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Contaminants in coastal waters of Norway 2013

Miljøgifter i norske kystområder 2013

Foreword

This report presents the investigations of contaminants in coastal waters of Norway 2013 which also represents the Norwegian contribution to Coordinated Environmental Monitoring Programme (CEMP, a part of and referred to in earlier reports as the Joint Assessment and Monitoring Programme JAMP). CEMP is administered by the Oslo and Paris Commissions (OSPAR) in their effort to assess and remedy anthropogenic impact on the marine environment of the North East Atlantic. The current focus of the Norwegian contribution is on the levels, trends and effects of hazardous substances. The results from Norway and other OSPAR countries provide a basis for a paramount evaluation of the state of the marine environment. OSPAR receives guidance from the International Council for the Exploration of the Sea (ICES).

The 2013 investigations were carried out by the Norwegian Institute for Water Research (NIVA) by contract from the Norwegian Environment Agency (*Miljødirektoratet* where the former Climate and Pollution Agency is now a part of). The project leader at the Norwegian Environment Agency is Bård Nordbø.

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Abstract

This programme examines the levels, trends and effects of contaminants in biota along the coast of Norway. The 2013-investigation included analyses of 120 different contaminants or biological effect parameters in five types of samples (blue mussel, dog whelk, common periwinkle, cod and passive samplers). The contaminants include metals, organochlorines (e.g. PCB, DDT), PAH, polybrominated diphenyl ethers (PBDE), perfluroinated alkylated substances (PFAS) as well as contaminants that have recently received more attention such as hexabromcyclododecane (HBCD), chlorinated paraffins (SCCP, MCCP), phosphorus flame retardants (PFR), bisphenol A (BPA), tetrabrombisphenol A (TBBPA), phthalates and akylphenols. In the report, thirty representative substances or parameters were chosen for analyses of 750 time series (last 10 years). Of these there were statistically significant trends in 90 cases: 66 (9 %) were downwards and 24 (3 %) upwards. The dominance of downward trends indicated that contamination is decreasing for the measured substances. The downwards trends for TBT-concentrations and effect parameter (VDSI) confirmed that the legislation banning the use of TBT has been effective. Of the same 750 cases, 399 could be classified by the environmental classification system used by the Norwegian Environment Agency, 360 (90 %) were classified as insignificantly polluted, 27 (7 %) as moderately polluted, 10 (3 %) as markedly polluted, 1 (<1 %) as severely polluted and 1 (<1 %) as extremely polluted. Some cases warrant special concern, such as upward trend for mercury in cod fillet and high concentrations of several organic pollutants in cod liver from the Inner Oslofjord. Very high concentrations of DDE in mussels from the Sørfjord were related to earlier use of DDT as pesticide in orchards along the fjord.

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1. Miljøgifter	1. Contaminants
2. Biologiske effekter	2. Biological effects
3. Marin	3. Marine
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English summary

This programme examines the levels, trends and effects of contaminants along the coast of Norway, including some new contaminants that have recently received more attention. As such, the programme provides a basis for assessing the state of the environment for the coastal waters with respect to contaminants. Most trends were downwards. However there are also cases that warrant special concern, for example upward trend for mercury in cod fillet from the Inner Oslofjord and high concentrations of PCB, hexabromocyclododecane (α–HBCD) and medium chain chlorinated paraffins (MCCP) in cod liver from the same area.

Monitoring contaminants and associated parameters along the Norwegian coast contributes to OSPAR's Coordinated Environmental Monitoring Programme (CEMP). The 2013 investigation monitored blue mussel (32 stations), dog whelk (8 stations), common periwinkle (1 station), cod (14 stations) and seawater using passive sampling (3 stations) along the coast of Norway from the Oslofjord and Hvaler region in the southeast to the Varangerfjord in the northeast. The stations are located both in areas with known or presumed point sources of contaminants, in areas of diffuse load of contamination like city harbour areas, and in more remote areas exposed to presumed low and diffuse pollution. The programme included analyses of metals (Hg, Cd, Pb, Cu, Zn, Ag, As, Ni, Cr and Co), organochlorines (PCBs), pesticides (DDE), brominated flame retardants (PBDEs), perfluorinated compounds (PFAS), hexabromcyclododecanes (HBCD), short and medium chained chlorinated paraffins (SCCP and MCCP), organophosphorus flame retardants (PFRs), bisphenol A (BPA), tetrabrombisphenol A (TBBPA) as well as biological effects parameters. Analyses of phthalates and akylphenols were included in this programme for the first time.

The results from 2013 (exclusive passive sampling) supplied data for a total of 2205 data sets (contaminant-station-species) on 120 different contaminants. Thirty representative contaminants and biological effect parameters were chosen for presentation in this report. This selection has 750 time series of which there were statistically significant trends in 90 cases: 66 (8.8 %) were downwards and 24 (3.2%) upwards. The downward trends were primarily associated with concentrations of metals (53 %), tributyltin (TBT, 16.7 %) and effect of TBT (VDSI - *vas deferens* sequence index, 10.6 %). The dominance of downward trends indicates that contamination is decreasing. The upward trends were mainly associated with metals (91.7 %), primarily mercury (33.3 %).

Of the 399 cases that could be classified by the system of the Norwegian Environment Agency (Molvær *et al.* 1997), 360 (90.2 %) were classified as insignificantly polluted (Class I), 27 (6.8 %) as moderately polluted (Class II), 10 (2.5 %) as markedly polluted (Class III), 1 (0.3 %) as severely polluted (Class IV) and 1 (0.3 %) as extremely polluted (Class V). Even though most concentrations observed can be considered moderately polluted or better, the 3.1% of the cases that were worse cannot be disregarded. For example the extremely polluted blue mussel in the Sørfjord due to DDE.

Passive samplers were deployed at three sites and included investigations of alkylphenols, HBCD and PBDEs. The results were mostly below limits of detection (particularly for the Hvaler and Ålesund sites). Only BDE47, α-HBCD and para-t-octylphenol could be measured in waters of the Oslofjord. Para-t-nonylphenol was also measured above limits of detection at Ålesund. Concentrations appear in line with data from the previous reports.

Concentrations of contaminants in fish

Cod fillet from the Inner Oslofjord and Ålesund harbour was markedly polluted by mercury. The Inner Oslofjord had a significant upward trend for mercury for the period 1984-2013. There are currently no data to support hypotheses about local mechanisms such as runoff or altered trophic links that could account for this increase.

Cod liver from the Inner Oslofjord and Kristiansand harbour were markedly polluted with PCB. Contamination of cod was otherwise generally low (insignificantly or moderately polluted). The high concentrations of PCB observed in cod liver in the Inner Oslofjord are probably related to urban activities in combination with little water exchange with the outer fjord.

Polybrominated diphenyl ethers (PBDEs) have been investigated in cod liver since 2005. In 2013, the concentration of sum PBDE was highest in the Inner Oslofjord and second highest in the Kristiansand harbour. PBDE was lowest in cod from Lofoten. BDE47 was the dominant PBDE in all samples. As for PCB, the high concentrations of PBDE are probably related to urban activities and water exchange conditions.

Perfluoralkyl compounds (PFAS) have been investigated in cod liver since 2005. PFOS, an abundant PFAS, was highest in cod from the Inner Oslofjord and lowest in Tromsø harbour. PFOSA, also an abundant PFAS, was highest in the Inner Oslofjord and lowest in harbours of Trondheim, Skrova and Tromsø. PFAS are found in a wide range of products including fire-fighting foam, surfactants and surface protector for industrial and consumer applications and has a worldwide distribution in different environmental compartments. The differences between the stations cannot be fully explained, but it appears likely that as for PCB and PBDE a combination of urban sources and restricted water exchange provide the highest concentrations in the Inner Oslofjord.

Concentrations of contaminants in blue mussel

Blue mussel from one station in the Sørfjord was extremely polluted with DDE. Mussels from one station in the Hardangerfjord were markedly polluted with the same contaminant. Contamination of this substance is related to earlier use of DDT as pesticide in orchards along the fjord (ca.1945-1970).

One station in the Inner Oslofjord and one station from the Inner Ranfjord were markedly contaminated with one or more groups of PAHs most likely related to urban and old industrial activities. No trends were detected for these cases. Contamination of blue mussel was otherwise generally low (insignificantly or moderately polluted).

New contaminants

Of the hexabromcyclododecanes, α–HBCD was the most abundant diastereomer. Cod liver from Inner Oslofjord had the highest median concentration of HBCD. The high concentrations of HBCD are probably related to urban activities, as well as a reduced water exchange with the outer fjord.

Of the chlorinated paraffins concentrations of medium chain chlorinated paraffins (MCCP) were significantly higher in blue mussel from the Inner Oslofjord compared to the other stations. MCCP in cod liver was highest in the Inner Trondheimsfjord followed by Kristiansand harbour, Inner Oslofjord and Inner Sørfjord. Mussels filter surface waters, whereas cod are generally exposed to deeper water masses, hence concentrations in these two organisms are not readily comparable. The specific sources of the MCCPs are unknown, but could be the result of industrial activity in these fairly restricted areas. Further investigations are warranted.

Most concentrations of organophosphorus flame retardants (PFRs) were below the detection limits in blue mussel and cod, and no conclusions could be drawn regarding the differences among the stations.

Bisphenol A was not detected in blue mussel or cod, and no conclusion can be drawn regarding possible differences between stations.

Biological effects

The ICES/OSPARs assessment criterion[1] (background assessment criteria, BAC) for OH-pyrene in cod bile was exceeded at all four stations in 2013 and indicates that the fish have been exposed to PAH. The median concentration of OH-pyrene metabolites in bile from cod in the Inner Oslofjord was about 41 % lower than in 2011 and 21 % lower than in 2012, but still above the ICES/OSPARs BAC.

The ALA-D activity in the Inner Oslofjord in 2013 was higher than in 2011 and lower than in 2012. Reduced activities of ALA-D reflect higher exposure to lead. However, the median concentration of lead in cod liver decreased from 2012 to 2013.

The median concentration of CYP1A protein levels and EROD activity in the Inner Oslofjord was higher than in 2012, but lower than in 2011 and still below the ICES/OSPARs BAC indicating possible impact by planar PCBs, PCNs, PAHs or dioxins.

The effects from TBT on dog whelk were relatively low (VDSI<0.531) at all eight stations. There were significant downward trends for all stations, except for Brashavn where no significant trend could be seen and previous VDSI levels were low. The results indicate that the legislation banning the use of TBT has been effective.

[1] Assessement criteria have specifically been compiled for the assessment of CEMP monitoring data on hazardous substances. They do not represent target values or legal standards.

Stable isotopes

Results showed very similar isotopic signatures in 2012 and 2013, suggesting a persistent spatial trend more than a temporal trend. The $\delta^{15}N$ data in cod is assessed in relation to concentrations of selected contaminants. As fish grow, they feed on larger prey organisms, thus a small increase in trophic level is likely to occur. At specific stations, concentrations of mercury and PCB-153 (contaminants with well-known biomagnifying properties) increased with higher $\delta^{15}N$, i.e. higher concentrations in individuals with slightly higher trophic position.

Sammendrag

I denne undersøkelsen er nivåer, trender og effekter av miljøgifter overvåket langs norskekysten. I tillegg er det gjort analyser av enkelte nyere miljøgifter som stadig får større oppmerksomhet. Undersøkelsen gir grunnlag for vurdering av miljøstatus for miljøgifter langs kysten. Resultatene viser at det hovedsakelig var nedadgående trender for de undersøkte miljøgiftene. Det er imidlertid noen resultater som gir grunn til bekymring, for eksempel oppadgående trend for kvikksølv i torskefilét fra indre Oslofjord og høye konsentrasjoner av PCB, heksabromsyklododekan (α–HBCD) og mellomkjedede klorparafiner (MCCP) i torskelever fra samme område.

Undersøkelsen bidrar til OSPARs koordinerte miljøovervåkingsprogram *Coordinated Environmental Monitoring Programme* (CEMP). I 2013 omfattet overvåkingen miljøgifter i blåskjell (32 stasjoner), purpursnegl (8 stasjoner), strandsnegl (én stasjon), torsk (14 stasjoner) og sjøvann ved hjelp av passive prøvetaking (3 stasjoner) langs norskekysten fra Oslofjord-Hvaler området i sørøst til Varangerfjorden i nordøst. Stasjonene er plassert både i områder med kjente eller antatt kjente punktkilder av miljøgifter, i områder med diffus tilførsel av miljøgifter slik som byens havneområder, og i fjerntliggende områder med antatt lav eller diffus eksponering for miljøgifter. Undersøkelsen omfatter overvåking av metaller (Hg, Cd, Pb, Cu, Zn, Ag, As, Ni, Cr og Co), klororganiske forbindelser (PCBer), pestisider (DDE), bromerte flammehemmere (PBDEer), perfluorerte alkylstoffer (PFAS), heksabromsyklododekan (HBCD), korte- og mellomkjedete klorparafiner (SCCP og MCCP), fosfororganiske flammehemmere (PFRer), bisfenol A (BPA), tetrabrombisfenol A (TBBPA) samt biologiske parametre. For første gang er det inkludert analyser av ftalater og alkylfenoler i denne undersøkelsen.

2013-resultatene (eksklusive passive prøvetakere) omfatter totalt 2205 datasett (miljøgifter-stasjoner-arter) for 120 forskjellige miljøgifter. Et utvalg på 30 representative miljøgifter og biologiske parametre presenteres i denne rapporten. Dette utvalget består av 750 tidsserier hvorav 90 viste statistisk signifikante trender: 66 (8,8%) var nedadgående og 24 (3,2%) var oppadgående. De nedadgående trendene omfattet primært metaller (53%), tributyltinn (TBT, 16,7%) og effekt av TBT (VDSI – sædlederindeks, 10,6%). Dominansen av nedadgående trender indikerer avtagende nivåer av miljøgifter. De oppadgående trendene var i hovedsak metaller (91,7%) og primært kvikksølv (33,3%).

Av de 399 tidsseriene som kunne klassifiseres i henhold til Miljødirektoratets klassifiseringssystem (Molvær *et al.* 1997), var 360 (90,2%) klassifisert som ubetydelig-lite forurenset (klasse I), 27 (6,8%) som moderat forurenset (klasse II), 10 (2,5%) som markert forurenset (klasse III), 1 (0,3%) som sterkt forurenset (klasse IV) og 1 (0,3%) som meget sterkt forurenset (klasse V). Selv om det fleste observerte nivåene kan betraktes som moderat forurenset eller bedre, så kan det likevel ikke ses bort ifra de 3,1% som var mer forurenset. Et eksempel på dette er blåskjell i Sørfjorden som var meget sterkt forurenset av DDE.

Passive prøvetakere ble utplassert tre steder og inkluderte undersøkelser av alkylfenoler, HBCD og PBDE. Resultatene var stort sett under deteksjonsgrensen (særlig for prøver fra Hvaler og Ålesund). Bare BDE47, α-HBCD, og para-t-octylfenol ble observert i vann fra indre Oslofjord. Para-t-nonylfenol ble målt over deteksjonsgrensen i Ålesund. De påviste konsentrasjonene samsvarer med tidligere rapporterte data.

Konsentrasjoner av miljøgifter i fisk

Torskefilét fra indre Oslofjord og Ålesund havn var markert forurenset av kvikksølv. For torsk fra indre Oslofjord var det en signifikant oppadgående trend for kvikksølv i filét for perioden 1984-2013. Det finnes ikke data som støtter hypoteser som kan forklare denne økningen slik som lokale prosesser som avrenning eller endring av trofisk nivå.

Torskelever fra indre Oslofjord og Kristiansand havn var markert forurenset av PCB. Torsk var ellers generelt lite forurenset (ubetydelig eller moderat forurenset). De høye konsentrasjonene av PCB som ble observert i torskelever fra indre Oslofjord har trolig sammenheng med urbane aktiviteter i kombinasjon med lav vannutskifting med ytre fjord.

Polybromerte difenyletere (PBDEer) er undersøkt i torskelever siden 2005. I 2013 var konsentrasjonen av sum PBDE høyest i torsk fra indre Oslofjord og nest høyest i Kristiansand havn. Torsk fra Lofoten hadde lavest konsentrasjon av PBDE. BDE47 var den dominerende av PBDEene i alle prøvene. Som for PCB, er urban aktivitet og vannutskiftingsforhold trolig årsaker til de høye nivåene.

Perfluorerte alkystoffer (PFAS) har blitt undersøkt i torskelever siden 2005. PFOS, en PFAS-forbindelse, var høyest i torskelever fra indre Oslofjord og lavest i Tromsø havn. PFOSA, også en PFAS-forbindelse, var høyest i torskelever fra indre Oslofjord og lavest i Trondheim havn, Skrova og Tromsø. PFAS er funnet i et bredt spekter av produkter inkludert brannskum, tensider og overflatebeskytter for industrielle og private aktører, og har en verdensomspennende distribusjon. Nivåforskjellene mellom de ulike områdene kan foreløpig ikke forklares fullt ut, men det er sannsynlig at en kombinasjon av urbane kilder og begrenset vannutskifting gir de høyeste konsentrasjonene i indre Oslofjord, slik som resultatet var for PCB og PBDE**.**

Konsentrasjoner av miljøgifter i blåskjell
Blåskjell fra én stasjon i Sørfjorden var meget sterkt forurenset av DDE. I Hardangerfjorden var blåskjell fra én stasjon markert forurenset av den samme miljøgiften. Forurensning av denne miljøgiften skyldes tidligere bruk av DDT som sprøytemiddel i frukthager langs fjorden (ca. 1945-1970).

Én stasjon i indre Oslofjord og én stasjon i indre Ranfjorden var markert forurenset av en eller flere PAH-forbindelser. Dette er mest sannsynlig relatert til urban aktivitet og gammel industrivirksomhet. Det ble ikke påvist trender for disse tilfellene. Blåskjellstasjonene som er omfattet i denne undersøkelsen var ellers generelt lite forurenset (ubetydelig til moderat forurenset).

Nye miljøgifter
Av heksabromsyklododekaner var α-HBCD den mest dominerende isomeren. Torskelver fra indre Oslofjord hadde den høyeste median-konsentrasjonen av HBCD. De høye HBCD-konsentrasjonene er sannsynligvis relatert til urbane aktiviteter, samt lav vannutskifting med ytre fjord.

Det var signifikant høyere nivå av mellomkjedete klorerte parafiner (MCCP) i blåskjell fra indre Oslofjord sammenlignet med de andre stasjonene. MCCP i torskelever var høyest i indre Trondheimsfjord etterfulgt av Kristiansand havn, indre Oslofjord og indre Sørfjord. Blåskjell filtrerer overflatevann, mens torsk generelt er eksponert for dypere vannmasser, derav vil konsentrasjonene i disse to organismene ikke være direkte sammenlignbare. De spesifikke kildene til MCCP er ukjent, men kan være et resultat av industriell aktivitet i disse relativt begrensede områdene. Dette bør undersøkes nærmere.

De aller fleste konsentrasjonene av fosfororganiske flammehemmere (PFRer) var under deteksjonsgrensene i blåskjell og torsk, så ingen konklusjoner kan trekkes når det gjelder forskjeller mellom stasjonene.

Bisfenol A ble ikke påvist i blåskjell eller torsk, så ingen konklusjon kan trekkes vedrørende mulige forskjeller mellom stasjonene.

Biologiske effekter
ICES/OSPARs vurderingskriterium for bakgrunnsnivå[21] («background assessment criteria», BAC) for OH-pyren i torskegalle ble overskredet på alle de fire stasjonene i 2013, og dette viser at fisken har vært eksponert for PAH. Median-konsentrasjonen av OH-pyren metabolitter i torskegalle fra indre Oslofjord var ca 41% lavere enn i 2011 og 21% lavere enn i 2012, men var fortsatt over ICES/OSPARs BAC.

ALA-D aktivitet i indre Oslofjord i 2013 var høyere enn i 2011 og lavere enn i 2012. Redusert aktivitet av ALA-D tyder på høyere eksponering for bly. Fra 2012 til 2013 har imidlertid median-konsentrasjonen av bly i torskelever avtatt.

Nivåene av CYP1A protein og EROD-aktivitet i indre Oslofjord var høyere enn i 2012, men lavere enn i 2011, og var fortsatt under ICES/OSPARs BAC som indikerer mulig effekt av plane PCBer, PCNer, PAHer eller dioksiner.

Effektene av TBT på purpursnegl var relativt lave (VDSI <0.531) på alle de åtte stasjonene. Det var signifikant nedadgående trender på alle stasjonene bortsett fra for Brashavn der ingen signifikant trend kunne ses og tidligere VDSI-nivåer var lave. Resultatene indikerer at forbudet mot bruk av TBT har vært effektivt.

[2] Vurderingskriteriene er spesielt utarbeidet for vurdering av CEMP-overvåkingsdata for farlige forbindelser. De representerer ikke målverdier eller juridiske standarder.

Stabile isotoper

Resultater viste svært like isotop-signaturer i 2012 og 2013, noe som tyder på en vedvarende steds trend heller enn en temporær trend. Data for stabile isotoper ($\delta^{15}N$) i torsk er vurdert i sammenheng med konsentrasjoner av utvalgte miljøgifter. Fisk spiser større byttedyr etterhvert som de vokser, og dette medfører ofte overgang til høyere trofisk nivå. Det ble funnet økende konsentrasjon av kvikksølv og PCB-153 (miljøgifter med kjente biomagnifiserende egenskaper) med økende nivå av $\delta^{15}N$, dvs. høyere konsentrasjoner i individer på noe høyere trofisk nivå.

Contents

1. Introduction

1.1 Background

The programme "Contaminants in coastal waters of Norway" (*Miljøgifter i norske kystområder* - MILKYS) is administered by the Norwegian Environment Agency (*Miljødirektoratet*). The programme focuses on the levels, trends and effects of hazardous substances in fjords and coastal waters, which also represents the Norwegian contribution to the Coordinated Environmental Monitoring Programme (CEMP). CEMP is a common European monitoring programme under the auspices of Oslo and Paris Commissions (OSPAR). The Norwegian contribution to CEMP addresses several aspects of OSPAR's assessment of hazardous substances. For this report, all the results are considered part of the Norwegian contribution to the CEMP programme.

The objective for the performed monitoring is to obtain updated information on levels and trends of selected hazardous substances known or suspected to have a potential for causing detrimental biological effects

Concentrations of hazardous substances in sediment, pore water, mussels and fish constitute time-integrating state indicators for coastal water quality. With respect to organisms, many of these substances have a tendency to accumulate in their tissues (bioaccumulation), and show higher concentrations relative to their surroundings (water and in some cases also sediment). Hence, it follows that substances may be detected, which would otherwise be difficult to detect when analysing water or sediment only. Using concentrations in biota as indicators, as opposed to using water or sediment, are of direct ecological importance as well as being important for human health considerations and quality assurance related to commercial interests involved in harvesting marine resources.

MILKYS applies the OSPAR CEMP methods. These OSPAR methods suggest *inter alia* monitoring of blue mussel, snails, and Atlantic cod on a yearly basis.

An overview of MILKYS stations in Norway is shown in maps in Appendix D. The program has included the monitoring of sediment, seawater and biota, the main emphasis being:

- Oslofjord-area, including the Hvaler area, Singlefjord and Grenlandfjords area, since 1981
- Sørfjord/Hardangerfjord since 1987
- Orkdalsfjord area and other areas in outer Trondheimsfjord, 1984-1996 and 2004-2005
- Arendal and Lista areas since 1990
- Lofoten area since 1992
- Coastal areas of Norway's northern most counties Troms and Finnmark since 1994

The previous investigations have shown that the Inner Oslofjord area has elevated levels of polychlorinated biphenyls (PCBs) in cod liver, mercury, lead and zinc in sediments and moderately elevated concentrations of mercury in cod fillet. Investigations of the Sørfjord/Hardangerfjord have shown elevated levels of PCBs, dichlorodiphenyltrichloroethane (DDT, using dichlorodiphenyldichloroethylene (DDE) - principle metabolite of DDT as an indicator), cadmium, mercury and lead. Investigations in Orkdalsfjord focused on three blue mussel stations. The results from these investigations have been reported earlier (Green *et al.* 2007, Green & Ruus 2008). It can be noted that environmental status is classified according to environmental quality criteria based on the classification system of the Norwegian Environment Agency (Molvær *et al.* 1997), or presumed background levels (Appendix C) and must not be confused with limit values for human consumption and associated advice issued by the Norwegian Food Safety Authorities.

In addition to the monitoring of Oslofjord area and Sørfjord/Hardangerfjord MILKYS also includes the annual monitoring of contaminants at selected stations in Lista and Bømlo areas on the south and west coast of Norway, respectively. During the periods 1993-1996 and 2006-2007 MILKYS also included sampling of blue mussel from reference areas along the coast from Lofoten to the Russian border. The sampling also includes fish from four key areas north of Lofoten in the Finnsnes-Skjervøy area, Hammerfest-Honningsvåg area, and Varanger Peninsula area. Fish from the Lofoten and Varanger Peninsula areas are sampled annually. The

intention is to assess the level of contaminants in reference areas, areas that are considered to be little affected by contaminants, and to assess possible temporal trends.

Biological effects methods, BEM or biomarkers were introduced in the Norwegian MILKYS in 1997. The purpose of these markers is, by investigations on molecular/cell/individual level, to give warning signals if biota is affected by toxic compounds, i.e. contaminants, and to assist in establishing an understanding of the specific mechanisms involved. The reason to use biological effects methods within monitoring programmes is to evaluate whether marine organisms are affected by contaminant inputs. Such knowledge cannot be derived from tissue levels of contaminants only. One reason is the vast number of chemicals (known and unknown) that are not, and cannot be, analysed. Another reason is the possibility of combined effects ("cocktail effects") of multiple chemical exposures. In addition to enabling conclusions on the health of marine organisms, some biomarkers assist in the interpretation of contaminant bioaccumulation. The biological effects component of MILKYS includes imposex in gastropods as well as biomarkers in fish. The methods were selected for specificity as to which contaminants impact the method and robustness.

The state of contamination is divided into three issues of concern: levels, trends and effects. Different monitoring strategies are used, in particular with regard to the selection of indicator media (blue mussel, gastropod, cod liver etc.) and selection of chemical analyses. Sample frequency is annual for biota). The programme underwent an extensive revision in 2012, both in regard to stations and chemical analyses. Monitoring of flatfish was discontinued but three more cod-stations were added bringing the total to 15. The blue mussel stations were reduced from 38 to 26. Choice of chemical analyses for each station has changed considerably after 2011 (Appendix E). Pesticide and dioxin analyses were discontinued with the except for DDTs at some stations in the Sørfjord/Hardangerfjord. However, many new analyses were added, including analyses of: short- and medium chain chlorinated paraffins (SCCP and MCCP), phenols (bisphenol A, tetrabrombisphenol A), phosphorus flame retardants and stabile isotopes. The Norwegian Pollution and Reference Indices (cf. Green *et al.* 2012a) are not included in the revised programme but passive sampling of contaminants in water has been added.

The change in the programme has meant that many time series were at risk of being discontinued. This was the case for the 2013 investigation. However independent funding from the Norwegian Ministry of Climate and Environment ensured that some of these time series could be maintained. This involved extra analyses (mostly pesticides) of MILKYS-samples, and collection and analyses of some blue mussel and flatfish stations that otherwise would have been discontinued. This additional funding for 2013 also ensured that investigation of biological effect in cod from the Inner Sørfjord and from Bømlo north on the West Coast could be continued. The results for blue mussel and cod from these investigations are included in this report.

Where possible, MILKYS is integrated with other national monitoring programmes to achieve a better practical and scientific solution to assessing the levels, trends and effects of micropollutants. In particular, this concerns sampling for the Norwegian sample bank, a programme funded by the Norwegian Ministry of Climate and Environment to sustain time trend monitoring and local (county) investigations. There is also coordination with Comprehensive Study on Riverine Inputs and Direct Discharges (RID) and The Norwegian Costal Monitoring Programme (*Kystovervåkingsprogrammet*, KYO). Both programmes are operated by NIVA on behalf of Norwegian Environment Agency.

1.2 Purpose

An aim of the Norwegian Environment Agency is to obtain an overview of the status and trends of the environment as well as to assess the importance of various sources of pollution. The Norwegian Environment Agency seeks to develop a knowledge-base for the public and for the management of the environment.

The programme Contaminants in Coastal Waters of Norway (MILKYS) is used as a tool to promote cessation of discharges, emissions and losses of hazardous substances by the year 2020. This will be accomplished though:

1. Monitoring the levels of a selection of hazardous substances in biota and water;
2. Evaluating the bioaccumulation of priority hazardous substances in biota of coastal waters;
3. Assessing the effectiveness of previous remedial action;
4. Considering the need for additional remedial action;
5. Assessing the risk to biota in coastal waters;
6. Fulfilling obligations to regional sea convention (OSPAR).

MILKYS is part of the Norwegian contribution to CEMP and is designed to address issues relevant to OSPAR (cf. OSPAR 2007, SIME 2004a) including OSPAR priority substances (SIME 2004b). The programme will also contribute to the demands on Norway by the EU Water Framework Directive (WFD) (2000/60/EC) and its daughter directive the Environmental Quality Standards Directive (EQSD – 2013/39/EU). The results can also be useful in addressing aspects of the EU's Marine Strategy Framework Directive (MSFD) (2008/56/EC). One of the goals of WFD and MSFD is to achieve concentrations of hazardous substances in the marine environment near background values for naturally occurring substances and close to zero for manmade synthetic substances. OSPAR has also adopted this goal (OSPAR 1998).

2. Material and methods

2.1 Sampling

2.1.1 Stations

Samples for the investigation of contaminants were collected along the Norwegian coast, from the Swedish border in the south to the Russian border in the north (*Figure 1*, *Figure 2, Figure 3,* Appendix D). The sampling involved blue mussel at 32 stations where 34 were planned (including eight funded directly by the Ministry of Climate and Environment – see Chapter 1.1), dog whelk at eight stations where nine stations were planned, periwinkle at one station and cod at 14 stations where 15 stations were planned. In addition, contaminants in seawater were investigated using passive sampling at three stations.

Samples were collected annually and analysed according to OSPAR guidelines (OSPAR 2003b and OSPAR 2012)[3]. The data was screened and submitted to ICES by agreed procedures (ICES 1996). Blue mussel, gastropods (dog whelk and periwinkle) and Atlantic cod are the target species selected for MILKYS to indicate the degree of contamination in the sea. Blue mussel is attached to shallow-water surfaces, thus reflecting exposure at a fixed point (local pollution). Mussels and snails are abundant, robust and widely monitored in a comparable way. The species are, however, restricted to the shallow waters of the shore line. Cod is a widely distributed and commercially important fish species. It is a predator and, as such, will reflect contamination levels in their prey.

As mentioned above (see Chapter 1.1) the results from some supplementary monitoring to maintain long-term trends are included in this report. These concern some contaminants in blue mussel and cod (cf. *Table 2*).

Some details on methods applied in previous years of monitoring are provided in Chapter 2.8.

[3] See also www.ospar.org/eng/ > measures > list of other agreements

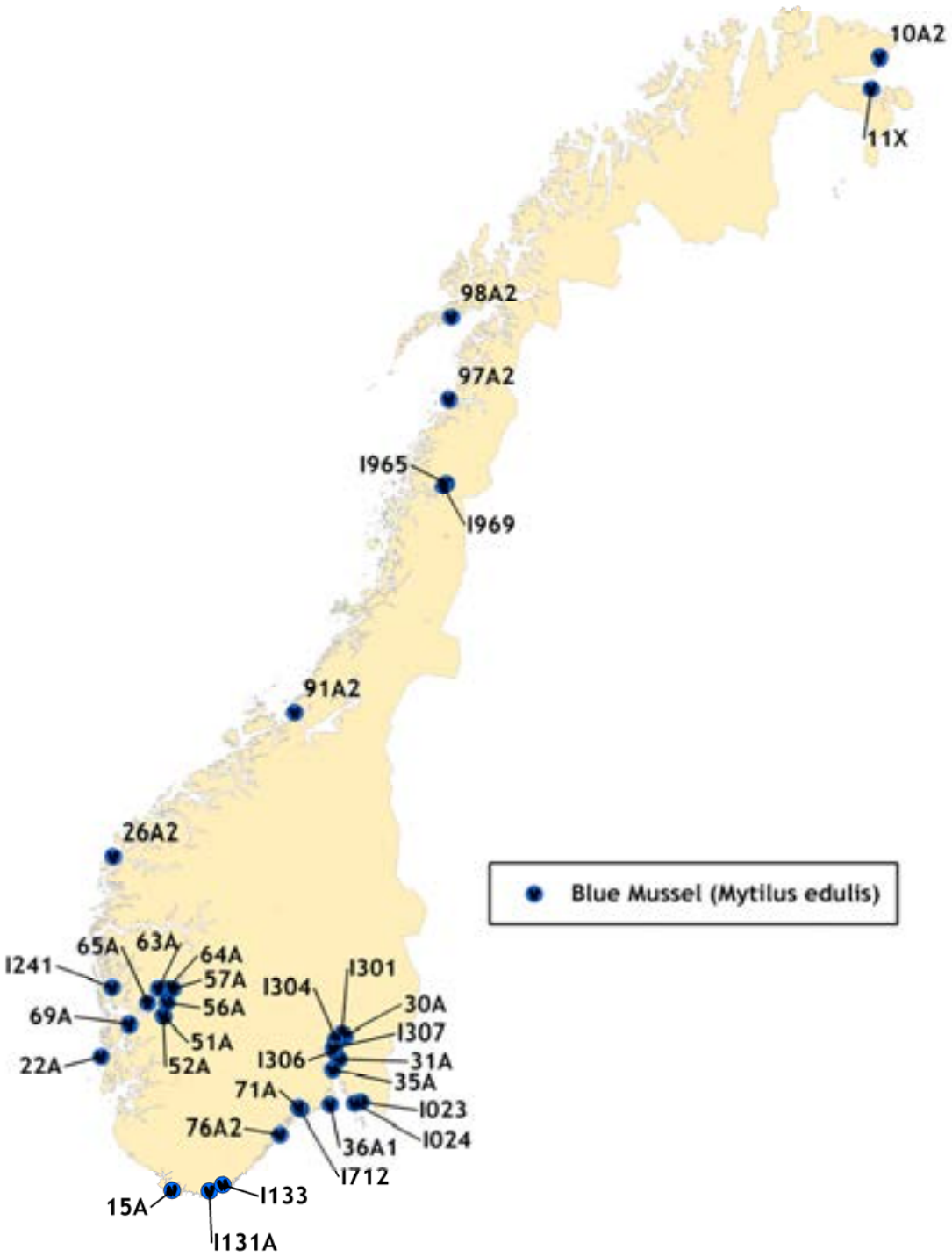

Figure 1. Stations where blue mussel was sampled in 2013. See also station information in detailed maps in Appendix D.

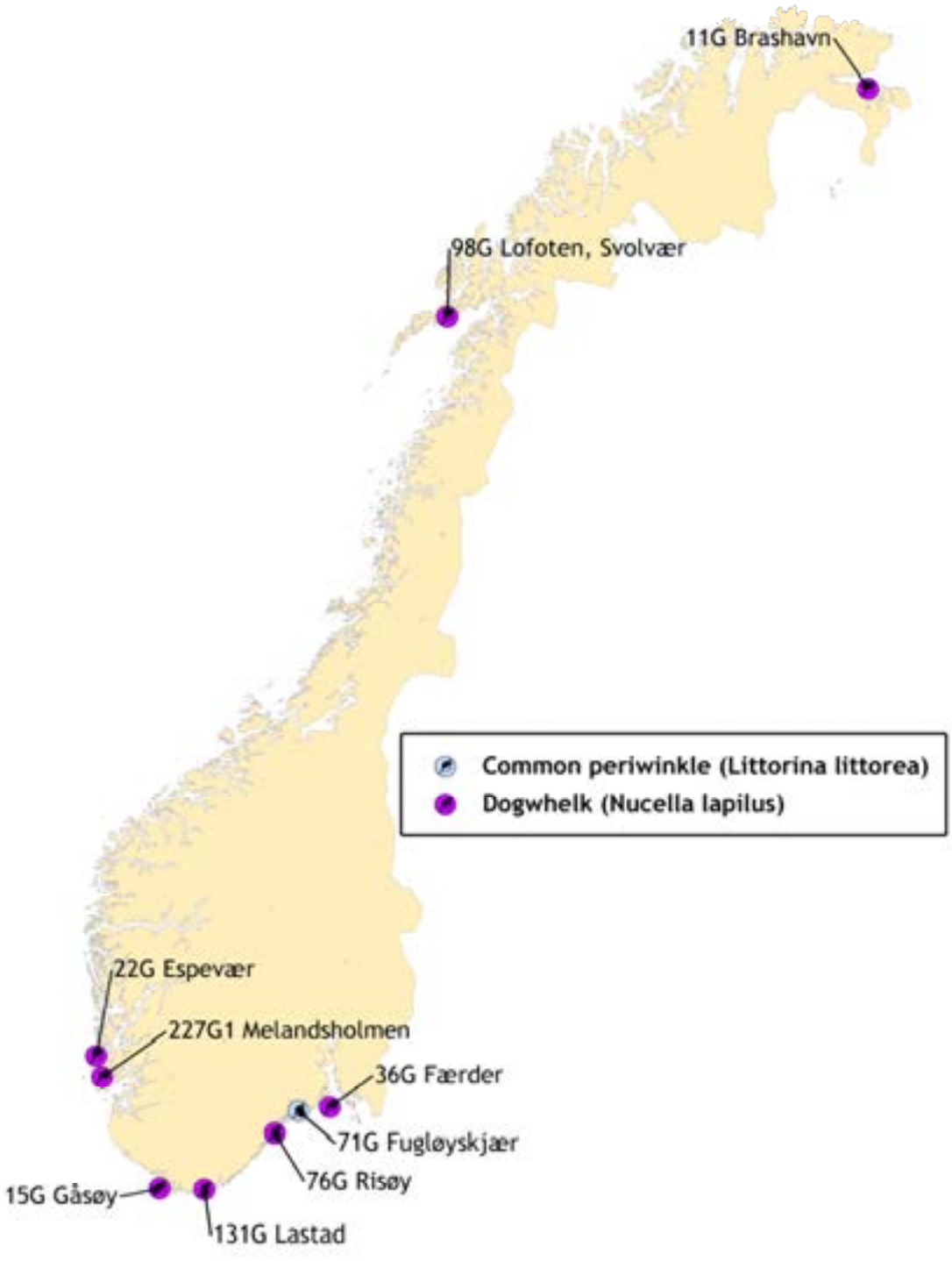

Figure 2. Stations where dog whelk and periwinkle were sampled in 2013. See also station information in detailed maps in Appendix D.

