 -0.111 (wet wt)	0.5 (w.w.)	Kallenborn *et al.* 2004
PFOS	mussel	Finland, Porvoo	0.222-0.290 (wet wt)	0.5 (w.w.)	Kallenborn *et al.* 2004
PFOS	mussel	Sweden, Kristian-stad	Nd-0.069 (wet wt)	0.5 (w.w.)	Kallenborn 2004
PFOS	mussel	Iceland, Gufunes bay	Nd	0.5 (w.w.)	Kallenborn *et al.* 2004
PFOS	*blue mussel*	*Norway, coast*	*Nd*	*1 w.w. (6 d.w.)*	*This study*
PFOS	cod liver	Barents sea	1.07-2.85	0.23	Haukås *et al.* 2007
PFOS	whole cod	Canadian western artic	0.3-0.7	0.2	Powley *et al.* 2008
PFOS	*cod liver*	*Norway, coast*	*Nd - 570*	*2-6 w.w. (3-9 d.w.)*	*This study*
PFOSA	sediment	Japan	Nd – 4.1	0.6	Senthilkumar *et al.* 2007
PFOSA	sediment	Norway, Hamar	Nd	0.1 (w.w.)	Kallenborn *et al.* 2004
PFOSA	sediment	Norway, Gålås	Nd	0.1 (w.w.)	Kallenborn *et al.* 2004
PFOSA	sediment	Farao Islands, Tor-shavn	Nd	0.1 (w.w.)	Kallenborn *et al.* 2004
PFOSA	sediment	Finland, porvoo	Nd	0.1 (w.w.)	Kallenborn *et al.* 2004
PFOSA	sediment	Sweden, Kristian-stad	Nd	0.1 (w.w.)	Kallenborn 2004
PFOSA	sediment	Iceland, Gufunes Bay	Nd	0.1 (w.w.)	Kallenborn *et al.* 2004
PFOSA	*sediment*	*Norway, coast*	*Nd*	*1 d.w. (0.4 w.w.)*	*This study*
PFOSA	mussel	Japan	Nd – 4.1	0.6	Senthilkumar *et al.* 2007
PFOSA	mussel	Norway, Hamar	Nd	0.1 (w.w.)	Kallenborn *et al.* 2004
PFOSA	mussel	Norway, Gålås	Nd	0.1 (w.w.)	Kallenborn *et al.* 2004
PFOSA	mussel	Farao Islands, Tor-shavn	Nd	0.1 (w.w.)	Kallenborn *et al.* 2004

Compound	Matrix	Study area	Concentration (µg/kg d.w.)	LOD (µg/kg d.w.)*	Reference
PFOSA	mussel	Finland, porvoo	Nd	0.1 (w.w.)	Kallenborn *et al.* 2004
PFOSA	mussel	Sweden, Kristian-stad	Nd	0.1 (w.w.)	Kallenborn *et al.* 2004
PFOSA	mussel	Iceland, Gufunes Bay	Nd	0.1 (w.w.)	Kallenborn *et al.* 2004
PFOSA	*blue mussel*	*Norway, coast*	*Nd*	*1 w.w. (6 d.w.)*	*This study*

*) note exceptions

3.3 Organochlorines

Organochlorines included trichloroethylene (TRI), tetrachloroethylene, alachlor, A and B isomers of endosulfan, 3 isomers of trichlorobenzene, hexachlorobutadiene (HCBD) and 4-chlor-a-(4-chlorphenyl)-a-(trichlormethyl)- benzenmethanol (dicofol). These were investigated in up to 10 sediment samples, up to 9 blue mussel samples and 25 cod liver samples (***Table 6***, ***Table 19***). Analysis of tetrachloroehtylene in all matrixes and trichloroethylene in sediments were not successful. Of all substances only trichloroethylene was detected in one cod liver sample from Lofoten. The concentration was 5 µg/kg w.w. and can be considered low when compared the detection limits found for the other liver samples which ranged from <4 to <25 g/kg w.w.

Hexachlorobutadiene (HCBD) is the only substance in this investigation where an EU Environmental Quality Standard (EQS) can be applied directly. The so called EQSD directive 2008/105/EC specifies an EQS of 55 µg/kg w.w. for "prey tissue". HCBD was not detected in blue mussel or cod liver where the detection limit was 1 and 5 µg/ kg w.w., respectively.

Table 19. Concentrations of the perfluorinated organic compounds trichloroethylene (TRI), tetrachloroethylene (TET), alachlor (ALA), endosulfan isomers (ENDOA, ENDOB), trichlorobenzene isomers (TRCB0, TRCB1, TRCB2, TRCB3), hexachlorobutadiene (HCBD), and 4-chlor-a-(4-chlorphenyl)-a-(trichlormethyl)- benzenmethanol (dicofol) in sediment (µg/ kg d.w.), blue mussel and cod liver (µg/kg w.w.). Values above the detection limit are shaded. Samples that could not be quantified because of interference (F) are marked (cf. chapter 2.3.9).

Matrix	station	TRI	TET	ALA	ENDOA	ENDOB
sediment	Inner Oslofjord, core 1	-	-	<35	<35	<35
sediment	Inner Oslofjord, core 3	-	-	<30	<30	<30
sediment	Outer Oslofjord, core 7	-	-	<25	<25	<25
sediment	South Norway, Lista, core 14	-	-	<20	<20	<20
sediment	South Norway, Lista, core 15	-	-	<20	<20	<20
sediment	West Norway, Sotra, core 4	-	-	<20	<20	<20
sediment	Lofoten, core 22	-	-	<60	<60	<60
sediment	Lofoten, core 24	-	-	<20	<20	<20
sediment	Varangerfjorden, core 28	-	-	-	-	-
sediment	Varangerfjorden, core 30	-	-	-	-	-
blue mussel	Inner Oslofjord, Gresholmen	<0.9	F	<15	<15	<15
blue mussel	Inner Oslofjord, Gåsøya	<1.1	F	<15	<15	<15
blue mussel	Inner Oslofjord, Ramtonholmen	<1	F	<15	<15	<15
blue mussel	Outer Oslofjord, Færder	<0.9	F	<15	<15	<15
blue mussel	South Norway, Bjørkøya	<1.3	F	<15	<15	<15
blue mussel	Sørfjord, Eitrheimsneset	<0.8	F	<15	<15	<15
blue mussel	West Norway, Espevær (west)	<1.1	F	<15	<15	<15
blue mussel	Lofoten	<0.6	F	<15	<15	<15
blue mussel	Varangerfjord	<1.1	F	<15	<15	<15
cod liver	Inner Oslofjord, ind.no.7	<6	F	<75	<150	<150
cod liver	Inner Oslofjord, ind.no.9	<4	F	<50	<100	<100
cod liver	Inner Oslofjord, ind.no.10	<4	F	<50	<100	<100
cod liver	Inner Oslofjord, ind.no.13	<4	F	<75	<150	<150
cod liver	Inner Oslofjord, ind.no.23	<7	F	<75	<150	<150
cod liver	Outer Oslofjord, ind.no.19	<4	F	<50	<100	<100

Matrix	station	TRI	TET	ALA	ENDOA	ENDOB
cod liver	Outer Oslofjord, ind.no.21	<4	F	<50	<100	<100
cod liver	Outer Oslofjord, ind.no.23	<5	F	<50	<100	<100
cod liver	Outer Oslofjord, ind.no.24	<5	F	<50	<100	<100
cod liver	Outer Oslofjord, ind.no.25	<4	F	<50	<100	<100
cod liver	South Norway, Lista, ind.no.1	<8	F	<50	<100	<100
cod liver	South Norway, Lista, ind.no.10	<8	F	<75	<150	<150
cod liver	South Norway, Lista, ind.no.15	<13	F	<75	<150	<150
cod liver	South Norway, Lista, ind.no.16	<6	F	<50	<100	<100
cod liver	South Norway, Lista, ind.no.23	<11	F	<50	<100	<100
cod liver	West Norway, Karihav, ind.no.9	<7	F	<75	<150	<150
cod liver	West Norway, Karihav, ind.no.12	<7	F	<75	<150	<150
cod liver	West Norway, Karihav, ind.no.14	<7	F	<75	<150	<150
cod liver	West Norway, Karihav, ind.no.15	<25	F	<75	<150	<150
cod liver	West Norway, Karihav, ind.no.17	<14	F	<75	<150	<150
cod liver	Lofoten, ind.no.3	5	F	<50	<100	<100
cod liver	Lofoten, ind.no.10	<14	F	<50	<100	<100
cod liver	Lofoten, ind.no.14	<12	F	<50	<100	<100
cod liver	Lofoten, ind.no.17	<5	F	<50	<100	<100
cod liver	Lofoten, ind.no.22	<11	F	<50	<100	<100

Table 19 cont.