Figure 3. Stations where cod was sampled in 2013. Note that biological effects methods were applied to cod samples from the Inner Oslofjord. See also station information in detailed maps in Appendix D.

2.1.2 Atlantic cod

Fifteen individuals of Atlantic Cod (*Gadus morhua)* were to be sampled for each station. This was accomplished at 14 stations, Hammerfest area (*Figure 3*) being the exception.

The cod were sampled from 1 September to 21 December 2013. All the cod were sampled by local fishermen except for the cod in the Inner Oslofjord (st. 30B) that was collected by NIVA by trawling from the research vessel *F/F Trygve Braarud* owned and operated by the University of Oslo. If possible cod were sampled in five length classes (*Table 1*), three individuals in each class. Tissue samples from each fish were prepared in the field and stored frozen (-20°C) until analysis or the fish was frozen directly and later prepared at NIVA.

Table 1. Target length groups for sampling of cod.

Size-class	Cod (mm)
1	370-420
2	420-475
3	475-540
4	540-615
5	615-700

Livers were in general not large enough to accommodate all the analyses planned. The Inner Trondheimsfjord was the only station where all 15 individuals had sufficient liver size to complete the analyses. The general lack of material was partially compensated for by making pooled samples of livers. These are noted in the tables below. The statistical concerns using pooled samples or individual cod samples are discussed in Chapter 3.7.

Even with intensive sampling and pooling the planned number of analyses was not met (see Appendix E) It was agreed with Norwegian Environment Agency that some of the budget saved could be used to do supplementary analyses on cod samples collected in 2012 and 2013 (see *Table 2*). The selection focused on impacted areas where specific contaminants were of concern. However, the selection was restricted to sample-remains after previous analyses had been conducted. This led an imbalanced sampling scheme but it was judged that the results would provide some indication of levels present.

The supplementary analyses of cod sampled in 2012 included phthalates (not previously included as a parameter). The supplementary analyses also included analyses of cod fillet on the same contaminants that were analysed in the liver from the same individual. The latter was done to assess the suitability of replacement of cod liver with cod fillet as an indicator tissue.

The supplementary analyses in 2013 include analyses of PBDEs, PFCs, alkyphenols, triklosan, DDP, diuron and igarol as well as analyses of SCCP and MCCP in selected, stored samples from 1990 (see *Table 2*). The results from these additional analyses were not available in time to be included in this report and will be included in the next report (2014).

2.1.3 Blue mussel

Sufficient sample of blue mussel (*Mytilus edulis*), both with respect to count and mass, were found at 32 of the 34 stations planned (including eight funded directly by the Ministry of Climate and Environment). The stations are located as shown in *Figure 1*(see also maps in Appendix D). The stations were chosen to represent highly polluted or reference locations distributed along the Norwegian coast. It has been shown that the collected species are not all *Mytilus edulis* (Brooks & Farmen 2013) but possible differences in contaminant uptake were assumed to be negligible and not taken into account for this investigation.

The blue mussel samples were collected from August 31 to November 11, 2013. For Færder (36A) in the Outer Oslofjord and Risøy (76A) there were insufficient quantities of blue mussel and alternative sites were chosen; Røssesund at the southern end of Tjøme (36A1) and Risør area (76A2), respectively. The station in the Røssesund is located 7.7 km north of st. 36A. Risør station is located 1.2 km north of st. 76A in Søndeledfjord. It also can be noted that mussels from Måløy (26A2) on the West coast were collected in 2012 and 2013. This

station is located about 9 km north of Hamnen (26A). For the time being the results from these new stations will be treated separately and not used in the time series for 36A, 76A and 26A.

Generally, blue mussel was not abundant on the exposed coastline from Lista (southern Norway) to the north of Norway. A number of samples were collected from dock areas, buoys or anchor lines. All blue mussel was collected by NIVA except for the blue mussel collected in the Ranfjord, Lofoten and Varangerfjord, which were collected by local contacts.

Three pooled samples of 20 individuals each were collected in the size range of 3-5 cm. Shell length was measured by slide callipers. The blue mussel was scraped clean on the outside by using knives or scalpels before taking out the tissue for the analysis. Mussels were shucked and frozen (-20°C).

2.1.4 Dog whelk and periwinkle

Concentrations and effects of organotin were investigated at eight stations for dog whelk (*Nucella lapillus*) and one station for periwinkle (*Littorina littorea*) (*Figure 2*, see also maps in Appendix D). TBT-induced development of male sex-characters in females, known as imposex, was quantified by the *Vas Deferens Sequence Index* (VDSI) analysed according to OSPAR-CEMP guidelines. The VDSI ranges from zero (no effect) to six (maximum effect) (Gibbs *et al.* 1987). Detailed information about the chemical analyses of the animals is given in Følsvik *et al.* (1999).

Effects (imposex) and concentrations of organotin in dog whelk or periwinkle were investigated using 50 individuals from each station. Individuals were kept alive in a refrigerator (at +4°C) until possible effects (imposex) were quantified. All snails were sampled by NIVA except for the dog whelk collected in Lofoten and in the Varangerfjord. The snail samples were collected from 24 September to 30 October 2013.

2.2 Chemical analyses of biological samples

2.2.1 Choice of chemical analyses and target species/tissues

An overview of chemical analyses 2013 is shown in *Table 2.* Note that the table also includes an overview of supplementary analyses of 2012 and 2013 samples as well as supplementary investigations funded by the Ministry of Climate and Environment. The results of the supplementary analyses of 2013 samples were not available in time for this.

Table 2. Analyses and target organisms 2013 and supplementary analyses of 2012 and 2013 samples. The value indicates the total number of stations investigated of which those funded by the Ministry of Climate and Environment as a supplement are indicated in parentheses.*

Parameter	Blue mussel	Dog whelk	Common periwinkle	Cod fillet	Passive samplers	Cod liver	Cod bile	Cod blood
Metals Cadmium (Cd), copper (Cu), lead (Pb), zinc (Zn), silver (Ag), arsenic (As), chrome (Cr), nickel (Ni), cobalt (Co) and tin (Sn)	32 (8)					13		
Mercury (Hg) Total-Hg	32 (8)			14				
PAH-16	10							
PCB-7 PCB-28, 52, 101, 118, 138, 153, and 180	29 (8)					13		
OCS, 5CS, HCB, HCH	0 (15)					0 (7)		
∑DDT p-p`-DDT, p-p`-DDE, p-p`-DDD	18 (15)					8 (7)		
Polybrominated diphenyl ethers (PBDE) BDE47, 99, 100, 126, 153, 154, 183, 196 and 209	10				3	9		
Hexabromcyclododecane (HBCD) α, ß, γ-HBCD	8				3	11		
Tetrabrombisphenol A (TBBPA)	9					10		
Bisphenol A (BPA)	9					10		
Perfluorinated alkylated substances (PFAS) PFNA, PFOA, PFHpA, PFHxA, PFOS, PFBS, PFOSA						8		
Chlorinated paraffins SCCP (C10-C13) and MCCP (C14-C17)	8					11		
Alkylphenol Octylphenol, nonylphenol					3			
Organotin monobutyltin (MBT), dibutyltin (DBT), tributyltin (TBT), trifenyltin (TPT)	7*	8	1					
Phosphorus flame retardants (PFR) tri-iso-butylphosphate (TIBP) tributylphosphate (TBP) tri(2-chlorethyl)phosphate (TCEP) tri(1-chlor-2-propyl)phosphate (TCPP) tri(1,3-dichlor-2-propyl)phosphate (TDCP) tri(2-butoxyethyl)phosphate (TBEP) triphenylphosphate (TPhP) 2-ethylhexyl-di-phenylphosphate (EHDPP) tetrekis-(2-chloroethyl)dichlorisopentyldiphosphate (V6) dibutylphenylphosphate (DBPhP)	7					11		

Parameter	Blue mussel	Dog whelk	Common periwinkle	Cod fillet	Passive samplers	Cod liver	Cod bile	Cod blood
butyldiphenylphosphate (BdPhP)								
tris(2-ethylhexyl)phosphate (TEHP)								
tris-o-cresylphosphate (ToCrP)								
tricresylphosphate (TCrP)								
PAH metabolite (including OH-pyrene)							3 (2)	
EROD						3 (2)		
CYP1A						3 (2)		
ALA-D								3 (2)
VDSI		8						
Stable isotopes (SIA)	15					14		
$\delta^{15}N$ and $\delta^{13}C$								
Supplementary analyses for 2012 samples								
Phthalates (18 samples)						*5*		
DBP (dibutylphthalate),								
DEHP (di2-ethylhexyl phthalate),								
BBP (benzylbutylphthalate),								
DIBP (di-isobutylphthalate)								
HBCD (2 samples)				*2*				
TBBPA, BPA (14 samples)				*4*				
SCCP, MCCP (14 samples)				*2*				
PFR (10 samples)				*1*				
Nonylphenol and octylphenol (25 samples)				*5*				
PCB (25 samples)				*3*				
PBDE (25 samples)				*3*				
Supplementary analyses for 2013 samples								
Phthalates (44 samples)	*4*					*4*		
PBDE [1] (9 samples)	*3*							
PFC [2] (20 samples)	*3*					*1*		
SCCP, MCCP (125 samples)						*2[3]*		
Akylphenol (20 samples)	*3*					*1*		
Triklosan (44 samples)	*4*					*4*		
DDP (dodecylphenol) (44 samples)	*4*					*4*		
Diuron, Igarol (50 samples)	*6*					*4*		

*) Supplementary investigations funded by the Ministry of Climate and Environment involved additional analyses on samples from blue mussel stations 30A, I301, I304, 31A, 36A1, 71A, I712, 51A, 56A, 65A, 22A, 10A2 and 11X; cod stations30B, 36B, 15B, 53B, 23B, 98B1 and 10B; as well as all analyses for blue mussel stations: 52A, 57A, 63A, 69A, I133, I306, I307

[1]) Including: BDE28, -47, -99, -100, -153, -154, -183, -196, -202, -206, -207 and -209

[2]) Including: PFBS, PFHxS, PFOS, br-PFOS, 6:2 FTS, ipPFNS, PFDS, PFDoS, PFOSA N-EtFOSE, N-MeFOSE, N-EtFOSA, N-MeFOSA, N-MeFOSEA, N-EtFOSEA, and perfluorerte karboksylsyrer (6-14 C-atomer): PFBA, PFPA, PFHxA, PFHpA, PFOA, PFNA, PFDA, PFUnA, PFDoA, PFTrA, PFTA

[3]) West coast station (st. 23B in 1994, 1997, 2005, 2013), Inner Sørfjord (st. 53B in 1990, 1994, 1997, 2000, 2005, 2009)

An overview of the applied analytic methods is presented in *Table 3*. Chemical analyses were performed separately for each cod liver, if possible, otherwise a pooled sampled was taken. Mercury was analysed on a fillet sample from each cod. Furthermore, Biological Effects Methods (BEM) were performed on individual cod.

Table 3. Overview of method of analyses (See Appendix B for description of chemical codes). Limit of detection (LOD) or limit of quantification (LOQ1) is indicated.

Name	[CAS-number]	Lab.	LOD	LOQ1	Est. uncertainty	Standard or internal method	Accreditation status
Metals							
cadmium (Cd)	7440-43-9	**NIVA/EFM**		0,001 mg/kg	20 %	Standard method NS EN ISO 17294-2	ISO 17025, accredited
copper (Cu)	7440-50-8	**NIVA/EFM**		0,03 mg/kg	20 %	Standard method NS EN ISO 17294-2	ISO 17025, accredited
lead (Pb)	7439-92-1	**NIVA/EFM**		0,03 mg/kg	20 %	Standard method NS EN ISO 17294-2	ISO 17025, accredited
zinc (Zn)	7440-66-6	**NIVA/EFM**		0,5 mg/kg	20 %	Standard method NS EN ISO 17294-2	ISO 17025, accredited
silver (Ag)	7440-22-4	**NIVA/EFM**		0,03 mg/kg	20 %	Standard method NS EN ISO 17294-2	ISO 17025, accredited
arsenic (As)	7440-38-2	**NIVA/EFM**		0,03 mg/kg	20 %	Standard method NS EN ISO 17294-2	ISO 17025, accredited
chrome (Cr),	7440-47-3	**NIVA/EFM**		0,02 mg/kg	20 %	Standard method NS EN ISO 17294-2	ISO 17025, accredited
nickel (Ni)	7440-02-0	**NIVA/EFM**		0,04 mg/kg	20 %	Standard method NS EN ISO 17294-2	ISO 17025, accredited
cobalt (Co)	7440-48-4	**NIVA/EFM**		0,005 mg/kg	20 %	Standard method NS EN ISO 17294-2	ISO 17025, accredited
tin (Sn)	7440-31-5	**NIVA/EFM**		0,1 mg/kg	20 %	Standard method NS EN ISO 17294-2	ISO 17025, accredited
Total-Hg	7439-9-76	**NIVA/EFM**		0,005 mg/kg	25 %	Standard method	ISO 17025, accredited
PCBs							
PCB-28	7012-37-5	**NIVA/EFM**		0,05 µg/kg low fat, 1 µg/kg high fat	40 %	Internal method	ISO 17025, "flexible" accreditation
PCB-52	35693-99-3	**NIVA/EFM**		0,05 µg/kg low fat, 1 µg/kg high fat	30 %	Internal method	ISO 17025, "flexible" accreditation
PCB-101	37680-73-2	**NIVA/EFM**		0,05 µg/kg low fat, 1 µg/kg high fat	40 %	Internal method	ISO 17025, "flexible" accreditation
PCB-118	31508-00-6	**NIVA/EFM**		0,05 µg/kg low fat, 1 µg/kg high fat	30 %	Internal method	ISO 17025, "flexible" accreditation
PCB-138	35065-28-2	**NIVA/EFM**		0,05 µg/kg low fat, 1 µg/kg high fat	30 %	Internal method	ISO 17025, "flexible" accreditation
PCB-153	35065-27-1	**NIVA/EFM**		0,05 µg/kg low fat, 1 µg/kg high fat	40 %	Internal method	ISO 17025, "flexible" accreditation
PCB-180	35065-29-3	**NIVA/EFM**		0,05 µg/kg low fat, 1 µg/kg high fat	40 %	Internal method	ISO 17025, "flexible" accreditation
p-p`-DDT	50-29-3	**NIVA/EFM**		0,2 µg/kg low fat, 4 µg/kg high fat	60 %	Internal method	ISO 17025, "flexible" accreditation
p-p`-DDE	82413-20-5	**NIVA/EFM**		0,05 µg/kg low fat, 1 µg/kg high fat	40 %	Internal method	ISO 17025, "flexible" accreditation
p-p`-DDD	72-54-8	**NIVA/EFM**		0,1 µg/kg low fat, 2 µg/kg high fat	50 %	Internal method	ISO 17025, "flexible" accreditation
PBDEs							
BDE47	5436-43-1	**NIVA/EFM**		0,005 µg/kg mussels, 0,1 µg/kg high fat	30 %	Internal method	ISO 17025, soon to be accredited
BDE99	60348-60-9	**NIVA/EFM**		0,01 µg/kg mussels, 0,1 µg/kg high fat	40 %	Internal method	ISO 17025, soon to be accredited
BDE100	189084-64- 8	**NIVA/EFM**		0,01 µg/kg mussels, 0,1 µg/kg high fat	40 %	Internal method	ISO 17025, soon to be accredited
BDE126*	366791-32-4	**NIVA/EFM**		0,01 µg/kg mussels	50 %	Internal method	ISO 17025, soon to be accredited
BDE153	68631-49-2	**NIVA/EFM**		0,02 µg/kg mussels, 0,1 µg/kg high fat	40 %	Internal method	ISO 17025, soon to be accredited
BDE154	207122-15-4	**NIVA/EFM**		0,02 µg/kg mussels, 0,1 µg/kg high fat	40 %	Internal method	ISO 17025, soon to be accredited
BDE183	207122-16-5	**NIVA/EFM**		0,03 µg/kg mussels, 0,3 µg/kg high fat	40 %	Internal method	ISO 17025, soon to be accredited
BDE196	32536-52-0	**NIVA/EFM**		0,05 µg/kg mussels, 0,3 µg/kg high fat	40 %	Internal method	ISO 17025, soon to be accredited
BDE209	1163-19-5	**NIVA/EFM**		0,5 µg/kg mussels, 0,5 µg/kg high fat	50 %	Internal method	ISO 17025, soon to be accredited
α, ß, γ-HBCD	134237-α (-50-6), ß (-51-7), γ (-52-8)	**EF-GFA**		0,006 ng/g	40 %	Internal method, validated	ISO 17025
Tetrabrombisphenol A (TBBPA)	79-94-7	**EF-GFA**		0,5 ng/g	40 %	Internal method, validated	ISO 17025
Bisphenol A (BPA)	80-05-7	**EF-GFA**		1-5 ng/g	40 %	Internal method, validated	ISO 17025
PFAS							
PFNA	375-95-1	**NIVA**	0,5 µg/kg		65 %	Internal method, validated	Not accredited but follows the routines and systems of ISO 17025
PFOA	335-67-1	**NIVA**	1 µg/kg		70 %	Internal method, validated	Not accredited but follows the routines and systems of ISO 17025
PFHpA	375-85-9	**NIVA**	0,4 µg/kg		60 %	Internal method, validated	Not accredited but follows the routines and systems of ISO 17025
PFHxA	307-24-4	**NIVA**	0,4 µg/kg		65 %	Internal method, validated	Not accredited but follows the routines and systems of ISO 17025
PFOS	1763-23-1	**NIVA**	0,5 µg/kg		25 %	Internal method, validated	Not accredited but follows the routines and systems of ISO 17025

Name	[CAS-number]	Lab.	LOD	LOQ1	Est. uncertainty	Standard or internal method	Accreditation status
PFBS	29420-49-3	**NIVA**	0,4 µg/kg		30 %	Internal method, validated	Not accredited but follows the routines and systems of ISO 17025
PFOSA	4151-50-2	**NIVA**	1 µg/kg		45 %	Internal method, validated	Not accredited but follows the routines and systems of ISO 17025
S/MCCP							
SCCP (C10-C-13)	85535-84-8	**EF-GFA**		0,6-3,5 ng/g	50 %	Internal method based on AIR OC 147, validated	ISO 17025
MCCP (C14-C17)	85535-85-9	**EF-GFA**		5-10 ng/g	50 %	Internal method based on AIR OC 147, validated	ISO 17025
Phenols							
Octylphenol	27193-28-8 (1806-26-4, 67632-66-0, 140-66-9,)	**EF-GFA**		10-50 ng/g	40 %	Internal method, validated	ISO 17025
4-nonylphenol	104-40-5 (25154-52-3, 84852-15-3)	**EF-GFA**		10-50 ng/g	40 %	Internal method, validated	ISO 17025
Tin compounds							
Monobutyltin (MBT)	2406-65-7 (78763-54-9)	**EF-GFA**		0,5 ng/g	40 %	Internal method, validated	ISO 17025
Dibutyltin (DBT)	1002-53-5	**EF-GFA**		0,5 ng/g	40 %	Internal method, validated	ISO 17025
Tributyltin (TBT)	688-73-3	**EF-GFA**		0,5 ng/g	30 %	Internal method, validated	ISO 17025
Trifenyltin (TPT)	668-34-8	**EF-GFA**		0,5 ng/g	40 %	Internal method, validated	ISO 17025
PFRs							
tri-iso-butylphosphate (TIBP)*	126-71-6	**EF-GFA**		100-1000 ng/1 g fat	40 %	Internal method, under development	ISO 17025
tributylphosphate (TBP)	126-73-8	**EF-GFA**		100-1000 ng/1 g fat	40 %	Internal method, under development	ISO 17025
tri(2-chlorethyl)phosphate (TCEP)	115-96-8	**EF-GFA**		100-1000 ng/1 g fat	40 %	Internal method, under development	ISO 17025
tri(1-chlor-2-propyl) phosphate (TCPP)	13674-84-5	**EF-GFA**		100-1000 ng/1 g fat	40 %	Internal method, under development	ISO 17025
tri(1,3-dichlor-2-propyl) phosphate (TDCP)	13674-87-8	**EF-GFA**		100-1000 ng/1 g fat	40 %	Internal method, under development	ISO 17025
tri(2-butoxyethyl) phosphate (TBEP)	78-51-3	**EF-GFA**		100-1000 ng/1 g fat	40 %	Internal method, under development	ISO 17025
triphenylphosphate (TPhP)	115-86-6	**EF-GFA**		100-1000 ng/1 g fat	40 %	Internal method, under development	ISO 17025
2-ethylhexsyl-di-phenylphosphate (EHDPP)*	1241-94-7	**EF-GFA**		100-1000 ng/1 g fat	40 %	Internal method, under development	ISO 17025
tetra is-(2-chloroethyl)dichlorisopentyldiphosphate (V6)		**EF-GFA**		100-1000 ng/1 g fat	40 %	Internal method, under development	ISO 17025
dibutylfenylphosphate (DBPhP)**	2528-36-1	**EF-GFA**		100-1000 ng/1 g fat	40 %	Internal method, under development	ISO 17025
butyldifenylphosphate (BdPhP)**	2752-95-6	**EF-GFA**		100-1000 ng/1 g fat	40 %	Internal method, under development	ISO 17025
tris(2-etylheksyl)phosphate (TEHP)*	78-42-2	**EF-GFA**		100-1000 ng/1 g fat	40 %	Internal method, under development	ISO 17025
tris-o-kresylphosphate (ToCrP)*	78-30-8	**EF-GFA**		100-1000 ng/1 g fat	40 %	Internal method, under development	ISO 17025
trikresylphosphate (TCrP)	1330-78-5	**EF-GFA**		100-1000 ng/1 g fat	40 %	Internal method, under development	ISO 17025
Phthalates							
Dibutylphthalate (DBP)	84-74-2	**EF-Sofia**		500 µg/kg	40 %		Not accredited
Dibutyladipat (DBPA)		**EF-Sofia**		500 µg/kg	40 %		Not accredited
Diethylhexcyladipate (DEHA)		**EF-Sofia**		2000 µg/kg	40 %		Not accredited
Di(2-ethylhexyl)-phthalate (DEHP)	117-81-7	**EF-Sofia**		1000 µg/kg	40 %		Not accredited
Dietylphthalate (DEP)		**EF-Sofia**		500 µg/kg	40 %		Not accredited

Name	[CAS-number]	Lab.	LOD	LOQ1	Est. uncertainty	Standard or internal method	Accreditation status
Diethyladipat (DEPA)	85-68-7	**EF-Sofia**		500 µg/kg	40 %		Not accredited
Benzylbutylphthalate (BBP)		**EF-Sofia**		300 µg/kg	40 %		Not accredited
Diisobutylphthalate (DIBP)	84-69-5	**EF-Sofia**		500 µg/kg	40 %		Not accredited
Diisodectylyphthalate (DIDP)		**EF-Sofia**		5000 µg/kg	40 %		Not accredited
Diisoheptylphthalate (DIHP)		**EF-Sofia**		5000 µg/kg	40 %		Not accredited
1,2-Cyclohexane dicarboxylic acid diisononyl ester (DINCH)		**EF-Sofia**		500 µg/kg	40 %		Not accredited
Diisobutyl adipate (DIPA)		**EF-Sofia**		300 µg/kg	40 %		Not accredited
Dimethylphthalate (DMP)		**EF-Sofia**		500 µg/kg	40 %		Not accredited
Di-n-octylphthalte (DNOP)		**EF-Sofia**		500 µg/kg	40 %		Not accredited
Diphenylphthalate (DPF)		**EF-Sofia**		500 µg/kg	40 %		Not accredited
Dinonylphthalte+diisononylphthalate (SDD)		**EF-Sofia**		n.a.	40 %		Not accredited
Tributyl-o-acetylcitrate (TOA)		**EF-Sofia**		n.a.	40 %		Not accredited
BEM							
VDSI		**NIVA**			10-20%	ICES TIMES 24	Not accredited
EROD		**NIVA**			10-20%	ICES TIMES 13	Not accredited
CYP1A		**NIVA**			10-20%	ICES TIMES 23	Not accredited
ALA-D		**NIVA**			20 %	ICES TIMES 34	Not accredited

2.2.2 Laboratories and brief method descriptions

The 2013 samples were largely analysed by Eurofins in Moss and by one of the Eurofins laboratories in Germany (GFA). NIVA was responsible for the PFAS analyses. A brief description of the analytical methods used follows (from Green *et al.* 2008a).

Metals were analysed at Eurofins-Moss according to NS EN ISO 17294-2. Metals were extracted using nitric acid and quantified using Inductively Coupled Plasma Mass Spectrometry (ICP-MS), except for chromium, which was determined using GAAS or ICP-Atomic Emission Spectroscopy (ICP-AES). Mercury (total) has been analysed using Cold-Vapour AAS (CVAAS).

Polychlorinated biphenyls (PCBs) and other chlororganic hazardous substances were analysed at Eurofins-Moss using GC-MS. Fat content was extracted using a mixture of cyclohexane and acetone or iso-propanol on the target tissue. Among the individual PCBs quantified, seven (ΣPCB-7) are commonly used for interpretation of the results[4] (*Table 4*).

Table 4. Suggested PCB-congeners, which are to be quantified in biota (ICES 1986).

IUPAC/CB no.	Structure
28	2 4-4'
52	2 5-2'5'
101	2 4 5-2'5'
118	2 4 5-3'4'
138	2 3 4-2'4'5'
153	2 4 5-2'4'5'
180	2 3 4 5-2'4'5'

Polycyclic aromatic hydrocarbons (PAH) were analysed at Eurofins Moss using a gas chromatograph (GC) coupled to a mass-selective detector (MSD). The individual PAHs are distinguished by the retention time and/or significant ions. All seven potential carcinogenic PAHs (IARC 1987) are included in the list of single components determined to constitute the total concentration of PAH.

Organic tin compounds were analysed at Eurofins GFA in 2013/2014 using GC-MS detection.

Analyses of polybrominated diphenylether (PBDE) in cod liver were done at Eurofins Moss in 2013/2014. Results are given based on the total extractable fat content of the target tissue using a GC-Negative Chemical Ionization (NCI)-MS.

Analysis of perfluoralkyl compounds (PFAS) in cod liver 2013 were done at NIVA. The general procedures include extractions with solvents using ultrasonic bath before intensive clean up and LC/MS/MS-analysis (ESI negative mode). From 2013 LC-qTOF has been used for detection and quantification.

Previously most of the analyses were performed at NIVA, using different procedures and instrumentation. In order to minimize methodical disturbance in time series, the transfer of analyses from NIVA to Eurofins Moss has also included several intercalibrations between the two labs.

The new analyses introduced in 2012/2013 were done by Eurofins. Chlorinated paraffins (SCCP (C10-C13), MCCP (C14-C17)), phosphorus flame-retardant (PFR) and nonyl- and octylphenols were determined by GC-MS at Eurofins GFA. Determination of bisphenol A (BPA) and tetrabromobisphenol A (TBBPA) were done at Eurofins GFA by GC-MS while hexabromocyclododecane (α, ß, γ-HBCD) were determined by LC-MS-MS also by Eurofins GFA.

For fish, the target tissues for quantification of hazardous substances are; liver and fillet(*Table 3*), whereas for the biological effects methods (BEM) liver; blood and bile is used (cf. *Table 5*). In addition, the age, sex, and visual pathological state for each individual are determined. Other measurements include: fish weight and length, weight of liver, liver dry weight and fat content (% total extractable fat), the fillet dry weight and its % fat content. These measurements are stored in the database and published periodically (e.g. Shi *et al.* 2008).

[4] Several marine conventions (e.g. OSPAR and HELCOM[4]) use ΣPCB-7 to provide a common basis for PCB assessment.

The mussels are analysed for all contaminants including organotin. The shell length of each mussel is measured. On a bulk basis the total shell weight, total soft tissue weight, dry weight and % fat content is measured. These measurements are stored in the database and published periodically.

The dog whelk are analysed for organotin compounds and biological effects (imposex[5]).

2.3 Biological effects analysis

Five biological effects methods (BEM), including the measurement of OH-pyrene have been applied on an annual basis for this investigation. Each method in theory is generally indicative of one or a group of contaminants. For EROD and CYP1A however, some interaction effects are known. Analysis of OH-pyrene in bile is not a measurement of biological effects, per se. It is included here, however, since it is a result of biological transformation (biotransformation) of PAHs, and is thus a marker of PAH exposure. An overview of the methods, tissues sampled and contaminant specificity is shown in *Table 5*. One of the major benefits of BEM used at the individual level (biomarkers) is the feasibility of integrating biological and chemical methods, as both analyses are done on the same individual.

BEM-sampling requires that the target fish is kept alive until just prior to sampling. Sampling for BEM-analyses is performed by trained personnel, most often under field conditions. Immediately after the fish are inactivated by a blow to the head samples are collected and stored in liquid nitrogen. Analyses of a metabolite of pyrene (OH-pyrene) were done on bile samples stored at -20°C.

Table 5. The relevant contaminant-specific biological effects methods applied on an annual basis.

Code	Name	Tissue sampled	Specificity
OH-pyrene	Pyrene metabolite	fish bile	PAH
ALA-D	δ-aminolevulinic acid dehydrase inhibition	fish red blood cells	Pb
EROD-activity	Cytochrome P4501A-activity (CYP1A/P4501A1, EROD)	fish liver	planar PCB/PCNs, PAHs, dioxins
CYP1A	Relative amount of cytochrome P450 1A-protein	fish liver	Supporting parameter for EROD-activity
TBT	Imposex	snail soft tissue	organotin

2.3.1 Rationale and overview

A thorough analysis and review of BEM-results has been performed twice since their inclusion in 1997 (Ruus *et al.* 2003; Hylland *et al.* 2009). Clear relationships were shown between tissue contaminants, physiological status, and responses in BEM parameters in cod (Hylland *et al.* 2009). Although metals contributed substantially to the models for ALA-D (and also for metallothionein - MT included in the programme 1997-2001) and organochlorines in the model for CYP1A activity, other factors were also shown to be important. Liver lipid and liver somatic index (LSI) contributed for all three BEM-parameters, presumably reflecting the general health of the fish. Size or age of the fish also exerted significant contributions to the regression models. It was concluded that the biological effect methods clearly reflected relevant processes in the fish even if they may not be used alone to indicate pollution status for specific locations at given times. Furthermore, the study showed that it is important to integrate a range of biological and chemical methods in any assessment of contaminant impacts. Through continuous monitoring within CEMP, a unique BEM time series /dataset are generated, that will also be of high value as a basis of comparison for future environmental surveys.

Biological effect methods were first included in the programme in 1997, after which some modifications have been done. In 2002, reductions were made in parameters and species analysed. There have also been improvements in the methods, such as discontinuation of single wavelength fluorescence and use of HPLC in the analysis of bile metabolites since 2000.

[5] Vas Deferens Stage Index

The CEMP-programme for 2013 included five biological effects methods (BEM) (cf. ***Table 5***).

Measures of OH-pyrene, EROD-activity and CYP1A increase with increased exposure to their respective inducing contaminants. The activity of ALA-D on the other hand is inhibited by contamination (i.e., lead), thus lower activity means a response to higher exposure.

2.4 Passive sampling with silicone rubber passive samplers

2.4.1 Principle of passive sampling for hydrophobic contaminants

Passive sampling is based on the diffusive movement of substances from the environmental matrix being sampled into a polymeric device (initially free of the compounds of interest) in which contaminants absorb. For the passive sampling of hydrophobic compounds the best known sampler is the SemiPermeable Membrane Device (SPMD) comprising a low density polyethylene membrane containing a triolein lipid phase (Huckins *et al.* 2006). Currently, single phase polymeric samplers constructed from material such as low density polyethylene or silicone rubber are used as a result of their robustness (Allan *et al.* 2009a, Allen *et al.* 2009b, Allan *et al.* 2010, Allan *et al.* 2011). At equilibrium, the mass of a chemical absorbed in the sampling device can be translated into a freely dissolved contaminant concentration in the water that the device was exposed to through K_{sw}, the sampler-water partition coefficient. Passive sampling techniques have been the subject of much development over the last two decades (Vrana *et al.* 2005). For hydrophobic contaminants with $\log K_{ow}$ > 5-6, polymeric samplers have a large capacity. For typical deployment periods of a few weeks, equilibrium between the sampler and water will not be attained for these chemicals. Uptake in the linear mode (i.e. far from equilibrium) is therefore time-integrative for the deployment period in water. The resulting time-integrated freely dissolved concentration can be estimated if *in situ* sampling rates, R_s, equivalent amount of water sampled per unit of time (L d^{-1}) are known. Sampling rates can be estimated from the dissipation of performance reference compounds (PRC), analogues of compounds of interest (but not present in the environment) spiked into the samplers prior to exposure (Booij *et al.* 1998, Huckins *et al.* 2002).

Passive sampling based on silicone rubber is increasingly being used for routine monitoring of water and sediment. These have been used within the Tilførselsprogrammet (2009-2013) for monitoring a range of contaminants at Andøya, Bjørnøya and Jan Mayen. Deployments were in most at least 200 days. For the riverine input and discharge programme (2013-), silicone rubber passive samplers have also been chosen. The reason for this choice is that we have recently shown that there is a likely restriction of the sampling of voluminous molecules such as brominated diphenyl ethers when using polyethylene (Allan *et al.* 2013). This can affect the accurate estimation of sampling rates for these compounds from standard PRCs.

Passive samplers were deployed at three sites, Hvaler, Oslofjord and Ålesund for periods of just under one year and analysed for performance reference compounds (to estimate sampling rates), alkylphenols (octyl and nonylphenols), hexabromocyclododecane (HBCD) and polybrominated diphenyl ethers (PBDEs).

2.4.2 Methodology (field and lab)

Samplers used for this project include silicone rubber passive samplers (for analysis and for specimen banking), low density polyethylene (for specimen banking), and Polar Chemical Integrative Samplers (for specimen banking).

Samplers made of AlteSil silicone rubber (nominal size of 1000 cm^2 and 30 g, strips 100 cm long and 2.5 cm wide) were prepared in the NIVA laboratory following standard procedures. In short, the silicone rubber samplers were placed in a Soxhlet extractor for 24 hour cleaning using ethyl acetate. This step removes a significant amount of non-polymerized oligomers. Samplers were then left to dry before further cleaning with methanol. PRCs (deuterated PAHs and fluoroPCBs) were spiked into the samplers using a methanol-water solution (Booij *et al.* 2002). Polyethylene membranes were prepared from polyethylene purchased from Brentwoods Plastics Inc. Samplers (1m long and 2.5 cm tubing) were soaked in hexane overnight to remove oligomers and clean the samplers. This step was repeated with fresh hexane. Samplers were then soaked in methanol prior to spiking with PRCs (according to Booij *et al.* 2002). Onced spiked with PRCs, samplers were kept in the freezer at -20 °C until deployment. POCIS devices were purchased from Exposmeter AB (Sweden).

Two sets of replicate silicone samplers were deployed at each of the three sites (Oslofjord, Ålesund havn and Hvaler) using SPMD canisters and samplers mounted on spider holders. Two control samplers were used to assess potential contamination of the samplers during preparation and deployment procedures and to assess initial PRC concentrations. Triplicate POCIS devices were exposed at each of the three stations (one control sample per site was used). The deployment duration are shown in *Table 6*. Samplers were deployed for 277 to 320 days depending on the station. Exact coordinates for the sampling stations are also given in *Table 6*.

Table 6. Coordinates for sampling stations, deployment and retrieval dates and exposure times for samplers deployed at the three stations.

Sampling station	Coordinates	Deployment date	Retrieval date	Exposure time (d)
Oslofjord (*304PP*)	N59° 5' 47.58" E11° 3' 2.628"	05.09.2013	22.07.2014	320
Hvaler (*HPP*)	N59° 5' 47.58" E11° 3' 2.628"	14.10.2013	25.07.2014	284
Ålesund harbour (*APP*)	N59° 5' 47.58" E11° 3' 2.628"	01.11.2013	05.08.2014	277

Once back in the laboratory, all samplers were kept in the freezer at -20 °C until extraction and analysis.

Silicone rubber passive sampling devices were kept at -20 °C until analysis. Replicate samplers (30 g each) and a control from each station were extracted. Additional preparation control samplers and QA spiked samplers were analysed together with exposed samplers. The initial step consisted in cleaning the surface of the samplers with milliQ water and drying before extraction. Samplers were placed in clean glass jars with surrogate standards of substances of interest before extraction with pentane (200 mL) overnight. This extraction was repeated with fresh pentane and pentane extracts were combined. Extracts were reduced and split for the different analyses.

For PRCs and alkylphenols, the extract was cleaned up by gel permeation chromatography (GPC). One fraction of the extract was then analyzed by GC-MS to determine PRC concentrations. The other fraction of the extract was derivatised (with a solution of N,O-bis(trimethylsilyl) trifluoroacetamide and trimethylchlorosilane) before determination of alkyl phenolic substances by GC-MS.

For PBDEs and HBCD, the extract was cleaned up with concentrated sulphuric acid. The extract was then split into two. One fraction of the extract was cleaned up by acetonitrile partitioning before PBDEs determination by GC-MS. The solvent of the second fraction was changed to methanol before determination of HBCD isomers by LC-MS-MS.