matrix	station	TRCBO	TRCB1	TRCB2	HCBD	dicofol
sediment	Inner Oslofjord, core 1	<10	<10	<10	<2	m
sediment	Inner Oslofjord, core 3	<9	<9	<9	<2	<10
sediment	Outer Oslofjord, core 7	<8	<8	<8	<1	<2
sediment	South Norway, Lista, core 14	<6	<6	<6	<1	<2
sediment	South Norway, Lista, core 15	<6	<6	<6	<1	F
sediment	West Norway, Sotra, core 4	<6	<6	<6	<1	F
sediment	Lofoten, core 22	<7	<7	<7	<4	<40
sediment	Lofoten, core 24	<7	<7	<7	<1	<3
sediment	Varangerfjorden, core 28	-	-	-	-	-
sediment	Varangerfjorden, core 30	-	-	-	-	-
blue mussel	Inner Oslofjord, Gresholmen	<1	<1	<1	<1	<2
blue mussel	Inner Oslofjord, Gåsøya	<1	<1	<1	<1	<12
blue mussel	Inner Oslofjord, Ramtonholmen	<1	<1	<1	<1	<2
blue mussel	Outer Oslofjord, Færder	<1	<1	<1	<1	<0.7
blue mussel	South Norway, Bjørkøya	<1	<1	<1	<1	<1
blue mussel	Sørfjord, Eitrheimsneset	<1	<1	<1	<1	F
blue mussel	West Norway, Espevær (west)	<1	<1	<1	<1	<1
blue mussel	Lofoten	<1	<1	<1	<1	<1
blue mussel	Varangerfjord	<1	<1	<1	<1	<2
cod liver	Inner Oslofjord, ind.no.7	<5	<5	<5	<5	F
cod liver	Inner Oslofjord, ind.no.9	<5	<5	<5	<5	F
cod liver	Inner Oslofjord, ind.no.10	<5	<5	<5	<5	<60
cod liver	Inner Oslofjord, ind.no.13	<5	<5	<5	<5	F
cod liver	Inner Oslofjord, ind.no.23	<5	<5	<5	<5	<50
cod liver	Outer Oslofjord, ind.no.19	<5	<5	<5	<5	<20
cod liver	Outer Oslofjord, ind.no.21	<5	<5	<5	<5	<20
cod liver	Outer Oslofjord, ind.no.23	<5	<5	<5	<5	F
cod liver	Outer Oslofjord, ind.no.24	<5	<5	<5	<5	F
cod liver	Outer Oslofjord, ind.no.25	<5	<5	<5	<5	<25
cod liver	South Norway, Lista, ind.no.1	<5	<5	<5	<5	F
cod liver	South Norway, Lista, ind.no.10	<5	<5	<5	<5	<70
cod liver	South Norway, Lista, ind.no.15	<5	<5	<5	<5	<100
cod liver	South Norway, Lista, ind.no.16	<5	<5	<5	<5	<60
cod liver	South Norway, Lista, ind.no.23	<5	<5	<5	<5	<50
cod liver	West Norway, Karihav, ind.no.9	<5	<5	<5	<5	<50
cod liver	West Norway, Karihav, ind.no.12	<5	<5	<5	<5	<60
cod liver	West Norway, Karihav, ind.no.14	<5	<5	<5	<5	<60
cod liver	West Norway, Karihav, ind.no.15	<5	<5	<5	<5	<60
cod liver	West Norway, Karihav, ind.no.17	<5	<5	<5	<5	<80
cod liver	Lofoten, ind.no.3	<5	<5	<5	<5	<80
cod liver	Lofoten, ind.no.10	<5	<5	<5	<5	<90
cod liver	Lofoten, ind.no.14	<5	<5	<5	<5	<50
cod liver	Lofoten, ind.no.17	<5	<5	<5	<5	F
cod liver	Lofoten, ind.no.22	<5	<5	<5	<5	F

Discussion, organochlorines

Concentrations of trichloroethylene, alachlor, endosulfan, trichlorobenzenes hexachlorobutadien (HCBD) and dicofol in sediment, blue mussel and cod liver were not detected, with one minor exception. However, the LODs were high compared to previous studies of endosulfan and HCBD (**Table 20**, **Table 21** and **Table 22**).

The use and emissions of some of these substances is restricted. Økland *et al.* (2005) noted that: Alochlor has never been used in Norway, endosulfan has been banned from 1997, trichlorobenzenes have not been registered in the Norwegian Product Register since 1995, and nor use or emissions of HCBD are known for 10 years.

It should be noted that all of the substances are included on EUs list of priority substances (cf. EQSD). Furthermore, no PNEC values were found for sediment, blue mussel and cod which would give an indication of possible toxic effects these compounds might have on the environment at this level of detection. This, and perhaps the too high LODs, emphasises the need for further research to establish useful environmental quality standards. Hence, for these reasons further research to establish useful environmental quality standards is needed.

Table 20. Comparison to previous measurements of endosulfan in recipient; µg/ kg dry weight for sediment. Unless otherwise specified, the highest detection limit and highest concentration quantified is indicated.

Matrix	Study area	Value	Reference
sediment	Norway, coast	<0.01 - <0.19	Schlabach *et al.* 2007
sediment	*Norway, coast*	*<20-<60*	*This study*

Table 21. Comparison to previous measurements of HCBD in recipient; µg/ kg dry weight for sediment. Unless otherwise specified, the highest detection limit and highest concentration quantified is indicated.

Matrix	Study area	Value	Reference
sediment	Norway, coast	<0.03	Bakke *et al.* 2007
sediment	Norway, reference	0.01-0.16	Bakke *et al.* 2008
sediment	*Norway, coast*	*<1*	*This study*

Table 22. Review of limit of detection (LOD) for endosulfan and trichlorobenzene. "Nd" indicates not detected. Values from this study indicated in gray; approximate conversion of other basis in parentheses assuming 40, 16 and 66 % dry weight for sediment, blue mussel and cod liver, respectively.

Compound	Matrix	Study area	Concentration (µg/kg d.w.)	LOD (µg/kg d.w.)	Reference
Endosulfan	sediment	Baltic Sea	*Nd*	0.3	Falandysz *et al.* 2004
Endosulfan	*sediment*	*Norway, coast*	*Nd*	*20-60*	*This study*
Endosulfan	mussel	Baltic Sea	*Nd*	0.3	Falandysz *et al.* 2004
Endosulfan	*blue Mussel*	*Norway, coast*	*Nd*	*15 w.w. (90 d.w.)*	*This study*
Endosulfan	cod liver	Greenland	12-18		Vorkamp *et al.* 2004
Endosulfan	*cod liver*	*Norway, coast*	*Nd*	*100-150*	*This study*
Trichlorobenzene	sediment	Baltic Sea	*Nd*		Sternbeck *et al.* 2003
Trichlorobenzene	*sediment*	*Norway, coast*	*Nd*	*7-10*	*This study*
Trichlorobenzene	mussel	Baltic Sea	*Nd*		Sternbeck *et al.* 2003
Trichlorobenzene	*blue Mussel*	*Norway, coast*	*Nd*	*1 w.w. (6 d.w.)*	*This study*

3.4 Cyclodienes

The cyclodienes aldrin, dieldrin, endrin, and isodrin were investigated in 8 sediment samples, 9 blue mussel samples and 25 cod liver samples (***Table 23***). Only dieldrin was detected in cod liver samples from two of the five fish collected in Southern Norway (Lista). The values were low, 31.5 and 39 µg/ kg w.w., considering that the detection limit for the other cod liver samples ranged from 25 to 50µg/ kg w.w.

Table 23. Concentrations of the cyclodienes aldrin (ALD), dieldrin (DIELD), endrin (END), and isodrin (ISOD) in sediment (µg/ kg d.w.), blue mussel and cod liver (µg/ kg w.w.). Values above the over detection limit are shaded.

matrix	station	ALD	DIELD	END	ISOD
sediment	Inner Oslofjord, core 1	<35	<35	<35	<35
sediment	Inner Oslofjord, core 3	<30	<30	<30	<30
sediment	Outer Oslofjord, core 7	<25	<25	<25	<25
sediment	South Norway, Lista, core 14	<20	<20	<20	<20
sediment	South Norway, Lista, core 15	<20	<20	<20	<20
sediment	West Norway, Sotra, core 4	<20	<20	<20	<20
sediment	Lofoten, core 22	<40	<40	<40	<40
sediment	Lofoten, core 24	<20	<20	<20	<20
sediment	Varangerfjorden, core 28	-	-	-	-
sediment	Varangerfjorden, core 30	-	-	-	-
blue mussel	Inner Oslofjord, Gresholmen	<10	<10	<10	<10
blue mussel	Inner Oslofjord, Gåsøya	<10	<10	<10	<10
blue mussel	Inner Oslofjord, Ramtonholmen	<10	<10	<10	<10
blue mussel	Outer Oslofjord, Færder	<10	<10	<10	<10
blue mussel	South Norway, Bjørkøya	<10	<10	<10	<10
blue mussel	Sørfjord, Eitrheimsneset	<10	<10	<10	<10
blue mussel	West Norway, Espevær (west)	<10	<10	<10	<10
blue mussel	Lofoten	<10	<10	<10	<10
blue mussel	Varangerfjord	<10	<10	<10	<10
cod liver	Inner Oslofjord, ind.no.7	<75	<50	<75	<50
cod liver	Inner Oslofjord, ind.no.9	<50	<25	<50	<25
cod liver	Inner Oslofjord, ind.no.10	<50	<25	<50	<25
cod liver	Inner Oslofjord, ind.no.13	<75	<50	<75	<50
cod liver	Inner Oslofjord, ind.no.23	<75	<50	<75	<50
cod liver	Outer Oslofjord, ind.no.19	<50	<25	<50	<25
cod liver	Outer Oslofjord, ind.no.21	<50	<25	<50	<25
cod liver	Outer Oslofjord, ind.no.23	<50	<25	<50	<25
cod liver	Outer Oslofjord, ind.no.24	<50	<25	<50	<25
cod liver	Outer Oslofjord, ind.no.25	<50	<25	<50	<25
cod liver	South Norway, Lista, ind.no.1	<50	<25	<50	<25
cod liver	South Norway, Lista, ind.no.10	<75	<50	<75	<50
cod liver	South Norway, Lista, ind.no.15	<75	<50	<75	<50
cod liver	South Norway, Lista, ind.no.16	<50	31.7	<50	<25
cod liver	South Norway, Lista, ind.no.23	<50	39	<50	<25
cod liver	West Norway, Karihav, ind.no.9	<75	<50	<75	<50
cod liver	West Norway, Karihav, ind.no.12	<75	<50	<75	<50
cod liver	West Norway, Karihav, ind.no.14	<75	<50	<75	<50
cod liver	West Norway, Karihav, ind.no.15	<75	<50	<75	<50
cod liver	West Norway, Karihav, ind.no.17	<75	<50	<75	<50
cod liver	Lofoten, ind.no.3	<50	<25	<50	<25
cod liver	Lofoten, ind.no.10	<50	<25	<50	<25
cod liver	Lofoten, ind.no.14	<50	<25	<50	<25
cod liver	Lofoten, ind.no.17	<50	<25	<50	<25
cod liver	Lofoten, ind.no.22	<50	<25	<50	<25

Discussion, cyclodienes

Though concentrations of cyclodienes in sediment, blue mussel and cod liver were not detected (with two exceptions) the LODs were high compared to other studies (***Table 24***, ***Table 25***).

It should be noted that all four cyclodienes are included on EUs list of priority substances (cf. EQSD). Furthermore, no PNEC values were found for sediment, blue mussel and cod which would give an indication of possible toxic effects these compounds might have on the environment at this level of detection. This, and perhaps the too high LODs, emphasises the need for further research to establish useful environmental quality standards.

Table 24. Comparison to previous measurements of dieldrin in recipient; µg/ kg dry weight for sediment. Unless otherwise specified, the highest detection limit and highest concentration quantified is indicated.

Matrix	Study area	Value	Reference
sediment	Norway, coast	<0.03-(1.39)-<1.49	Schlabach *et al.* 2007
sediment	*Norway, coast*	*<20 - <40*	*This study*

Table 25. Comparison to previous measurements of endrin in recipient; µg/kg dry weight for sediment. Unless otherwise specified, the highest detection limit and highest concentration quantified is indicated.

Matrix	Study area	Value	Reference
sediment	Norway, coast	<0.04-<1.80	Schlabach *et al.* 2007
sediment	*Norway, coast*	*<20 - <40*	*This study*

Table 26. Review of limit of detection (LOD) for cyclodienes. "Nd" indicates not detected. Values from this study marked in gray; approximate conversion of other basis in parentheses assuming 40, 16 and 66 % dry weight for sediment, blue mussel and cod liver, respectively.

Compound	Matrix	Study area	Concentration (µg/kg d.w.)	LOD (µg/kg d.w.)	Reference
Drins	sediment	Baltic Sea	Nd	0.2-1.2	Falandysz *et al.* 2004
Drins	*sediment*	*Norway, coast*	*nd*	*20-40*	*This study*
Drins	mussel	Baltic Sea	Nd	0.2-1.2	Falandysz *et al.* 2004
Drins	*blue mussel*	*Norway, coast*	*Nd*	*10 w.w. (60 d.w.)*	*This study*
Drins	cod	Greenland	48-57		Vorkamp *et al.* 2004
Drins	*cod liver*	*Norway, coast*	*Nd-39 w.w. (60 d.w.)*	*25-75 w.w. (33-112 d.w.)*	*This study*
ALD/END	fish	Canadian pristine environment (four-horn sculpin)	Nd	0.1-0.3	Bright *et al.* 1995
ALD/END	fish	Canadian contmi-nated environment (four-horn sculpin)	Nd	0.1-0.3	Bright *et al.* 1995
ALD/END	*cod liver*	*Norway, coast*	*Nd*	*25-75 w.w. (33-112 d.w.)*	*This study*
DIELD	fish	Canadian pristine environment (four-horn sculpin)	1-3		Bright *et al.* 1995
DIELD	fish	Canadian contmi-nated environment (four-horn sculpin)	3.9-7.4		Bright *et al.* 1995
DIELD	*cod liver*	*Norway, coast*	*Nd-39 w.w. (60 d.w.)*	*25-50 w.w. (33-75 d.w.)*	*This study*

3.5 Phenols/ chlorophenols, isoproturon and DEHP

Pentachlorophenol, nonylphenol and isoproturon were investigated in 5-8 sediment samples, 9 blue mussel samples and 25 cod liver samples (***Table 27***). Di(2-ethylhexyl)-phthalate (DEHP) was also investigated in 8 sediment samples. Interference or insufficient sample materiale prohibited quantification in many cases, and for all cases concerning octylphenol and for biota DEHP (***Table 6***). No concentrations above the detection limit were detected.

Table 27. Concentrations of pentachlorophenol (PCP), octylphenol (OCP), nonylphenol (NOP), isoproturon (ISO), and di(2-ethylhexyl)-phthalate (DEHP) in sediment (µg/kg d.w.), blue mussel and cod liver (µg/kg w.w.). No concentrations above the detection limit were detected. Samples that could not be quantified because of interference (F) are indicated. (cf. chapter 2.3.9).

matrix	station	PCP	OCP	NOP	ISO	DEHP
sediment	Inner Oslofjord, core 1	F	F	F	<10	<300
sediment	Inner Oslofjord, core 3	<3	F	<15	<10	<150
sediment	Outer Oslofjord, core 7	<1	F	<4	<8	<70
sediment	South Norway, Lista, core 14	<0.7	F	<3	<6	<100
sediment	South Norway, Lista, core 15	F	F	F	<6	<50
sediment	West Norway, Sotra, core 4	F	F	F	<6	<125
sediment	Lofoten, core 22	<140	F	<100	<13	<750
sediment	Lofoten, core 24	<7	F	<15	<10	<80
sediment	Varangerfjorden, core 28	-	-	-	-	-
sediment	Varangerfjorden, core 30	-	-	-	-	-
blue mussel	Inner Oslofjord, Gresholmen	<0.5	F	<3	<5	F
blue mussel	Inner Oslofjord, Gåsøya	<6	F	<15	<5	F
blue mussel	Inner Oslofjord, Ramtonholmen	<0.7	F	<7	<5	F
blue mussel	Outer Oslofjord, Færder	<0.7	F	<3	<5	F
blue mussel	South Norway, Bjørkøya	<1	F	<4	<5	F
blue mussel	Sørfjord, Eitrheimsneset	<0.7	F	<14	<5	F
blue mussel	West Norway, Espevær (west)	<0.5	F	<5	<5	F
blue mussel	Lofoten	<0.8	F	<6	<5	F
blue mussel	Varangerfjord	<0.6	F	<4	<5	F
cod liver	Inner Oslofjord, ind.no.7	F	F	F	<10	F
cod liver	Inner Oslofjord, ind.no.9	<35	F	<30	<10	F
cod liver	Inner Oslofjord, ind.no.10	<70	F	<70	<10	F
cod liver	Inner Oslofjord, ind.no.13	F	F	F	<10	F
cod liver	Inner Oslofjord, ind.no.23	<20	F	<70	<10	F
cod liver	Outer Oslofjord, ind.no.19	<3	F	<25	<10	F
cod liver	Outer Oslofjord, ind.no.21	<1	F	<40	<10	F
cod liver	Outer Oslofjord, ind.no.23	F	F	F	<10	F
cod liver	Outer Oslofjord, ind.no.24	F	F	F	<10	F
cod liver	Outer Oslofjord, ind.no.25	<3	F	<25	<10	F
cod liver	South Norway, Lista, ind.no.1	F	F	F	<10	F
cod liver	South Norway, Lista, ind.no.10	<3	F	<120	<10	F
cod liver	South Norway, Lista, ind.no.15	<20	F	F	<10	F
cod liver	South Norway, Lista, ind.no.16	<4	F	<100	<10	F
cod liver	South Norway, Lista, ind.no.23	<1	F	<150	<10	F
cod liver	West Norway, Karihav, ind.no.9	<20	F	<80	<10	F
cod liver	West Norway, Karihav, ind.no.12	<25	F	<80	<10	F
cod liver	West Norway, Karihav, ind.no.14	<40	F	<50	<10	F
cod liver	West Norway, Karihav, ind.no.15	<60	F	<70	<10	F
cod liver	West Norway, Karihav, ind.no.17	F	F	<70	<10	F
cod liver	Lofoten, ind.no.3	<4	F	<140	<10	F
cod liver	Lofoten, ind.no.10	<3	F	F	<10	F
cod liver	Lofoten, ind.no.14	<2	F	F	<10	F
cod liver	Lofoten, ind.no.17	F	F	F	<10	F
cod liver	Lofoten, ind.no.22	F	F	F	<10	F