2.4.3 Quality assurance: Spiked samplers

A set of silicone rubber passive sampling devices for QA purposes was prepared following a similar procedure to that used for standard samplers. Instead of spiking PRCs, target substances in known amounts were added to the samplers using the methanol-water solution (Booij *et al.* 2002). Substances added included alkylphenolic substances, polybrominated diphenyl ethers and hexabromocyclododecane isomers. Once the batch was ready, six QA spiked samplers were randomly selected for extraction and analysis to determine the mean concentration and the reproducibility of the spiking of different samplers. The remaining QA spiked samplers were put into tins and stored in the freezer at -20 °C until use. The table below shows mean concentrations (n = 6) obtained in QA spiked samplers for alkylphenolic substances, HBCD isomers and PBDE congeners. Mean concentrations measured are within 89-120 % of the nominal concentrations across the range of substances spiked into the samplers. Relative standard deviations of amounts spiked into the samplers vary from 4 to 19 % across the range of compounds (Appendix G).

2.4.4 Passive sampling data processing

Freely dissolved concentrations were calculated using the boundary-layer controlled uptake model given in Rusina *et al.* (2010) and using the non-linear least square method to estimate sampling rates as a function of $\log K_{sw}$/MW (Booij & Smedes, 2010) from the performance reference compound data. Polymer-water partition coefficients for PRCs and for alkylphenols were not corrected for temperature or salt content of the water (but can be at a later stage if needs be). For PRCs (deuterated PAHs), K_{sw} values were from Smedes *et al.* (2009). For para-n-octylphenol and para-n-nonylphenol, $\log K_{sw}$ values were 4.43 and 5.08, respectively

(unpublished). Correlation of $logK_{sw}$ values with hexadecane-water partition coefficients (from Cosmotherm software), $logK_{hdw}$ were used to estimate $logK_{sw}$ for para-t-octylphenol and para-t-nonylphenol. Ultimately a measured value of K_{sw} for these compounds will be preferable. For PBDEs and HBCD, K_{sw} (not available for these substances) were estimated using the regression of $logK_{sw}$ with $logK_{ow}$ for PCBs for AlteSil silicone rubber.

2.5 Information on quality assurance

2.5.1 International intercalibrations

The laboratories have participated in the Quality Assurance of Information for Marine Environmental Monitoring in Europe (QUASIMEME) international intercalibration exercises and other proficiency testing relevant to chemical and imposex analyses. For chemical analyses, these include Round 73 of October 2013-January 2014, which apply to the 2013 samples. These QUASIMEME exercises included nearly all the contaminants as well as imposex analysed in this programme. The quality assurance programme is corresponding to the 2012 programme (cf. Green *et al.* 2013).

NIVA participated in the QUASIMEME Laboratory Performance Studies "imposex and intersex in Marine Snails BE1" in June-August 2012. Shell height, penis-length-male, penis-length-female, average-shell-height and female-male-ratio were measured. NIVA got the score satisfactory for all parameters except number of females for one sample, which got the score questionable. The score for VDSI was satisfactory for both samples tested.

2.5.2 Analyses of certified reference materials

In addition to the QUASIMEME exercises, certified reference materials (CRM) and in-house reference materials are analysed routinely with the MILKYS samples. It should be noted that for biota the type of tissue used in the CRMs does not always match the target tissue for analysis. Uncertain values identified by the analytical laboratory or the reporting institute are flagged in the database. The results are also "screened" during the import to the database at NIVA and ICES.

The laboratories used for the chemical testing are accredited according to ISO/IEC 17025:2005.

2.6 Classification of environmental quality

There are several systems that can be used to classify the concentrations of contaminants observed. No system is complete in that it covers all the contaminants and target species-tissues investigated in this programme. The national classification system prepared by the Norwegian Environment Agency (*Miljødirektoratet*) has been the most used and in investigations similar to this programme and it is applied here. It is the most complete system and provides assessment criteria for five classes of contamination, where Class I is the best class (lowest concentration). This system is built on presumed background concentrations and the degree above this level. It is currently under revision to accommodate the concern that elevated concentrations of contaminants can be harmful for the environment. This risk-based approach is the basis for EU directives which have defined Environmental Quality Standards (EQS). Exceedances of EQS are interpreted as potentially harmful to the environment and remedial action should be implemented. Two main challenges with the EQS that prevent them from being easily applied are that they are generally not species or tissue specific and they can be in conflict with the national limits. The EQS apply to the whole organism whereas in fish monitoring is generally done on a specific tissue[6]. The EQS can be considerably higher or lower than the national Class II (moderately polluted). For example for hexachlorobenzen (HCB) the EQS is 10 µg/kg w.w., whereas Class I and II are 0.1 and 0.3 µg/kg w.w. for blue mussel, respectively, and 0.2 and 0.5 µg/kg w.w. in cod fillet, respectively; or for mercury the EQS is 20 µg/kg w.w. whereas Class I and II are 40 and 100 µg/kg w.w. for blue mussel, respectively, and 100 and 300 µg/kg w.w. in cod fillet, respectively (cf. *Table 7* and Appendix C). These anomalies warrant the need to have clear guidance as to how the EQS should be applied and how to explain the difference in the two systems. Even so, the EQS have been discussed where possible when assessing the results from this programme.

Assessing the risk to human consumption that elevated concentrations of contaminants in seafood might have has not been the task of this programme and hence, the EU foodstuff limits have not been applied.

Focus for the 2013 investigation is on the principle cases where median concentrations exceeded the upper limit to Class I in the environmental quality classification system of the Norwegian Environment Agency (cf. Molvær *et al.* 1997). In addition to this, the EU directive 2013/39/EU where Environmental Quality Standards (EQS) for biota are defined are considered (*Table 7*, *Table 10*). The Norwegian Environment Agency defines most classes on a wet weight basis, the exception being for metals in blue mussel which are on a dry weight basis. The EQS and OSPAR time trend methods of analyses are based on wet weight concentrations. To harmonize the presentation classification and trendanalyses for these results the class limits for metals in blue mussel were unofficially converted to a wet weight basis where needed. The relevant part of the Norwegian Environment Agency system is shown in Appendix C.

The choice of base by OSPAR is aimed at meeting several considerations: scientific validity, uniformity for groups of contaminants for particular tissues and a minimum loss of data. As to the latter, the choice of base will affect the number of data that can be included in the assessment, depending on available information on dry weights, wet weights and lipid weights.

[6] The concentration of a contaminant can vary considerably from tissue to tissue. Hence, monitoring is usually based on tissues with high concentrations and that are of sufficient size to meet the constraints of the analyses. In this regard fish liver and fish fillet are the most commonly used tissues in monitoring.

Table 7. The Water Framework Directive (WFD) Environmental Quality Standards for "biota" [1] *(cf. Environmental Quality Standard Directive-2013/39/EU) and the Class I and V (upper limit to insignificant and extreme degree of pollution, respectively) in the environmental classification system of the Norwegian Environment Agency (NEA) (Molvær et al. 1997). Concentrations in µg/kg wet weight. Note: EQS used for assessing water with passive sampling are treated separately (see Appendix G, Table 40).*

Hazardous substance	**EQS biota** [1]	**NEA – blue mussel Class I - V**	**NEA – cod-liver Class I – V**	**NEA – cod-fillet Class I - V**
Brominated diphenylether [2]	0.0085			
Fluoranthene	30 [3]			
Benzo(a)pyrene	5 [3]	1 - 30		
Benzo(b)fluoranthene	[3]			
Benzo(k)fluoranthene	[3]			
Benzo(g,h,i,)perylene	[3]			
Indeno(1,2,3-cd)-pyrene	[3]			
Polyaromatic hydrocarbons (PAH) [4]		50 – 5000		
Hexachlorobenzene (HCB)	10	0.1 - 5	20 - 40	0.2 - 5
Hexachlorobutadiene (HCBD)	55			
Mercury and its compounds	20	40 – 800 [5]		100 – 1000
Dicofol	33			
Perfluorooctane sulfonic acid and its derivatives (PFOS)	9.1			
Dioxins and dioxin-like compounds	0.0065 [6]			
Hexabromocyclododecane (HBCD)	167			
Heptachlor and heptachlorexpoxide	0.0067			

1) Fish unless otherwise stated. An alternative biota taxon, or another matrix may be monitored instead, as long as the EQS applied provides an equivalent level of protection.
2) Sum of BDE congener numbers 28 (tri), 47 (tetra), 99 (penta), 100 (penta), 153 (hexa) and 154 (hexa)
3) Crustaceans and molluscs. (Monitoring of these PAHs not appropriate for fish)
4) The sum of tri- to hexacyclic PAH compounds named in EPA protocol 8310 minus naphthalene (dicyclic)-totalling 15 compounds, so that the classification system of the Norwegian Environment Agency can be applied.
5) Conversion assuming 20% dry weight.
6) Sum of PCDD+PCSF+PCB-DL TEQ

The system has five classes from Class I, insignificantly polluted, to Class V, extremely polluted. However, the system does not cover all the contaminants for the species and tissues used in CEMP. To assess concentrations not included in the system provisional presumed high background values were used (cf. Appendix C). The factor by which this limit or the Class I limit is exceeded is calculated (cf. Appendix F). High background concentration corresponds to the upper limit to Class I; insignificantly polluted, which in this context has no statistical implications.

The median concentrations are assessed according to the system of the Norwegian Environment Agency, but where this is not possible, presumed high background levels are used. It should be noted that there is in general a need for periodic review and supplement of the list of limits used in the classification system in the light of results from reference localities and introduction of new analytical methods, and/or units. Because of changes in the limits, assessments of presumed high background levels over the years may not correspond.

Recommendations for changes to Class I (cf. Knutzen & Green 2001, Green & Knutzen 2003) have been taken into account in this report. Revisions to corresponding Classes II-V have not been done, but the Norwegian Environment Agency is currently reviewing their classification system.

The results can also be useful as part of the implementation of The Water Framework Directive (WFD) (2000/60/EC) ratified by Norway in 2009, and the Marine Strategy Directive (MSFD) (2008/56/EC), which by late 2014 has not yet been ratified by Norway. These two directives together concern all waters out to territorial borders. They are the main policies at the EU level designed to achieve good "ecological" (WFD) or "environmental and chemical" (MSFD) status, herein termed GES, in the European marine environment, by the year 2015 (2021 for Norway) and 2020 at the latest, respectively. The directives also set out to ensure the continued protection and preservation of the environment and the prevention of deterioration. The Norwegian framework regulation on water management (the Water Regulation) was adopted on December 15th 2006, and

incorporates the WFD into Norwegian law. The Environmental Quality Standards (EQS) for 45 priority substances or groups of substances have been outlined in the EQS Directive (EQSD) (2013/39/EU replacing directive 2008/105/EC). Several of these substances are monitored by MILKYS. The EQS apply to concentrations in water, and for fifteen substances biota (*Table 7*, *Table 10*). There is also a provision which allows a country to use other EQS in sediment and biota provided these offer the same level of protection as the EQS set for water. It should be noted that application of the EQS set may be in conflict with the best class by the Norwegian Environment Agency system for classification of environmental quality; e.g. lower than the Class I for mercury and higher for Class V for HCB in blue mussel. This has not been resolved and for this report, only the system of the Norwegian Environment Agency will be used.

Proposed background assessment criteria (BAC) for EROD and OH-pyrene (ICES 2011) and VDSI (OSPAR 2005) were used to assess the results (***Table 8***).

Table 8. Assessment criteria for biological effects measurements using background assessment concentration (BAC) and Environmental assessment criteria (EAC) (ICES 2011, OSPAR 2005). Note that Assessment criteria have specifically been compiled for the assessment of CEMP monitoring data on hazardous substances. They do not represent target values or legal standards (OSPAR 2009).

Biological effect	Applicable to:	BAC	EAC	Units, method
EROD	cod liver	145	-	pmol/min/ mg microsomal protein
OH-pyrene	cod liver	21*	-	ng/ml; HPLC-F
VDSI	dog whelk, periwinkle	0.3	2	(OSPAR 2005)

*) Values in this report are normalized and the unit of the assessment criterion is ng/ml, without normalization to absorbance at 380nm. Normalization in this investigation reduced the values by a factor of about 30.

2.7 Statistical time trends analysis

2.7.1 The model approach

A simple model approach has been developed to study time trends for contaminants in biota based on median concentration (ASMO 1994). The method has been applied to Norwegian data and results are shown in Appendix E. The results can be presented as shown in ***Figure 4***.

The model approach uses a Loess smoother based on a running six-year interval where a non-parametric curve is fitted to median log-concentration (Nicholson *et al.* 1991, 1994 and 1997 with revisions noted by Fryer & Nicholson 1999). The concentrations are on the preferred basis of wet weight as mentioned above. Supplementary analyses were performed on a dry weight basis for blue mussel data and lipid weight basis for chlororganic contaminants in blue mussel and fish liver (see Appendix F). For statistical tests based on the fitted smoother to be valid the contaminants indices should be independent to a constant level of variance and the residuals for the fitted model should be log-normally distributed (cf. Nicholson *et al.* 1998). A constant of +1 was added to VDSI data prior to log transformation to enable analysis of observations that were equal to zero.

An estimate was made of the power of the temporal trend series expressed as the percent change that the test is able to detect. The power is based on the percentage relative standard deviation (RLSD) estimated using the robust method described by ASMO (1994) and Nicholson *et al.* (1998). The estimate was made for series with at least five years of data.

The assessment method used up to and including the 2011 investigation have differed slightly from the method now employed by OSPAR in that a linear trend for the whole time series period was tested whereas OSPAR currently tests the difference in smoothed annual concentration at the beginning of the time series compared the concentration at the end of the time series. This report presents an assessment in line with the current OSPAR approach.

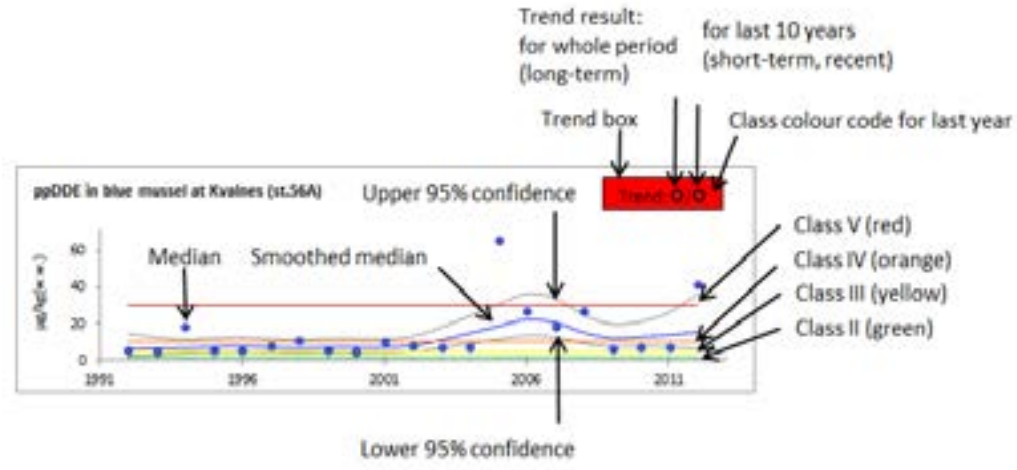

Figure 4. Example of time series that shows the median concentration (blue dots), running mean of median values (Loess smoother – blue line) and 95 % confidence intervals (grey lines). The horizontal lines indicate the lower boundaries to the classes of pollution in the system of the Norwegian Environment Agency : Class II (green line, moderate=upper boundary to Class I (insignificantly polluted, also herein termed as "acceptable")), III (yellow line, marked), IV (orange line, severe) and V (red line, extreme) (cf. Table 37), or alternatively the Class II boundary is replaced by the upper boundary to provisional "high background level" as in which case no class-boundaries are shown. Further, if there are no classes the background concentration is indicated by a light grey line (see text and refer to Appendix C). For biota, trend analyses (shown in the trend box) were done on time series with five or more years and the results, before the slash "/" (i.e. long-term trend which means the entire time series), are indicated by an upward (↑) or downward (↓) arrow where significant trends were found, or a zero (O) if no trend was detected. Where there was sufficient data a time series analysis was performed for the last ten-year for the period 2004-2013 (short-term or recent trend) and the result is shown after the slash. A small filled square (▪) indicates that chemical analysis has been performed, but data either were insufficient to do a trend analysis or was not presented. The trend box is also coloured with respect to the Norwegian Environment Agency classification system as it applies to the final year: blue (Class I), green (Class II), yellow (Class III), orange (Class IV) or red (Class V). In addition, the box may be coloured dark grey or light grey. Dark grey indicates concentrations higher than estimated high background levels. Light grey indicates concentrations lower than background levels. Note that scales for the x axis and y axis can vary from figure to figure.

The term "significant" refers to the results of a statistical analysis at 0.05 significance level used for detecting differences between the beginning and the end of the time series and can be found in the tables in Appendix F. In this appendix the statistical significance (p) is given as well as the annual detectable change (%) that can be detected with statistical probability of 90% (Power) in two-sided testing with a 10% significance level (alpha).

No attempt has been made to compensate for differences in size groups or number of individuals of blue mussel or fish in this study. However, investigations prior to 2007 showed significant differences between "small" and "large" fish. With respect to blue mussel, there is some evidence that concentrations do not vary significantly among the three size groups employed for this study (i.e. 2-3, 3-4 and 4-5 cm) (WGSAEM 1993).

The statistical analysis of time trends was carried out on all the results, including those for biological effects parameters.

2.7.2 Treatment of values below the detection limit

Values below the limit of detection are set to half of the value of this limit for calculation for use in time trends or set to zero when included in a sum (e.g. ΣPCB-7). This is in accordance to EU directive (2009/90/EC). The annual median is classified as less-than if over half of the values are below the limit of detection and is assigned the median value prefixed with a "<" sign in Appendix F, however when presented in tables of the main text on half of this value is shown. It should be noted that the detection limit can vary within and among sets of samples and comparisons of detection limits should be made with caution.

In calculating trends a time series must have at most only one "less-than median" provided it is not the first in the series. The effect that a less-than value has on the trend analysis has not been quantified; however, the results should be treated with caution because the dominance of values below the limit of quantification could invalidate the statistical assumption behind the analysis (Rob Fryer, pers. comm.).

2.8 Previous methods

This section provides some notes concerning methods applied previously.

Since 2009, the monitoring included the three cod-stations in the harbour areas of: Kristiansand (st. 13BH), Trondheim (st. 80BH) and Tromsø (st. 43BH) and since 2012 cod in the harbour area of Ålesund (st. 28B) and Hammerfest (st. 45B) have been added. The Norwegian MILKYS has been expanded since 1989 to include monitoring also in more diffusely polluted areas. Sufficient samples have not always been practical to obtain. When this applies to blue mussel, a new site in the vicinity is often chosen. This was the case for three blue mussel stations: As for fish, the quota of 25 individuals (±10%) prior to 2012 and 15 individuals in 2013 was not always met.

Prior to 2012, 25 individuals of cod was the target number. This revision was agreed at Hazardous Substances and Eutrophication Committee (HASEC, 2012) and derived from an initiative by The Norwegian Environment Agency. At the request of the agency NIVA analysed how the precision of trend assessments will be affected by changes in the monitoring program for hazardous substances in biota (Bjerkeng, 2012). Two issues were addressed that concerned cod:

- **The first issue** (monitoring with 2 or 3 years intervals instead of yearly) has been studied by running the Norwegian CEMP trend assessment procedure on subsets of data corresponding to monitoring each 2nd or 3rd year, running over all possible starting points. It cannot be recommended generally to decrease the monitoring frequency in cases where possible trends are of concern. It may be considered for stations where established time series show concentrations well below levels of any concern, and without any upward trend over a number of years.

- **The second issue** (changing the number of cod livers) has been studied by analysing long cod liver time series with approximately 25 fish per sample (year). It can be concluded that reducing the number of replicates per sampling location from 25 to 20 fish has only a marginal effect on the trend detection ability, increasing the minimum detectable trend under given conditions by only 2-7 %. A reduction to 15 fish would increase the detectable trend by 3-22 % (less than 10 % for most stations and parameters). These increases show a reduced ability to detect trends when reducing the number of replicates, but the effect is generally small or moderate.

It was largely on the basis of this report that the number of cod samples was reduced from 25 to 15.

A third issue coupled to the revision discussed above applied to blue mussel (HASEC, 2012):

- **The third issue** (reducing number of yearly samples for mussel monitoring) has been studied by analysing subsets of mussel data in the Norwegian CEMP program from the Grenland region southwest of Oslo, and from Sørfjord in Hardanger, in both cases supplemented by data from local or regional monitoring programs. Reducing from three to a single pooled sample of mussel per year for a station may lead to a considerable reduction in trend detection ability. A more cautious reduction, to fewer (in practice two), but still more than one sample, could probably be implemented without a large effect on the ability to detect trends.

There is some evidence that the effect of shell length and difference in bulk sample size are of little or no significance (WGSAEM 1993; Bjerkeng & Green 1994). However, for historical reasons, three size groups of blue mussel (*Mytilus edulis*) have been sampled from most of the stations: 2-3, 3-4 and 4-5 cm. In order to obtain the wet weight necessary for analyses and potential reanalyses of all variables (usually about 50g), fifty to hundred individuals were sampled for each class. In 1992 a stricter approach (ICES 1992) was applied for new stations north of the Bømlo area at which 3 pooled samples of 20 individuals each were collected in the size range of 3-5 cm. All blue mussel samples from the new stations are collected according to this ICES method.

For certain stations and prior to the 2012-investigations the intestinal canal was emptied (depuration) in mussels (cf. Green *et al.* 2012). There is some evidence that for a specific population/place the depuration has no significant influence on the body burden of the contaminants measured (cf. Green 1989; Green *et al.* 1996). This practice was terminated after 2011. Mussels were shucked and frozen (-20°C).

3. Results and discussion

3.1 General information on measurements

A summary of the levels and trends in contaminants or their effects in Atlantic cod, blue mussel, dog whelk and periwinkle along the coast of Norway in 2013 is shown in *Table 10*. More details on trend analyses for the entire monitored period that include results from either 2012 or 2013 are shown in Appendix F. The results from 2013 present data for a total of 2205 data sets (contaminant-station-species) on 120 different contaminants. Unless otherwise stated assessment of trends in the text below refer to long-term trends, i.e. for the whole sampling period, whereas a short-term trend refers to the analysis on data for the last 10 years, i.e. 2004-2013 and can also be referred to as recent trend.

Time trend analyses were performed on a selection of 30 representative contaminants or their effect (VDSI), and included data for 2013 and totalled 750 data series (*Table 9*). In 43 of the 750 cases, median concentrations were in Class II or higher in the Norwegian Environment Agency classification system (Molvær *et al.* 1997) or above what is expected in only diffusely contaminated areas (collectively termed: "over presumed high background concentrations"). The overview presented below is primarily based on the 750 data series, of which recent and significant trends were registered in 90 cases: 66 (8.8 %) downwards trends and 24 (3.2 %) upwards (*Figure 5A*). Of the 399 cases that could be classified by the system of the Norwegian Environment Agency, 90.2 % were classified as insignificantly polluted (Class I), 6.8 % as moderately polluted (Class II), 2.5 % as markedly polluted (Class III), 0.3 % as severely polluted (Class IV) and 0.3 % as extremely polluted (Class V, *Figure 5B*). The downward trends were primarily associated with metals (53 %), Tributyltin (TBT, 16.7 %) and Vas Deferens Sequence Index (VDSI) (the effect of TBT) (10.6 %) (*Figure 6A*). The upward trends were also mainly associated with metals (91.7 %), primarily Hg (33.3 %). The 12 cases that were classified as Class III, IV or V concerned organic contaminants for the most part (*Figure 6B*). The results are discussed in more detail below.

Primary focus were on those cases where median concentrations in 2013 were over presumed high background level (>Class I, insignificantly polluted, acceptable levels) and where significant upward trends were found and to a lesser degree where there were no significant trends or significant downward trends. The evaluation focused secondarily on cases where median concentrations in 2013 were below presumed high background level (<Class I, insignificantly polluted) in combination with significant upward trends. An overview of trends, classification and median concentrations is presented in Appendix F. The results are presented by classes and with results for observed trend analyses.

*Table 9. Selection of representative contaminants and number of time series assessed for each target species-tissue. Counts include supplementary investigations funded by the Ministry of Climate and Environment and are marked with an asterisk " * " [1].The specific results are shown in Table 10.*

Contaminant/BEM	Description	Cod, liver	Cod fillet	Blue mussel	Dog whelk, periwinkle	TOTAL
Ag	silver	13		32*		**45**
As	arsenic	13		32*		**45**
Cd	cadmium	13		32*		**45**
Co	cobalt	13		32*		**45**
Cr	chromium	13		32*		**45**
Cu	copper	13		32*		**45**
Hg	mercury		14	32*		**46**
Ni	nickel	13		32*		**45**
Pb	lead	13		32*		**45**
Zn	zinc	13		32*		**45**
PCB-7 (CB_S7)	sum of PCB congeners 28+52+101+118+138+153+180	13		29*		**42**
ppDDE (DDEpp)	p,p'-DDE (a DDT metabolite)	7*		18*		**25**
HBCDa	α–hexabromocyclododecane	11		8		**19**
SCCP	short chain chlorinated paraffin (C10-C13)	11		8		**19**
MCCP	medium chain chlorinated paraffin (C14-C17)	11		8		**19**
BDE47	tetrabromdiphenylether	9		10		**19**
BDE100	pentabromdiphenylether	9		10		**19**
BDE209	decabromdiphenylether	9		10		**19**
PAHs (P_S)	sum nondicyclic PAHs			10		**10**
KPAHs (PK_S)	sum carcinogen PAHs			10		**10**
BKF	benzo[k]fluoranthene			10		**10**
B[ghi]P	benzo[ghi]perylene			10		**10**
ICDP	Indeno[1,2,3-cd]pyrene			10		**10**
B[a]P	benzo[a]pyrene			10		**10**
FLU	Fluoranthene			10		**10**
PFOS	perfluorooctanoic sulfonate	8				**8**
PFOSA	perfluorooctylsulfonate acid amide	8				**8**
PFBS	Potassium perfluorobutanesulfonat	8				**8**
TBT	tributyltin (formulation basis)			7*	9	**16**
VDSI	Vas Deferens Sequence Index				8	**8**
TOTAL		**221**	**14**	**498**	**17**	**750**

1) Supplementary investigations funded by the Ministry of Climate and Environment involved additional analyses on samples from blue mussel stations 30A, I301, I304, 31A, 36A1, 71A, I712, 51A, 56A, 65A, 22A, 10A2 and 11X; cod stations 30B, 36B, 15B, 53B, 23B, 98B1 and 10B; as well as all analyses for blue mussel stations: 52A, 57A, 63A, 69A, I133, I306, I307.

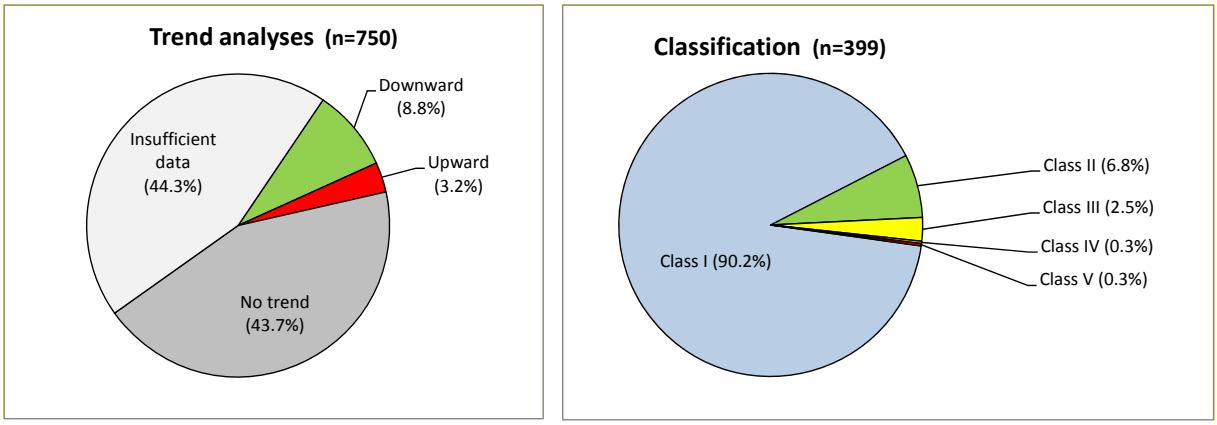

Figure 5. Summary of the results from short-term trend analyses (A) and classification in Norwegian Environment Agency system (B) for 30 selected contaminants (cf. Table 9). Colour coding in Figure B refers to classification colours (cf. Table 37).

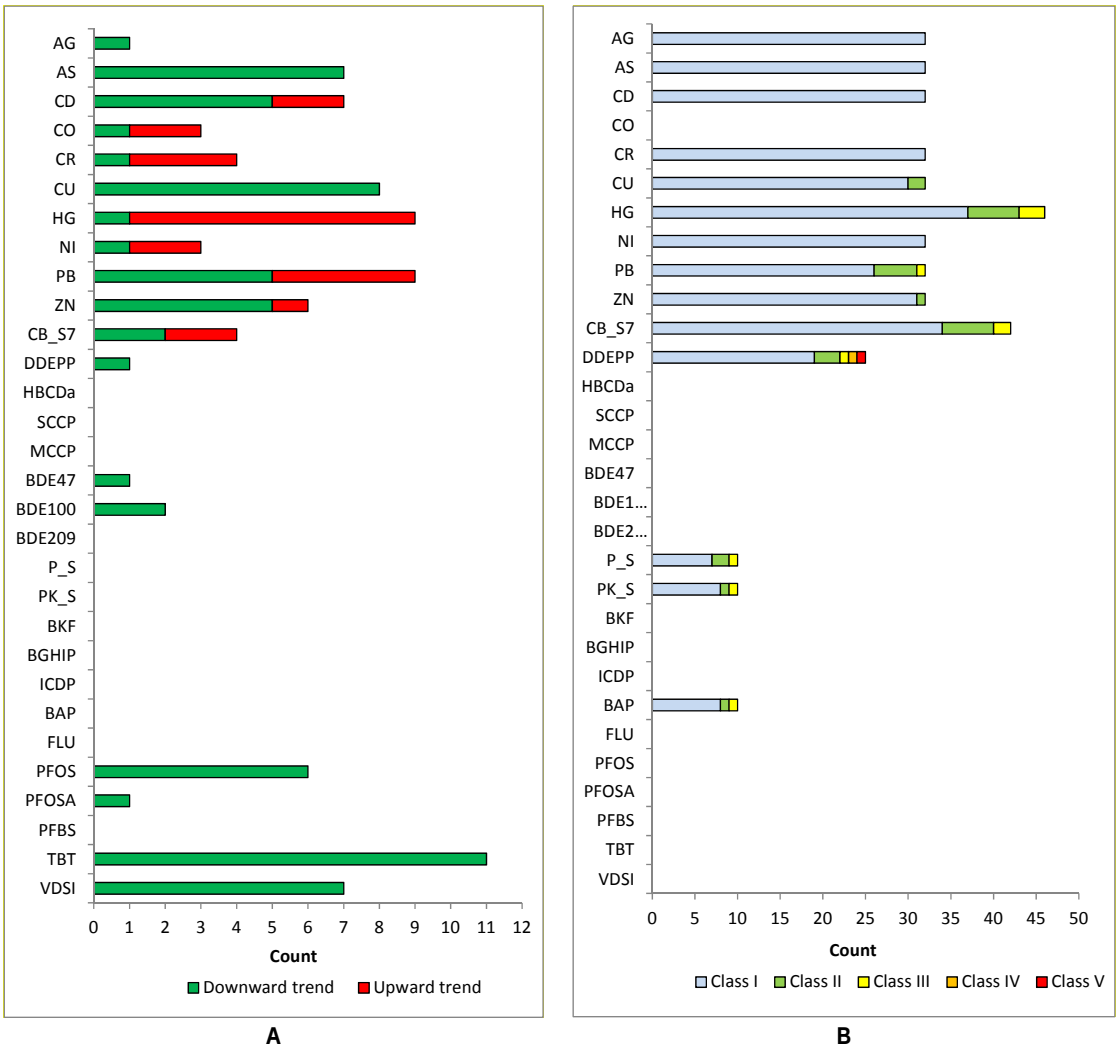

Figure 6. Summary of short-term trends (A) and classification in Norwegian Environment Agency system (B) for each of the 30 selected contaminants (cf. Table 9, abbreviations are defined in Appendix B). Colour coding in Figure B refers to classification colours (cf. Table 37).