Discussion, phenols/chlorophenols, isoproturon and DEHP

Pentachlorphenol was not detected in sediment, blue mussel and cod liver. The LOD ranged from 0.7 to 7 µg/ kg d.w., for sediment, disregarding the replicate sample from Lofoten with unusually high detection limits, and from 0.5 to 6 µg/ kg w.w. for blue mussel. These LODs were about 10 times the LODs found in previous studies (***Table 28***) or below the maximum concentrations found in other studies (***Table 31***). With the exception noted, the LODs for sediment were well below the predicted no effect concentration (PNECs) of 12 µg/kg d.w. in marine sediments in the revised SFT risk assessment tool (SFT 2007). With this consideration and because this substance is not in use in Norway (Økland *et al.* 2005), pentachlorphenol therefore pose no risk to the environment.

Table 28. Comparison to previous measurements of pentachlorophenol in recipient; µg/ kg dry weight for sediment and µg/kg wet weight for blue mussel. Unless otherwise specified, the highest detection limit and highest concentration quantified is indicated.

Matrix	Study area	Value	Reference
sediment	Norway, coast	Nd-0.76	Bakke *et al.* 2007
sediment	Norway, coast	Nd	Bakke *et al.* 2008
sediment	*Norway, coast*	*<0.7-<7* [1]	*This study*
blue mussel	Norway, coast	Nd-0.10	Bakke *et al.* 2007
blue mussel	*Norway, coast*	*<0.5-<6*	*This study*

1) In addition, one sample from Lofoten with LOD og 140 µg/kg d.w.

Nonylphenol was not detected in sediment, blue mussel and cod liver. The LODs ranged from 3 to 5 µg/kg d.w. for sediment, about 100 times that found in a previous study (***Table 29***, ***Table 31***). However, the maximum LOD was well below the PNEC of 18 µg/ kg for nonylphenol in marine sediments (SFT 2007). Furthermore, nonylphenols have been mainly banned in Norway from 2002 (Økland *et al.* 2005). For these reasons and assuming that this study has sufficiently low LOD, nonylphenol should pose no risk to the environment.

Table 29. Comparison to previous measurements of nonyphenol in recipient; µg/ kg dry weight for sediment. Unless otherwise specified, the highest detection limit and highest concentration quantified is indicated.

Matrix	Study area	Value	Reference
sediment	Barents Sea	<1.28	Bakke *et al.* 2008
sediment	*Norway, coast*	*<3-<100*	*This study*

Isoproturon was not detected in sediment, blue mussel, and cod liver. It was also not detected in a Swedish survey (***Table 31***). Considering these obsersvations and that isoproturon has been banned in Norway from 2006 (Økland *et al.* 2005), this substance should represent a low risk to the environment. However, no PNEC-data were found for sediment, blue mussel and cod which would give an indication of possible toxic effects these compounds might have on the environment at this level of detection. Furthermore, some isoproturon is on the list of priority substances under EU's Water Framework Directive. This emphasises the need for further research to establish useful environmental quality standards and should be sufficient reasons to continue investigating the levels and trends of these substances.

DEHP was not detected in sediment. The LOD ranged from 50 to 750 µg/ kg d.w. in the samples; in an order of magnitude of the concentrations found in other investigations (***Table 30***, ***Table 31***). DEHP has been banned in small-children products (Økland *et al.* 2005). However, no PNEC-data were found for sediment, blue mussel and cod which would give an indi-

cation of possible toxic effects these compounds might have on the environment at this level of detection. Furthermore, some DEHPs are on the list of priority substances under EU's Water Framework Directive. This emphasises the need for further research to establish useful environmental quality standards and should be sufficient reasons to continue investigating the levels and trends of these substances.

Table 30. Comparison to previous measurements of DEHP in recipient; µg/ kg dry weight for sediment. Unless otherwise specified, the highest detection limit and highest concentration quantified is indicated.

Matrix	Study area	Value	Reference
sediment	Norway	73.5-339	Bakke *et al.* 2007
sediment	Barents Sea	1160-57690	Bakke *et al.* 2008
sediment	*Norway, coast*	*<50-<750*	*This study*

Table 31. Review of limit of detection (LOD) for phenols, isoproturon, and DEHP. "Nd" indicates not detected. Values from this study marked in gray; approximate conversion of other basis in parentheses assuming 40, 16 and 66 % dry weight for sediment, blue mussel and cod liver, respectively.

Compound	Matrix	Study area	Concentration (µg/kg d.w.)	LOD (µg/kg d.w.)	Reference
PCP	sediment	Baltic Sea	Nd-10		Sternbeck *et al.* 2003
PCP	sediment	Swedish Coastline	0-28		Palm *et al.* 2002
PCP	*sediment*	*Norway, coast*	*Nd*	*0.7-7* [1]	*This study*
PCP	mussel	Baltic Sea	Nd-10		Sternbeck *et al.* 2003
PCP	mussel	Swedish Coastline	0-28		Palm *et al.* 2002
PCP	*blue mussel*	*Norway, coast*	*Nd*	*0.5-6 w.w. (3-36 d.w.)*	*This study*
PCP	fish	Swedish coastline (mixed biota samples)	50-350	1	Palm *et al.* 2002
PCP	*cod liver*	*Norway, coast*	*Nd*	*1-70 w.w. (1.5-105 d.w.)*	*This study*
NOP	sediment	Sweden, lake	67-5300		Sternbeck *et al.* 2003
NOP	sediment	Sweden, Stockholm	12-610		Sternbeck *et al.* 2003
NOP	sediment	Sweden, coast	nd-380		Sternbeck *et al.* 2003
NOP	sediment	China	2976		Fen *et al.* 2007
NOP	sediment	New York	4120		Ferguson *et al.* 2001
NOP	sediment	China	12.9-1159.99		Zhang *et al.* 2009
NOP	sediment	Danube river, Austria	20-180		Micic & Hofmann 2009
NOP	*sediment*	*Norway, coast*	*Nd*	*3-100*	*This study*
NOP	mussel	Sweden, lake	67-5300		Sternbeck *et al.* 2003
NOP	mussel	Sweden, Stockholm	12-610		Sternbeck *et al.* 2003
NOP	mussel	Sweden, coast	Nd-380		Sternbeck *et al.* 2003
NOP	mussel	China	2976		Fen *et al.* 2007
NOP	mussel	New York	4120		Ferguson *et al.*

Compound	Matrix	Study area	Concentra-tion (µg/kg d.w.)	LOD (µg/kg d.w.)	Reference
					2001
NOP	mussel	China	12.9-1159.99		Zhang *et al.* 2009
NOP	mussel	Danube river, Austria	20-180		Micic & Hofmann 2009
NOP	*blue mussel*	*Norway, coast*	*Nd*	*3-14 w.w. (18-84 d.w.)*	*This study*
ISO	sediment	Baltic Sea	Nd		Sternbeck *et al.* 2003
ISO	sediment	Central Stock-holm	Nd		Sternbeck *et al.* 2003
ISO	sediment	*Norway, coast*	*Nd*	*6-13*	*This study*
ISO	mussel	Baltic Sea	Nd		Sternbeck *et al.* 2003
ISO	mussel	Central Stock-holm	Nd		Sternbeck *et al.* 2003
ISO	*blue mussel*	*Norway, coast*	*Nd*	*5 w.w. (30 d.w.)*	*This study*
DEHP	sediment	Baltic Sea	60-600		Sternbeck *et al.* 2003
DEHP	sediment	Svalbard	Nd	60	Evenset *et al.* 2009
DEHP	*sediment*	*Norway, coast*	*Nd*	*50-750*	*This study*

1) In addition, one sample from Lofoten with LOD og 140 µg/kg d.w.