*Table 10. Overview of samples collected in 2013 with indication of levels and trends in concentrations of contaminants monitored. Classification is based on observed concentrations in cod, blue mussel, dog whelk and periwinkle. Tissues: soft body (SB), muscle (MU), liver (LI) and whole organism (WO). The classification system of the Norwegian Environment Agency is used for biota (Molvær et al. 1997: Classes: I (blue), II (green), III (yellow), IV (orange) and V (red) (see Appendix D). For biota, trend analyses were done on time series with five or more years An upward (↑) or downward (↓) arrow before the slash "/" indicates where significant trends were found, or a zero (O) if no trend was detected. Where there was sufficient data a time series analysis was performed for the period 2004-2013 and the result is shown after the slash. A small filled square (▪) indicates that chemical analysis has been performed, but either data were insufficient to do a trend analysis or was not presented. Results marked with a star (★) indicate that there is insufficient data above the detection limit. Dark grey indicates concentrations higher than estimated high background levels. Light grey indicates concentrations lower than high background levels. Note: Class limits for ΣDDT are used for ppDDE. Stations marked with an asterisk(*) or a small filled diamond (⬩) indicate supplementary investigations funded by the Ministry of Climate and Environment.*

Station	Station name	species	tissue	Ag	As	Co	Cd	Cr	Cu	Hg	Ni	Pb	Zn	PCB7	DDEPP	HBCDA	SCCP	MCCP	BDE47	BDE100	BDE209	PAH16	KPAH	BKF	BGHIP	ICDP	BAP	FLU	PFOS	PFOSA	PFBS	TBT	VDSI
02B	Hvaler	Cod	LI	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪		▪/▪	▪/▪	▪/▪	▪/▪		▪/▪	▪/▪	▪/▪															
02B	Hvaler	Cod	MU							▪/▪																							
10A2	Skallneset	Blue mussel	SB	O/O	↓/↓	O/O	O/O	O/O	O/O	↓/O	O/O	O/O	O/O	↓/O	★/O⬩																		
10B	Varangerfjord	Cod	LI	O/O	O/O	O/O	↓/O	★/★	↓/↓		★/★	★/★	↓/O	↓/O	↓/O⬩																		
10B	Varangerfjord	Cod	MU							O/↑																							
11G	Brashavn	Dog Whelk	SB																												★/★		
11G	Brashavn	Dog Whelk	WO																														O/O
11X	Brashavn	Blue mussel	SB	O/O	↓/↓	O/O	O/O	O/O	O/O	O/O	O/O	O/O	O/O	O/O	★/O⬩																		
131G	Lastad	Dog Whelk	SB																												↓/↓		
131G	Lastad	Dog Whelk	WO																														↓/↓
13B	Kristiansand harbour	Cod	LI	O/O	↓/↓	O/O	O/O	↓/↓	O/O		↓/↓	★/★	O/O	O/O		▪/▪	▪/▪	▪/▪	O/O	O/O	★/★								O/O	★/★	★/★		
13B	Kristiansand harbour	Cod	MU							O/O																							
15A	Gåsøy	Blue mussel	SB	↓/↓	↓/↓	O/O	O/O	O/O	O/O	O/O	O/O	O/↑	↓/O	O/↑																			
15B	Farsund area	Cod	LI	O/O	O/O	O/O	O/O	★/★	O/O		O/O	★/★	O/O	O/O	O/O⬩																		
15B	Farsund area	Cod	MU							O/↑																							
15G	Gåsøy	Dog Whelk	SB																												↓/↓		
15G	Gåsøy	Dog Whelk	WO																														↓/↓
227G1	Melandsholmen	Dog Whelk	SB																												↓/↓		
227G1	Melandsholmen	Dog Whelk	WO																														↓/↓
22A	Espevær	Blue mussel	SB	★/★	O/O	O/O	O/↓	↑/↑	O/O	O/↓	O/O	↓/↓	↓/O	↓/O	O/O⬩																↓/↓		
22G	Espevær	Dog Whelk	SB																												↓/↓		
22G	Espevær	Dog Whelk	WO																														↓/↓
23B	Bømlo north	Cod	LI	O/O	O/O	O/O	O/O	★/★	O/O		★/★	★/★	O/O	O/O	↓/O⬩	▪/▪	▪/▪	▪/▪	↓/O	↓/O	★/★								O/↓	★/★	★/★		
23B	Bømlo north	Cod	MU							O/↑																							
26A2	Måløy	Blue mussel	SB	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪		▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪												
28B	Ålesund area	Cod	LI	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪		▪/▪	▪/▪	▪/▪	▪/▪		▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪												
28B	Ålesund area	Cod	MU							▪/▪																							
30A	Gressholmen	Blue mussel	SB	O/O	O/O	O/O	O/O	O/O	↑/O	O/O	↑/↑	O/O	O/O	O/O	O/O⬩	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	O/O	O/O	★/★	★/O	★/★	★/★	O/O				↓/↓	
30B	Inner Oslofjord	Cod	LI	O/O	↓/↓	O/O	↑/O	★/★	↓/O		O/O	↓/↓	O/O	O/O	O/O⬩	▪/▪	▪/▪	▪/▪	O/O	O/↓	★/★								O/↓	O/O	★/★		
30B	Inner Oslofjord	Cod	MU							↑/↑																							
31A	Solbergstrand	Blue mussel	SB	O/O	▪/▪	O/O	O/O	O/O	O/O	↓/O	O/O	↓/O	O/O	O/O	O/O																	▪/▪	
35A*	Mølen	Blue mussel	SB	★/★	O/O	O/O	↓/O	O/O	O/↓	O/↑	O/O	O/O	O/↓	↓/O																			
36A1	Tjøme	Blue mussel	SB	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪⬩	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪											▪/▪	
36B	Færder area	Cod	LI	O/O	O/O	O/O	↓/O	★/★	↓/↓		O/O	★/★	↓/O	O/↓	↓/O⬩	▪/▪	▪/▪	▪/▪	↓/O	O/O	★/★								↓/↓	O/O	★/★		
36B	Færder area	Cod	MU							O/O																							
36G	Færder	Dog Whelk	SB																													↓/↓	
36G	Færder	Dog Whelk	WO																														↓/↓
43B2	Tromsø harbour	Cod	LI	O/O	↓/↓	O/O	O/O	★/★	O/O		O/O	★/★	↓/↓	O/O		▪/▪	▪/▪	▪/▪	↓/↓	↓/↓	★/★								↓/↓	★/★	★/★		
43B2	Tromsø harbour	Cod	MU							O/O																							
51A	Byrkjenes	Blue mussel	SB							↓/O				O/O	O/O																		
52A*	Eitrheimsneset	Blue mussel	SB	O/O	O/O	▪/▪	↓/O	O/O	O/O	↓/O	O/O	↓/O	↓/↓	O/O	O/O⬩																		
53B	Inner Sørfjord	Cod	LI											O/O	O/O	▪/▪	▪/▪	▪/▪	O/O	O/O	★/★								↓/↓	★/★	★/★		

Station	Station name	species	tissue	Ag	As	Co	Cd	Cr	Cu	Hg	Ni	Pb	Zn	PCB7	DDEPP	HBCDA	SCCP	MCCP	BDE47	BDE100	BDE209	PAH16	KPAH	BKF	BGHIP	ICDP	BAP	FLU	PFOS	PFOSA	PFBS	TBT	VDSI
53B	Inner Sørfjord	Cod	MU							○/○																							
56A	Kvalnes	Blue mussel	SB							○/○				↓/○	↑/○																		
57A*	Krossanes	Blue mussel	SB	▪/▪	▪/▪	▪/▪	↓/↓	▪/▪	○/↓	↓/○	▪/▪	↓/↓	↓/↓	↓/○	○/○◆																		
63A*	Ranaskjær	Blue mussel	SB	▪/▪	▪/▪	▪/▪	↓/↓	○/○	↓/○	○/○	▪/▪	↓/○	↓/○	↓/○	○/○◆																		
64A	Utne	Blue mussel	SB	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪																		
65A	Vikingneset	Blue mussel	SB	★/★	○/○	○/○	↓/↓	↑/↑	○/○	○/○	○/○	↓/↓	↓/○	↓/○	○/○																		
69A*	Lille Terøy	Blue mussel	SB	▪/▪	▪/▪	▪/▪	↓/↓	▪/▪	○/○	○/○	▪/▪	↓/↓	↓/↓	○/○																			
71A	Bjørkøya	Blue mussel	SB	★/★	↓/↓	○/○	↓/○	○/○	○/↓	↓/○	○/○	○/↑	○/○	↓/○	○/○◆		▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪					
71B	Grenslandsfjord	Cod	LI	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪		▪/▪	▪/▪	▪/▪			▪/▪	▪/▪	▪/▪															
71B	Grenslandsfjord	Cod	MU							▪/▪																							
71G	Fugløyskjær	Common periwinkle	SB																													○/○	
76A2	Risøy	Blue mussel	SB	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪◆																		
76G	Risøy	Dog Whelk	SB																													↓/↓	
76G	Risøy	Dog Whelk	WO																														↓/↓
80B	Inner Trondheimsfjord	Cod	LI	○/○	○/○	○/○	○/○	★/★	○/○		○/○	★/★	○/○	↓/↓		▪/▪	▪/▪	▪/▪	○/○	○/○	★/★								↓/↓	↓/↓	★/★		
80B	Inner Trondheimsfjord	Cod	MU							○/○																							
91A2	Outer Trondheimsfjord	Blue mussel	SB	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪		▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪												
96B	Helgeland	Cod	LI	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪		▪/▪	▪/▪	▪/▪	▪/▪																			
96B	Helgeland	Cod	MU							▪/▪																							
97A2	Bodø harbour	Blue mussel	SB	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪		▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪												
98A2	Lofoten, Svolvær	Blue mussel	SB	○/○	○/○	○/○	○/○	↑/↑	○/○	○/○	↑/↑	○/○	○/○	↓/○		▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪				□	▪/▪					
98B1	Lofoten, Skrova	Cod	LI	○/○	○/○	↑/↑	○/↑	★/★	○/○		○/○	★/★	↑/↑	↓/○	↓/↓◆	▪/▪	▪/▪	▪/▪	○/○	○/○	★/★								○/○	★/★	★/★		
98B1	Lofoten, Skrova	Cod	MU							○/○																							
98G	Lofoten, Svolvær	Dog Whelk	SB																													↓/↓	
98G	Lofoten, Svolvær	Dog Whelk	WO																														↓/↓
I023	Singlekalven	Blue mussel	SB	★/★	○/○	○/○	○/○	○/○	○/○	○/○	○/○	○/○	○/○	↓/○		▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪					
I024	Kirkøy	Blue mussel	SB	□	▪/▪	▪/▪	○/↑	▪/▪	↓/↓	○/○	▪/▪	↑/↑	○/○																				
I131A	Lastad	Blue mussel	SB	★/★	○/○	↓/↓	○/○	○/○	○/○	○/○	○/○	○/○	○/○									○/○	○/○	★/★	○/○	★/★	★/★	○/○					
I133*	Odderøy	Blue mussel	SB	○/○	○/○	○/○	○/○	○/○	○/○	○/○	○/○	↑/↑	○/○	↓/↑	↓/○◆																	↓/↓	
I241	Nordnes	Blue mussel	SB	★/★	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	○/○	○/○		▪/▪			▪/▪	▪/▪	▪/▪												
I301	Akershuskaia	Blue mussel	SB	★/★	○/○	○/○	○/○	○/○	○/○	○/○	○/○	↓/○	↓/○	↓/○	↓/○◆							○/○	○/○	○/○	○/○	○/○	★/○	○/○				↓/↓	
I304	Gåsøya	Blue mussel	SB	★/★	○/○	○/○	○/○	○/○	○/○	○/↑	○/○	○/○	○/○	↓/○	○/○◆							○/○	○/○	★/★	★/★	★/★	★/★	○/○				▪/▪	
I306*	Håøya	Blue mussel	SB	★/★	▪/▪	▪/▪	○/○	▪/▪	↓/↓	○/↑	▪/▪	○/○	○/○	○/○																			
I307*	Ramtonholmen	Blue mussel	SB	★/★	○/○	▪/▪	○/○	○/○	↓/↓	○/○	○/○	○/○	○/○	↓/○																			
I712	Croftholmen	Blue mussel	SB	★/★	○/○	○/○	○/○	○/○	○/○	○/↑	○/○	○/○	○/○						▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪					
I965	Moholmen	Blue mussel	SB	★/★	○/○	○/○	○/○	○/○	○/○		○/○	○/○	○/○									○/○	○/○	○/○	○/○	○/○	○/○	○/○					
I969	Bjørnebærviken	Blue mussel	SB	○/○	○/○	↑/↑	○/○	○/○	○/○		○/○	○/○	○/○									○/○	○/○	○/○	○/○	○/○	○/○	○/○					

3.2 Levels and trends

3.2.1 Mercury (Hg)

Important levels exceeding Class I

Cod fillet from Ålesund harbour (st. 28B) was markedly polluted (Class III) by Hg in both 2012 and 2013. Cod fillet from the Grenlandsfjord (st. 71B) and Ålesund (st. 28B) were also markedly polluted. Cod fillet from the Inner Sørfjord (st. 53B) was moderately polluted (Class II) by Hg in both 2012 and 2013. Cod fillet from Færder (st. 36B), Kristiansand harbour (st. 13B), Farsund (st. 15B) and Bømlo north (st. 23B) were also moderately polluted. Blue mussel at Kvalnes (st. 56A) in the Mid Sørfjord was moderately polluted (Class II) by Hg. All other blue mussel stations showed background levels (Class I) of Hg.

Class increased since 2012

The concentration of Hg in cod fillet from the Grenlandsfjord area (st. 71B) had increased from being moderately polluted (Class II, 0.184 mg/kg w.w.) in 2012 to being markedly polluted (Class III, 0.324 mg/kg w.w.) in 2013. Cod fillet from Færder (st. 36B), Kristiansand (st. 13B) and Farsund (st. 15B) showed background (Class I) concentrations of Hg in 2012, but was moderately polluted (Class II) in 2013.

Upward trends

Cod fillet from the Inner Oslofjord (st. 30B) was markedly polluted (Class III) by Hg and showed both significant upward long-term and short-term trends in both 2012 and 2013 (*Table 10, Figure 7*)**.** The median concentration had decreased from 0.34 mg/kg w.w. in 2012 to 0.318 mg/kg w.w. in 2013.

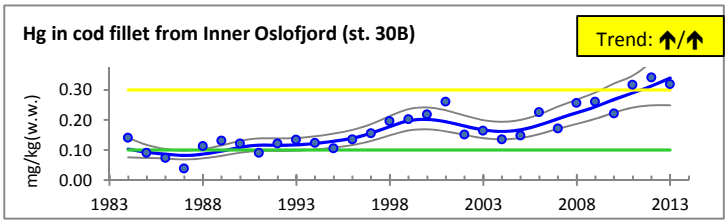

Figure 7. Median concentrations (mg/kg w.w.) of mercury in cod fillet from 1984 to 2013 in the Inner Oslofjord (st. 30B).

Concentrations of Hg in cod fillet from Farsund area (st. 15B) and Bømlo north (st. 23B) on the west coast showed significant upward short-term trends. There was background concentration (Class I) of Hg in cod fillet from the Varangerfjord, but a significant upward short-term trend was observed in both 2012 and 2013.

Blue mussel at Croftholmen (st. I712) in the Grenlandsfjord area had background levels (Class I) in 2013, but a significant upward short-term trend was observed. Mussels in the Inner Oslofjord at Gåsøya (st. I304), Håøya (st. I306) and in the Outer Oslofjord at Mølen (st. 35A), also showed significant upward short-term trends but within background levels.

Class decreased since 2012

Hg-concentrations in cod fillet from Hvaler (st. 02B) and the Inner Trondheimsfjord (st. 80B), and blue mussel from Bjørkøya (st. 71A) and Croftholmen (st. I712) had decreased from being moderately polluted (Class II) in 2012, to being insignificantly polluted (Class I) in 2013.

Downward trends/low levels

There was no significant long-term trend in cod fillet from the Varangerfjord in 2013 while it was a significant downward long-term trend in 2012. At Bjørkøya (st. 71A) in the Grenlandsfjord area, Hg-concentrations in blue mussel had decreased to background levels (Class I) in 2013, and a significant downward long-time trend was detected (*Table 10, Figure 8).*

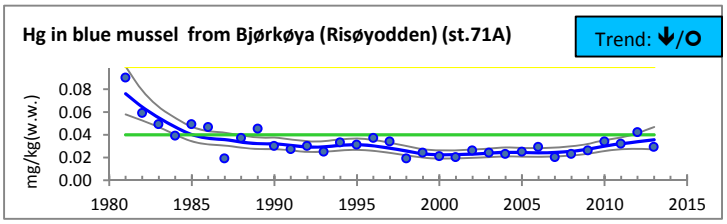

Figure 8. Median concentrations (mg/kg w.w.) of mercury in blue mussel from 1981 to 2013 in the Grenlandsfjord area (Bjørkøya, st. 71A).

Significant downward long-term trends were also observed in the Oslofjord at Solbergstrand (st. 31A), in the Sørfjord at Byrkjenes (st. 51A), Eitrheimsneset (st. 52A) and Krossanes (st. 57A), and in the Varangerfjord at Skallneset (st. 10A2). Blue mussel at Espevær (st. 22A) on the west coast showed a significant downward short-term trend.

General, large scale trends

For the period 1990-2006, OSPAR (2010) found 70-75% reduction in riverine and direct discharges of Hg to the North Sea and sediment from the North Sea showed a predominance of downward over upward significant trends. The long-term trends in Norwegian coastal waters are generally consistent with these OSPAR-results. Seven long-term trends were found for Hg in cod and six downward long-term trends were found for Hg in blue mussel. Significant upward long-time trend was only found for cod fillet in the Inner Oslofjord.

Discharges of Hg from rivers in Norway have been in the range 99 to 242 kg during 2010 to 2012 (Skarbøvik *et al.* 2013). There was insufficient data to assess a trend.

When considering recent short-term (2004-2013) trends for both cod and blue mussel, significant trends are, however, with one exception (blue mussel at Espevær) either not detected or upward (*Table 10, Figure 9*). The reason for the recent upwards trend is not known and it should be emphasized that they mostly reflect variations within background levels.

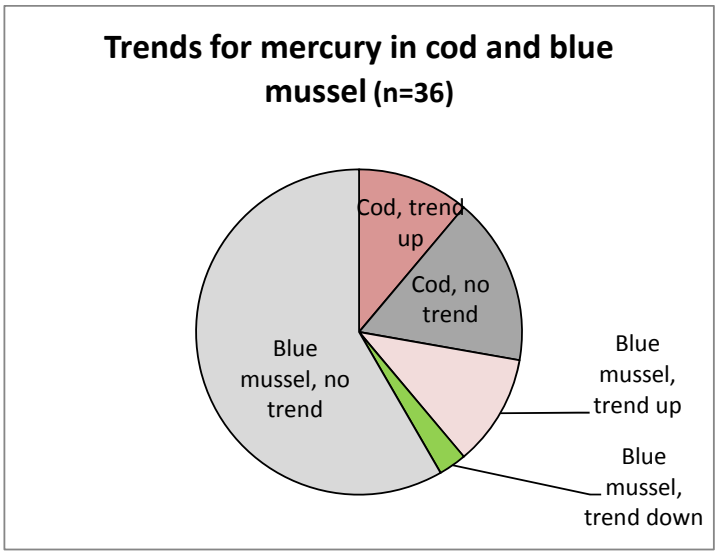

Figure 9. Frequency of short-term (recent) trends (2004-2013) for mercury in cod fillet and blue mussel. Only downward recent (short-term) in blue mussel trend at Espevær (st. 22A) on the west coast was detected.

Emissions of Hg to air from land-based industries showed essentially a decrease from 2002 to 2009, and no change or an increase from 2009 to 2013 (*Figure 10*) and provided no support for the 2004-2013 increasing short-term trends. The discharges to water varied between 108 kg Hg in 2012 to 260 kg Hg in 2004 in the period 2002-2013.

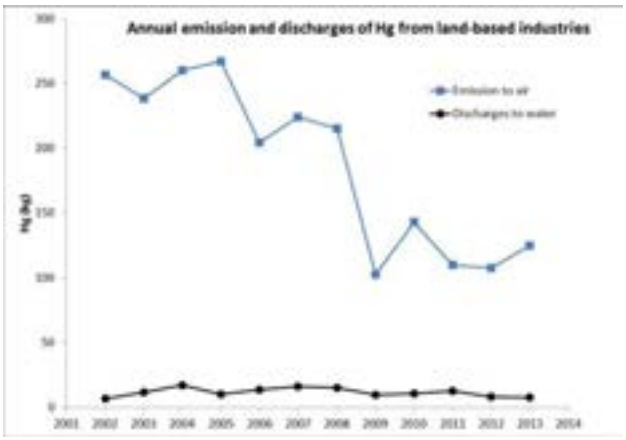

Figure 10. Annual emissions of Hg to air and discharges to water from land-based industries in the period 2002-2013 (data from www.norskeutslipp.no). Note that this category excludes emissions and discharges from municipal treatment plants, land runoff, transportation and offshore industry.

Inner Oslofjord

The reasons for the upward trends of Hg in cod fillet from the Inner Oslofjord are not clear. Though the relationship between Hg and fish length is well established (e.g. Green & Knutzen 2002, Juhlshamn *et al.* 2013, Jones *et al.* 2013) fish length could not explain entirely the upward trend. Green & Knutzen (2003) found a significant relationship between Hg and length in 1198 cod collected during the period 1990-2000 as part of the CEMP (see Chapter 1.1). The cod were caught in areas remote from presumed point sources and hence represent a baseline for such a correlation. Using their equation the predicted and measured concentrations of Hg in cod from the inner Oslofjord were compared. No significant correlation was found for the entire period but a significant correlation was found for the last ten years. This indicates that the upward trend could partly but not entirely explain the increase. Further investigations are warranted to quantify the influence that fish length has on temporal trends. Upward trends of Hg have also been registered in freshwater fish species of Norway (see Fjeld *et al.*2010).

Two stations in the Inner Oslofjord and Mølen in the Outer Oslofjord showed significant upward short-term trends of Hg in blue mussel, but within background levels (Class I). Other investigations in the Inner Oslofjord (Berge 2014) also found insignificantly polluted (Class I) blue mussel, and that cod fillet from Bekkelaget and Frognerkilen was moderately polluted (Class II) in 2010 and 2013. Atmospheric deposition is a major source to the seas surrounding Norway and considerably larger than other sources such as riverine discharges, shipping and offshore installations (Green *et al.* 2013). Historical data on entry of Hg to the Inner Oslofjord is not available. Bjerkeng *et al.* (2009) found that more than 60% of the Hg input to Bunnefjorden was from atmospheric deposition. Present discharge of Hg to the Inner Oslofjord has been calculated to be around 7.3 kg/year (Berge *et al.* 2013a).

Fjeld *et al.* (2010) point to observations that the atmospheric deposition of Hg in Southeast Norway has decreased significantly over the last years (Wängberg *et al.* 2010), and thus they expected to find a decrease or unchanged levels of Hg in fish (inland waters). They suggested that increased wash-out of humus substances in inland water can lead to increased microbial activity in the sediment and increased methylation of Hg. This would make Hg more bioavailable. The amount of particles in the surface water in the Inner Oslofjord has however been reduced over several decades (Berge *et al.* 2013b) and the input of organic carbon to the sediments in the Inner Oslofjord have more likely been reduced. The factors controlling methylation processes in sediments are not well understood and it should not be ruled out that change in organic carbon input and deep water renewals may have altered redox conditions towards increased methylation at the sediment water boundary. Other possible mechanisms might be weakened photodemethylation in surface waters or altered trophic links, e.g. a shift in cod diet to prey items with higher Hg-content. It should be noted that detecting the impact of changes in discharges/inputs of mercury will also depend on how well fish biotmetrics (length, age and growth rates) are taken into account (Jones *et al.* 2013).

Other studies
Blue mussel from Langøya in the Holmestrandfjord in 2013 was up to moderately polluted (Class II) by Hg at some locations (Gitmark *et al.* 2014). Hg in cod fillet was still declining in the Grenlandsfjord during the period from 2008 to 2012, but the level in the Frierfjord was still higher than in 1999 (Ruus *et al.* 2013a). Blue mussel at seven stations in the Kristiansandsfjord in 2013 was insignificantly polluted (Class I) or slightly above (Schøyen *et al.* 2014). The concentrations of metals and Hg in blue mussel in the Sørfjord had decreased significantly during the last 25 years due to remedial actions performed by the local industry (Ruus *et al.* 2013b).

Environmental Quality Standards (EQS)
EU has provided Environmental Quality Standard (EQS) of 0.02 mg/kg w.w. in biota for "fish" (cf. *Table 7*) which is below the upper limit of insignificantly polluted (Class I) blue mussel (0.04 mg/kg w.w.). Applying this EQS for blue mussel, concentrations of Hg were above the EQS applied for biota at Mølen (st. 35A, 0.022 mg/kg w.w.) in the Outer Oslofjord, Kirkøy (st. I024, 0.023 mg/kg w.w.) in the Hvaler area, Bjørkøya (st. 71A, 0.029 mg/kg w.w.) and Croftholmen (st. I712, 0.024 mg/kg w.w.) in the Grenlandsfjord area. This was also the result at Byrkjenes (st. 51A, 0.038 mg/kg w.w.), Eitrheimsneset (st. 52A, 0.025 mg/kg w.w.), Kvalnes (st. 56A, 0.043 mg/kg w.w.) and Krossanes (st. 57A, 0.027 mg/kg w.w.) in the Sørfjord, and in the Hardangerfjord at Vikingneset (st. 65A, 0.021 mg/kg w.w.).

The EQS for fish are based on analyses on whole fish. Therefore, the EQS cannot be directly compared to concentrations found in certain tissues of fish. We have in this study only measured Hg in fillet. Converting concentrations in fillet to concentrations in whole fish is uncertain, and would probably be an overestimate because Hg accumulates more in the muscle than in other tissues (Kwasniak & Falkowska 2012). If it is assumed, for this exercise, that the same concentration is found in all tissue types, then the results of Hg (in cod fillet) would have exceeded the EQS (0.020 mg/kg w.w.) for all 2013-samples, as it did for all 2012-samples.

3.2.2 Cadmium (Cd)

Levels exceeding Class I
All cod liver was at background levels and all blue mussel was insignificantly polluted (Class I).

Upward trends
For cod liver, there was significant upward long-time trend in the Inner Oslofjord (st. 30B) and significant upward short-term trend in Lofoten (st. 98B1) (*Table 10*). There was a significant upward short-term trend in blue mussel at Kirkøy (st. I024) in the Hvaler area.

Class decreased since 2012
Blue mussel from Croftholmen (st. I712) was moderately polluted (Class II) with Cd in 2012 and at background level (Class I) in 2013.

Downward trends/low levels
All concentrations of Cd in cod liver and blue mussel were low, i.e. within background levels (Appendix C). There were significant downward long-time trends of Cd in cod from Færder (st. 36B) and in the Varangerfjord (st. 10B). In blue mussel, there were significant downward long-time and short-term trends at Krossanes (st. 57A) in the Outer Sørfjord, from Ranaskjær (st. 63A), Vikingneset (st. 65A), Lille Terøy (st. 69A) in the Hardangerfjord. There were significant downward long-time trends for blue mussel at Mølen (st. 35A), Bjørkøya (st. 71A) and at Eitrheimsneset (st. 52A) in the Inner Sørfjord.

Other studies
Other reports have also shown blue mussel insignificantly polluted with Cd in the Inner Oslofjord 2006-2013 (Berge 2014) and at Odderøy and Svensholmen in the Kristiansandsfjord 2010-2013 (Schøyen *et al.* 2014). Mussels were, however, up to moderately polluted with Cd at Langøya in the Holmestrandfjord in 2013 (Gitmark *et al.* 2014).

General, large scale
Discharges of Cd to water from land-based industries showed a decrease from 2007 (686 kg Cd/year) to 2013 (264 kg Cd/year) (*Figure 11*). The emission of Cd to air showed a gradually decrease from 2002 (352 kg Cd/year) to 2013 (77 kg Cd/year).

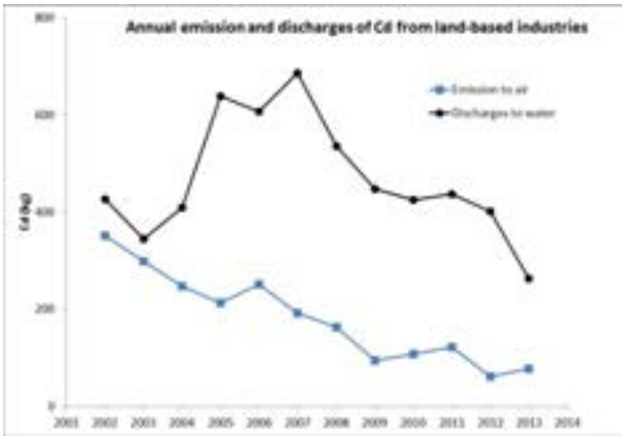

Figure 11. Annual emissions of Cd to air and discharges to water from land-based industries in the period 2002-2013 (data from www.norskeutslipp.no). Note that this category excludes emissions and discharges from municipal treatment plants, land runoff, transportation and offshore industry.

The discharge of Cd to water from local industry in Skien has gradually increased from 0.01 kg/year in 2004 to 0.12 kg/year in 2013 (www.norskeutslipp.no). The discharge of Cd to water from local industry in Odda in the Inner Sørfjord has decreased from 130 kg/year in 2007 to between 30 and 40 kg/year in the period 2008-2013 (www.norskeutslipp.no). It is difficult to link the concentrations of Cd to any local or transboundary change.

During 1990 to 2012, a significant downward trend has been found for discharges of Cd from Norwegian rivers (Skarbøvik *et al.* 2013).

3.2.3 Lead (Pb)

Important levels exceeding Class I
The presence of Pb in blue mussel exceeded Class I (insignificantly polluted) at six of the 32 blue mussel stations (*Table 10*). The highest level (5.7 mg Pb/kg w.w.) was found in blue mussel from Odderøy (st. I133) in the Kristiansandsfjord. Blue mussel from this location was markedly polluted (Class III). Blue mussel at Gressholmen (st. 30A) in the Inner Oslofjord, Kirkøy (st. I024) in the Hvaler area, Croftholmen (st. I712) in the Grenlandsfjord area, Eitrheimsneset (st. 52A) in the Inner Sørfjord and Moholmen (st. I965) in the Ranfjord were moderately polluted (Class II) with Pb.

Class increased since 2012
The Pb-concentrations at Gressholmen (st. 30A) in the Inner Oslofjord and Croftholmen (I712) in the Grenlandsfjord area had increased from being on background level (Class I) in 2012 to being moderately polluted in 2013.

Upward trends
Blue mussel from Kirkøy (st. I024) and Odderøy (st. I133) showed both significant upward long-time and short-term trends. Blue mussel from Gåsøy (st. 15A) and Bjørkøya (st. 15A) also showed significant upward short-term trends.

Downward trends/low levels
Observed concentrations of Pb in cod liver were at background level at all stations (*Table 10*). Significant downward long-term trends were found in cod liver from the Inner Oslofjord (st. 30B) and in the Inner Sørfjord (st. 53B) in both 2012 and 2013. At eight stations, data was inadequate for trend analysis in cod liver due to concerns about the limit of detections.

Of the 24 time trend series performed for blue mussel, eight revealed significant downward long-time trends. All blue mussel stations in the Inner and Outer Oslofjord had low concentrations of Pb. A significant downward long-time trend was observed for mussel at Eitrheimsneset, and mussel were moderately polluted (Class II).

Other studies
Monitoring of mussels in the Inner Oslofjord in 2006 to 2013 showed that mussels were up to moderately polluted (Class II) by Pb (Berge 2014) and that mussels were up to moderately polluted by Pb from Langøya in the Holmestrandfjord in 2013 (Gitmark *et al.* 2014). Blue mussel from Odderøy in the Kristiansandsfjord was markedly polluted with Pb in 2012 and 2013, while mussels in the inner fjord were insignificantly polluted and mussels in the outer fjord were moderately polluted (Schøyen *et al.* 2014). Emissions of Pb to air from land-based industries in Kristiansand showed an increase from 2011 (110 kg Pb/year) to 2013 (187 kg Pb/year).

General, large scale
There were low levels of Pb in cod liver and significant downward long-term trends from five areas (Inner Oslofjord, Færder, Gåsøy (Ullerø), Inner Sørfjord and Bømlo north), even in the vicinity of highly populated areas such as Oslo. EU banned leaded-fuel in road vehicles 1 January 2000, but some countries had banned the fuel beforehand (e.g. Sweden, Germany, Portugal). The results indicate that the ban of Pb in gasoline has had a positive effect.

OSPAR (2010) found 50-80% reduction in riverine and direct discharges of Pb to the North Sea for the period 1990-2006. During 1990 to 2012, a significant downward trend has been found for discharges of Pb from Norwegian rivers (Skarbøvik *et al.* 2013).

Discharges of Pb to water from land-based industries showed a decrease from 2010 (6841 kg Pb/year) to 2013 (1256 kg Pb/year) (*Figure 12*).

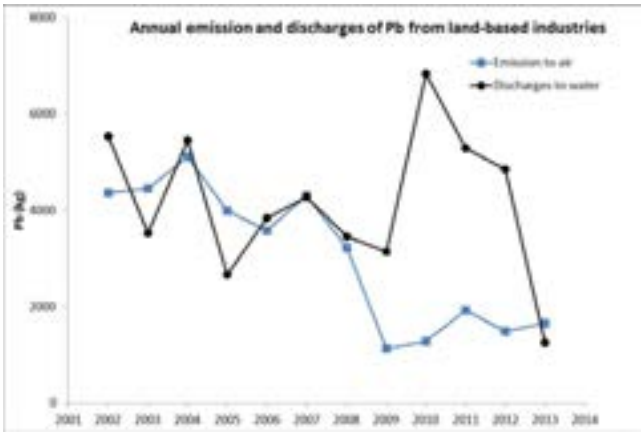

Figure 12. Annual emissions of Pb to air and discharges to water from land-based industries in the period 2002-2013 (data from www.norskeutslipp.no). Note that this category excludes emissions and discharges from municipal treatment plants, land runoff, transportation and offshore industry.

3.2.4 Copper (Cu)

Important levels exceeding Class I
Blue mussel at Gressholmen (st. 30A) and Bodø harbour (st. 97A2) was moderately polluted (Class II) with Cu.

Class increased since 2012
Concentrations of Cu in blue mussel at Gressholmen (st. 30A) in the Inner Oslofjord and Bodø harbour (st. 97A2) had increased to moderately polluted (Class II) in 2013 from being at background levels (Class I) the previous year.

Upward trends
In blue mussel from Gressholmen (st. 30A), a significant upward long-time trend was found.

Downward trends/low levels
Cod liver from all stations had Cu-concentrations at background levels in 2013, as observed in 2012. A significant downward long-time trend was observed in cod liver from the Inner Oslofjord (st. 30B) in 2013, which was not seen in the previous year 2012 when no trend was found. In the Færder area (st. 36B) and in the Varangerfjord (st. 10B) there were significant downward short-term trends in cod liver in addition to the long-term trends which also were seen in 2012. Both significant downward long-time trends and short-term trends were found at Bømlo north (st. 23B) in 2012, but no trends were found in 2013.

In blue mussel, both significant downward long-time and short-term trends were observed at Ramtonholmen (st. I307) and Håøya (st. I306) in the Inner Oslofjord and at Kirkøy (st. I024) in the Hvaler area, unlike the previous year where no trends were seen. No trends were observed at Bjørkøya (st. 71A) and Krossanes (st. 57A) in 2012, but significant downward short-term trends were detected in 2013.

Other studies
Blue mussel from the Inner Oslofjord was up to moderately polluted by Cu (Berge 2014). Most of the blue mussel stations at Langøya in the Holmestrandfjord had background levels of Cu in 2013 (Gitmark *et al.* 2014). The concentrations of Cu at all seven blue mussel stations in the Kristiansandsfjord in 2013 were at background levels (Schøyen et al. 2014).

General, large scale
Discharges of Cu to water from land-based industries showed a gradually decrease from 2005 (90 186 kg Cu/year) to 2013 (41 772 kg Cu/year) (*Figure 13*).

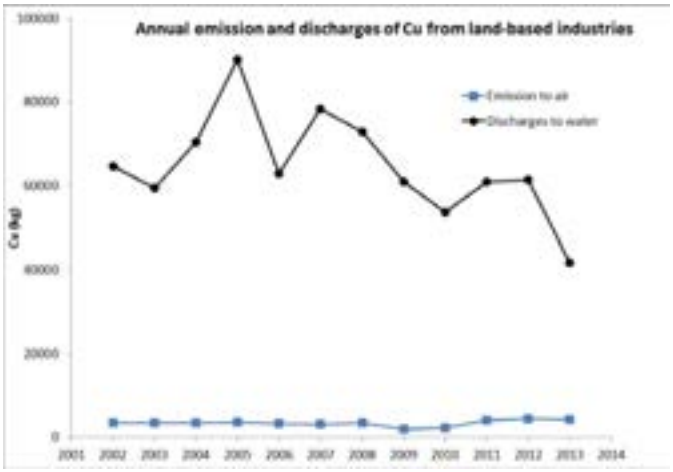

Figure 13. Annual emissions of Cu to air and discharges to water from land-based industries in the period 2002-2013 (data from www.norskeutslipp.no). Note that this category excludes emissions and discharges from municipal treatment plants, land runoff, transportation and offshore industry.

During 1990 to 2012, a significant downward trend has been found for discharges of Cu from Norwegian rivers (Skarbøvik *et al.* 2013).

3.2.5 Zinc (Zn)

Important levels exceeding Class I or background level
Cod liver from Grenland (st. 71B) and Kristiansand harbour (st. 13B) had concentrations that exceeded background levels. Blue mussel at Moholmen (st. I965) was moderately polluted (Class II).

Class increased since 2012
Blue mussel at Moholmen (st. I965) was insignificantly polluted (Class I) with Zn in 2012 and moderately polluted (Class II) in 2013.

Upward trends
Both significant upward long-term and short-term due to Zn were found in cod liver from Lofoten (st. 98B1). No upward trends were found in blue mussel.

Class decreased since 2012
Observed concentrations of Zn in blue mussel from Moholmen (st. I965) in the Ranfjord revealed moderately pollution (Class II) in 2013, but were at background level (Class I) in 2012. Concentrations of Zn in cod liver from Lofoten (st. 98B1) had decreased to an acceptable level in 2013 compared with previous year, and showed both significant upward long-time and short-term trends compared with no trends in 2012. Cod liver at Ålesund (st. 28B) had acceptable level of Zn in 2013, but the concentration exceeded background level the previous year.

Downward trends/low levels
Cod liver from Bømlo north (st. 23B) showed no trends in 2013, but both significant downward long-time and short-term trends were found the previous year.

Other studies
Other studies also documented low levels of Zn in blue mussel. Most of the mussels had low levels of Zn at Langøya in the Holmestrandfjord in 2013 (Gitmark *et al.* 2014). All seven blue mussel stations in the Kristiansandsfjord were insignificantly polluted by Zn in the period 2010 to 2013 (Schøyen *et al.* 2014).

General, large scale
Discharges of Zn to water from land-based industries showed a gradually decrease from 2005 (200 785 kg Zn/year) to 2013 (77 901 kg Zn/year) (*Figure 14*).

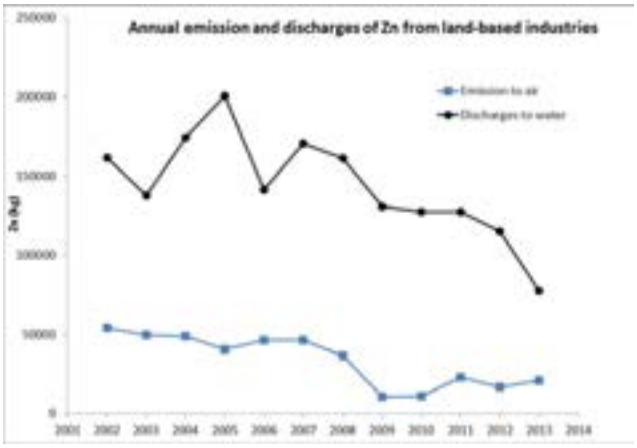

Figure 14. Annual emissions of Zn to air and discharges to water from land-based industries in the period 2002-2013 (data from www.norskeutslipp.no). Note that this category excludes emissions and discharges from municipal treatment plants, land runoff, transportation and offshore industry.

During 1990 to 2012, a significant downward trend has been found for discharges of Zn from Norwegian rivers (Skarbøvik *et al.* 2013).

3.2.6 Silver (Ag)

Levels
There were no changes in classes for Ag in blue mussel from 2012 to 2013, and only background levels (Class I) were observed. The environmental classifications system does not include Ag in cod.

The highest concentration (4.2 mg/kg w.w.) in cod liver was found in cod from the Inner Oslofjord, as in 2012 (5 mg/kg w.w.). The second highest concentration (0.81 mg/kg w.w.) was found in cod liver from Lofoten (st. 98B1). The lowest concentration (0.059 mg/kg w.w.) was found in the Inner Trondheimsfjord (st. 80B).

Trends
There were both significant downward long-time and short-term trends in blue mussel from Gåsøy (st. 15A) close to Mandal. At 13 stations, data was inadequate for performing trend analysis due to concerns about the limit of detections.

Other studies
The highest Ag-concentrations were found in cod from the Inner Oslofjord in both 2012 and 2013. Equivalent concentration in the gills of Atlantic salmon was found to be lethal (Farmen *et al.* 2012), which indicates the need for a classification system to assess the possible effects in cod. There are no historical data on the amounts of Ag entering the Inner Oslofjord. The use of silver (nano-silver) as an antibacterial agent in some textiles and consumer products may be a possible explanation for the relatively high concentrations observed in the Inner Oslofjord. The highest level of Ag in cod liver from the Inner Oslofjord was 10.7 mg/kg w.w. in 2009. Effects of use of nano-silver are also most likely to be first observed in densely populated area with several wastewater treatment plants like the Inner Oslofjord.

Another investigation showed that blue mussel from seven stations in the Kristiansandsfjord was insignificantly polluted (Class I) by Ag in 2013 (Schøyen *et al.* 2014).

Wastewater treatment plant discharges and discharges from mine tailings are considered major and important sources of silver to the aquatic environment (Tappin *et al.* 2010). The incorporation of silver nanoparticles into consumer products is of clear concern in terms of inputs to wastewater treatment plants (Nowack 2010). Silver has very low toxicity to humans; however this is not the case for microbe and invertebrate communities. There is increasing focus on the occurrence of Ag in both wastewater treatment plant effluent and sludge due to the increasing use of nanosilver in consumer products. Recent studies have shown that much of the silver entering wastewater treatment plants is incorporated into sludge as silver sulphide nanoparticles (Ag_2S), although little is known about the species that occurs in discharged effluent (Kim *et al.* 2010, Nowack 2010). From a study of eight Norwegian wastewater treatment plants, concentrations of silver in effluent ranged from 0.01 to 0.49 µg/L, and concentrations in sludge ranged from <0.01 to 9.55 µg/g (Thomas *et al.* 2011).

General, large scale
Discharges of Ag to water from land-based industries showed a decrease from 2005 (2.36 kg Ag/year) to 2009 (0,1 kg Ag/year), and then a gradually increase to 2012 (0.62 kg Ag/year) and a slightly decrease to 2013 (0.41 kg Ag/year) (***Figure 15***).

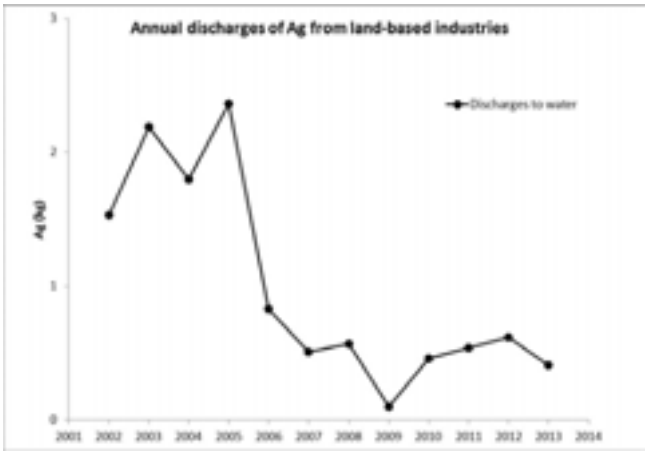

Figure 15. *Annual discharges of Ag to water from land-based industries in the period 2002-2013 (data from www.norskeutslipp.no). Note that this category excludes discharges from municipal treatment plants, land runoff, transportation and offshore industry.*

3.2.7 Arsenic (As)

Levels

Relevant values for background levels of As are not available for cod. The highest concentration was found in cod liver from Ålesund (st. 28B, 12 mg As/kg w.w.) and the lowest value was found in Tromsø harbour (st. 43B2, 2.8 mg As/kg w.w.).

There were no changes in classes for As in blue mussel from 2012 to 2013, and all mussels were insignificantly polluted (Class I).

Trends

There were both significant downward long-time and short-term trends in the cod liver from the Inner Oslofjord (st. 30B), Kristiansand harbour (st. 13B) and Tromsø harbour (st. 43B2).

In blue mussel, there were both significant downward long-time and short-term trends at Bjørkøya (st. 71A) in the Grenlandsfjord, Gåsøy (st. 15A) close to Mandal, and Skallneset (st. 10A2) and Brashavn (st. 11X) in the Varangerfjord.

Other studies

Blue mussel in the Inner Oslofjord was up to moderately polluted by As from 2006 to 2013 (Berge 2014) and mussels were also up to moderately polluted by As at Langøya in the Holmestrandfjord in 2013 (Gitmark *et al.* 2014). Most blue mussel stations in the Kristiansandsfjord were moderately polluted by As (Schøyen *et al.* 2014).

General, large scale trends

Discharges of As to water from land-based industries showed an increase from 2008 (516 kg As/year) to 2010 (2587 kg As/year), and then a decrease to 2013 (1504 kg As/year) (*Figure 16*). Emission to air had gradually decreased from 2002 (1240 kg As/year) to 2013 (566 kg As/year).

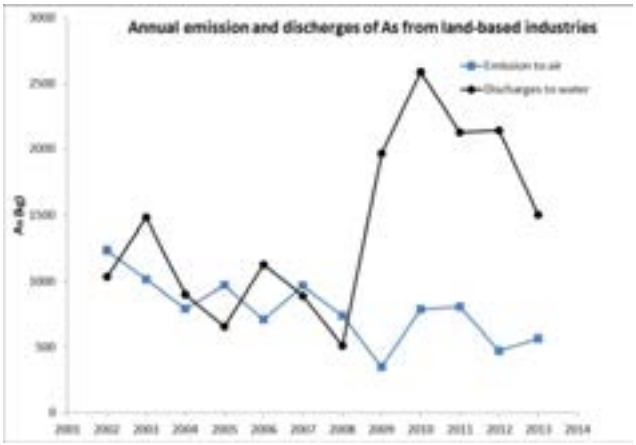

Figure 16. Annual emissions of As to air and discharges to water from land-based industries in the period 2002-2013 (data from www.norskeutslipp.no). Note that this category excludes emissions and discharges from municipal treatment plants, land runoff, transportation and offshore industry.

3.2.8 Nickel (Ni)

Levels

The national environmental classifications system does not include Ni in cod. The highest concentration was found in cod liver from Ålesund (st. 28B, 0.158 mg Ni/kg w.w.). Cod from Kristiansand harbour (st. 13B) had significant long-term and short-term downward trends. At the two stations Bømlo north (st. 23B) and Varangerfjorden (st. 10B), data was inadequate to perform trend analysis due to concerns about the limit of detections.

There were no changes in classes from 2012 to 2013 for Ni in blue mussel, and only background levels (Class I) were observed.

Trends

Both significant upward long-term and short-term trends were found in blue mussel at Gressholmen (st. 30A) in the Inner Oslofjord and in Lofoten (st. 98A2).

Other studies

All blue mussel stations in the Inner and Outer Oslofjord showed acceptable (background) levels of Ni. Other investigations found that mussels were up to moderately polluted by Ni at Langøya in the Holmestrandfjord in 2013 (Gitmark *et al.* 2014). Blue mussel was insignificantly polluted by Ni in the Kristiansandsfjord in 2013 (Schøyen *et al.* 2014).

General, large scale

Emissions of Ni to air and discharges to water from land-based industries had decreased gradually from 2002 to 2013 (*Figure 17*).

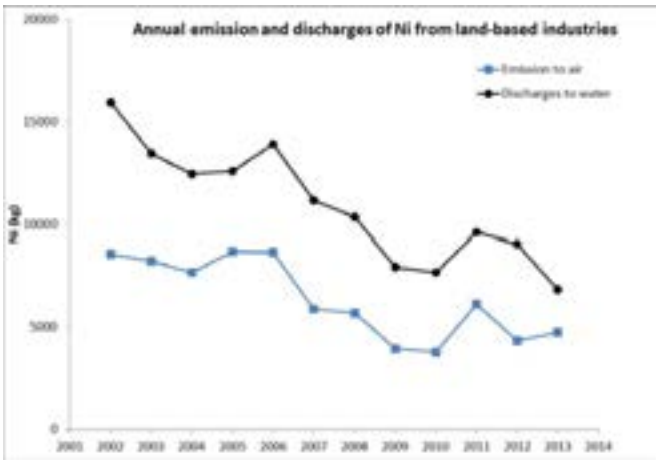

Figure 17. Annual emissions of Ni to air and discharges to water from land-based industries in the period 2002-2013 (data from www.norskeutslipp.no). Note that this category excludes emissions and discharges from municipal treatment plants, land runoff, transportation and offshore industry.

During 1990 to 2012, a significant downward trend has been found for discharges of Ni from Norwegian rivers (Skarbøvik *et al.* 2013).

3.2.9 Chromium (Cr)

Levels

Relevant values for background levels of Cr are not available for cod. The highest concentration in cod liver was found in cod liver from the Grenlandsfjord (st. 71B, 0.06 mg Cr/kg w.w.).

There were no changes in classes from 2012 to 2013 for Cr in blue mussel. All mussels were insignificantly polluted (Class I) by Cr.

Trends

Significant downward long-term and short-term trends were found in the Kristiansand harbour (st. 13B). A significant downward long-term trend was shown in the Inner Trondheimsfjord (st. 80B). At eight stations, data was inadequate due to concerns about the limit of detections.

Both significant upward long-term and short-term trends were found in blue mussel at Vikingneset (st. 65A) in the Hardangerfjord, Espevær (st. 22A) on the west coast and in Lofoten (st. 98A2).

Other studies

Blue mussel from the Inner Oslofjord was insignificantly polluted by Cr in 2006 to 2013 (Berge 2014). Mussels from one station at Langøya in the Holmestrandfjord were markedly polluted (Class III) by Cr (Gitmark *et al.* 2014). Blue mussel at all seven stations in the Kristiansandsfjord had background levels of Cr in 2013 (Schøyen *et al.* 2014).

General, large scale trends

Emissions of Cr to air and discharges to water from land-based industries are shown in *Figure 18*.

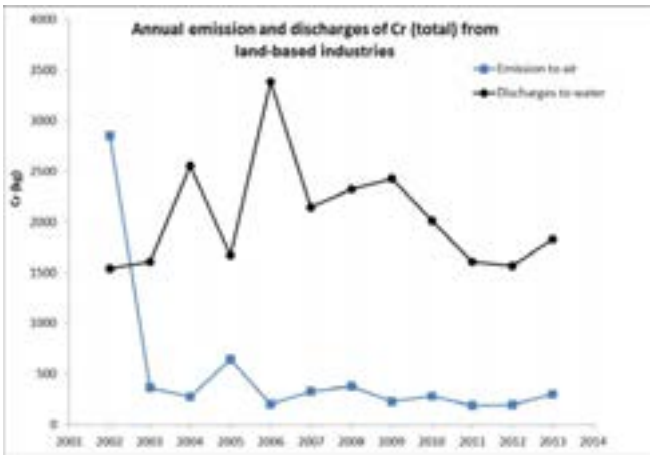

Figure 18. Annual emissions of Cr to air and discharges to water from land-based industries in the period 2002-2013 (data from www.norskeutslipp.no). Note that this category excludes emissions and discharges from municipal treatment plants, land runoff, transportation and offshore industry.

3.2.10 Cobalt (Co)

Levels

There is no national classification for Co in blue mussel or cod.

Trends

Both significant upward long-term and short-term trends were observed in cod liver at Lofoten (st. 98B1).

There were no trends in blue mussel at Moholmen (st. I965) in the Inner Ranfjord in 2013, although there were both significant upward long-term and short-term trends the previous year. There were significant upward long-term and short-term trends at Bjørnbærviken (st. I969) in the Inner Ranfjord in 2013, as in 2012. There were significant downward long-term and short-term trends at Lastad (st. 131A) close to Mandal.

General, large scale trends

Discharges of Co to water from land-based industries showed decreasing values from 2011 (754 kg Co/year) to 2013 (411 kg Co/year) (*Figure 19*). A review of discharges to area of the Ranfjord did not include Co (www.norskeutslipp.no).

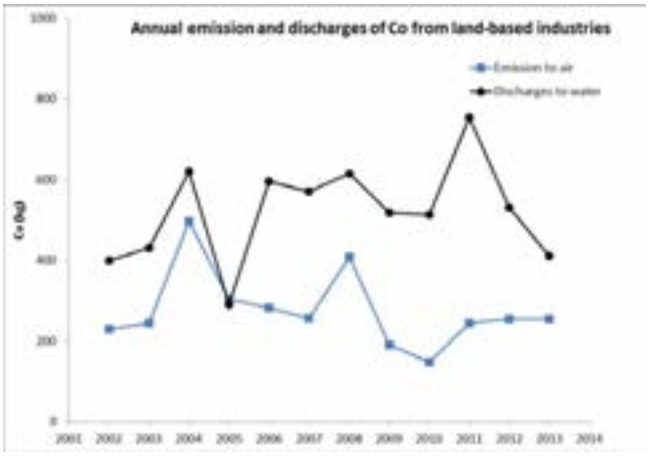

Figure 19. Annual emissions of Co to air and discharges to water from land-based industries in the period 2002-2013 (data from www.norskeutslipp.no). Note that this category excludes emissions and discharges from municipal treatment plants, land runoff, transportation and offshore industry.

3.2.11 Tributyltin (TBT)

Levels and trends

There were no changes in classes or trends in 2013 from 2012. However it should be noted that the 2013 data from Brashavn (st. 11G) in the Varangerfjord was inadequate for trend analysis due to concerns about the limit of detections.

Concentrations of TBT in dog whelk (Nucella lapillus)

There is no national classification for TBT-concentrations in dog whelk. Except for Brashavn where data was inadequate due to concerns about the limit of detections in 2013, all TBT trends were still downward in 2013, as in 2012. Both significant downward long-term and short-term trends were found at Færder (st. 36G), Risøy (st. 76G) close to Risør, Lastad (st. 131G) close to Mandal, Gåsøy (Ullerø) (st. 15G) at Lista, Melandsholmen (st. 227G1) in the Karmsundet, Espevær (st. 22G) at the west coast and Lofoten (st. 98G). The highest organotin level was found at Melandsholmen close to Haugesund (9.85 µg/kg w.w.) on the west coast of Norway, and the lowest value was observed at Brashavn (<0.674).

Concentrations of TBT in common periwinkle (Littorina littorea)

There were no changes in trends from 2012 to 2013. There were no significant trends of TBT at Fugløyskjær in the Grenland area, and the TBT-concentration was 3.09 µg/kg w.w.

Biological effects of TBT (imposex/VDSI) in dog whelk

The effects from TBT were low (VDSI<0.531) at all eight stations investigated in 2013. There were significant downward trends at all the stations, except for at Brashavn where no trends were found. It can be noted that VDSI values at this location have been low during the whole monitoring period. No effects (VDSI=0) were found at Færder, Risøy, Gåsøy (Ullerø), Espevær and Brashavn. These results, including Lastad (VDSI=0.03) were below the OSPARs Background Assessment Criteria (BAC=0.3, OSPAR 2009). The VDSI was 0.53 at Melandsholmen and 0.46 at Lofoten. These results were over BAC but below the OSPARs Ecotoxicological Assessment Criteria (EAC=2, OSPAR 2009).

General, large scale trends

The results show that the Norwegian legislation banning application of organotins on ships shorter than 25 meters in 1990 and longer than 25 meters in 2003, has been effective in reducing imposex in dog whelk populations. Some of the previously effected gastropod populations have also re-established. The international convention that was initiated by the International Maritime Organization (IMO) did not only ban application of organotins on ships after 2003 but also stated that organotins after 2008 could not be part of the system for preventing fouling on ships. VDSI in dog whelk was around level 4 in all dog whelk stations before the ban in 2003, except for the Varangerfjord where the VDSI had been low in the whole monitoring period. It was a clear decline in VDSI as well as TBT at nearly all stations between 2003 and the total ban in 2008 (*Figure 20* and *Figure 21*). The exceptions being for VDSI for snails from Varangerfjord and periwinkles from the Grenlandsfjord area. In the Varangerfjord the VDSI has remained low (<0.3) for the entire investigation period. After 2008 the VDSI has been close to zero at many of the stations. A typical example of decreasing trends is shown for Færder in *Figure 22*.

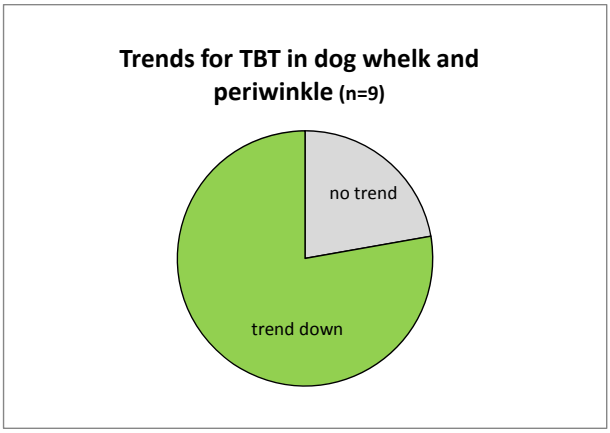

Figure 20. Frequency of trends for TBT in dog whelk and periwinkle. No upward trends were detected.

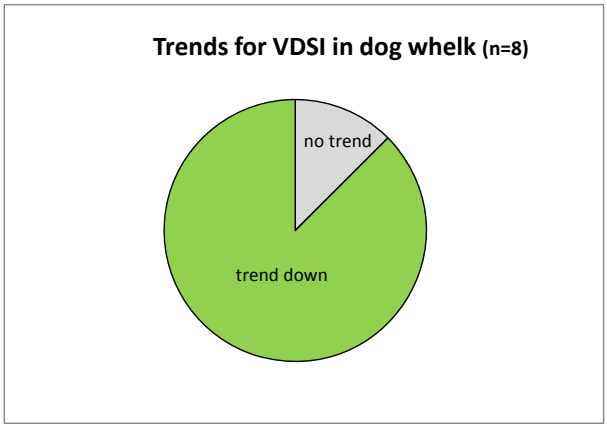

Figure 21. Frequency of trends for VDSI in dog whelk (1991-2013). No upward trends were detected.

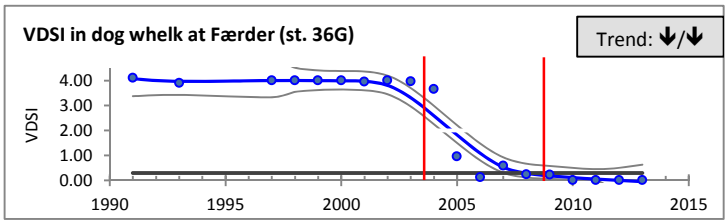

Figure 22. Change in VDSI for dog whelk from Færder (st. 36G). The vertical red line indicates the initial ban of TBT in 2003 and total ban in 2008.

Discharges of tributyltin and trifenyltin to water from land-based industries from 2002 to 2013 (*Figure 23*). The values were high in 2003 (0.49 kg tributyltin and trifenyltin/year) and 2009 (0.50 kg tributyltin and trifenyltin/year).

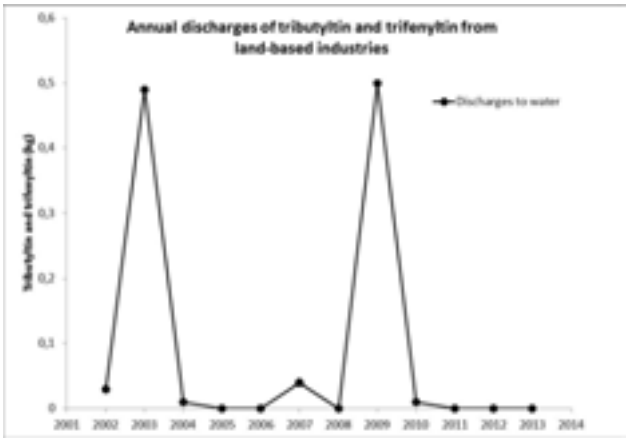

Figure 23. Annual discharges of tributyltin and trifenyltin to water from land-based industries in the period 2002-2013 (data from www.norskeutslipp.no). Note that this category excludes discharges from municipal treatment plants, land runoff, transportation and offshore industry.

3.2.12 Polychlorinated biphenyls (ΣPCB-7)

Important levels exceeding Class I

Cod liver from the Inner Oslofjord (st. 30B) (*Figure 24*) and Kristiansand harbour (st. 13B) were markedly polluted (Class III) with PCB-7, while cod liver from the Inner Sørfjord (st. 53B) and Ålesund (st. 28B) were moderately polluted (Class II).

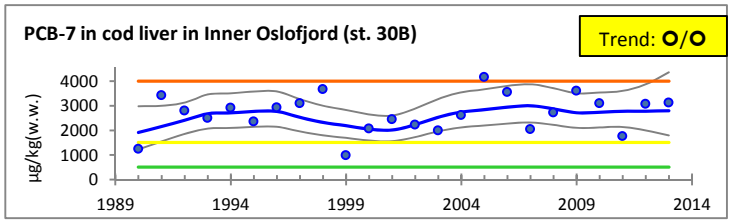

Figure 24. Median concentrations (mg/kg w.w.) of PCB-7 in cod liver from 1990 to 2013 in the Inner Oslofjord (st. 30B).

Mussels from Akershuskaia (st. I301) and Gressholmen (st. 30A) in the Inner Oslofjord were still moderately polluted (Class II) in 2013, as in 2012. Mussels at Gåsøy (st. 15A) and Nordnes in Bergen harbour (st. I241) were also moderately polluted (Class II).

Class increased since 2012

Cod liver from Kristiansand harbour (st. 13B) was markedly polluted (Class III) by PCBs in 2013 compared to moderately polluted (Class II) in 2012. In the Inner Sørfjord (st. 53B), cod fillet was moderately polluted (Class II) in 2013, compared to background (Class I) value in 2012.

The concentrations in mussels at Gåsøy (Ullerø) (st. 15A) had increased from being at background level (Class I) in 2012 to being moderately polluted (Class II) in 2013.

Upward trends

No upward trends for PCB-7 were found in cod liver. There were upward short-term trends for PCB-7 in blue mussel at Gåsøy (Ullerø) (st. 15A) and Odderøy (st. I133) in the Kristiansandsfjord.

Class decreased since 2012

Blue mussel in the Outer Trondheimsfjord (st. 91A2) was moderately polluted (Class II) in 2012 and insignificantly polluted (Class I) in 2013.

Downward trends/low levels

There were significant downward long-time trends for PCB-7 in cod liver from the Inner Trondheimsfjord (st. 80B), Lofoten (st. 98B1) and in the Varangerfjord (st. 10B). There were significant downward short-term trends from Færder (st. 36B) and the Inner Trondheimsfjord (st. 80B). There were 14 downward long-time trends for PCB-7 in blue mussel.

Comparison of concentrations in liver and fillet

Comparison of concentrations in cod liver and cod fillet (2012-samples) in the same individuals were investigated in 12 cases from the Inner Oslofjord, four from the Outer Oslofjord and nine from Kristiansand harbour (*Table 12*). The results show that PCBs were detectable in fillet for all the PCB congeners except CB28 and CB52. CB52 was only detected in fillet from cod from the Inner Oslofjord. The concentrations in liver in corresponding fish were consistently higher than concentrations in fillet; on an average of 207 to 219 times higher, except for CB52 where the average was 256. On a lipid weight basis the average was 3.3 (range: 3.1-3.4) and the correlation there was a considerably better correlation; r^2 varied between 0.05 and 0.88 on a wet weight basis but varied from 0.69 to 0.98 on a lipid weight basis (*Table 11*, *Figure 25*). An r^2 of one would be a perfect correlation. Even if the sample with high PCB is removed the correlation coefficients do not change much; the r^2 varied between 0.70 and 0.90.

The ratios between PCBs in liver and fillet compared reasonably well to earlier investigations (Green & Knutzen 2003). Good correlation may allow calculation of concentrations in one tissue from concentrations measured in the other tissue, e.g. if the size of the liver is insufficient, However a more thorough investigation is needed before it can be recommended to replace analyses of liver with analyses of fillet.

Table 11. Correlation (r^2) between PCBs in cod liver and fillet on wet weight (w.w.) and lipid weight (l.w.) basis in cod liver and fillet from Inner Oslofjord, Outer Oslofjord and Kristiansand harbour.

PCB congener	Count 2012	w.w.	l.w.
CB52	12	0.88	0.98
CB101	25	0.81	0.97
CB118	25	0.48	0.85
CB138	25	0.29	0.76
CB153	25	0.12	0.70
CB180	25	0.05	0.69

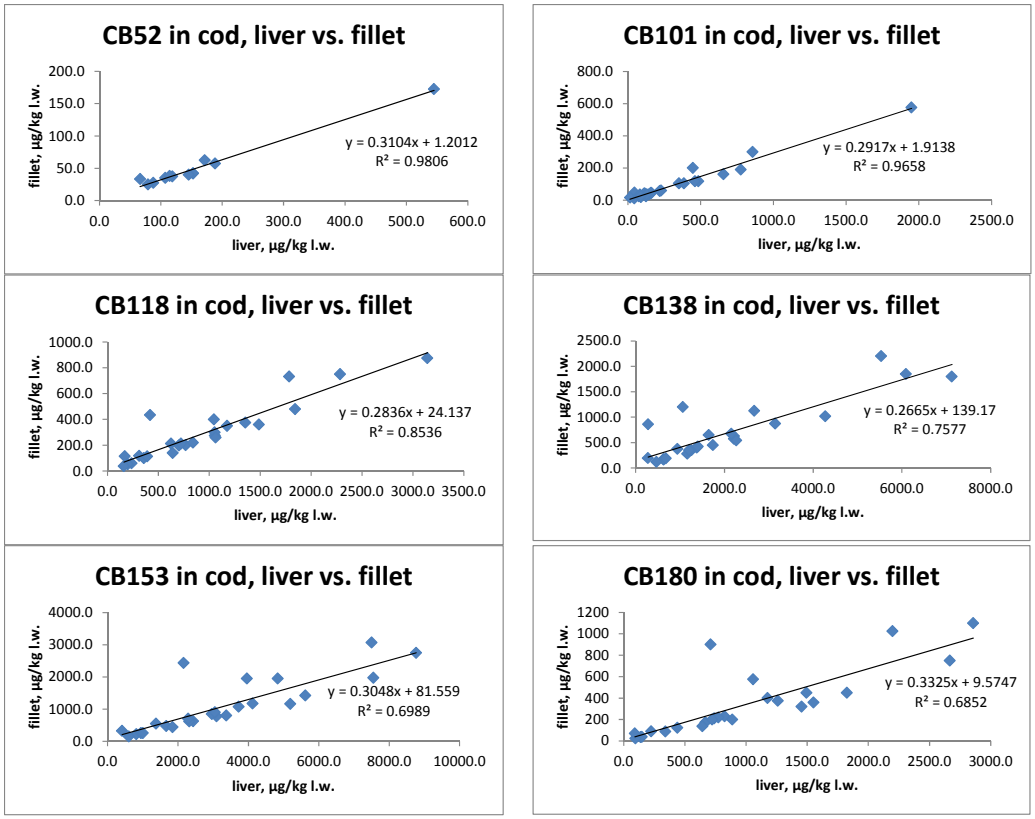

Figure 25. Correlation between concentrations (mg/kg l.w.) of six PCBs in cod liver and fillet from Inner Oslofjord, Outer Oslofjord and Kristiansand harbour.

Table 12. Concentration (µg/kg w.w.) of PCBs in cod liver and fillet. The shaded areas indicate values below the detection limit. Values shown are one half of the detection limit.

Component	Code	Liver	Fillet	CB28	CB28	CB52	CB52	CB101	CB101	CB118	CB118	CB138	CB138	CB153	CB153	CB180	CB180
Species and sampling localiti	2012	lipid %	lipid %	Liver	Fillet	Liver	Fillet	Liver	Fillet	Liver	Fillet	Liver	Fillet	Liver	Fillet	Liver	Fillet
Cod																	
Inner Oslofjord (st. 30B)	301-1	38.8	0.4	5.7	0.025	34	0.11	85	0.23	410	1.1	860	2.3	1200	3.1	320	0.92
Inner Oslofjord (st. 30B)	301-10	5.6	0.3	0.5	0.025	3.7	0.1	25	0.6	100	2.2	310	6.6	420	9.2	160	3.3
Inner Oslofjord (st. 30B)	301-13	10.5	0.4	2.1	0.025	18	0.25	90	1.2	240	3	640	7.4	920	11	280	3
Inner Oslofjord (st. 30B)	301-14	54.1	0.4	7	0.025	58	0.14	190	0.42	570	1.2	1200	2.5	1600	3.4	400	0.84
Inner Oslofjord (st. 30B)	301-15	49.4	0.4	12	0.025	93	0.23	190	0.42	380	0.8	860	1.8	1200	2.5	330	0.69
Inner Oslofjord (st. 30B)	301-2	34.2	0.4	4.4	0.025	27	0.1	78	0.24	240	0.79	430	1.4	570	1.9	150	0.49
Inner Oslofjord (st. 30B)	301-3	41.3	0.4	12	0.025	49	0.15	200	0.47	560	1.5	1300	3.5	1700	4.7	520	1.5
Inner Oslofjord (st. 30B)	301-4	29.7	0.5	2.9	0.025	34	0.19	48	0.23	250	1.1	410	2	690	3.1	230	1.1
Inner Oslofjord (st. 30B)	301-5	47.7	0.4	16	0.058	260	0.69	930	2.3	1500	3.5	3400	7.2	3600	7.9	870	1.8
Inner Oslofjord (st. 30B)	301-7	37.4	0.5	5.3	0.025	57	0.21	290	0.95	690	2.4	1600	5.1	2100	7.1	580	1.8
Inner Oslofjord (st. 30B)	301-8	28.9	0.5	4.6	0.025	44	0.21	190	0.81	430	1.8	82	4.3	1500	5.8	420	1.6
Inner Oslofjord (st. 30B)	301-9	28.2	0.5	5.3	0.025	41	0.2	130	0.59	300	1.3	640	2.7	950	4	250	1
Færder area (st. 36B)	361-1	27	0.5	1.4	0.025	7.7	0.025	40	0.19	64	0.3	170	0.86	220	1.1	37	0.18
Færder area (st. 36B)	361-2	19	0.5	0.5	0.025	1.6	0.025	8.3	0.057	38	0.26	120	0.83	180	1.3	28	0.19
Færder area (st. 36B)	361-3	16.7	0.5	0.5	0.025	0.5	0.025	15	0.1	27	0.19	79	0.6	100	0.75	16	0.12
Færder area (st. 36B)	361-5	6.7	0.4	0.5	0.025	0.5	0.025	7.7	0.17	21	0.47	63	1.5	92	2.2	15	0.36
Kristiansand harbour (st. 13B)	131-11	24.9	0.5	7.3	0.025	7.5	0.025	31	0.12	160	0.7	290	1.4	460	2.2	160	0.69
Kristiansand harbour (st. 13B)	131-13	3.1	0.3	0.5	0.025	0.5	0.025	1.4	0.14	13	1.3	33	3.6	67	7.3	22	2.7
Kristiansand harbour (st. 13B)	131-14	9.1	0.4	0.5	0.025	1.1	0.025	10	0.16	57	0.85	150	2.6	440	7.8	200	4.1
Kristiansand harbour (st. 13B)	131-15	20.4	0.4	3.6	0.025	5	0.025	32	0.18	240	1.4	440	2.7	760	4.3	240	1.6
Kristiansand harbour (st. 13B)	131-2	58.8	0.5	15	0.025	14	0.025	76	0.18	210	0.5	400	0.96	590	1.3	200	0.44
Kristiansand harbour (st. 13B)	131-4	3.4	0.4	0.5	0.025	0.5	0.025	0.5	0.064	5.8	0.46	9.5	0.78	14	1.3	3.1	0.28
Kristiansand harbour (st. 13B)	131-5	17.4	0.4	0.5	0.025	2.9	0.025	13	0.096	68	0.45	210	1.4	530	3.6	260	1.8
Kristiansand harbour (st. 13B)	131-7	8.6	0.4	0.5	0.025	0.5	0.025	7.1	0.14	90	1.6	230	4.5	340	7.8	91	2.3
Kristiansand harbour (st. 13B)	131-8	24.9	0.4	5.9	0.025	6.4	0.025	22	0.1	180	0.85	350	1.7	570	2.8	180	0.8

Inner Oslofjord
Cod liver from the Inner Oslofjord was markedly polluted with ΣPCB-7, while blue mussel from Akershuskaia and Gressholmen was moderately polluted. Mussel at other stations in the Oslofjord like Gåsøya, Ramtonholmen, Håøya, Solbergstrand, Mølen and Tjøme were insignificantly polluted with ΣPCB-7.

Other studies
The high concentrations of ΣPCB-7 in cod liver from the Inner Oslofjord have been confirmed in another study which showed that cod liver from Bekkelaget and Frognerkilen was markedly to severely polluted (Class III-IV) by PCBs in 2006 to 2013 (Berge 2014). A certain decrease in concentration of PCBs in cod from Bekkelagsbassenget based on wet weight could be observed, but the decrease was not significant and not evident on fat basis. Monitoring of blue mussel in the Inner Oslofjord showed that mussels were up to markedly polluted by ΣPCB-7 in the period 2006 to 2013 (Berge 2014). A study of flounder liver from the Inner Oslofjord in 2013 showed apparently lower (a factor of~7) median concentration of ΣPCB-7 than in cod in 2012 (Ruus *et al.* 2014, in press).

Historical data on entry of PCB to the Inner Oslofjord is not available. Present entry of PCB to the fjord has however been calculated to be around 3.3 kg/year (Berge *et al.* 2013a). Run-off from urban surfaces is the most important contributor (2.1 kg/year). It is also anticipated that sediments in the fjord store much of the historic inputs of PCB, but their role as a current source of PCBs for uptake in biota is unclear. Parts of the Inner Oslofjord are densely populated with much urban activities. The high concentrations of PCB observed in cod liver are probably related to these activities, as well as reduced water exchange with the Outer fjord.

General, large scale trends
On a national level the results show that in general the concentrations of PCBs have decreased in both cod and blue mussel over the whole monitoring period; no long-term trends were registered. In Norway PCBs has been prohibited since 1980, but leakage from old products as well as landfills and natural deposits may still be a source of contamination. Production and new use of PCBs is also prohibited internationally through the ECE-POPs protocol and the Stockholm Convention.

Emissions of PCBs to air and discharges to water from land-based industries are shown in (*Figure 26*). Before 2009 occasional high emissions and discharges were reported, but throughout 2009-2013 the levels have been low. Investigations by Schuster *et al.* (2010) indicate that emissions in northern Europe have declined during the period 1994-2008 by about 50%.

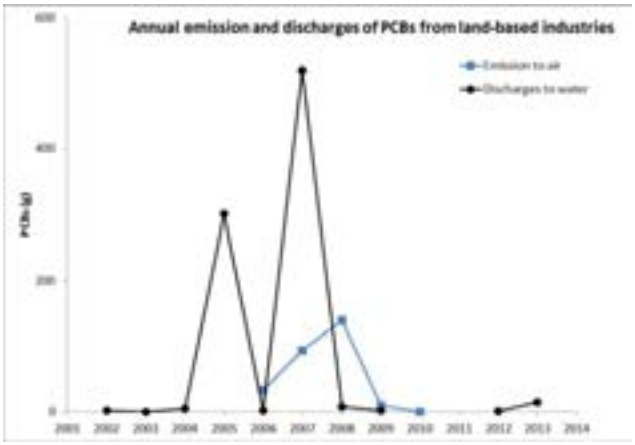

Figure 26. Annual emissions of PCBs to air and discharges to water from land-based industries in the period 2002-2013 (data from www.norskeutslipp.no*). No data for emissions to air are reported for 2002-2005 and 2011-2013. No data for discharges to water are reported for 2010-2011. Note that this category excludes emissions and discharges from municipal treatment plants, land runoff, transportation and offshore industry.*

3.2.13 Dichlorodiphenyldichloroethylene (ppDDE)

Important levels exceeding Class I

Cod liver from the Inner Sørfjord was markedly polluted (Class III) with ppDDE, while cod liver from the Inner Oslofjord was moderately polluted (Class II). Blue mussel at Kvalnes (st. 56A) in the Mid Sørfjord was extremely polluted (Class V) in 2012 and 2013, and the concentration had increased from 41.79 µg/kg w.w. in 2012 to 51 µg/kg w.w. in 2013 (*Figure 27*).

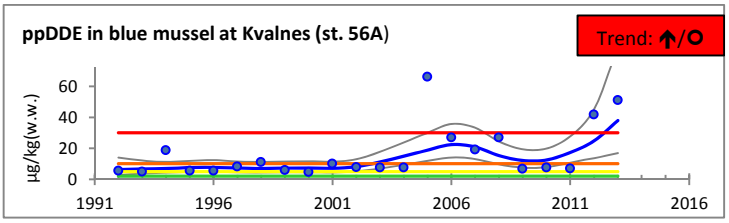

Figure 27. Median concentrations (mg/kg w.w.) of ppDDE in blue mussel from 1992 to 2013 in the Mid Sørfjord at Kvalnes (st. 56A).

Mussels at Utne (st. 64A) in the Outer Sørfjord were severely polluted (Class IV) with ppDDE. Mussels from Eitrheimsneset (st. 52A) in the Inner Sørfjord and Krossanes (st. 57A) in the Outer Sørfjord were both moderately polluted (Class II).

Class increased since 2012

The concentration of ppDDE in cod liver in the Inner Sørfjord (st. 53B) had increased from being moderately polluted (Class II) in 2012 to being markedly polluted (Class III) in 2013.

Mussels at Utne (st. 64A) in the Outer Sørfjord, which was a new station in 2012, were markedly polluted (Class III) in 2012 and had increased to being severely polluted (Class IV) in 2013.

Upward trends

A significant upward long-time trend was found in blue mussel at Kvalnes (st. 56A) in the Mid Sørfjord.

Class decreased since 2012

Blue mussel from Byrkjenes (st. 51A) in the Inner Sørfjord and Vikingneset (st. 65A) in the Hardangerfjord was moderately polluted (Class II) in 2012 and insignificantly polluted (Class I) with ppDDE in 2013.

Downward trends/low levels

Significant downward long-time trends were observed in cod liver from Færder (st. 36B), Bømlo north (st. 23B) on the west coast, Lofoten (st. 98B1) and in the Varangerfjord (st. 10B). A significant recent downward trend was also found in Lofoten.

There were significant downward long-time trends in blue mussel at Akershuskaia (st. I301) in the harbour of Oslo and at Odderøy (st. I133) in the Kristiansandsfjord, although no trends were observed in 2012.

At Skallneset (st. 10A2) and Brashavn (st. 11X) in the Varangerfjord, data was inadequate for trend analysis due to concerns about the limit of detections in 2013.

Inner Oslofjord

Liver from Bekkelaget and Frognerkilen in the Inner Oslofjord had low levels of DDT in 2006, 2009 and 2010, and background levels (Class I) were observed in 2013 (Berge 2014). Monitoring in the Inner Oslofjord showed that blue mussel was up to moderately polluted (Class II) by ΣDDE+DDD in 2013 (Berge 2014).