3.6 Silver, arsenic, chromium and nickel

Silver and nickel were investigated in 9 blue mussel samples whereas arsenic and chromium were investigated in both blue mussel and cod liver (***Table 6***, ***Table 32***).

Silver in blue mussel ranged from 0.003 to 0.019 µg/kg w.w., the highest concentration was found in Varangerfjord.

The range of **arsenic** in blue mussel was 1.38 - 4.91 µg/kg. The average concentration in the presumed contaminated areas (inner Oslofjord and inner Sørfjord) was 1.6 mg/kg d.w., and about half of 3.1 mg/kg d.w.; which was the average concentration of mussels from the outer Oslofjord, south Norway (Lista), west Norway (Espevær) and Lofoten. In cod liver the range was 2.4 - 57.5 µg/kg d.w. The average in cod liver from the inner Oslofjord was 29.9, over three times the next highest average found in southern Norway (Lista).

The range of **chromium** in blue mussel was 0.07 - 0.47 µg/kg w.w., the highest concentration was found in Varangerfjord. The metal was not detected in cod liver samples.

Nickel in blue mussel ranged from 0.07 to 0.32 µg/kg w.w. The highest value was found in Varangerfjord.

Table 32. Concentrations of silver (Ag), arsenic (As), chromium (Cr) and nickel (Ni) (mg/ kg d.w.). Values above the detection limit are shaded.

Matrix	Station	Ag	As	Cr	Ni
blue mussel	Inner Oslofjord, Gressholmen	0.009	1.48	0.2	0.13
blue mussel	Inner Oslofjord, Gåsøya	0.005	1.38	0.12	0.12
blue mussel	Inner Oslofjord, Ramtonholmen	0.005	1.73	0.35	0.17
blue mussel	Outer Oslofjord, Færder	0.008	2.39	0.07	0.16
blue mussel	South Norway, Bjørkøya	0.011	2.25	0.2	0.17
blue mussel	Sørfjord, Eitrheimsneset	0.008	1.96	0.07	0.07
blue mussel	West Norway, Espevær (west)	0.003	4.91	0.12	0.18
blue mussel	Lofoten	0.009	2.67	0.12	0.13
blue mussel	Varangerfjord	0.019	2.75	0.47	0.32
cod liver	Inner Oslofjord, ind.no.7		16.3	<0.2	
cod liver	Inner Oslofjord, ind.no.9		34.1	<0.2	
cod liver	Inner Oslofjord, ind.no.10		57.5	<0.2	
cod liver	Inner Oslofjord, ind.no.13		9.47	<0.2	
cod liver	Inner Oslofjord, ind.no.23		31.9	<0.2	
cod liver	Outer Oslofjord, ind.no.19		4.51	<0.2	
cod liver	Outer Oslofjord, ind.no.21		5.01	<0.2	
cod liver	Outer Oslofjord, ind.no.23		4.57	<0.2	
cod liver	Outer Oslofjord, ind.no.24		7.01	<0.2	
cod liver	Outer Oslofjord, ind.no.25		6.56	<0.2	
cod liver	South Norway, Lista, ind.no.1		7.21	<0.2	
cod liver	South Norway, Lista, ind.no.10		7.66	<0.2	
cod liver	South Norway, Lista, ind.no.15		3.48	<0.2	
cod liver	South Norway, Lista, ind.no.16		25.5	<0.2	
cod liver	South Norway, Lista, ind.no.23		5.19	<0.2	
cod liver	West Norway, Karihav, ind.no.9		2.64	<0.2	
cod liver	West Norway, Karihav, ind.no.12		3.61	<0.2	
cod liver	West Norway, Karihav, ind.no.14		2.76	<0.2	
cod liver	West Norway, Karihav, ind.no.15		2.78	<0.2	
cod liver	West Norway, Karihav, ind.no.17		2.85	<0.2	
cod liver	Lofoten, ind.no.3		3.39	<0.2	
cod liver	Lofoten, ind.no.10		2.4	<0.2	
cod liver	Lofoten, ind.no.14		2.48	<0.2	
cod liver	Lofoten, ind.no.17		2.78	<0.2	
cod liver	Lofoten, ind.no.22		3.32	<0.2	

Discussion, silver, arsenic, chromium and nickel

Silver was detected in all blue mussel samples but there was no evident difference between presumed contaminated areas (inner Oslofjord, inner Sørfjord) and areas more remote. This would indicate that levels are low. However, no PNEC-data were found for blue mussel and cod which would give an indication of possible toxic effects these compounds might have on the environment at this level of detection. This emphasises the need for further research to establish useful environmental quality standards and should be sufficient reasons to continue investigating the levels and trends of these substances.

Arsenic was detected in all blue mussel and cod liver samples. That the average from more perturbed areas (inner Oslofjord and inner Sørfjord) was less than other areas remote from presumed contamination, could indicate the influence of some transboundary contamination in the surface waters. Concentrations in both blue mussel and cod liver were in the range found in previous investigations (***Table 33***). However, no PNEC-data were found for blue mussel and cod which would give an indication of possible toxic effects these compounds might have on the environment at this level of detection. This emphasises the need for further research to establish useful environmental quality standards and should be sufficient reasons to continue investigating the levels and trends of these substances.

Table 33. Comparison with previous measurements of arsenic in blue mussel and cod liver mg/ kg dry weight.

Study area	Matrix	Value	Reference
Norway	Blue mussel	1.19-5.93	Bakke *et al.* 2007
Norway, coast	*Blue mussel*	*1.38-4.91*	*This study*
Norway	Cod liver	3.24-19.02	Bakke *et al.* 2007
Norway, coast	*Cod liver*	*2.4-57.5*	*This study*

Chromium was only detected in the blue mussel with no evident difference between presumed contaminated and less contaminated areas. The range was within the range found in a previous investigation (***Table 34***). Chromium was not detected in cod liver though the LOD was somewhat higher than in a previous investigation (***Table 34***). No PNEC-data were found for blue mussel and cod which would give an indication of possible toxic effects these compounds might have on the environment at this level of detection. This emphasises the need for further research to establish useful environmental quality standards and should be sufficient reasons to continue investigating the levels and trends of these substances.

Table 34. Comparison with previous measurements of chromium in blue mussel and cod liver mg/ kg dry weight.

Study area	Matrix	Value	Reference
Norway	Blue mussel	0.07-1.46	Bakke *et al.* 2007
Norway, coast	*Blue mussel*	*0.07-0.47*	*This study*
Norway	Cod liver	<0.04-0.05	Bakke *et al.* 2007
Norway, coast	*Cod liver*	*<0.2*	*This study*

For **nickel**, there was no evident difference between presumed contaminated and less contaminated areas. No PNEC-data were found for blue mussel which would give an indication of possible toxic effects these compounds might have on the environment at this level of detection. This emphasises the need for further research to establish useful environmental qual-

ity standards and should be sufficient reasons to continue investigating the levels and trends of these substances.

4. Conclusions

The concentrations of polybrominated diphenylethers (PBDE) and perfluorinated organic compounds are high enough to warrant continued monitoring, however, many of the other substances were not detected (***Table 35***).

The general lack of Predicted No Effect Concentrations (PNECs) or Environmental Quality Standard (EQS) for sediment or biota prevents an adequate means of assessing potential risk that the substances investigated in this study might have on the environment. The limit of detection (LOD) for many of these substances may not be sufficiently low to rule out potential risk.

Relevant PNECs and EQSs are under development and for the most part non-existent for the matrices concerned. Hence, it would be premature to discontinue any monitoring on a substance on the basis that it was not detected. When relevant EQS are made available the results from this and other studies should be reassessed.

Another consideration is the representativeness of the selected samples. The selection in this and previous screening exercises (e.g. Bakke *et al.* 2007, 2008; Fjeld *et al.* 2005, Green *et al.* 2008) provide valuable insight to concentrations that can be expected in some matrices in some areas. But in this study only twenty stations and three matrices were sampled. There is still a need to investigate other areas and matrices. Furthermore, considerable differences are found between individual fish (e.g. BDE47 in ***Figure 4***, PFOS in ***Figure 5***). Hence, caution is advised in extrapolating the geographical and temporal extent of these results or even when considering other tissues of the same species of different species.

Even though many of the substances have never been used (alachlor), have been banned or not registered for over 10 years (trichlorobenzenes, hexachlorobutadiene) in Norway, they may still represent a potential risk to the environment because they degrade slowly or can be transported to Norwegian waters via air or water currents. These attributes as well as their toxic nature and their ability to bioaccumulate are generally the main reasons that hazardous substances are listed in the EQSD.