Other studies

The Sørfjord area has a considerable number of orchards. Earlier use and the persistence of DDT and leaching from contaminated soil is probably the main reason for the observed high concentrations of ppDDE in the Sørfjord area. It must however be noted that the use of DDT products have been prohibited in Norway since 1970. Green *et al.* (2004) concluded that the source of ppDDE was uncertain. Analyses of supplementary stations between Kvalnes and Krossanes in 1999 indicated that there could be separate sources at several locations (Green *et al.* 2001). A more intensive investigation in 2002 with seven sampling stations confirmed that there were two main areas with high concentrations north of Kvalnes and near Urdheim south of Krossanes (Green *et al.* 2004). Skei *et al.* (2005) concluded that the variations in concentrations of ΣDDT and the ratio between p,p'-DDT/p,p'DDE (insecticide vs. metabolite) in blue mussel from Byrkjenes and Krossanes corresponds with periods with much precipitation and is most likely a result of wash-out from sources on shore. Botnen & Johansen (2006) deployed passive samplers (SPMD- and PCC-18 samplers) at 12 locations along the Sørfjord to sample for DDT and its derivates in sea water. Blue mussel and sediments were also taken at some stations. The results indicated that further and more detailed surveys should be undertaken along the west side of the Sørfjord between Måge and Jåstad, and that replanting of old orchards might release DDT through erosion. Concentrations of ΣDDT in blue mussel in the Sørfjord in 2008-2011 showed up to Class V (extremely polluted) at Utne (Ruus *et al.* 2009, 2010a, 2011, 2012). There was high variability in the concentrations of ΣDDT in replicate samples from Utne, indicating that the station is affected by DDT-compounds in varying degree, dependent on local conditions. The highest concentrations of ppDDE in sediment were observed in Mid Sørfjord (Green *et al.* 2010b).

Increased ΣDDT-concentrations in blue mussel from the Sørfjord were discussed by Ruus *et al.* (2010b). Possible explanations were increased transport and wash-out to the fjord of DDT sorbed to dissolved humus substances.

3.2.14 Polycyclic aromatic hydrocarbons (PAHs)

Important levels exceeding Class I

The concentrations of PAHs in blue mussel exceeded Class I (insignificantly polluted) at three of the 10 blue mussel stations. Mussels from Moholmen (st. I965) in the Ranfjord were markedly polluted (Class III). Mussels from Akershuskaia (st. I301) in the harbour of Oslo and Bjørnbærviken (st. I969) in the Ranfjord, were moderately polluted (Class II). All other blue mussel stations had concentrations of PAHs at background levels.

Class increased since 2012

Mussels at Moholmen (st. I965) in the Ranfjord were moderately polluted (Class II) in 2012 and markedly polluted (Class III) in 2011 and 2013.

Class decreased since 2012

Blue mussel at Akershuskaia (st. I301) in the harbour of Oslo was markedly polluted (Class III) in 2012, and moderately polluted (Class II) in 2011 and 2013.

Trends

No significant trends were observed.

Other studies

Monitoring of blue mussel in another study in the Inner Oslofjord showed that mussels were up to markedly polluted by PAH-16 at Rådhuskaia/Pipervika in 2013 (Berge 2014). Mussels at all other stations were up to moderately polluted in the period from 2006 to 2013 (Berge 2014). Another investigation documented that mussels were up to moderately polluted by PAHs at Langøya in the Holmestrandfjord in 2013 (Gitmark *et al.* 2014). Blue mussel at two stations in Kristiansandsfjord was moderately polluted by PAHs in 2013 (Schøyen *et al.* 2014). Remedial action has been implemented to reduce the impact of PAHs in the Kristiansandsfjord. The Ranfjord has received discharges of PAHs from local industry for a number of years. No trends were detected for PAHs in blue mussel in the Ranfjord for the period 1995 (Bjørnbærviken) or 2001 (Moholmen) to 2013.

General, large scale trends

Emissions of PAHs to air and discharges to water from land-based industries from 2012 to 2013 can be seen in *Figure 28*. The emission to air has decreased gradually from 2005 (178 682.76 kg PAHs/year) to 2013 (36 955.72 kg PAHs/year).

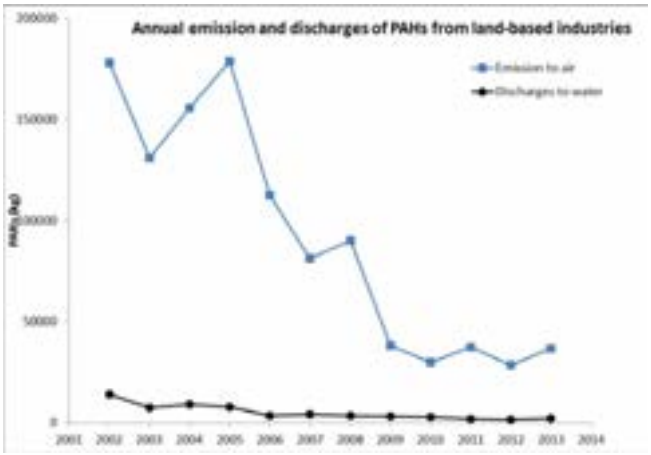

Figure 28. Annual emissions of PAHs to air and discharges to water from land-based industries in the period 2002-2013 (data from www.norskeutslipp.no*). Note that this category excludes emissions and discharges from municipal treatment plants, land runoff, transportation and offshore industry.*

Environmental Quality Standards (EQS)

The EQS (2013/39/EC) for fluoranthene (30 µg/kg w.w.) in biota for "molluscs" was exceeded at Moholmen (st. I965) (67 µg/kg w.w.) and Bjørnbærviken (st. I969) (52 µg/kg w.w.) in the Ranfjord.

3.2.15 Sum carcinogenic polycyclic aromatic hydrocarbons (KPAHs)

Important levels exceeding Class I

The concentrations of the potentially most carcinogenic PAHs (KPAHs, cf. Appendix B) in blue mussel exceeded Class I (insignificantly polluted) from two of 10 stations. Blue mussel in the Ranfjord was markedly polluted (Class III) at Moholmen (st. I965) and moderately polluted (Class II) at Bjørnbærviken (st. I969). Mussels at other stations were at background levels (Class I).

Class decreased since 2012

Blue mussel from Akershuskaia (st. I301) in the harbour of Oslo was moderately polluted (Class II) in 2012 and insignificantly polluted (Class I) in 2013.

Trends

No significant trends were observed.

Other studies

Blue mussel from the Inner Oslofjord was found to be severely polluted by KPAH at Rådhuskaia/Pipervika in 2013, and mussels from all other stations were up to moderately polluted in the period 2006 to 2013 (Berge 2014). Mussels from Langøya in the Holmestrandfjord in 2013 were up to markedly polluted by KPAH (Gitmark *et al.* 2014). Blue mussel at Odderøy and Svensholmen in the Kristiansandsfjord were markedly polluted by KPAH in 2013, as in 2012 (Schøyen *et al.* 2014).

3.2.16 Benzo[a]pyrene B[a]P

Important levels exceeding Class I

The highest concentration (8.2 µg/kg w.w.) was found at Moholmen (st. I965) in the Ranfjord where the mussels were markedly polluted (Class III) by B[a]P. The second highest concentration (2.8 µg/kg w.w.) was found at Bjørnbærviken (st. I969) in the Ranfjord where the mussels were moderately polluted (Class II). Other mussels were at background levels (Class I).

Class decreased since 2012

The concentration of B[a]P in blue mussel from Akershuskaia (st. I301) had decreased two classes from markedly polluted (Class III) in 2012 to insignificantly polluted (Class I) in 2013.

Trends

No trends were observed. At four stations, data was inadequate for trend analysis.

Other studies

Monitoring of blue mussel in another investigation in the Inner Oslofjord showed that mussels were severely polluted by B[a]P at Rådhuskaia/Pipervika in 2013 (Berge 2014, in prep.). Mussels were up to moderately polluted by B[a]P at Langøya in the Holmestrandfjord in 2013 (Gitmark *et al.* 2014). Blue mussel from Odderøy and Svensholmen in the Kristiansandsfjord were markedly polluted by B[a]P in 2013 (Schøyen *et al.* 2014).

High concentrations in the Ranfjord are most likely related to harbour and industrial activities.

Environmental Quality Standards (EQS)

The EQS (2013/39/EC) for B[a]P is 5 µg/kg w.w. in biota for "fish". Applying this EQS for blue mussel, concentrations of B[a]P were above the EQS applied for biota only at Moholmen (st. I965, 8.2 µg/kg w.w.).

3.2.17 Polybrominated diphenyl ethers (PBDEs)

Levels of cod liver

Tetrabromodiphenyl ether (BDE47) was the dominant congener in cod liver and was highest in the Inner Oslofjord (st. 30B, 45.5 µg/kg w.w.) (*Figure 29*). The lowest BDE47-concentration in liver was found in cod from Lofoten (st. 98B1, 1.6 µg/kg w.w.).

Significant downward long-time and short-term trends where observed for the polybrominated diphenyl ethers (PBDEs) BDE47,-99 and -100 in liver from cod caught in Tromsø harbour (st. 43B2) in 2013. There was insufficient data to do temporal trend analysis for these congeners in 2012. At eight stations, data for PBDE153, -183, -196, -209 was inadequate for trend analysis due to concerns about the limit of detections in 2013. This was also the case regarding PBDE99 at four stations.

The standard deviation varied considerably among stations, also for other PBDEs. The highest deviations were found at Ålesund (st. 28B) for BDE47, -100 and -154. This could be because relatively few (6) individual fish were analysed and the individual variation is more evident than results based on more samples. There were significant downward long-time and short-term trends for BDE47 in cod from Tromsø harbour (st. 43B2), and significant downward long-time trends in cod from Færder (st. 36B) and Bømlo north (st. 23B). BDE100 was the second most dominant PBDE (*Table 13*).

In the urban areas like Oslo and Ålesund, some of the BDE-congeners in cod liver had significantly higher levels than in remote areas like Færder and Bømlo north (Tukey-Kramer HSD test).

PBDEs have been investigated annually in cod liver since 2005. In the Inner Oslofjord (st. 30B), cod have also been analysed for PBDE in 1993, 1996 and 2001 (*Figure 30*). Samples for similar analyses were also collected from the Færder area (st. 36B) in 1993 and 1996, and from Bømlo north (st. 23B) on the west coast in 1996 and 2001. In 2013, PBDEs were analysed in cod from nine stations (*Table 13*). Of the PBDEs, only congeners BDE47, -100 and -154 were over the detection limit in at least half of the samples from each station.

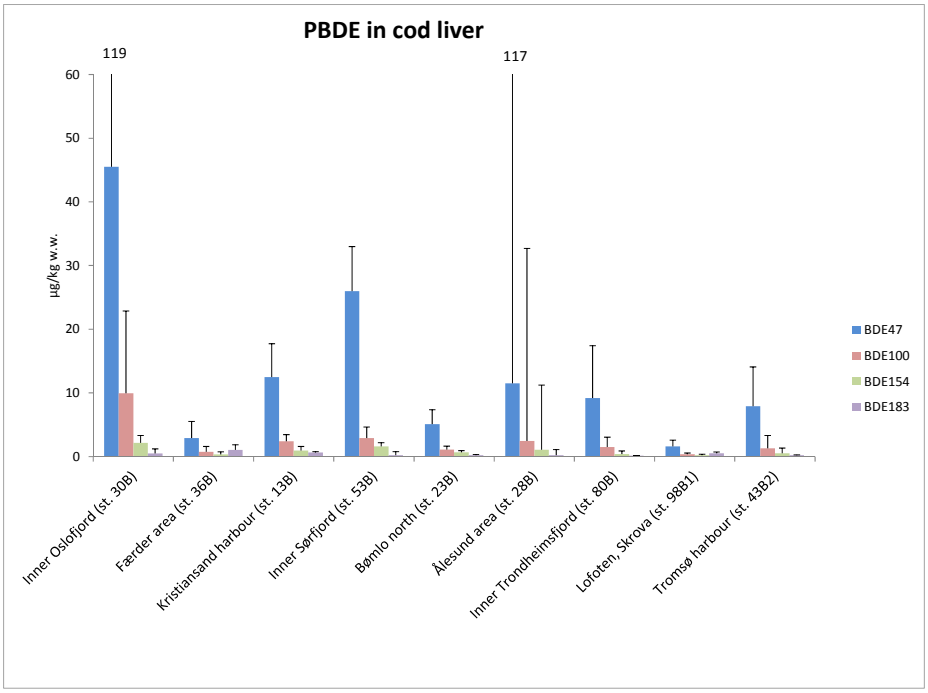

Figure 29. Median concentrations (µg/kg w.w.) of PBDEs in cod liver in 2013. Only the results are shown where concentrations were above the detection limit for half or more of the samples. The error bar indicates one standard deviation above the median.

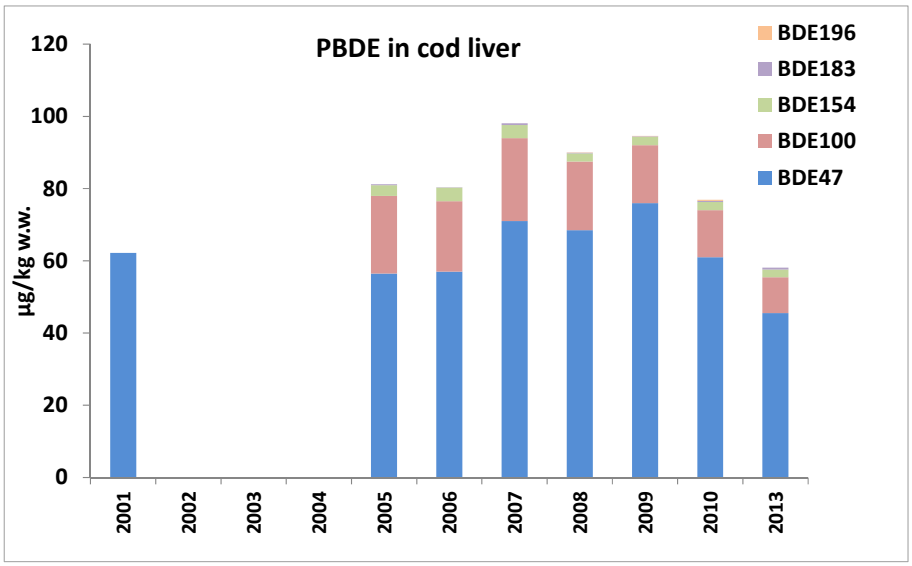

Figure 30. Median concentrations (µg/kg w.w.) of PBDEs in cod liver from 2001 to 2013 in the Inner Oslofjord (st. 30B).

Comparison of concentrations in liver and fillet

Comparison of concentrations in cod liver and cod fillet (2012 samples) in the same individuals were investigated in 12 cases from the Inner Oslofjord, four from the Outer Oslofjord and nine from Kristiansand harbour (*Table 14*). The results show that PBDEs were detectable in fillet for BDE47 in nine cases and BDE100 in four cases. The concentrations in cod liver were consistently higher than concentrations in fillet; on an average of 247 and 191 times higher for BDE47 and BDE100, respectively showing a similar distribution to PCB.

Table 13 Median concentrations (µg/kg w.w.) and standard deviations for PBDE congeners in cod liver, 2013. Count indicates number of samples analysed. The first number within the parentheses indicates the number of pooled samples included. The second number within the parentheses indicates for mussels the total number of individuals used in all pooled samples and for cod the number individuals in each pooled sample. Shaded values are below one half the detection limit, and indicate that over half of the values are below this limit. The standard deviation is based on all values. Caution should be used when comparing such values because the limit of detection can vary both within and among samples. Detectable data information (D.d.i.) indicates the number of data above the limit of detection (if any) and the numbers within the square brackets indicate the minimum and maximum values in this category.

Component	Count	BDE47			BDE99			BDE100			BDE126			BDE153		
Species and sampling localitiy	2013	Med.	S.d.	D.d.i	Med.	S.d.	D.d.i	Med.	S.d.	D.d.i	Med.	S.d.	D.d.i	Med.	S.d.	D.d.i
Blue mussel																
Gressholmen (st. 30A)	3(3-204)	0.058	0.007	3[0.0543-0.0673]	0.037	0.003	3[0.0331-0.0399]	0.014	0.001	3[0.0138-0.0163]	0.001	0.000		0.001	0.000	
Tjøme (st. 36A1)	3(3-50)	0.029	0.003	3[0.0248-0.031]	0.013	0.001	3[0.0107-0.0129]	0.008	0.000	3[0.0074-0.0081]	0.001	0.000		0.001	0.000	
Singlekalven (st. I023)	3(3-33)	0.016	0.002	3[0.0152-0.0183]	0.008	0.001	3[0.0078-0.0089]	0.003	0.000	3[0.0034-0.0039]	0.001	0.000		0.001	0.000	
Bjørkøya (st. 71A)	3(3-20)	0.029	0.003	3[0.0254-0.0312]	0.019	0.001	3[0.018-0.0202]	0.009	0.001	3[0.0086-0.0105]	0.001	0.001		0.001	0.001	
Croftholmen (st. I712)	2(2-9)	0.030	0.009	2[0.0231-0.0364]	0.023	0.010	2[0.0162-0.0304]	0.012	0.004	2[0.0088-0.0148]	0.001	0.000		0.001	0.000	
Nordnes (st. I241)	2(2-20)	0.216	0.001	2[0.215-0.217]	0.130	0.012	2[0.122-0.139]	0.045	0.002	2[0.0435-0.0463]	0.001	0.000		0.009	0.000	2[0.0083-0.0087]
Måløy (st. 26A2)	3(3-53)	0.026	0.001	3[0.0236-0.0258]	0.011	0.001	3[0.0111-0.0126]	0.007	0.000	3[0.0067-0.0072]	0.001	0.000		0.001	0.000	
Outer Trondheimsfjord (st. 91A2)	3(3-72)	0.041	0.005	3[0.0368-0.0464]	0.013	0.002	3[0.0118-0.0155]	0.011	0.001	3[0.01-0.0124]	0.001	0.000		0.001	0.000	
Bodø harbour (st. 97A2)	3(3-230)	0.052	0.020	3[0.0309-0.0704]	0.029	0.008	3[0.0193-0.0362]	0.018	0.008	3[0.0113-0.0267]	0.001	0.000		0.001	0.000	
Lofoten, Svolvær (st. 98A2)	3(3-99)	0.012	0.001	3[0.0103-0.012]	0.004	0.000	3[0.0034-0.0043]	0.004	0.000	3[0.0038-0.0046]	0.001	0.000		0.001	0.000	
Cod, liver																
Inner Oslofjord (st. 30B)	16(2-3)	45.500	73.144	16[11-300]	0.620	0.488	14[0.18-1.6]	9.950	12.902	16[4.1-58]	0.570	0.933	13[0.17-3.58]	0.120	0.092	10[0.11-0.41]
Færder area (st. 36B)	10(3-7)	2.900	2.617	10[0.68-7.8]	0.180	0.064	9[0.13-0.31]	0.745	0.842	10[0.35-2.9]	0.050	0.055	2[0.22-0.24]	0.050	0.133	1[0.52]
Kristiansand harbour (st. 13B)	10(6-2)	12.500	5.226	10[5.4-21]	0.105	0.016	5[0.11-0.15]	2.400	1.040	10[0.76-3.7]	0.050	0.000		0.050	0.000	
Inner Sørfjord (st. 53B)	6(4-6)	26.000	6.986	6[17-35]	0.050	0.061	1[0.25]	2.900	1.731	6[1.6-5.8]	0.050	0.000		0.050	0.000	
Bømlo north (st. 23B)	16(2-2)	5.100	2.255	16[2.1-9.9]	0.185	0.412	11[0.11-1.4]	1.100	0.551	16[0.24-2.2]	0.050	0.000		0.050	0.000	
Ålesund area (st. 28B)	6	11.500	105.106	6[3.5-270]	0.180	0.268	3[0.26-0.79]	2.450	30.242	6[1-77]	0.050	0.065	1[0.26]	0.050	0.000	
Inner Trondheimsfjord (st. 80B)	15	9.200	8.215	15[3.2-36]	0.240	0.200	11[0.12-0.83]	1.500	1.542	15[0.51-6.7]	0.050	0.000		0.050	0.000	
Lofoten, Skrova (st. 98B1)	15(2-6)	1.600	0.978	15[0.92-4.8]	0.050	0.058	6[0.13-0.27]	0.380	0.169	14[0.18-0.74]	0.050	0.000		0.050	0.000	
Tromsø harbour (st. 43B2)	15(3-3)	7.900	6.176	15[2.4-27]	0.210	0.552	11[0.1-2.2]	1.300	2.000	15[0.13-8.3]	0.050	0.000		0.050	0.088	1[0.44]

Table 13 (cont.)

Component	Count	BDE154			BDE183			BDE196			BDE209			BDESS		
Species and sampling localitiy	2013	Med.	S.d.	D.d.i	Med.	S.d.	D.d.i	Med.	S.d.	D.d.i	Med.	S.d.	D.d.i	Med.	S.d.	D.d.i
Blue mussel																
Gressholmen (st. 30A)	3(3-204)	0.001	0.000		0.002	0.003	1[0.009]	0.004	0.000		0.039	0.002		0.202	0.009	
Tjøme (st. 36A1)	3(3-50)	0.001	0.000		0.002	0.000		0.003	0.001		0.032	0.008		0.119	0.008	
Singlekalven (st. I023)	3(3-33)	0.001	0.000		0.002	0.000		0.003	0.000		0.027	0.004		0.092	0.006	
Bjørkøya (st. 71A)	3(3-20)	0.001	0.001		0.001	0.002		0.003	0.003		0.041	0.030		0.143	0.034	
Croftholmen (st. I712)	2(2-9)	0.001	0.000		0.001	0.000		0.002	0.000		0.019	0.001		0.109	0.022	
Nordnes (st. I241)	2(2-20)	0.007	0.000	2[0.0065-0.0069]	0.006	0.001	2[0.0051-0.0066]	0.003	0.000		0.030	0.003		0.477	0.011	
Måløy (st. 26A2)	3(3-53)	0.001	0.000		0.002	0.000		0.003	0.000		0.030	0.001		0.115	0.004	
Outer Trondheimsfjord (st. 91A2)	3(3-72)	0.001	0.000		0.001	0.000		0.003	0.001		0.028	0.052		0.129	0.061	
Bodø harbour (st. 97A2)	3(3-230)	0.001	0.000		0.002	0.000		0.003	0.000		0.029	0.005		0.169	0.041	
Lofoten, Svolvær (st. 98A2)	3(3-99)	0.001	0.000		0.002	0.000		0.004	0.000		0.034	0.002		0.102	0.003	
Cod, liver																
Inner Oslofjord (st. 30B)	16(2-3)	2.150	1.157	16[0.91-5.4]	0.495	0.715	11[0.35-2.7]	0.150	0.000		0.250	0.000		60.270	85.734	
Færder area (st. 36B)	10(3-7)	0.355	0.398	10[0.2-1.5]	1.035	0.820	8[0.61-3.1]	0.150	0.000		0.250	0.000		6.030	4.252	
Kristiansand harbour (st. 13B)	10(6-2)	0.935	0.654	10[0.49-2.5]	0.630	0.151	10[0.36-0.86]	0.150	0.000		0.250	0.000		17.575	6.700	
Inner Sørfjord (st. 53B)	6(4-6)	1.600	0.580	6[0.66-2.3]	0.200	0.572	2[0.97-1.8]	0.150	0.000		0.250	0.000		31.880	8.745	
Bømlo north (st. 23B)	16(2-2)	0.655	0.285	16[0.32-1.2]	0.200	0.106	3[0.45-0.75]	0.150	0.000		0.250	0.000		8.300	3.328	
Ålesund area (st. 28B)	6	1.080	10.146	6[0.74-26]	0.200	0.887	2[0.56-2.6]	0.150	0.000		0.250	0.000		16.425	146.525	
Inner Trondheimsfjord (st. 80B)	15	0.390	0.480	15[0.13-2.1]	0.150	0.000		0.150	0.000		0.250	0.000		12.640	10.359	
Lofoten, Skrova (st. 98B1)	15(2-6)	0.200	0.160	13[0.12-0.68]	0.520	0.197	13[0.34-1]	0.150	0.000		0.250	0.000		3.740	1.178	
Tromsø harbour (st. 43B2)	15(3-3)	0.530	0.808	15[0.21-2.9]	0.200	0.073	3[0.52-0.64]	0.150	0.000		0.250	0.000		13.480	8.557	

Table 14. Concentration (µg/kg w.w.) of PBDE in cod liver and fillet. The shaded areas indicate value below the detection limit and that the values shown are one half of the detection limit.

Component	Code	BDE47	BDE47	BDE99	BDE99	BDE100	BDE100	BDE126	BDE126	BDE153	BDE153	BDE154	BDE154	BDE183	BDE183	BDE196	BDE196	BDE209	BDE209
Species and sampling localiti	2012	Liver	Fillet	Liver	Fillet	Liver	Fillet	Liver	Fillet	Liver	Fillet	Liver	Fillet	Liver	Fillet	Liver	Fillet	Liver	Fillet
Cod																			
Inner Oslofjord (st. 30B)	301-1	34	0.05	1.3	0.05	5.8	0.05	0.05	0.05	0.05	0.05	1.7	0.05	1.8	0.15	7.99	0.15	0.25	0.25
Inner Oslofjord (st. 30B)	301-10	7.9	0.14	0.05	0.05	5	0.1	0.4	0.05	0.17	0.05	0.51	0.05	0.49	0.15	0.44	0.15	0.25	0.25
Inner Oslofjord (st. 30B)	301-13	22	0.26	0.14	0.05	7.1	0.11	0.05	0.05	0.19	0.05	2.7	0.05	1.5	0.15	1.36	0.15	0.25	0.25
Inner Oslofjord (st. 30B)	301-14	40	0.05	1.1	0.05	12	0.05	0.05	0.05	0.05	0.05	3.2	0.05	0.53	0.15	0.7	0.15	0.25	0.25
Inner Oslofjord (st. 30B)	301-15	49	0.05	2.3	0.05	11	0.05	0.05	0.05	0.05	0.05	2.1	0.05	0.33	0.15	0.33	0.15	0.25	0.25
Inner Oslofjord (st. 30B)	301-2	26	0.05	1.1	0.05	5.6	0.05	0.05	0.05	0.05	0.05	1.6	0.05	1	0.15	5.1	0.15	0.25	0.25
Inner Oslofjord (st. 30B)	301-3	54	0.14	1.1	0.05	14	0.05	0.05	0.05	0.13	0.05	2.9	0.05	0.15	0.15	0.15	0.15	0.25	0.25
Inner Oslofjord (st. 30B)	301-4	14	0.05	0.05	0.05	4.9	0.05	0.05	0.05	0.05	0.05	1.8	0.05	0.15	0.15	2.52	0.15	0.25	0.25
Inner Oslofjord (st. 30B)	301-5	290	0.62	1	0.05	67	0.16	0.05	0.05	0.15	0.05	7.6	0.05	1.2	0.15	2.28	0.15	0.25	0.25
Inner Oslofjord (st. 30B)	301-7	55	0.22	0.39	0.05	23	0.1	0.05	0.05	0.05	0.05	4.4	0.05	1.3	0.15	4.08	0.15	0.25	0.25
Inner Oslofjord (st. 30B)	301-8	32	0.14	0.48	0.05	15	0.05	0.05	0.05	0.05	0.05	4	0.05	0.56	0.15	0.66	0.15	0.25	0.25
Inner Oslofjord (st. 30B)	301-9	38	0.17	0.39	0.05	3.9	0.05	0.05	0.05	0.05	0.05	1.9	0.05	0.15	0.15	1.24	0.15	0.25	0.25
Færder area (st. 36B)	361-1	9.1	0.05	0.05	0.05	2.3	0.05	0.05	0.05	0.17	0.05	1.7	0.05	0.7	0.15	3.4	0.15	0.25	0.25
Færder area (st. 36B)	361-2	4.6	0.05	0.05	0.05	1.5	0.05	0.05	0.05	0.05	0.05	1.2	0.05	0.15	0.15	2.04	0.15	0.25	0.25
Færder area (st. 36B)	361-3	4.8	0.05	0.05	0.05	1.4	0.05	0.05	0.05	0.05	0.05	0.77	0.05	0.15	0.15	1.42	0.15	0.25	0.25
Færder area (st. 36B)	361-5	3	0.05	0.05	0.05	1.1	0.05	0.05	0.05	0.05	0.05	0.66	0.05	0.15	0.15	1.12	0.15	0.25	0.25
Kristiansand harbour (st. 13B)	131-11	29	0.12	0.05	0.05	2.9	0.05	0.05	0.05	0.05	0.05	3.4	0.05	0.15	0.15	0.15	0.15	0.25	0.25
Kristiansand harbour (st. 13B)	131-13	0.79	0.05	0.18	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.15	0.15	1.4	0.15	0.25	0.25
Kristiansand harbour (st. 13B)	131-14	4.7	0.05	0.05	0.05	0.64	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.6	0.15	1.3	0.15	0.25	0.25
Kristiansand harbour (st. 13B)	131-15	31	0.11	0.43	0.05	5.9	0.05	0.05	0.05	0.05	0.05	0.57	0.05	0.15	0.15	0.54	0.15	0.25	0.25
Kristiansand harbour (st. 13B)	131-2	11	0.05	0.58	0.05	2.7	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.15	0.15	1.29	0.15	0.25	0.25
Kristiansand harbour (st. 13B)	131-4	0.33	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.15	0.15	0.15	0.15	0.25	0.25
Kristiansand harbour (st. 13B)	131-5	8.5	0.05	0.12	0.05	0.61	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.46	0.15	1.66	0.15	0.25	0.25
Kristiansand harbour (st. 13B)	131-7	6.1	0.05	0.18	0.05	1.3	0.05	0.05	0.05	0.26	0.05	0.45	0.05	0.15	0.15	1.53	0.15	0.25	0.25
Kristiansand harbour (st. 13B)	131-8	26	0.05	0.05	0.05	2.7	0.05	0.05	0.05	0.05	0.05	3.5	0.05	0.15	0.15	0.15	0.15	0.25	0.25

Blue mussel

Levels in blue mussel

PBDEs were investigated in blue mussel for the first time in 2012. Only congeners BDE47, 99 and 100 showed concentrations above the detection limit for half or more of the samples at a station (*Table 13*, *Figure 31*, *Table 10*). The most dominant congener in 2013 was BDE47, unlike the previous year when BDE209 was the dominant congener. BDE47, 99 and -100 were detected at all 10 stations. For both of these congeners the highest median concentrations were found in mussels from Nordnes in Bergen harbour (st. I241) (0.216 µg BDE47/kg w.w. and 0.045 µg BDE100/kg w.w.). The highest concentrations of BDE153 (0.009 µg/kg w.w.), BDE154 (0.007 µg/kg w.w.) and BDE183 (0.006 µg/kg w.w.) were also found at the same mussel station. There was insufficient data to do a temporal trend analysis.

Blue mussel from Nordnes in the Bergen harbour area showed significantly higher concentrations of BDE47, -99, and -100 than mussels from all the other stations (Tukey-Kramer HSD test).

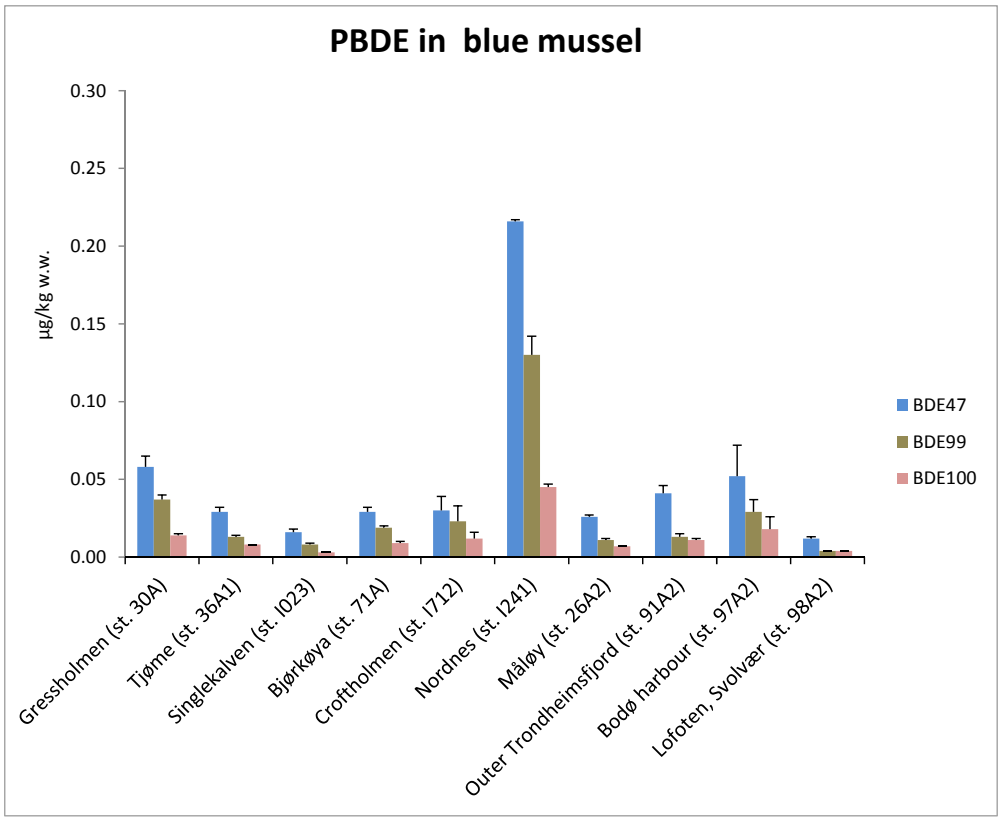

Figure 31. Median concentrations (µg/kg w.w.) of PBDEs in blue mussel in 2013. Only the results are shown where concentrations were above the detection limit for half or more of the samples. The error bar indicates one standard deviation above the median.

Environmental Quality Standards (EQS)

The EQS (2013/39/EC) for brominateddiphenylethers (0.0085 µg/kg w.w.) in biota for "fish" is the sum of the concentrations of congener numbers 28, 47, 99, 100, 153 and 154. This EQS applies to whole fish. Therefore, the EQS cannot be directly compared to concentrations found in different tissues of fish. The median concentration of PBDE47 alone in cod liver would have exceeded this EQS value at all stations. These results might indicate that the EQS might be too high to be a useful criterion to judge the condition of biota with respect to this contaminant.

Inner Oslofjord

Parts of the Inner Oslofjord are densely populated with much urban activities and accompanying existence of PBDE in certain products. The high concentrations of PBDE observed in cod are probably related to these activities, as well as reduced water exchange with the Outer fjord. A study of flounder liver from the Inner Oslofjord in 2013 showed generally substantially lower (e.g. a factor of~35 for BDE47) than the median

concentration measured in cod in 2012 (Ruus *et al.* 2014, in press). The congener BDE47 was also dominating at three blue mussel stations (Frognerkilen, Alna and Bekkelaget) in the Inner Oslofjord in 2013 (Ruus *et al.* 2014, in press).

Other studies
Median concentrations for the sum of PBDE found at presumed reference stations like Lofoten, Færder, Utsira and Bømlo-Sotra indicate that a high background level in diffusely contaminated areas might be about 30 µg/kg w.w. for cod liver (Fjeld *et al.* 2005). This is higher than the sum of the medians BDE47, -100, -154,-183, and -196 found at MILKYS cod stations in the Inner Oslofjord (cf. *Figure 29*) and higher than the average concentrations found at two cod stations in the North Sea (14.6 and 15.4 µg/kg w.w.) (Green *et al.* 2011) and three cod stations in the Norwegian Sea (5.89, 12.9 and 19 µg/kg w.w.) (Green *et al.* 2012a). It cannot be disregarded that this high background concentration might be too high. The median found in the Inner Oslofjord for just BDE47 was 45.5 µg/kg w.w., which was within the interval for sum PBDE of 37-112 µg/kg w.w. found in other contaminated areas (Fjeld *et al.* 2005, Berge *et al.* 2006).
Bakke *et al.* (2007b) found mean concentrations of sum of PBDE in remote areas to be within the range 3.4-29.0 µg/kg w.w.

The congeners BDE47 and -100 were observed to be most dominant. The low concentrations of BDE99 are probably due to the debromination to BDE47. Investigations of brown trout (*Salmo trutta)*, smelt (*Osmerus eperlanus*) and vendace (*Coregonus albula*) in lake Mjøsa showed that the decrease was greatest for BDE99, which probably is due to a biotransformation (debromination) to BDE47 (Fjeld *et al.* 2012).

General, large scale trends
There were few significant trends. Of recent trends only, three of 32 were significant; one downward (BDE100 in the Inner Oslofjord) and two upward (BDE153 in the Inner Sørfjord and Bømlo north). Of long-term trends only three of 32 were significant; two downward (BDE47 from Bømlo north and Outer Oslofjord) and one upward (BDE153 in the Inner Sørfjord). These results do not reflect the general decreasing trend of penta-mix PBDEs (that includes BDE100, Law *et al.* 2014), PBDEs in European emissions (Schuster *et al.* 2010) and in marine mammals in the Arctic and North Atlantic since 2000 (Rotander *et al.* 2012). It can be noted that after 2002 a sharp decline in concentrations of PBDEs (as well as PFCs) was observed in blood from newborns in New York state (Ma *et al.* 2013).

The only reported discharge of PBDEs was 6.83 PBDE kg in 2002 from land-based industries to water (reported in www.norskeutslipp.no).

3.2.18 Perfluoralkyl compounds (PFAS)

Levels and trends
PFOS and PFOSA at all stations revealed assumed background concentrations. Significant downward trends for PFOS were dominating in 2013, unlike the previous year when no trends were observed.

PFAS
In this monitoring programme perfluroalkyl compounds (PFAS) have been analysed annually in cod liver since 2005. Samples collected in the Inner Oslofjord (st. 30B) and Bømlo north (st. 23B) in 1993 have also been analysed for PFAS from. In 2013, PFAS were analysed in cod liver from eight stations (*Table 10* and *Figure 32*).

PFOS
The median concentration of perfluoroctonoic sulphonate (PFOS) was highest in the Inner Oslofjord (st. 30B, 3.24 µg/kg w.w.) and lowest from the Inner Trondheimsfjord (st. 80B, 0.15 µg/kg w.w.) (*Table 10*). The concentration found in 2013 in the Inner Oslofjord was half of what was found in 2012, and at Færder the concentrations had decreased from 6.7 µg/kg w.w. in 2012 to 0.775 µg/kg w.w.in 2013. No trends were observed in 2012, but significant downward trends were identified in 2013 at six of the eight stations. There were significant downward long-time and short-term trends for PFOS at Færder (st. 36B), in the Inner Sørfjord (st. 53B), the Inner Trondheimsfjord (st. 80B) and at Tromsø harbour (st. 43B2). Significant downward short-term trends were observed in the Inner Oslofjord (st. 30B) and Bømlo north (st. 23B).

PFOSA

Perfluorooctane sulphonamide (PFOSA) had a maximum median concentration of 7.16 µg/kg w.w. in the Inner Oslofjord and a minimum at Trondheim and Tromsø (0.34 µg/kg w.w.). The concentration of PFOSA was higher than PFOS in the Inner Oslofjord and Færder (***Figure 32***, ***Figure 33)***. The median concentrations of the remaining PFAS were below the detection limit at Færder, Inner Sørfjord, Trondheim and Tromsø (*Table 10, Table 15*).

Cod from the Inner Oslofjord had significant higher levels of PFOS, PFOSA and PFDcS in liver than all other stations (Tukey-Kramer HSD test).

Environmental Quality Standards (EQS)

The EQS (2013/39/EC) for PFOS in biota (fish) is 9.1 µg/kg w.w. which applies to whole fish. Therefore, the EQS cannot be directly compared to concentrations found in different tissues of fish. We have in this study only measured PFOS in liver and have not considered converting fillet to whole fish because this conversion is uncertain. If it is assumed, for this exercise, that the same concentration is found in cod liver is the same for the whole fish, then the results of PFOS would not be exceeded at any station.

Inner Oslofjord

Parts of the Inner Oslofjord are densely populated with much urban activities including presence of PFOSA in certain products. The high concentrations of PFOSA observed in cod are probably related to these activities, as well as reduced water exchange with the Outer fjord. PFOS was the dominant PFAS in cod liver in the Inner Oslofjord in 2009 (median 48 µg/kg w.w.) compared with PFOSA (41.5 µg/kg w.w.). In 2010, 2011, 2012 and 2013, PFOSA dominated (18, 19, 10 and 7 µg/kg w.w., respectively) more than PFOS (16, 5, 7 and 3 µg/kg w.w., respectively). Schøyen & Kringstad (2011) analysed PFAS in cod blood samples from the same individuals which were analysed in the MILKYS (former CEMP) programme in 2009 from the Inner Oslofjord (Green *et al.* 2010b). They found that PFOSA was the most dominant PFAS-compound with a median level 6 times higher than for PFOS. The median level of PFOSA in cod blood was about 5 times higher than in liver. The median level of PFOS in cod liver was about 1.5 times higher than in blood. Further, PFNA was also detected in cod blood. Rundberget *et al.* 2014 investigated cod from Inner Oslofjord (st. 30B) in the period 2009 to 2013 and found that blood was the preferred matrix for analysing PFAS. The levels of PFOS were roughly the same in blood as in liver and bile, but levels of other PFAS were higher in blood and therefor easier to detect. A study of flounder liver from the Inner Oslofjord in 2013 showed higher median concentration of PFOS than in cod in 2012, while the median concentration of PFOSA was lower in cod from 2012 (Ruus *et al.* 2014, in press).

Other studies

Median concentrations of PFOS in cod from presumed reference stations like Lofoten, Kvænangen/Olderfjord north of Skjervøy and the Varangerfjord indicated that high background concentrations in only diffusely contaminated areas might be around 10 µg/kg w.w. (Bakke *et al.* 2007b). All concentrations observed in this study were lower. The average concentration of PFOS in cod from two stations in the North Sea was 1.55 and 0.95 µg/kg w.w. (Green *et al.* 2011) and from three stations in the Norwegian Sea was 0.75, 0.82 and 11 µg/kg w.w. (Green *et al.* 2012b).

Fjeld *et al.* (2011) found only PFOS and PFOSA in quantifiable amounts in the three fish species brown trout (*Salmo trutta)*, smelt (*Osmerus eperlanus*) and vendace (*Coregonus albula*) in lake Mjøsa for the period 2008-2010. In 2011, Fjeld *et al.* (2012) also detected PFOA, PFDcA and PFUnA in addition to PFOS and PFOSA. PFOS was found to be the dominant compound in all three species.

PFOA has been strictly regulated nationally in consumer products from June 2014[7]. PFOA-data at all stations was inadequate due to concerns about the limit of detections.

General, large scale trends

Six of the eight stations showed significant downward trends in PFOS for the period 2005 to 2013. Significant downward trends for PFOS were dominating in 2013, unlike the previous year when no trends were observed. This could reflect the overall trends in production and use of PFAS for the past 30 years (Nost *et al.* 2014,

[7] http://www.miljodirektoratet.no/no/Nyheter/Nyheter/2014/Mars-2014/Overgangsordning-for-miljogiften-PFOA-i-forbrukerprodukter/

Axmon *et al.* 2014), though why this was not seen in the previous year is uncertain. A decrease in concentrations of PFAS in Sweden has been reported for food items (Johansson *et al.* 2014) and herring (Ullah *et al.* 2014). A sharp decline in concentrations of PFAS (as well as PBDEss) after 2002 was found in dried blood spots from newborns in New York state (Ma *et al.* 2013).

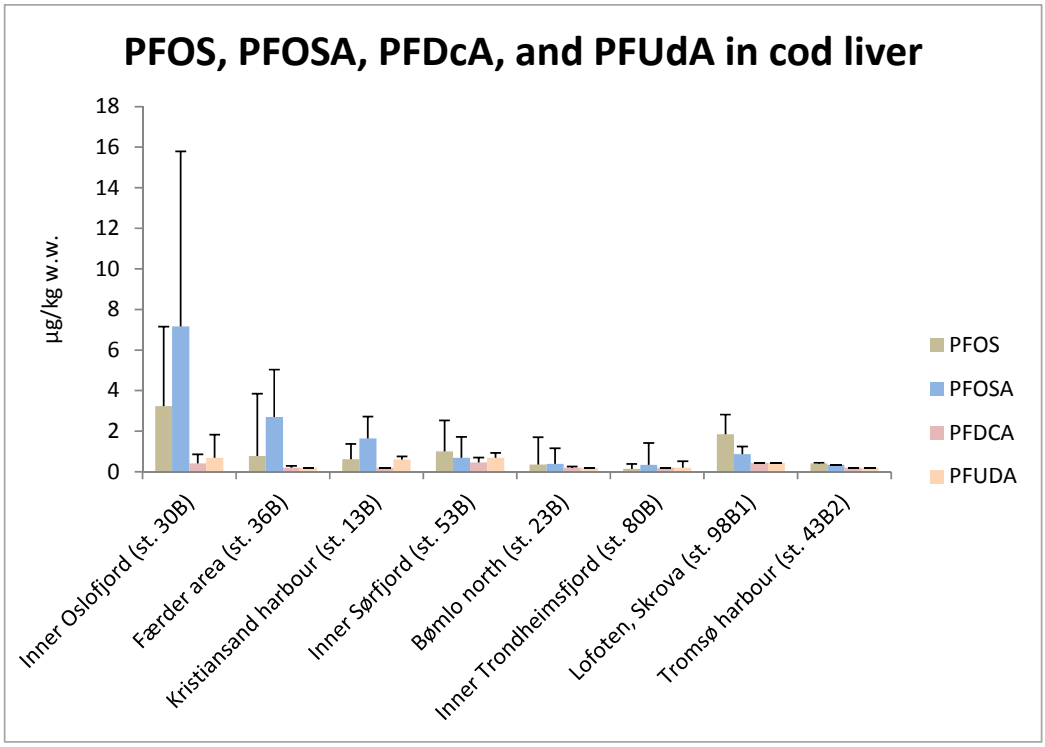

Figure 32. Median concentrations (µg/kg w.w.) of four PFAS compounds in cod liver in 2013. The error bar indicates one standard deviation above the median. PFDcA and PFUdA values for some stations are below the limit of detection – see Table 15).

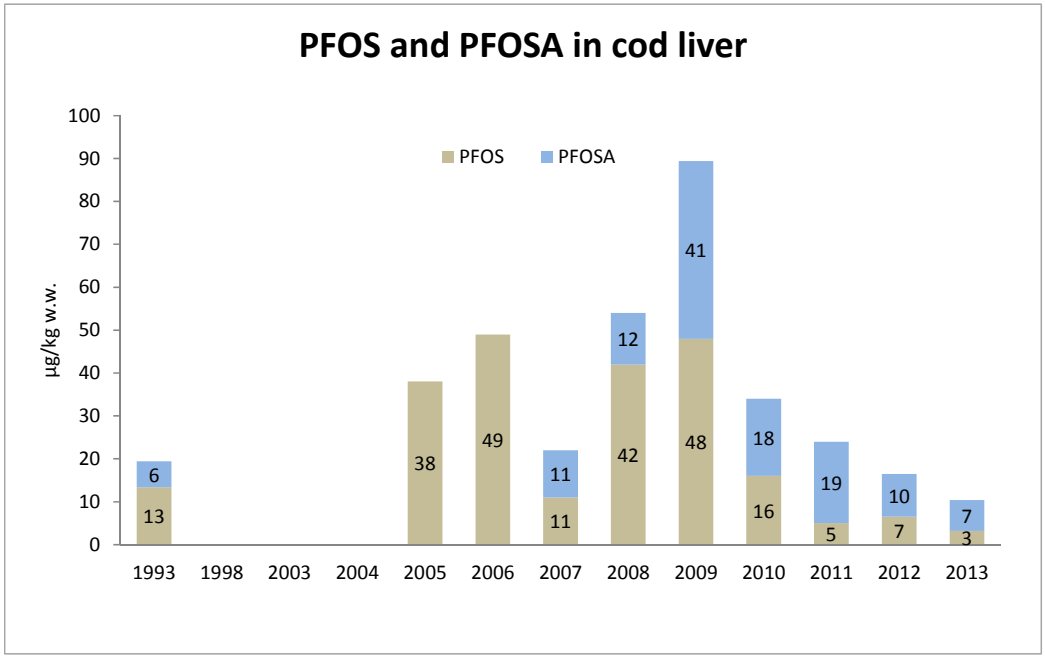

Figure 33. Median concentrations (µg/kg w.w.) of PFOS and PFOSA in cod liver from 1993 to 2013 in the Inner Oslofjord (st. 30B).

Table 15. Median concentrations (µg/kg w.w.) standard deviations of the PFAS-compounds analysed in cod liver in 2013. The first number within the parentheses indicates the number of pooled samples included. The second number within the parentheses indicates for cod the number individuals in each pooled sample. Shaded values are below one half the detection limit, and indicate that over half of the values are below this limit. The standard deviation is based on of all values. Caution should be used when comparing such values because the limit of detection can vary both within and among samples. Detectable data information (D.d.i.) indicates the number of data above the limit of detection (if any) and the numbers within the square brackets indicate the minimum and maximum values in this category.

Component	Count	PFBS			PFDCA			PFDCS			PFHpA			PFHxA			PFHXS		
Species and sampling localitiy	2013	Med.	S.d.	D.d.i.	Med.	S.d.	D.d.i.	Med.	S.d.	D.d.i.	Med.	S.d.	D.d.i.	Med.	S.d.	D.d.i.	Med.	S.d.	D.d.i
Cod, liver																			
Inner Oslofjord (st. 30B)	16(2-3)	0.05	0		0.41	0.452	8[0.42-1.31]	0.48	0.376	16[0.11-1.88]	0.2	0		0.2	0		0.05	0	
Færder area (st. 36B)	10(3-7)	0.05	0		0.2	0.092		0.05	0		0.2	0		0.2	0		0.05	0	
Kristiansand harbour (st. 13B)	10(6-2)	0.05	0		0.2	0	1[0.42]	0.05	0		0.02	0		0.02	0		0.05	0	
Inner Sørfjord (st. 53B)	6(4-6)	0.05	0		0.455	0.241	3[0.51-0.66]	0.05	0	2[0.11-0.12]	0.02	0		0.02	0		0.05	0.005	
Bømlo north (st. 23B)	16(2-2)	0.05	0		0.2	0.054		0.05	0		0.2	0		0.2	0		0.05	0.015	
Inner Trondheimsfjord (st. 80B)	15	0.05	0		0.2	0		0.05	0		0.2	0		0.2	0.033		0.05	0	
Lofoten, Skrova (st. 98B1)	15(2-6)	0.12	0	9[0.12-0.25]	0.45	0	8[0.45-0.84]	0.05	0		0.2	0		0.2	0		0.05	0	
Tromsø harbour (st. 43B2)	15(3-3)	0.05	0		0.2	0		0.05	0		0.02	0		0.02	0		0.05	0	

Table 15. (cont.)

Component	Count	PFNA			PFOA			PFOS			PFOSA			PFUDA		
Species and sampling localitiy	2013	Med.	S.d.	D.d.i.	Med.	S.d.	D.d.i.	Med.	S.d.	D.d.i.	Med.	S.d.	D.d.i.	Med.	S.d.	D.d.i.
Cod, liver																
Inner Oslofjord (st. 30B)	16(2-3)	0.2	0.08		0.2	0		3.24	3.91	16[0.84-7.67]	7.16	8.636	16[2.3-30.2]	0.68	1.155	14[0.4-2.23]
Færder area (st. 36B)	10(3-7)	0.2	0.118		0.2	0		0.78	3.07	10[0.12-1.99]	2.705	2.328	10[0.37-11.9]	0.2	0	
Kristiansand harbour (st. 13B)	10(6-2)	0.2	0.033		0.2	0		0.61	0.76	10[0.41-1.5]	1.65	1.074	10[0.38-3.92]	0.595	0.167	9[0.42-1.4]
Inner Sørfjord (st. 53B)	6(4-6)	0.2	0.822	1[0.74]	0.2	0.214		1	1.53	6[0.27-1.92]	0.685	1.027	6[0.47-1.51]	0.685	0.241	5[0.56-1]
Bømlo north (st. 23B)	16(2-2)	0.2	0.166		0.2	0		0.36	1.35	16[0.14-1.74]	0.385	0.768	16[0.15-1.24]	0.2	0	
Inner Trondheimsfjord (st. 80B)	15	0.2	0		0.2	0		0.15	0.23	12[0.1-1.24]	0.34	1.076	15[0.18-0.7]	0.2	0.313	
Lofoten, Skrova (st. 98B1)	15(2-6)	0.2	0	3[0.4-0.43]	0.2	0		1.84	0.98	15[0.92-5.06]	0.88	0.367	15[0.41-2.3]	0.45	0	9[0.45-1.84]
Tromsø harbour (st. 43B2)	15(3-3)	0.2	0		0.2	0		0.41	0.03	15[0.18-1.21]	0.34	0	15[0.12-0.87]	0.2	0	3[0.42-0.64]

3.3 New contaminants

3.3.1 Hexabromcyclododecane (HBCD)

HBCD is a persistent pollutant with a high potential for bioaccumulation. HBCD is one of the substances identified as priority hazardous substances **(**Directive 2013/39/EU). The EQS (167 µg/kg w.w.) refers to fish and this threshold was not exceeded by any median median concentration if it is assumed that this median applies to the whole organism and not just the liver. Cod from the Inner Oslofjord had the highest concentration of HBCD in the liver (*Figure 34*). HBCD is here the sum of the α–, β–, and γ–diastereomers. The median concentration of HBCD in cod liver from the Inner Oslofjord was 18.09 µg/kg w.w., but there was considerable variation (*Table 16*). Parts of the Inner Oslofjord are densely populated driving urban activities which could bring about use of products containing HBCD. The high concentrations of HBCD observed in cod are probably related to such products, as well as to reduced water exchange with the outer fjord.

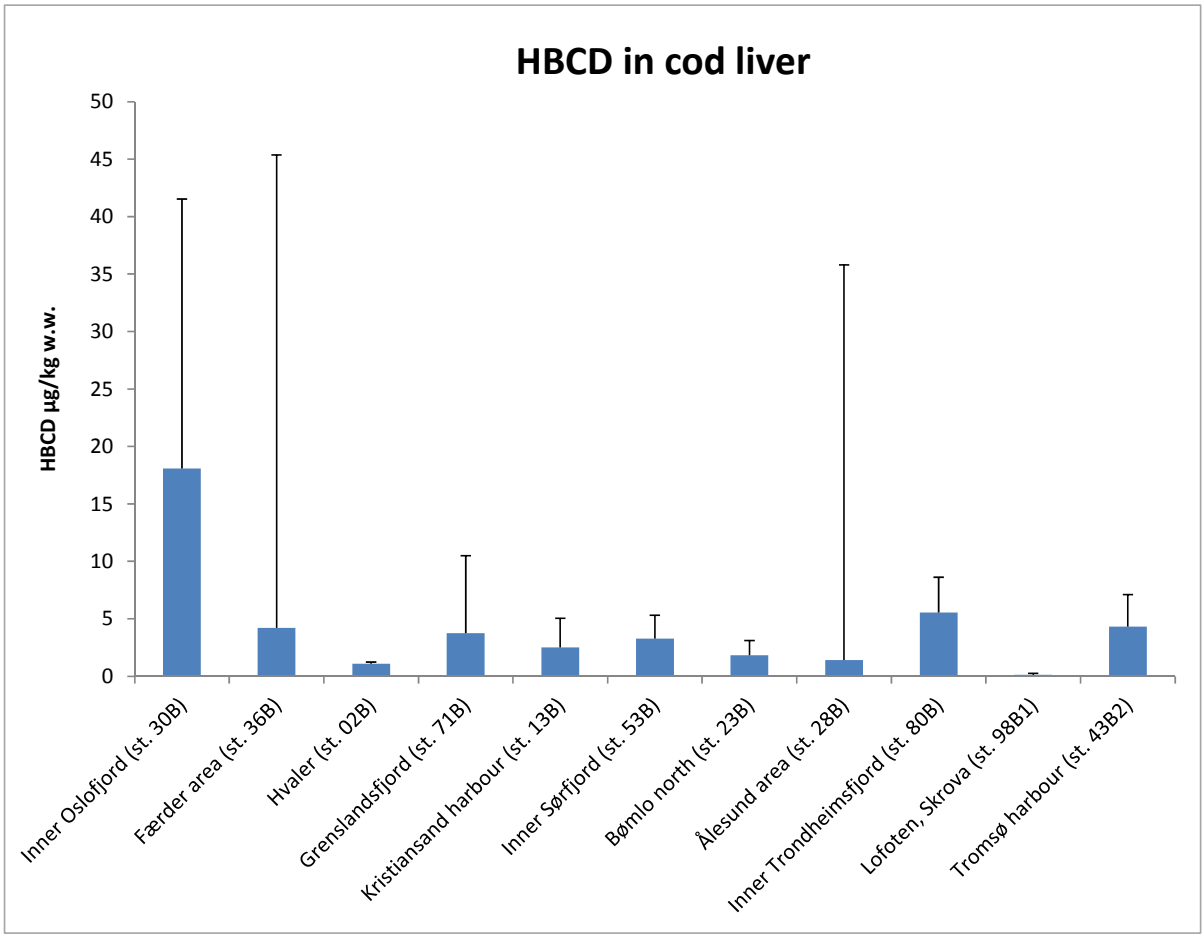

Figure 34. Median concentration (µg/kg w.w.) of HBCD (sum of the α–, β–, and γ–diastereomers in cod liver in 2013. The error bar indicates one standard deviation above the median.

Table 16. Median concentration (µg/kg w.w.) with standard deviation of HBCD (sum of the α–, β–, and γ–diastereomers) in cod liver and blue mussel. Count indicates number of samples analysed. The first number within the parentheses indicates the number of pooled samples included. The second number within the parentheses indicates for mussels the total number of individuals used in all pooled samples and for cod the number individuals in each pooled sample. Shaded values are below one half the detection limit, and indicate that over half of the values are below this limit. The standard deviation is based on all values. Caution should be used when comparing such values because the limit of detection can vary both within and among samples. Detectable data information (D.d.i.) indicates the number of data above the limit of detection (if any) and the numbers within the square brackets indicate the minimum and maximum values in this category.

Component	Count	HBCDD		α–HBCD			β–HBCD			γ–HBCD		
Species and sampling localitiy	2013	Med.	S.d.	Med.	S.d.	D.d.i.	Med.	S.d.	D.d.i.	Med.	S.d.	D.d.i.
Blue mussel												
Gressholmen (st. 30A)	3(3-204)	0.175	0.030	0.160	0.025	3[0.14-0.19]	0.005	0.001	3[0.004-0.005	0.010	0.006	3[0.01-0.02]
Tjøme (st. 36A1)	3(3-50)	0.073	0.080	0.060	0.012	3[0.06-0.08]	0.005	0.014	3[0.005-0.03]	0.008	0.054	3[0.005-0.1]
Singlekalven (st. I023)	3(3-33)	0.042	0.237	0.030	0.052	3[0.03-0.12]	0.006	0.043	2[0.004-0.08]	0.006	0.141	2[0.004-0.25]
Nordnes (st. I241)	2(2-20)	0.400	0.071	0.290	0.028	2[0.27-0.31]	0.030	0.000	2[0.03-0.03]	0.080	0.042	2[0.05-0.11]
Måløy (st. 26A2)	3(3-53)	0.056	0.006	0.050	0.006	3[0.05-0.06]	0.002	0.000		0.002	0.000	
Outer Trondheimsfjord (st. 91A2	3(3-72)	0.117	0.039	0.070	0.031	3[0.05-0.11]	0.007	0.004	3[0.003-0.01]	0.008	0.020	3[0.003-0.04]
Bodø harbour (st. 97A2)	3(3-230)	0.077	0.038	0.060	0.025	3[0.03-0.08]	0.007	0.004	2[0.007-0.01]	0.010	0.009	2[0.01-0.02]
Lofoten, Svolvær (st. 98A2)	3(3-99)	0.026	0.006	0.02	0.006	3[0.01-0.02]	0.0015	0.000		0.002	0.000	
Cod, liver												
Inner Oslofjord (st. 30B)	10(4-3)	18.090	23.449	17.600	23.312	10[6.64-78.7]	0.085	0.062	10[0.02-0.21]	0.275	0.220	10[0.1-0.8]
Færder area (st. 36B)	3(3-7)	4.210	41.153	4.170	9.451	3[2.09-19.4]	0.020	9.691	3[0.01-16.8]	0.160	22.058	3[0.03-38.3]
Hvaler (st. 02B)	2(2-8)	1.106	0.142	1.075	0.148	2[0.97-1.18]	0.003	0.001		0.025	0.007	2[0.02-0.03]
Grenslandsfjord (st. 71B)	9(7-3)	3.760	6.742	3.720	6.746	9[1.57-23.2]	0.010	0.014	2[0.02-0.04]	0.010	0.022	3[0.05-0.07]
Kristiansand harbour (st. 13B)	6(6-2)	2.504	2.542	2.430	2.524	6[0.74-7.42]	0.015	0.032	5[0.01-0.09]	0.005	0.033	2[0.04-0.09]
Inner Sørfjord (st. 53B)	6(4-6)	3.275	2.028	3.030	1.760	6[1.21-5.59]	0.035	0.362	5[0.004-0.92]	0.080	0.143	6[0.007-0.39]
Bømlo north (st. 23B)	9(5-2)	1.840	1.271	1.810	1.046	9[0.77-3.95]	0.020	0.205	6[0.01-0.64]	0.030	0.127	8[0.02-0.35]
Ålesund area (st. 28B)	4	1.410	34.392	1.320	33.908	3[0.8-68.7]	0.045	0.266	3[0.02-0.56]	0.045	0.220	2[0.06-0.47]
Inner Trondheimsfjord (st. 80B)	15	5.550	3.063	5.300	2.840	15[1.75-13.1]	0.040	0.233	13[0.02-0.92]	0.160	0.085	14[0.03-0.29]
Lofoten, Skrova (st. 98B1)	3(3-6)	0.134	0.127	0.110	0.127	3[0.11-0.33]	0.002	0.002		0.008	0.008	2[0.006-0.02]
Tromsø harbour (st. 43B2)	15(3-3)	4.330	2.780	4.310	2.733	15[0.81-11.1]	0.030	0.102	13[0.01-0.42]	0.005	0.042	7[0.01-0.15]

Considering only α–HBCD, which was the most dominant diastereomers, concentrations in cod liver were significantly higher in the Inner Oslofjord than for seven of the other areas (Tukey-Kramer HSD test) (*Figure 35*). Individual variation was high in cod from the Inner Oslofjord and the Ålesund area. Furthermore, cod liver showed about-100 times higher concentrations than in blue mussel on a wet weight basis (compare *Figure 35* and *Figure 36*). The difference was smaller on a lipid basis. There are some indications of biomagnification for specific diastereomers of HBCD (Haukås 2009).

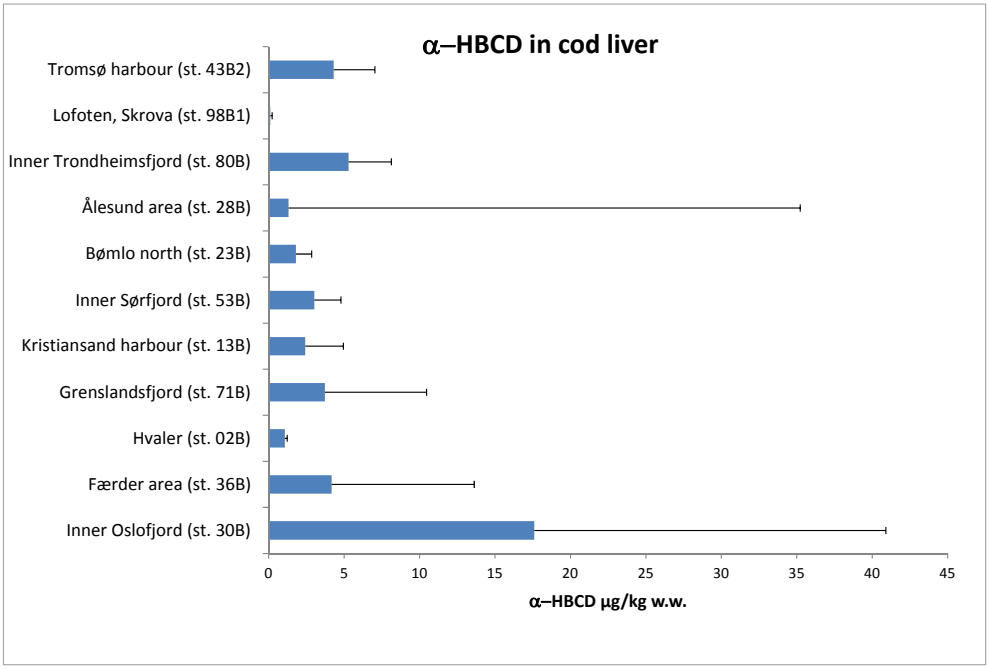

Figure 35. Mean concentration (µg/kg w.w.) of α–HBCD in cod liver in 2013. The error bar indicates one standard deviation above the mean.

Blue mussel from Bergen harbour (Nordnes) had concentrations of α–HBCD that were significantly higher than for all the other stations (Tukey-Kramer HSD test). The levels found in blue mussel from the Inner Oslofjord were significantly higher than for six of the other stations (Tukey-Kramer HSD test). The same level of contamination was found on two other stations in the Inner Oslofjord in 2013 (Ruus *et al.* 2014, in press).

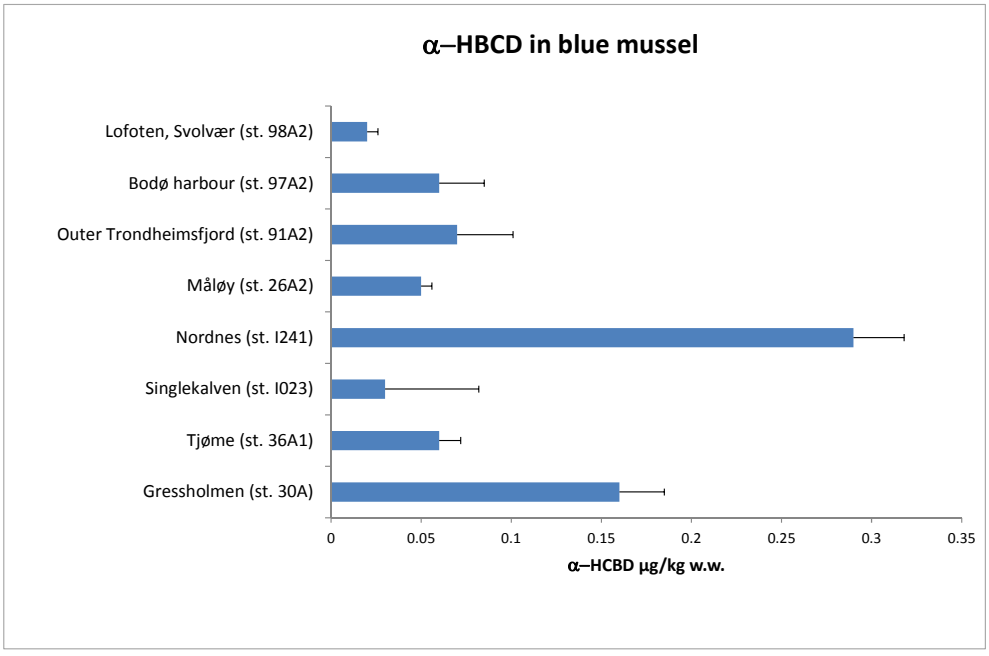

Figure 36. Mean concentration (µg/kg w.w.) of α–HBCD in blue mussel in 2013. The error bar indicates one standard deviation above the mean.

Comparison of concentrations in cod liver and cod fillet (2012 samples) in the same individuals were limited to only two cases (*Table 17*), but indicate that HBCD found in liver is two to four orders of magnitude higher than fillet.

Table 17. Concentration (µg/kg w.w.) of α–, β–, and γ–diastereomers of HBCD in cod liver and fillet. The shaded areas indicate value below the detection limit and that the values shown are one half of the detection limit.

Component	Code	α–HBCD	α-HBCD	β–HBCD	β–HBCD	γ–HBCD	γ–HBCD
Species and sampling localitiy	2012	Liver	Fillet	Liver	Fillet	Liver	Fillet
Cod, liver							
Oslo City area (st. 30B)	301-6	24.500	0.002	0.156	0.002	0.246	0.003
Karihavet area (st. 23B)	231-3	0.351	0.003	0.003	0.003	0.003	0.003

General, large scale

The discharges of HBCD to water from land-based industries showed a decrease from 2004 (12.90 kg HBCD/year) to 2005 (1.50 kg HBCD/year) (*Figure 37*).

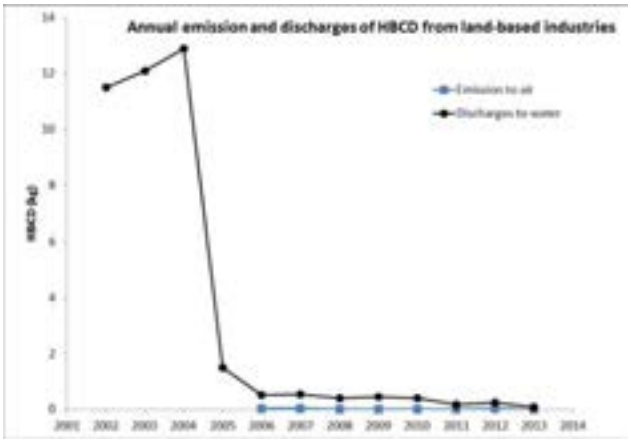

Figure 37. Annual emissions of HBCD to air and discharges to water from land-based industries in the period 2002-2013 (data from www.norskeutslipp.no). No data for emissions to air are reported for 2002-2005. Note that this category excludes emissions and discharges from municipal treatment plants, land runoff, transportation and offshore industry.

3.3.1 Chlorinated paraffins (SCCP and MCCP)

Chlorinated paraffins are subdivided according to their carbon chain length into short chain chlorinated paraffins (SCCPs, C_{10-13}) and medium chain chlorinated paraffins (MCCPs, C_{14-17}). There is an EQS for SCCP in water but not one for biota (cf. 2013/39/EU). SCCPs and MCCPs are classified as persistent with a high potential for bioaccumulation, and are toxic to aquatic organisms. Use and production of SCCPs are prohibited in Norway. However emission from old-.or imported products cannot be excluded. MCCPs are largely used as a flame retardant and as an additive to plastics, such as PVC, to increase flexibility. To a lesser degree MCCPs are used metal machinery as working fluids. MCCPs are mainly released to water in effluent from industry using them as metal working fluids. MCCP is used to a limited extent in Norwegian production, but may be found in imported products. There is, however, considerable uncertainty about the quantities in products used in Norway. There is an indication the discharges from the used of imported products has been reduced by 39 % from 1995 to 2010[8].

The concentration of SCCP in cod liver ranged from 4 to 186 µg/kg w.w., with highest concentration in cod from the Grenlandsfjord (*Figure 38*, *Table 18*). Reth *et al.* (2005) found similar levels of SCCP in cod from the North Sea and the Baltic Sea (19 to 143 ng/g w.w.). Concentrations observed in samples from urban areas are frequently higher than from other more sparsely populated areas.

[8] http://www.miljostatus.no/Tema/Kjemikalier/Noen-farlige-kjemikalier/Klorerte-parafiner/

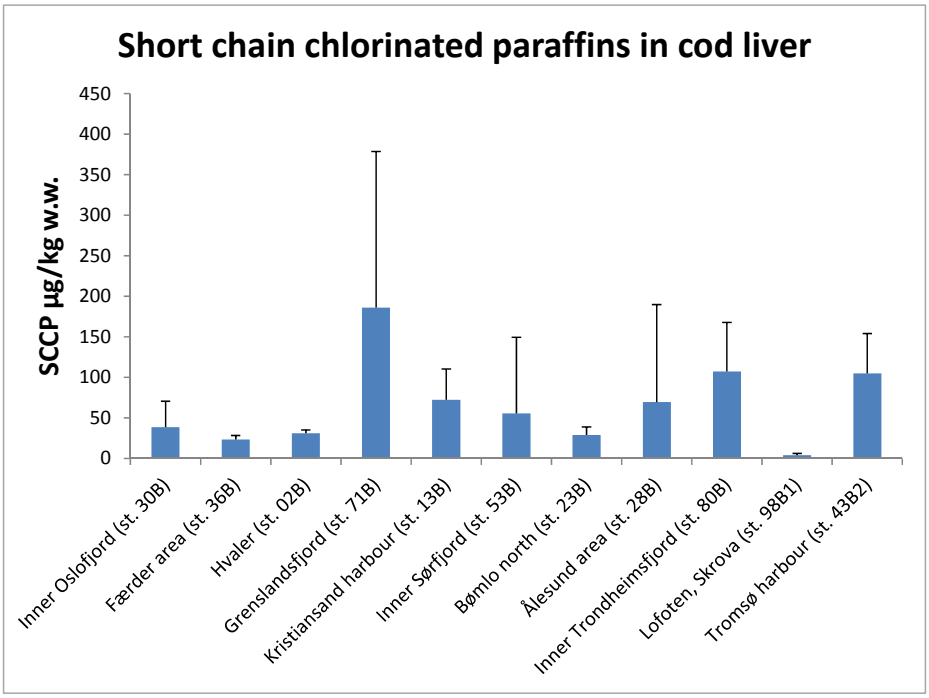

Figure 38. Median concentration (µg/kg w.w.) of SCCP in cod liver in 2013. The error bar indicates one standard deviation above the median.

The concentration of SCCP in blue mussel ranged from 1.23 to 11.3 µg/kg w.w. in this study and the highest concentration was found in the samples from Gressholmen in the Inner Oslofjord (*Figure 39*). In another study performed in 2013 in the Inner Oslofjord, higher concentrations of SCCP were observed (35.0 and 95.0 µg/kg w.w.) (Ruus *et al.* 2014, in press).

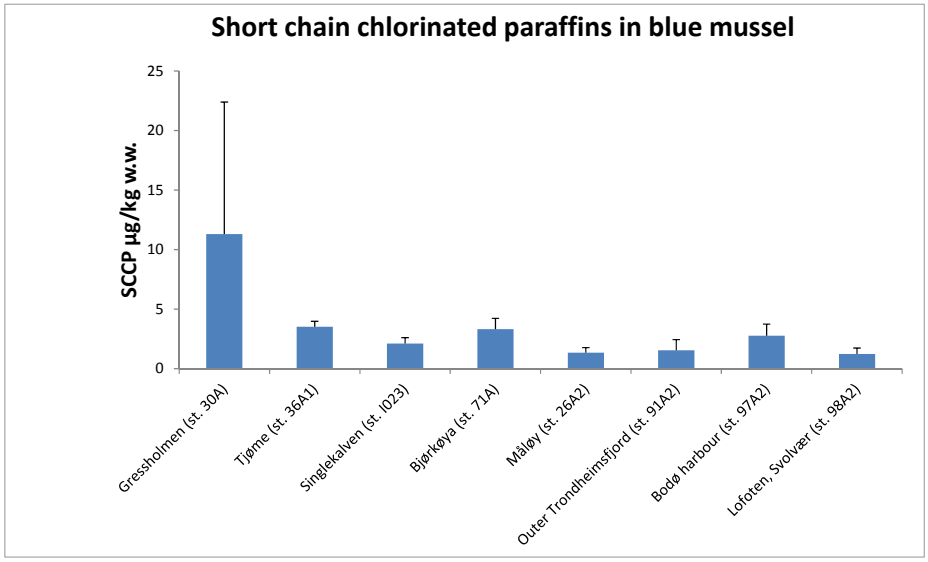

Figure 39. Median concentration (µg/kg w.w.) of SCCP in blue mussel in 2013. The error bar indicates one standard deviation above the median.

Cod from the Inner Trondheimsfjord had highest concentration of MCCPs with 243.0 µg/kg w.w. followed by Kristanasand harbour and Inner Oslofjord (*Figure 40, Table 18*). Cod from the Inner Sørfjord revealed a much higher concentration of MCCPs in 2012 than what is found for cod sampled in 2013. A possible explanation may be related to the high individual variation often observed in contaminated areas and differences in sample size between the two years. In 2012 only four individual samples from the Inner Sørfjord were analysed, whereas in 2013 two individual samples and four bulk samples (each from six cod) were analysed.