To continue to monitor these substances is advised for the above mentioned reasons, especially when there is insufficient information to do the contrary. This is also in line with the precautionary principle as established by both the Water Framework Directive (2000/60/EC), ratified by Norway in 2008, and the Marine Strategy Framework Directive (2008/56/EC), which is currently under discussion. A pragmatic approach would be to have different intensities of monitoring, with regard to distribution and number of stations and matrices, depending on the substance. A proposal for relative intensity of monitoring as high, moderate or low is provided (***Table 35***).

Table 35. Overview and ranges of the compounds and metals investigated with notation as to which are listed in Environmental Quality Standard Directive – EQSD (2008/105/EC). Results from review by Økland et al. *(2005) and existence of PNEC values (SFT 2007) in sediment are also noted. The range in limit of detection (LOD) is given if the substance was not detected or if the substance was detected but was within the LOD-range, in which case the range of detected concentrations is given in parentheses. The approximate factor of difference the LOD in this study has compared to previous studies is indicated in square brackets ([ ]). The suggested intensity of monitoring as high (A), moderate (B) or low (C) relative to other substances analysed in this study.*

Compound	Abbreviation	EQSD substance no.	Review (Økland *et al.* 2005)	PNEC values; sediment	Levels found sediment µg/kg d.w.	Levels found blue mussel, µg/kg w.w.	Levels found cod liver, µg/kg w.w.	Monitoring priority
Brominated compounds								
2,4,4'-tribromodiphenylether	BDE28	5			<0.04-0.02	<0.03	0.1-0.45	A [1]
2,2',4,4'-tetrabromodiphenylether	BDE47	5			<0.04-0.29	<0.03-0.46	1.4-100	A [1]
2,2',4,5'-tetrabromodiphenylether	BDE49				<0.04-<0.2	<0.04-<0.19	0.13-6.6	A [2]
2,3'4,4'-tetrabromodiphenylether	BDE66				<0.04-<0.2	<0.03-<0.07	<0.05-3.3	A [2]
2,3',4',6-tetrabromodiphenylether	BDE71				<0.04-<0.2	Not investigated	<0.03-<0.21	A [2]
3,3',4,4'-tetrabromdiphenyleter	BDE77				<0.05-<0.2	<0.03-<0.09	<0.05-<0.14	A [2]
2,2',3,4,4'-pentabromodiphenylether	BDE85		New use banned from 2004 (PeBDE)	Yes	<0.04-(0.06) -0.2	<0.03-0.07	<0.05-1.7	A
2,2',4,4',5-pentabromodiphenylether	BDE99	5	New use banned from 2004 (PeBDE)	Yes	<0.04-0.13	0.03-0.29	<0.05-25	A [1]
2,2',4,4',6-pentabromodiphenylether	BD100	5	New use banned from 2004 (PeBDE)	Yes	<0.04-(0.19)-<0.2	<0.03-0.15	0.24-4.1	A [1]
2,3',4,4',6-pentabromodiphenylether	BD119		New use banned from 2004 (PeBDE)	Yes	<0.1-<0.15	<0.04-0.11	<0.05-0.29	A
2,2',3,4,4',5'-hexabromodiphenylether	BD138				<0.1-<0.3	<0.03-<0.06	<0.08-0.53	A [2]
2,2',4,4',5,5'-hexabromodiphenylether	BD153	5			<0.04-<0.2	<0.03-<0.13	<0.03-0.55	A [1]
2,2',4,4',5,6'-hexabromodiphenylether	BD154	5			<0.04-<0.2	<0.03-<0.05	0.12-5.2	A [1]
2,2',3,4,4',5',6-heptabromdiphenyleter	BD183				<0.1-(0.21)-<0.3	<0.04-<0.05	<0.1-<0.2	A [2]
2,2',3,3',4,4',5,6'-octabromodiphenylether	BD196				<0.1-<0.3	<0.05	<0.1-<0.2	A [2]

Compound	Abbreviation	EQSD substance no.	Review (Økland *et al.* 2005)	PNEC values; sediment	Levels found sediment µg/kg d.w.	Levels found blue mussel, µg/kg w.w.	Levels found cod liver, µg/kg w.w.	Monitoring priority
2,2′,3,3′,4,4′,5,5′,6-nonabromodiphenylether	BD206				<0.1-0.33	<0.05	<0.15-<0.2	A [2]
2,2′,3,3′,4,4′,5,5′,6,6′-decabromodiphenylether	BD209				<0.2-3.3	<0.1-<0.3	<0.5-<15	A
Sum PBDE[13]					0.04-3.3	0.04-0.77	3.16-1.68	A
A-, β-, and γ-hexabromcyclododecane	HBCDD			Yes	<2-<10 [~10x]	<1-<2 [~10x]	<50-(66)-200 [~100x]	A [3]
bis-1,2(2,4,6-tribromphenoxy)ethane	BTBPE				<0.03-1.9	<0.05	<0.04-<0.17	A [3]
Dimethyltetrabrombisphenol A	TBBPA			Yes	<2-<20	(0.7) <1-<10	7.5-70.9	A [3]
Perfluorinated organic compounds								
perfluorobutane sulfonate	PFBS				<1	<10	<5-(5.3-8)-<12	A [3,4,]
perfluroroheptanoic acid	PFHPA				<1	<20	<1-<6	A [3,4,]
perflurorohexanoic acid	PFHXA				<1	<10	<1-<15	A [3,4,]
perfluorononanoic acid	PFNA				<1.5	<10	<1-<19	A [3,4,]
perfluoroctanoic acid (PFOA)	PFOA				<2.5	<10	<1-<40	A [3,4,]
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				<1 [~10x]	<5 [~10-1000x]	(1) <2-50 [~10-1000x]	A [3,4,]
perfluorooctanyl sulphonic acid (perfluoroctanoic sulfonate, perfluorooctane sulfonate)	PFOS	Annex III		Yes	<1 [~10x]	<10 [~10-100(-1000x)]	(1) <2-570 [~10-1000x]	A [1,3,4,]
Organochlorines								
trichloroethylene (TRI)	TRI	29b			Not investigated	<0.9-1.3	<4-(5)-<6	B [1,3,5]
Tetrachloroethylene	TET	29a			Not investigated	Not investigated	Not investigated	B [1,3,5]
Alachlor	ALA	1	Never used		<20-<60	<15	<50-<75	C [1,3]
Endosulfan	ENDOA ENDOB	14	Banned from 1997		<20-<60 [~10-100x]	<15 [~10-100x]	<100-<150	B [1,3]
1,2,3-, trichlorobenzene	TRCB0	31	Not registered in the Norwegian Product Register since 1995	Yes	<7-<10	<1	<5	B [1,3]
Hexachlorobutadiene	HCBD	17	No use/emissions for 10 years	Yes	<1-<2 [~10-100x]	<1	<5	B [1,3]
4-chlor-a-(4-chlorphenyl)-a-(trichlormethyl)-benzenmethanol,	DICOFOL	Annex III			<3-<40	<0.7-<12	<20-<100	C [1,3]
Cyclodienes								

[13] Limit of detection not included in sum of PBDE

Compound	Abbreviation	EQSD substance no.	Review (Økland *et al.* 2005)	PNEC values; sediment	Levels found sediment µg/kg d.w.	Levels found blue mussel, µg/kg w.w.	Levels found cod liver, µg/kg w.w.	Monitoring priority
Aldrin	ALD	9a			<20-<40 [~10-100x]	<10 [~10-100x]	<50-<75 [~10-100x]	C [1,3]
Dieldrin	DIELD	9a			<20-<40 [~10-100x]	<10 [~10-100x]	<50-(31.7-39)-<5o	C [1,3]
Endrin	END	9a			<20-<40 [~10-100x]	<10 [~10-100x]	<50-<75 [~10-100x]	C [1,3]
Isodrin*	ISOD	9a			<20-<40 [~10-100x]	<10 [~10-100x]	<25-<50	C [1,3]
Phenols/Chlorophenols								
Pentachlorophenol (PCP)	PCP	27	Not in use, may be present in imported products		<0.7-<140 [~1x]	<0.7-1 [~1x]	<1-<60 [~1x]	B [1,3]
octylphenol (4-(1.1,3,3-tetramethylbutyl)-phenol)	OCP	25	(Mainly) banne form 2002		Not investigated	Not investigated	Not investigated	B [1,3]
Nonylphenol (4-Nonylphenol)	NOP	24	(Mainly) banned from 2002		<3-<100 [~1-10x]	<3-<15	<25-150	B [1,3]
Isoproturon	ISO	19	Banned from 2006		<6-<13	<5	<10	B [1,3]
Phthalate								
Di(2-ethylhexyl)-phthalate	DEHP	12	Banned in small children products		<50-<750 [~1x]	Not investigated	Not investigated	A [1,3]
Metals								
Silver	Ag				Not investigated	0.003-0.019	Not investigated	A [3]
Arsenic	As			Yes	Not investigated	1.38-2.75	2.4-57.5	B [3]
Chromium	Cr			Yes	Not investigated	0.07-0.47	<0.2	B [3]
Nickel	Ni	23		Yes	Not investigated	0.07-0.37	Not investigated	B [1,3]

1) Specified under the EQSD.
2) Commonly included in analyses of polybrominated diphenylethers (PBDE).
3) Need for PNEC or EQS in relevant matrices to assess significance of LOD or concentrations detected.
4) Commonly included in analyses of perfluorinated organic compounds (PFC).
5) Still in use, though reduced 90%.

5. References

2000/60/EC. Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy. [Water Framework Directive]. http://www.europa.eu.int/comm/environment/water/water-framework/index_en.html

2008/56/EC. Directive 2000/56/EC of the European Parliament and of the Council of 17 June 2008 establishing a framework for Community action in the field of marine environmental policy. [Marine Strategy Framework Directive]. http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:32008L0056:EN:NOT

2008/105/EC. Directive 2008/105/EC of the European Parliament and of the Council of 16 December 2008 on environmental quality standards in the field of water policy, amending and subsequently repealing Council Directives 82/176/EEC, 83/513/EEC, 84/156/EEC, 84/491/EEC, 86/491/EEC, 86/280/EEC and amending Directive 2000/60/EC of the European Parliament and of the Council. http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:32008L0105:EN:NOT

ACGIH, 2001. Hexachlorobutadiene Documentation of Threshold Limit Values and Biological Exposure Indices. American Conference of Governmental Industrial Hygienists 7th Ed. Cincinnati, OH.

Amlund H., Ingebrigtsen, K., Hylland, K., Ruus, A., Eriksen D.Ø., Berntssen, M.H.G., 2006. Disposition of arsenobetaine in two marine fish species following administration of a single oral dose of [14C]arsenobetaine. Comparative Biochemistry and Physiology, Part C 143 171-178.

ATSDR, 1994. Toxicological Profile for Hexachlorobutadiene. Agency for Toxic Substances and Disease Registry. U.S. Department of Health and Human Services. Public Health Service.

Bakke, T., Boitsov, S., Brevik, E.M., Gabrielsen, G.W:, Green, N., Helgason, L.B:, Klungsøyr, J., Leknes, H, Miljeteig, C., Måge, A., Rolfsnes, B.E., Savinova, T., Schlabach, M., Skaare, B.B., Valdersnes, S., 2008. Mapping selected organic contaminants in Barents Sea 2007. SFT TA2400/2008. NIVA report 5589-2008. 117s.

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.

Becher G. 2005. The stereochemistry of 1,2,5,6,9,10-hexabromocyclododecane and its graphic representation. *Chemosphere* 58:989-991.

Berge, J.A., Schlabach, M., Fagerhaug, A., Rønneberg, J., E., Kartlegging av utvalgte miljøgifter i Åsefjorden og omkringliggende områder. Bromerte flammehemmere, klororganiske forbindelser, kvikksølv og tribromanisol. SFT TA 2146/2006. NIVA report 5132/2006. 73s + vedlegg.

Berger, U., Järnberg, U., Kallenborn, R., 2004. Perfluorinated alkylated substances (PFAS) in European Nordic environment. Organohalogen Compounds 66 4046:4052.

Bright DA, Dushenko, W.T., Grundy, S.L., Reimer, K.J. (1995). Effects of local and distant contaminant sources: polychlorinated biphenyls and other organochlorines in bottom-dwelling animals from an Arctic estuary. *Science of the Total Environment* 160-161: 265-283.

de Boer J, Wester PG, Klammer HJC, Lewis WE, Boon JP. 1998. Do flame retardants threaten ocean life? *Nature* 394:6688.

De Voogt, P., 2006. Report to the European Commission: PERFORCE, perfluorinated organic compounds in the European Environment. Contract no. 508967: FP6-NEST INSIGHT. The Netherlands Institute for Biodiversity and Ecosystem Dynamics. Universiteit van Amsterdam.

DnV, 2007. Miljøovervåking og grunnlagsundersøkelse i Region VI – Haltenbanken 2006, Main Report. Det norske Veritas rapport nr 2007-0025.

Drake, P.L., Hazelwood K.J., 2005. Exposure-related health effects of silver and silver compounds: A review. Annals of Occupational Hygiene 49, 575-585.

Dunnick, 1995. "Comparative carcinogenic effects of nickel subsulfide, nickel oxide, or nickel sulfate hexahydrate chronic exposures in the lung.". *Cancer research* 55 (22): 5251–6. PMID 7585584.

Evenset A., Leknes, H., Christensen, G.N., Warner, N., Remberger, M., Gabrielsen, G.W. (2009). Screening of new contaminants in samples from the Norwegian Arctic. SFT TA-2510/ 2009. Norwegian Pollution Control Authority.

Falandysz J, Strandberg, B. (2004). Persistent Organochlorine Compounds in Sludge and Sediments from the Gdańsk Region, Baltic Sea. *Polish Journal of Environmental Studies* 13: 133-138.

Fen JIN, Jian-ying, H.U., Min, Y.A.N.G. (2007). Vertical distribution of nonylphenol ethoxylates in sedimentary core from the Beipaiming Channel, North China. *Journal of Environmental Sciences* 19: 353-357.

Ferguson PL, Iden, C.R., Brownawell, B.J. (2001). Analysis of nonylphenol and nonylphenol ethoxylates in environmental samples by mixed-mode high performance liquid chromatography-electrospray mass spectrometry. *Journal of Chromatography A* 938: 79-91.

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.

Granmo Å, Ekelund R, Magnusson K, Berggren M. 1989. Lethal and sublethal toxicity of 4-Nonylphenol to the common mussel (*Mytilus edulis* L.). *Environ Pollut* 59:115-127.

Gerecke, A. C., Hartmann, P. C., Heeb, N. V., Kohler, H. P., Giger, W., Schmid, P., Zennegg, M. and Kohler, M. Anaerobic Degradation of Decabromodiphenyl Ether. *Environmental Science & Technology* 2005, *39*, 1078-1083.

Green, N., Schlabach, M., Bakke, T., Brevik, E.M., Dye, C., Herzke, D., Huber, S., Plosz, B., Remberger, M., Schøyen, M., Uggerud, H.T., Vogelsang, C., , 2008. Screening of selectred metals and new organic contaminants 2007. Phosphorus flame retardents, polyfluorinated organic compounds, nitro-PAHs, silver, platiunum and sucralose in air, waterwater treatement facilities, and recipients. SFT TA2367/2008. NIVA report 5569-2008. 104pp.

Hakk, H., Larsen, G., Bowers, J., 2004 Metabolism, tissue disposition, and excretion, of 1,2-bis(2,4,6-tribromophenoxy)ethane (btbpe) in male sprague-dawley rats. Chemosphere 54:1367-1374.

Haukås, M., Berger, U., Hop, H., Gulliksen, B., Grabrielsen, G.W., 2007. Bioaccumulation of per- and polyfluorinated alkyl substances (PFAS) in selected species from the Barents Sea food web. *Environmental Pollution* 148 (1) 360-371.

Heeb NV, Schweizer WB, Kohler M, Gerecke AC. 2005. Structure elucidation of hexabromocyclododecanes - a class of compounds with a complex stereochemistry. *Chemosphere* 61:65-73.

IARC. 2007. *Tetrachloroethylene*. IARC monograph. Vol. 63, p. 159. Last Updated May 20, 1997. Last retrieved June 22, 2007.

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

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

Kasprzak, 2003. "Nickel carcinogenesis.". *Mutation research* 533 (1-2): 67–97. PMID 14643413.

Law K, Halldorson T, Danell R, Stern G, Gewurtz S, Alaee M, Marvin C, Whittle M, Tomy G. 2006. Bioaccumulation and trophic transfer of some brominated flame retardants in a Lake Winnipeg (Canada) food web. *Environmental Toxicology and Chemistry* 25:2177-2186.

Law RJ, Herzke D, Harrad S, Morris S, Bersuder P, Allchin CR. 2008. Levels and trends of HBCDD and BDEs in the European and Asian environments, with some information for other BFRs. *Chemosphere* 73:223-241.

Law RJ, Kohler M, Heeb NV, Gerecke AC, Schmid P, Voorspoels S, Covaci A, Becher G, Janak K, Thomsen C. 2005. Hexabromocyclododecane challenges scientists and regulators. *Environmental Science & Technology* 39:281A-287A.

Lepom P, Sawal, G., Theobald, N., Warmbrunn-Suckrow, E. (2007). PBDEs and HBCD in Marine Sediments from the North Sea, Germany. 4th International Symposium on Brominated Flame Retardants, Amsterdam.

Lewis MA. 1992. The effects of mixtures and other environmental modifying factors on the toxicities of surfactants to freshwater and marine life. *Water Research* 26:1013-1023.

Lindström G, Wingfors H, Dam M, van Bavel B. 1999. Identification of 19 polybrominated diphenyl ethers in ling-finned pilot whale (Globicephala melas) from the Atlantic. *Arch Environ Contam Toxicol* 36:355-363.

Marshall, K. A:, 2003. *Chlorocarbons and Chlorohydrocarbons, Survey*," Kirk-Othmer Encyclopedia of Chemical Technology, John Wiley & Sons Inc, 2003, DOI: 10.1002/0471238961.1021182218050504.a01.pub2

Metcalf, R.L., 2002. "Insect Control" in Ullmann's Encyclopedia of Industrial Chemistry" Wiley-VCH, Weinheim. doi:10.1002/14356007.a14_263

Micic A, Hofmann, T. (2009). Occurence and behaviour of selected hydrophobic alkylphenolic compounds in the Danube river. *Environmental Pollution* 157: 2759-2768.

Morris S, Allchin, C.R., Zegers, B.N., Haftka, J.H.J., Boon, J.P., Belpaire, C., Leonards, P.E.G., van Leeuwen, S.P.J., de Boer, J. (2004). Distribution and Fate of HBCD and TBBPA Brominated Flame Retardants in North Sea Estuaries and Aquatic Food Webs. *Environmental Science and Technology* 38: 5497-5504.

Muir DCG, Backus S, Derocher AE, Dietz R, Evans TJ, Gabrielsen GW, Nagy J, Norstrom RJ, Sonne C, Stirling I, Taylor MK, Letcher RJ. 2006. Brominated flame retardants in polar bears (*Ursus maritimus*) from Alaska, the Canadian Arctic, East Greenland, and Svalbard. *Environmental Science & Technology* 40:449-455.

Neff JM. 2002. *Bioaccumulation in marine organisms. Effect of contaminants from oil well produced water*.452 pp. Elsevier, Oxford, UK.

Økland, T.E., 2005. Kostholdsråd i norske havner og fjorder. En gjennomgang av kostholdsråd i norske havner og fjorder fra 1960-tallet til i dag. Bergfald & Co. ISBN 82-92650-01-6. 269pp.

OSPAR 1997. JAMP [Joint Assessment and Monitoring Programme] Guidelines for Monitoring Contaminants in Biota (version 9.6.97) (including chapter updates 1998-1999). Oslo and Paris Commissions 40 pp.

OSPAR 2009 *in press*. Status and trend of marine chemical pollution. OSPAR Commission, London, 2009. Publication 395/2009. In press

Palm A.J.S., Remberger, M., Kaj L., Brorström-Lundén, E. (2002). Sreening of Pentachlorophenol (PCP) in the Environment. IVL B1474. Swedish Environmental Research Institute.

Powley CR, George, S.W., Russell, M.H., Hoke, R.A., Buck, R.C. (2008). Polyfluorinated chemicals in a spatially and temporally integrated food web in the Western Arctic. *Chemosphere* 70: 664-672.

Rossberg, M., et al., 2006. *Chlorinated Hydrocarbons.* Ullmann's Encyclopedia of Industrial Chemistry, Wiley-VCH Verlag GmbH & Co, 2006, DOI: 10.1002/14356007.a06_233.pub2.

Schlabach, M., Manø, S., Eckhardt, S., 2007. Measurement of Endosulfan, Dieldrin and Endrin in Norwegian Air and Sediment Samples. SFT TA2221/2007. NILU report OR 45/2007. 22pp.

Senthilkumar K, Ohi, E., Sajwan, K., Takasuga, T., Kannan, K. (2007). Perfluorinated compounds in river water, river sediment, marked fish and wildlife samples from Japan. *Bulletin of Environmental Contamination and Toxicology* 79: 427-431.

SFT, 2004. Bruken av PerFluorAlkylStoffer (PFAS) i produkter i Norge. URL: http://www.sft.no/publikasjoner/kjemikalier/2031/ta2031.pdf.

SFT, 2007: Nedfall av tungmetaller rundt norske industrier studert ved analyse av mose: Undersøkelse i 2005 TA2240/2007; URL: http://www.sft.no/publikasjoner/2240/ta2240.pdf

SFT, 2009: *Noen farlige stoffer* [Some dangerous substances] Available at http://www.miljostatus.no/Tema/Kjemikalier/Noen-farlige-kjemikalier/. Updated 1204_2009.

Sternbeck J, Brorström-Lunden, R., Remberger, M., Kaj, L., Palm, A., Junedahl, E., Cato, I. (2003). WFD priority substances in sediments from Stockholm and the Svealand region. IVL B1538. Swedish Environmental Research Institute.

USEPA, 1991. Hexachlorobutadiene. Integrated Risk Information System. Washington, DC: United States Environmental Protection Agency. Available at: http://cfpub.epa.gov/ncea/iris/index.cfm. Accessed 9/05/2008.

USEPA, 2006. Consumer Factsheet on: Pentachlorophenol. Washington, DC: United States Environmental Protection Agency. 2006-11-28 Available at: http://www.epa.gov/safewater/contaminants/dw_contamfs/pentachl.html. Accessed 26/02/2008.

Vorkamp K, Riget, F., Glasius, M., Pécseli, M., Lebeuf, M., Muir, D. (2004). Chlorobenzenes, chlorinated pesticides, coplanar chlorobiphenyls and other organochlorine compounds in Greenland biota. *Science of the Total Environment* 331: 157-175.

WHO, 1977. Silver. Summary of toxicological data of certain food additives. WHO food additives series. 1977; 12.

WHO, 2002. Silver and silver compounds: Environmental aspects. Concise International Chemical Assessment Document. 2002; 42.

Zhang X, Li, Q., Li, G., Wang, Z., Yan, C. (2009). Levels of estrogenic compounds in Xiamen Bay sediment, China. *Marine Pollution Bulletin* 85: 1210-1216.

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 Norsk institutt for vannforskning (NIVA)	ISBN-nummer 978-82-577-5611-6

Oppdragstakers prosjektansvarlig Norman Green	Kontaktperson SFT Bård Nordbø	TA-nummer 2564/2009
		SPFO-nummer 1060/2009

	År 2009	Sidetall 69	SFTs kontraktnummer 5009147

Utgiver NIVA SFT (NIVA-rapport 5876-2009)	Prosjektet er finansiert av SFT

Forfatter(e)
Norman Green, Kine Bæk, Alfhild Kringstad, Katherine Langford, Martine Muusse, Anders Ruus, Merete Schøyen, Marit Villø, Sigurd Øxnevad.

Tittel - norsk og engelsk

Basisovervåking av utvalgte prioriterte stoffer i Vanndirektivet, marin kartlegging 2004 – 2008. Bromerte flammehemmere, perfluorerte organiske forbindelser, dimetyltetrabrombisfenol A, isoproturon, syklodiener, di(2-etylheksyl)-ftalat, og utvalgte klororganiske forbindelser, fenoler og metaller i marine sedimenter, blåskjell og torskelever.

Screening of selected priority substances of the Water Framework Directive in marine samples 2004 - 2008. Brominated flame retardents, perfluorinated organic compounds, dimethyltetrabrombisphenol A, isoproturon, cyclodienes and di(2-ethylhexyl)-phthalate, and selected organochlorines, phenols and metals in marine sediment, blue mussel and cod liver.

Sammendrag – summary

This report investigated concentrations of silver, arsenic, chromium, nickel, brominated compounds including PBDEs and HBCDD, perfluorinated organic compounds including PFOS and PFOSA, organochlorines including trichloroethylene, endosulfan, trichlrorbenzene and HCBD, cyclodiene pesticides, selected phenols and chloro-phenols, isoproturon and DEHP. Analyses were done on samples from sediment from the period 2004 - 2008, and blue mussel and cod from 2008 collected under the Coordinated Environmental Monitoring Programme (CEMP). The report is a contribution implementation of the EU Water Framework Directive with respect to gaining more knowledge about some hazardous substances that are not routinely monitored.

4 emneord	4 subject words
Nasjonal screeningundersøkelse	National screening
PBDE	PBDE
PFC	PFC
Klororganiske forbindelser	Organochlorines

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

Om SFT

Statens forurensningstilsyn (SFT) er et direktorat under Miljøverndepartementet med 300 ansatte på Helsfyr i Oslo. SFT arbeider for en forurensningsfri framtid Vi iverksetter forurensningspolitikken og er veiviser, vokter og forvalter for et bedre miljø.

SFTs hovedoppgaver er å:

- overvåke og informere om miljøets tilstand og utvikling
- utøve myndighet og føre tilsyn etter forurensningsloven, produktkontrolloven og klimakvoteloven
- styre og veilede fylkesmennenes miljøvernavdelinger innen SFTs ansvarsområder
- gi råd til Miljøverndepartementet og tydeliggjøre behovet i sektorene for økt miljøinnsats
- delta i det internasjonale miljøvernsamarbeidet og utviklingssamarbeidet på miljøområdet

TA-2583/2009