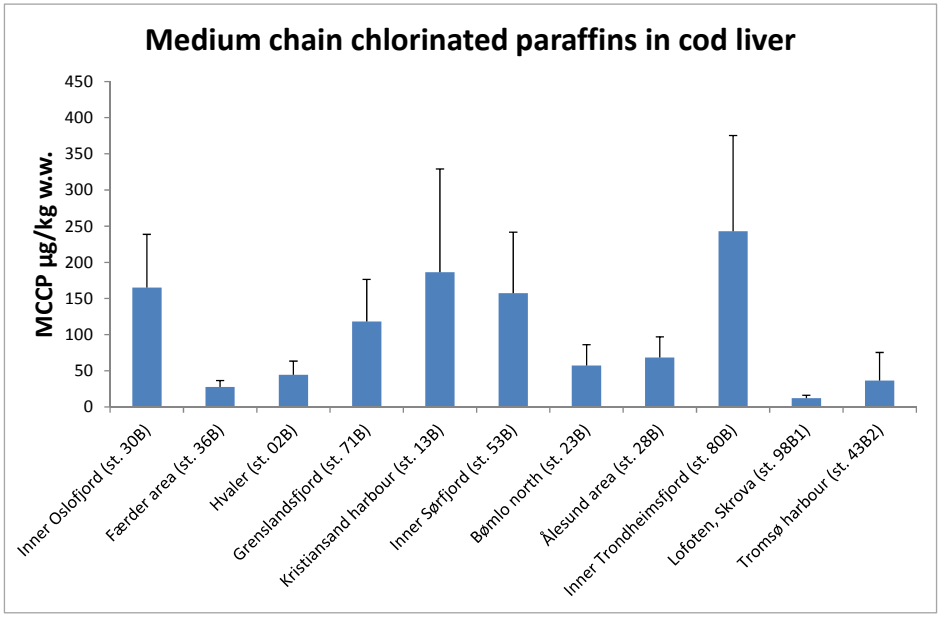

Figure 40. Median concentration (µg/kg w.w.) of MCCPs in cod liver in 2013. The error bar indicates one standard deviation above the median.

The concentration of MCCPs in blue mussel was lower than in cod, and ranged from 1.3 to 104.0 µg/kg w.w. Blue mussel from Gressholmen in the Inner Oslofjord had the highest concentration of MCCPs (*Figure 41*). The concentrations found there were significantly higher than for all the other stations (Tukey-Kramer HSD test). These results warrant further investigations of possible biomagnifying properties of MCCPs as concluded by Houde *et al.* (2008).

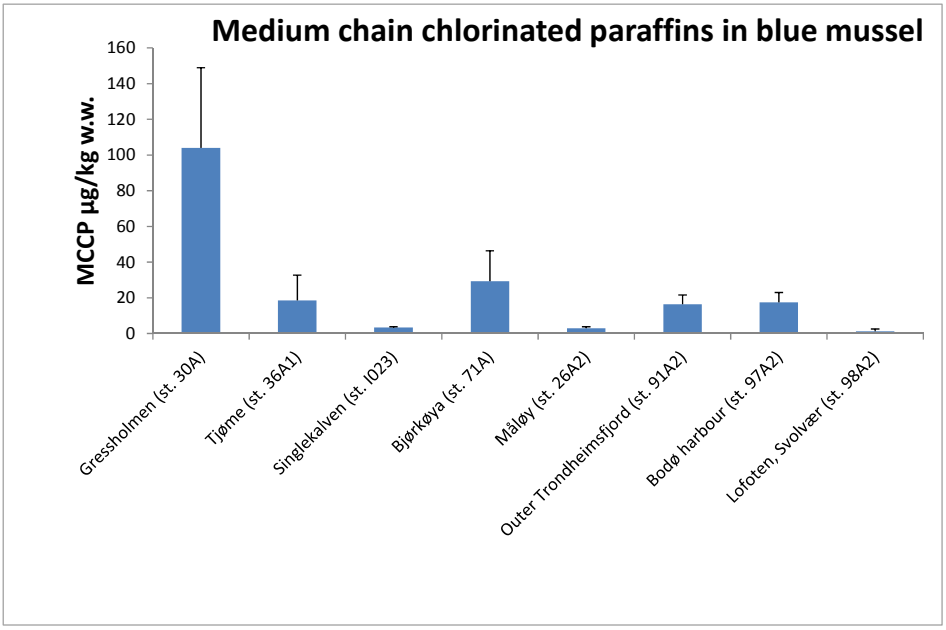

Figure 41. Median concentration (µg/kg w.w.) of MCCPs in blue mussel in 2013. The error bar indicates one standard deviation above the median.

Table 18. Median concentrations (µg/kg w.w.) with standard deviation of SCCPs and MCCPs in cod and blue mussel in 2013. Count indicates number of samples analysed. The first number within the parentheses indicates the number of pooled samples included. The second number within the parentheses indicates for mussels the total number of individuals used in all pooled samples and for cod the number individuals in each pooled sample. Shaded values are below one half the detection limit, and indicate that over half of the values are below this limit. The standard deviation is based on all values. Caution should be used when comparing such values because the limit of detection can vary both within and among samples. Detectable data information (D.d.i.) indicates the number of data above the limit of detection (if any) and the numbers within the square brackets indicate the minimum and maximum values in this category.

Component	Count	SCCP			MCCP		
Species and sampling localitiy	2013	Med.	S.d.	D.d.i	Med.	S.d.	D.d.i
Blue mussel							
Gressholmen (st. 30A)	3(3-204)	11.3	11.1	3[4.5-26.2]	104	44.9	3[34.1-118]
Tjøme (st. 36A1)	2(2-50)	3.52	0.45	2[3.2-3.84]	18.6	14.1	2[8.68-28.6]
Singlekalven (st. I023)	3(3-33)	2.11	0.49	3[1.56-2.53]	3.49	0.37	3[3.02-3.76]
Bjørkøya (st. 71A)	3(3-20)	3.32	0.9	3[2.23-4.02]	29.3	17.1	3[11-45.2]
Måløy (st. 26A2)	3(3-53)	1.33	0.44	3[1.17-1.99]	2.9	0.92	3[2.57-4.3]
Outer Trondheimsfjord (st. 91A2)	3(3-72)	1.55	0.88	3[0.77-2.53]	16.5	5.16	3[10.1-20.3]
Bodø harbour (st. 97A2)	3(3-230)	2.77	0.97	3[1.18-2.94]	17.5	5.58	3[14.5-25.3]
Lofoten, Svolvær (st. 98A2)	3(3-99)	1.23	0.5	3[0.6-1.59]	1.3	1.28	3[1.07-3.39]
Cod, liver							
Inner Oslofjord (st. 30B)	10(4-3)	38.4	32.2	10[17.4-116	165	73.6	10[45.6-289]
Færder area (st. 36B)	3(3-7)	23.1	4.94	3[20.7-30.2]	27.6	9	3[17-34.9]
Hvaler (st. 02B)	2(2-8)	30.8	4.24	2[27.8-33.8]	44.6	18.7	2[31.3-57.8]
Grenslandsfjord (st. 71B)	9(7-3)	186	192	9[88.9-711]	118	58.4	9[63-237]
Kristiansand harbour (st. 13B)	6(6-2)	72.4	37.7	6[32-124]	187	143	6[95.6-486]
Inner Sørfjord (st. 53B)	6(4-6)	55.6	93.7	6[24.6-275]	158	84.2	6[59.3-271]
Bømlo north (st. 23B)	9(5-2)	28.7	9.97	9[16.6-45.5]	57.2	28.8	9[3.56-73]
Ålesund area (st. 28B)	4	69.3	120	4[10.9-283]	68.4	28.7	4[41.6-109]
Inner Trondheimsfjord (st. 80B)	15	107	60.7	15[17-250]	243	132	15[14.5-457]
Lofoten, Skrova (st. 98B1)	3(3-6)	3.89	2.32	3[3.1-7.45]	12.1	3.92	3[8.9-16.7]
Tromsø harbour (st. 43B2)	15(3-3)	105	48.9	15[49.9-206	36.6	38.7	15[16.5-161]

Comparison of concentrations in cod liver and cod fillet (2012 samples) in the same individuals were limited to three cases from the Inner Trondheimsfjord and eight cases from Tromsø harbour (*Table 19*), and show that levels of SCCPs and MCCPs in liver were two to three orders of magnitude higher than in fillet. However, the correlation was poor for both SCCP and MCCP with R^2= 0.08 and 0.11, respectively. On a lipid weight basis there is a better but still poor correlation; r^2 was 0.19 and 0.30, respectively, on a lipid weight basis (*Table 20*, *Figure 42*). An r^2 of one would be a perfect correlation. Though concentrations in liver were generally higher than in fillet (by a factor of 3.9 and 4.5 for SCCP and MCCP, respectively), higher concentrations in liver corresponded to lower concentrations in fillet.

Table 19. Concentration (µg/kg w.w.) of SCCP and MCCP in cod liver and fillet.

Component Species and sampling localitiy	Code 2012	Liver lipid %	Fillet lipid %	SCCP Liver	SCCP Fillet	MCCP Liver	MCCP Fillet
Cod							
Inner Trondheimsfjord (st. 80B)	801-11	46	0.4	37.5	0.3	139.0	2.9
Inner Trondheimsfjord (st. 80B)	801-7	46.7	0.4	53.4	0.467	96	0.832
Inner Trondheimsfjord (st. 80B)	801-9	56.8	0.4	13.40	0.37	48.80	6.15
Tromsø harbour (st. 43B2)	9431-1	19.8	0.4	25.70	0.07	39.10	0.46
Tromsø harbour (st. 43B2)	9431-11	55.9	0.3	51.9	0.19	132	0.55
Tromsø harbour (st. 43B2)	9431-13	36.4	0.4	65.6		118	0.17
Tromsø harbour (st. 43B2)	9431-2	61.3	0.4	57.3	0.19	132	0.81
Tromsø harbour (st. 43B2)	9431-3	44.9	0.4	97.1	0.23	79.7	1.24
Tromsø harbour (st. 43B2)	9431-4	29.9	0.3	52.50	0.11	65.70	0.12
Tromsø harbour (st. 43B2)	9431-5	64.7	0.5	62.20	0.22	143.00	0.04
Tromsø harbour (st. 43B2)	9431-8	58.1	0.4	85.70	0.04	131.00	0.37

Table 20. Correlation (r^2) between SCCP and MCCP in cod liver and fillet on wet weight (w.w.) and lipid weight (l.w.) basis in cod liver and fillet from the Inner Trondheimsfjord and Tromsø harbour.

	Count 2012	w.w.	l.w.
SCCP	11	0.08	0.19
MCCP	11	0.11	0.30

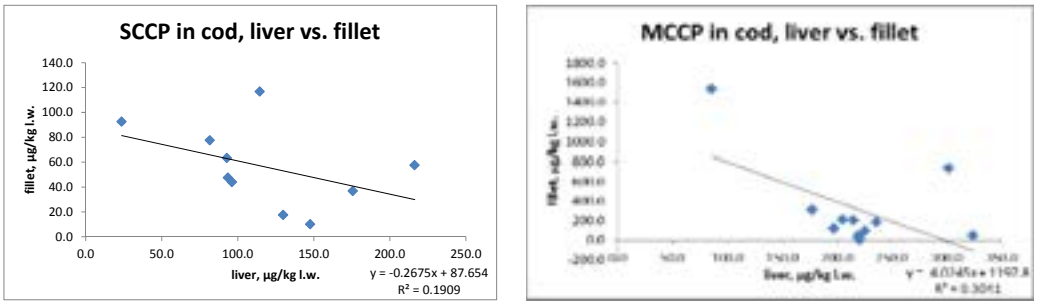

Figure 42. Correlation between concentrations (mg/kg l.w.) of SCCP and MCCP in cod liver and fillet from the Inner Trondheimsfjord and Tromsø harbour.

3.3.2 Organophosphorus flame retardants (PFRs)

Many of the PFRs are persistent and bioaccumulative. Some of the PFRs are classified as hazardous to the environment. These include: tri(2-chloroethyl)phosphate (TCEP), 2-ethylhexyl-di-phenylphosphate (EHDPP), tri(1,3-dichloro-2-propyl)phosphate (TDCP), tricresyl phosphate (TCrP) and triphenylphosphate (TPhP). TCEP is classified as harmful to reproduction. Some of the PFRs are suspected to be carcinogenic (TBP, TCEP and TDCP). TCEP is on the priority list of Norwegian Environment Agency[9]. These substances are used *inter alia* as a softener in vinyl plastics, as a flame retardant and as an additive in hydraulic fluids (van der Veen & de Boer, 2012). However there is no registered used of these substances and there is considerable uncertainty as to the quantities used in products in Norway.

The concentrations of PFRs were low; most of the results were below the detection limits (*Table 21*). The detection limits for mussels were lower or nearly the same as those found by Green *et al.* (2008b), but considerably higher (generally 2-10 times) in cod liver. It should be noted that PFRs are generally difficult to separate from the lipid portion of a sample even following extra clean-up, as was the case in this study. The difficulty to separate PFRs can lead to analytical interference and often result in a higher detection limit. This problem can vary from sample to sample. Hence more variable and higher detection limits can be found when compared to other contaminant groups such as PCBs (*Table 12*), PBDEs (*Table 13*) or PFAS (*Table 15*).

Comparison of concentrations in cod liver and cod fillet (2012 samples) in the same individuals were limited to ten cases from Tromsø harbour, however with one exception the median values were below the limit of detection for both tissues (*Table 22*). The exception was for TCPP that was detected in fillet in seven fish but the median value for the corresponding liver samples was below the limit of detection. The limit of detection for liver was higher than for fillet.

[9] *http://www.miljostatus.no/Tema/Kjemikalier/Kjemikalielister/Prioritetslisten/*

Table 21. Median concentrations (µg/kg w.w.) with standard deviation of PFRs in cod liver in 2013. Count indicates number of samples analysed. The first number within the parentheses indicates the number of pooled samples included. The second number within the parentheses indicates for mussels the total number of individuals used in all pooled samples and for cod the number individuals in each pooled sample. Shaded values are below one half the detection limit, and indicate that over half of the values are below this limit. The standard deviation is based on all values. Caution should be used when comparing such values because the limit of detection can vary both within and among samples. Detectable data information (D.d.i.) indicates the number of data above the limit of detection (if any) and the numbers within the square brackets indicate the minimum and maximum values in this category. (See description of abbreviations in Appendix B).

Component	Count	EHDPP			TBEP			TBP			TCEP			TCPP		
Species and sampling localitiy	2013	Med.	S.d.	D.d.i.	Med.	S.d.	D.d.i.	Med.	S.d.	D.d.i.	Med.	S.d.	D.d.i.	Med.	S.d.	D.d.i.
Blue mussel																
Gressholmen (st. 30A)	3(3-204)	1.5	1.0		3.5	0.6		1.5	0.6		27.5	1.7		33.3	1.8	3[32.7-36.1]
Singlekalven (st. I023)	3(3-33)	0.6	0.4		2.4	0.2		2.4	0.2		18.6	1.4				
Nordnes (st. I241)	1(1-20)	2.3	0.0		9.0	0.0		9.0	0.0		22.5	0.0		4.5	0.0	
Måløy (st. 26A2)	3(3-53), 2(2-53)*	1.3	4.8		3.5	0.3		2.0	2.0		28.0	2.6		40.4	0.5	3[40.2-41.2]
Outer Trondheimsfjord (st. 91A2)	2(2-58)	4.7	3.8		8.9	0.2		8.9	0.2		22.3	0.5		4.5	0.1	
Bodø harbour (st. 97A2)	3(3-230)	26.7	9.9	3[14.6-34.2]	3.5	0.6		1.0	1.2		27.5	3.6		38.8	3.0	3[37.4-43.1]
Lofoten, Svolvær (st. 98A2)	3(3-99)	0.5	1.2		3.5	0.6		2.0	1.2		26.5	2.1		35.0	1.6	3[34.7-37.6]
Cod, liver																
Inner Oslofjord (st. 30B)	8(2-3), 10(4-3)**	16.0	20.9		60.0	20.4		59.8	28.0		468.5	220.5		29.8	8.7	1[59.4]
Færder area (st. 36B)	3(3-7)	8.6	0.8		46.3	62.9		22.8	1.3		178.5	10.4				
Hvaler (st. 02B)	2(2-8)	10.4	0.5		41.7	1.8		41.7	1.8		104.3	5.0		20.9	1.0	
Grenslandsfjord (st. 71B)	9(7-3)	24.9	16.1		66.0	33.3		66.0	33.3		165.5	83.4		33.1	16.7	
Kristiansand harbour (st. 13B)	6(6-2)	25.8	65.1		44.7	65.1		39.2	8.8		98.0	21.9		19.6	4.4	
Inner Sørfjord (st. 53B)	6(4-6)	13.8	24.6		45.6	18.3		42.1	21.3		105.0	53.2		21.0	16.6	1[70.6]
Bømlo north (st. 23B)	9(5-2)	19.3	57.9		51.0	29.8		51.0	30.0		127.0	75.3		25.5	15.1	
Ålesund area (st. 28B)	4	23.1	18.1		40.1	34.3		40.1	34.3		100.3	85.8		20.1	17.1	
Inner Trondheimsfjord (st. 80B)	15	17.2	21.4	2[82.3-88.1]	58.5	14.0		58.5	14.0		146.5	34.7		29.3	7.0	1[143.0]
Lofoten, Skrova (st. 98B1)	1(1-6)	49.8	0.0		44.9	0.0		44.9	0.0		352.5	0.0		22.5	0.0	
Tromsø harbour (st. 43B2)	15(3-3)	25.0	19.2		66.0	20.6		66.0	20.6		164.5	51.4		32.9	20.8	

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*) Count 2(2-53) concerns TCrP

**) Count 10(4-3) concerns TBEP, TBP, TCEP and TIBP

Table 21. (cont.)

Component	Count	TCrP			TDCP			TEHP			TIBP			TOCRP			TPhP		
Species and sampling localitiy	**2013**	**Med.**	**S.d.**	**D.d.i.**	**Med.**	**S.d.**	**D.d.i.**	**Med.**	**S.d.**	**D.d.i.**	**Med.**	**S.d.**	**D.d.i.**	**Med.**	**S.d.**	**D.d.i.**	**Med.**	**S.d.**	**D.d.i.**
Blue mussel																			
Gressholmen (st. 30A)	3(3-204)	188.5	75.9		4.0	6.9		3.0	2.1		3.5	0.6		45.0	2.9		2.0	0.6	
Singlekalven (st. I023)	3(3-33)				1.2	0.1		1.8	0.1		2.4	0.2		35.6	2.7		1.8	0.1	
Nordnes (st. I241)	1(1-20)	133.0	0.0		4.5	0.0		6.8	0.0		9.0	0.0		135.0	0.0		6.8	0.0	
Måløy (st. 26A2)	3(3-53), 2(2-53)*	132.8	43.1		2.0	2.3		3.0	0.0		3.5	0.0		46.0	1.5		2.0	0.0	
Outer Trondheimsfjord (st. 91A2)	2(2-58)	131.5	2.8		4.5	0.1		12.0	1.1		8.9	0.2		134.0	2.8		6.7	0.2	
Bodø harbour (st. 97A2)	3(3-230)	149.5	39.1		8.0	15.1		7.5	14.4		3.5	0.0		45.5	6.2		2.5	0.8	
Lofoten, Svolvær (st. 98A2)	3(3-99)	103.5	5.0		6.0	7.8		3.5	1.5		3.5	0.0		44.0	3.5		2.0	0.0	
Cod, liver																			
Inner Oslofjord (st. 30B)	8(2-3), 10(4-3)**	927.5	255.3		29.8	8.7		67.8	231.1		25.3	40.0		890.0	1210.5		44.8	13.2	
Færder area (st. 36B)	3(3-7)				11.4	0.7		79.5	77.4		22.8	1.3		341.0	19.9		17.1	0.9	
Hvaler (st. 02B)	2(2-8)	692.5	190.9		20.9	1.0		151.0	76.4		41.7	1.8		625.0	28.3		31.3	1.5	
Grenslandsfjord (st. 71B)	9(7-3)	990.0	500.8		33.1	16.7		61.0	179.9		66.0	33.3		995.0	499.8		49.7	25.0	
Kristiansand harbour (st. 13B)	6(6-2)	787.5	260.9		19.6	4.4		210.5	339.3		39.2	8.8		680.0	381.5		29.4	6.6	
Inner Sørfjord (st. 53B)	6(4-6)	640.0	403.1		21.0	16.1	1[69.0]	155.0	272.5		42.1	21.3		630.0	385.2		31.6	20.3	
Bømlo north (st. 23B)	9(5-2)	850.0	419.0		25.5	17.0		292.0	430.8		51.0	30.0		765.0	715.2		38.2	22.5	
Ålesund area (st. 28B)	4	592.3	481.5		20.1	17.1		111.5	96.2		40.1	34.3		601.3	504.3		30.1	25.7	
Inner Trondheimsfjord (st. 80B)	15	970.0	253.8		29.3	7.0		51.5	141.2		58.5	14.0		890.0	214.8	1[69.0]	44.4	14.5	2[143.0-162.0]
Lofoten, Skrova (st. 98B1)	1(1-6)	755.0	0.0		22.5	0.0		56.0	0.0		44.9	0.0		1385.0	0.0		33.7	0.0	
Tromsø harbour (st. 43B2)	15(3-3)	1060.0	450.1		33.6	18.1		110.0	117.5		66.0	20.6		1000.0	352.3		50.5	24.1	

*) Count 2(2-53) concerns TCrP

**) Count 10(4-3) concerns TBEP, TBP, TCEP and TIBP

Table 22. Concentration (µg/kg w.w.) of PFRs in cod liver and fillet. The shaded areas indicate value below the detection limit and that the values shown are one half of the detection limit.

Component	Code	TBEP	TBEP	TBP	TBP	TCEP	TCEP	TCPP	TCPP	TCrP	TCrP	TDCP	TDCP	TPhP	TPhP
Species and sampling localitiy	**2012**	**Liver**	**Fillet**	**Liver**	**Fillet**	**Liver**	**Fillet**	**Liver**	**Fillet**	**Liver**	**Fillet**	**Liver**	**Fillet**	**Liver**	**Fillet**
Cod															
Tromsø harbour (st. 43B2)	9431-1	61.5	5	2.825	1	101	30	2.44	1	106	50.5	6.25	2.5	6.95	2
Tromsø harbour (st. 43B2)	9431-10	31.35	4.25	6.95	1	247	32.5	6	1	310.5	54	15.25	2	17	2.5
Tromsø harbour (st. 43B2)	9431-11	22.75	4.5	8.35	1	179.5	32.5	7	3.18	720	54	11.05	2.25	12.35	2.5
Tromsø harbour (st. 43B2)	9431-13	29	4	18.25	1	174	32.5	4.32	2.58	304	53.5	13.9	2	12	2.5
Tromsø harbour (st. 43B2)	9431-2	25	5	5.5	1	197	32.5	4.765	3.28	404	54	12.15	2.5	13.55	2.5
Tromsø harbour (st. 43B2)	9431-3	54.5	4.5	12.1	1	431	35	10.45	3.21	227.5	54	26.6	2.5	29.65	2.5
Tromsø harbour (st. 43B2)	9431-4	18.55	4	4.095	1	146	32.5	3.535	2.62	1005	53	9	2	14.65	2.5
Tromsø harbour (st. 43B2)	9431-5	26	4.5	5.75	1	205	35	4.96	5.28	187.5	57	12.65	2.5	14.1	2.5
Tromsø harbour (st. 43B2)	9431-6		4.5		1		32.5		3.86		54		2.25		2.5
Tromsø harbour (st. 43B2)	9431-8	33.6	4	7.4	1.25	265	32.5	6.4	1	940	54	22.45	2	20.95	2.5

3.3.3 Bisphenol A (BPA)

Bisphenol A is derived from epoxy resins and polycarbonate plastics (Belfroid *et al.*2002). Bisphenol A has been produced in large quantities world wide and therefore can be considered ubiquitous (Flint *et al.* 2012). It is an endocrine disruptor which can mimic oestrogen, and is also carcinogenic. Studies have shown that BPA can affect growth, reproduction and development in aquatic organisms. Bisphenol A is on the priority list of Norwegian Environment Agency[10] In a recent study bisphenol A was detected in 75 % of the cod liver samples from Byfjorden, Bergen, in the concentration range <4 – 46.3 ng/g w.w. (Langford *et al.* 2012).

The median concentrations of bisphenol A found in blue mussel were below the detection limit, and only two samples had concentrations above the detection limit (*Table 23*). Hence, no conclusion can be drawn regarding possible differences between stations. In another study, blue mussel from Bekkelaget in the Inner Oslofjord revealed concentration of BPA of 0.32 µg/kg w.w., and two other stations had concentrations below detection limit (Ruus *et al.* 2014, in press).

For all but one of the stations the concentrations of bispehol A in cod liver were below the detection limit (*Table 23*). In cod from Bømlo north detectable concentrations were found in four liver samples (1.1 to 6.4 µg/kg w.w.).

Table 23. Median concentrations (µg/kg w.w.) with standard deviation of bisphenol A (BPA) in mussel and cod liver in 2013. The first number within the parentheses indicates the number of pooled samples included. The second number within the parentheses indicates for mussels the total number of individuals used in all pooled samples and for cod the number individuals in each pooled sample. Shaded values are below one half the detection limit, and indicate that over half of the values are below this limit. The standard deviation is based on all values. Caution should be used when comparing such values because the limit of detection can vary both within and among samples. Detectable data information (D.d.i.) indicates the number of data above the limit of detection (if any) and the numbers within the square brackets indicate the minimum and maximum values in this category.

Component	Count	BPA		
Species and sampling localitiy	2013	Med.	S.d.	D.d.i.
Blue mussel				
Gressholmen (st. 30A)	3(3-204)	0.5	0.0	
Tjøme (st. 36A1)	3(3-50)	0.5	0.0	
Singlekalven (st. I023)	3(3-33)	0.5	0.0	
Bjørkøya (st. 71A)	3(3-20)	0.5	0.3	1[1.6]
Nordnes (st. I241)	2(2-20)	0.5	0.0	
Måløy (st. 26A2)	3(3-53)	0.5	0.0	
Outer Trondheimsfjord (st. 91A2)	3(3-72)	0.5	0.0	
Bodø harbour (st. 97A2)	3(3-230)	0.5	0.6	1[2.0]
Lofoten, Svolvær (st. 98A2)	3(3-99)	0.5	0.0	
Cod, liver				
Inner Oslofjord (st. 30B)	10(4-3)	0.5	0.0	
Færder area (st. 36B)	3(3-7)	0.5	0.0	
Hvaler (st. 02B)	2(2-8)	25.0	0.0	
Grenslandsfjord (st. 71B)	9(7-3)	10.0	22.6	
Kristiansand harbour (st. 13B)	6(6-2)	1.0	3.5	
Inner Sørfjord (st. 53B)	5(4-6)	1.0	2.0	
Bømlo north (st. 23B)	8(4-2)	1.0	1.8	4[1.1-6.4]
Ålesund area (st. 28B)	4	1.0	0.0	
Inner Trondheimsfjord (st. 80B)	14	1.0	1.1	
Tromsø harbour (st. 43B2)	15(3-3)	1.0	0.0	

[10] *http://www.miljostatus.no/Tema/Kjemikalier/Kjemikalielister/Prioritetslisten/*

Comparison of concentrations in cod liver and cod fillet (2012 samples) in the same individuals were assessed for 14 cases from four areas (*Table 24*). All concentrations in fillet were below the limit of detection (1 µg/kg w.w.). Eight of the fourteen results for liver were above the limit of detection (1.2-76.6 µg/kg w.w.). BPA detected in liver was 2-153 times higher than fillet.

Table 24. Concentration (µg/kg w.w.) of BPA in cod liver and fillet. The shaded areas indicate value below the detection limit. The values shown are one half of the detection limit.

Component	Code	BPA	BPA
Species and sampling localitiy	2012	Liver	Fillet
Cod			
Oslo City area (st. 30B)	301-11	3.87	0.50
Oslo City area (st. 30B)	301-12	76.60	0.50
Oslo City area (st. 30B)	301-6	1.18	0.50
Grenlandsfjord, Brevik area (st. 71B)	711-3	50.30	0.50
Grenlandsfjord, Brevik area (st. 71B)	711-4	4.15	0.50
Karihavet area (st. 23B)	231-10	30.30	0.50
Karihavet area (st. 23B)	231-14	17.80	0.50
Karihavet area (st. 23B)	231-15	10.50	0.50
Karihavet area (st. 23B)	231-3	0.50	0.50
Karihavet area (st. 23B)	231-4	0.50	0.50
Munkholmen, Inner Trondheimsfjord (st. 80B)	801-1	0.50	0.50
Munkholmen, Inner Trondheimsfjord (st. 80B)	801-2	0.50	0.50
Munkholmen, Inner Trondheimsfjord (st. 80B)	801-3	0.50	0.50
Munkholmen, Inner Trondheimsfjord (st. 80B)	801-6	0.50	0.50

3.3.4 Tetrabrombisphenol A (TBBPA)

Tetrabrombisphenol A is a brominated flame retardant. TBBPA is an endocrine disruptor and immunotoxicant.

Concentrations of TBBPA found in cod liver and fillet were below the limit of detection for all samples except for one (*Table 25*). The exception was for liver in one cod that had a concentration of 0.77 µg/kg w.w.

Table 25. Concentration (µg/kg w.w.) of TBBPA in cod liver and fillet. The shaded areas indicate value below the detection limit and that the values shown are one half of the detection limit.

Component	Code	TBBPA	TBBPA
Species and sampling localitiy	2012	Liver	Fillet
Cod			
Oslo City area (st. 30B)	301-11	0.77	0.01
Oslo City area (st. 30B)	301-12	0.02	0.01
Oslo City area (st. 30B)	301-6	0.09	0.04
Grenlandsfjord, Brevik area (st. 71B)	711-3	0.06	0.01
Grenlandsfjord, Brevik area (st. 71B)	711-4	0.08	0.01
Karihavet area (st. 23B)	231-10	0.06	0.02
Karihavet area (st. 23B)	231-14	0.04	0.01
Karihavet area (st. 23B)	231-15	0.08	0.01
Karihavet area (st. 23B)	231-3	0.04	0.04
Karihavet area (st. 23B)	231-4	0.09	0.01
Munkholmen, Inner Trondheimsfjord (st. 80B)	801-1	0.08	0.01
Munkholmen, Inner Trondheimsfjord (st. 80B)	801-2	0.08	0.01
Munkholmen, Inner Trondheimsfjord (st. 80B)	801-3	0.03	0.01
Munkholmen, Inner Trondheimsfjord (st. 80B)	801-6	0.03	0.04

3.3.5 Phthalates

Phthalates are mainly used as plasticizers and have large variety of usages such as in paints, building products, lubricants, dispersants, emulsifiers, electronics as well as personal-care products, pharmaceuticals, medical devices and food products. Phthalate comprise a number of substances one of which (di(2-thylhexyl)-phthalate or DEHP) is on the EQSD list a priority hazardous substances but has no EQS for biota. Eleven phthalates, including DEHP, were analysed in 2012 samples and for the first time as part of the MILKYS programme. In Norway since 1999 phthalates have been prohibited in toys and products for children less than three years of age. From January 1 2007 it has been prohibited for all toys for children to the age of 14.

Concentrations in cod liver-samples from 2012 were assessed for 18 cases in five fjord areas: the Oslofjord area, Grenlandsfjord area, South of Norway, Inner Sørfjord and the Varangerfjord (*Table 26*). All values were below the limit of detection, which varied from 0.15 mg/kg w.w. for BBP and DIPA to 1 mg/kg w.w. for DEHA. Bakke *et al.* (2007) found concentrations of DEHP in cod liver Oslofjord, Ålesund, Tromsø and Varanger to vary from 0.3 (Tromsø) to 55.7 (Varangerfjord) mg/kg w.w.

Table 26. Median concentration (mg/kg w.w.) of phthalates in cod liver. The shaded areas indicate value below the detection limit and that the values shown are one half of the detection limit.

Component	Count	BBP	DBP	DBPA	DEHA	DEHP	DEP	DEPA	DIBP	DIDP	DIHP	DINCH	DIPA	DMP	DNOP	DPF
Species and sampling localitiy	**2012**	**Med.**	**Med.**	**Med.**	**Med.**	**Med.**	**Med.**	**Med.**	**Med.**	**Med.**	**Med.**	**Med.**	**Med.**	**Med.**	**Med.**	**Med.**
Cod, liver																
Oslo City area (st. 30B)	5	0.15	0.25	0.25	1.00	0.50	0.25	0.25	0.25	2.50	2.50	0.25	0.15	0.25	0.25	0.25
Grenlandsfjord, Brevik area (st. 71B)	2	0.15	0.25	0.25	1.00	0.50	0.25	0.25	0.25	2.50	2.50	0.25	0.15	0.25	0.25	0.25
Gåsøy (Ullerø), Kristiansand area (st. 15A)	5	0.15	0.25	0.25	1.00	0.50	0.25	0.25	0.25	2.50	2.50	0.25	0.15	0.25	0.25	0.25
Inner Sørfjord (st. 53B)	3	0.15	0.25	0.25	1.00	0.50	0.25	0.25	0.25	2.50	2.50	0.25	0.15	0.25	0.25	0.25
Varangerfjord (st. 10B)	3	0.15	0.25	0.25	1.00	0.50	0.25	0.25	0.25	2.50	2.50	0.25	0.15	0.25	0.25	0.25

3.3.6 Alkylphenols

These substances are used in manufacturing antioxidants, lubricating oil additives, household detergents. They are also precursors for commercially important surfactants. Nonylphenol and octylphenol are two aklyphenols and are on the EQSD list of priority hazardous substances but have no EQS for biota. They were analysed in 2012 samples and for the first time as part of the MILKYS programme. In Norway since 2005 it has been prohibited to produce, import, export, sell or use nonylphenols, octylphenols or their etoxsilates with the exception of paints, varnish, lubricants and finished products.

Comparison of concentrations in cod liver and cod fillet in the same individuals were assessed for 14 cases: three from the Inner Oslofjord area, three from the Grenlandsfjord area, five from Bømlo north on the West coast, eight from the Inner Trondheimsfjord and six from Tromsø harbour (*Table 27*). Highest concentrations were found in liver tissue of cod from the Inner Oslofjord (Oslo city area) with an average of 43.1 and 18.4 µg/kg w.w. for 4-n-nonylphenol and 4-tert-octylphenol, respectively, for three samples. For all cod fillet samples, the median concentrations were below the limit of detection.

Table 27. Concentrations (µg/kg w.w.) of phenols in cod liver and fillet. The shaded areas indicate value below the detection limit and that the values shown are one half of the detection limit.

Component	Code	4-n-NP	4-n-NP	4-n-OP	4-n-OP	4-t-NP	4-t-NP	4-t-OP	4-t-OP
Species and sampling localitiy	2012	Liver	Fillet	Liver	Fillet	Liver	Fillet	Liver	Fillet
Cod									
Oslo City area (st. 30B)	301-11	4.02	2.5	19.2	5	n.a.	10	23.6	2.5
Oslo City area (st. 30B)	301-12	35.3	2.5	2.5	5	25.6	10	5	2.5
Oslo City area (st. 30B)	301-6	90.1	2.5	24.9	5	n.a.	10	26.7	2.5
Grenlandsfjord, Brevik area (st. 71B)	711-3	11.2	2.5	2.5	5	43.9	10	5	2.5
Grenlandsfjord, Brevik area (st. 71B)	711-4	2.5	2.5	28.3	5	n.a.	10	2.5	2.5
Grenlandsfjord, Brevik area (st. 71B)	711-7	n.a.	2.5		5		10		2.5
Karihavet area (st. 23B)	231-10	3.46	2.5	24	5	n.a.	10	13.8	2.5
Karihavet area (st. 23B)	231-14	29.9	2.5	12.9	5	90.6	10	6.64	2.5
Karihavet area (st. 23B)	231-15	2.23	2.5	24.1	5	n.a.	10	78.6	2.5
Karihavet area (st. 23B)	231-3	59.5	2.5	13.8	5	n.a.	10	9.19	2.5
Karihavet area (st. 23B)	231-4	32.7	2.5	14.8	5	n.a.	10	23.3	2.5
Munkholmen, Inner Trondheimsfjord (st. 80B)	801-1	2.5	2.5	19.6	5	n.a.	10	2.5	2.5
Munkholmen, Inner Trondheimsfjord (st. 80B)	801-11	2.5	2.5	13.4	5	87.6	10	2.5	2.5
Munkholmen, Inner Trondheimsfjord (st. 80B)	801-2	2.5	2.5	14.3	5	85.6	10	2.5	2.5
Munkholmen, Inner Trondheimsfjord (st. 80B)	801-3	2.5	2.5	9.34	5	20	10	2.5	2.5
Munkholmen, Inner Trondheimsfjord (st. 80B)	801-6	2.5	2.5	10.1	5	10	10	2.5	2.5
Munkholmen, Inner Trondheimsfjord (st. 80B)	801-7	2.5	2.5	19.3	5	n.a.	10	2.5	2.5
Munkholmen, Inner Trondheimsfjord (st. 80B)	801-8	2.5	2.5	15.5	5	93.2	10	2.5	2.5
Munkholmen, Inner Trondheimsfjord (st. 80B)	801-9	2.5	2.5	17.3	5	n.a.	10	2.5	2.5
Tromsø harbour (st. 43B2)	9431-1	2.5	2.5	2.5	5	38.1	10	5	2.5
Tromsø harbour (st. 43B2)	9431-2	2.5	2.5	2.5	5	32.8	10	5	2.5
Tromsø harbour (st. 43B2)	9431-3	2.5	2.5	2.5	5	29.6	10	5	2.5
Tromsø harbour (st. 43B2)	9431-4	2.5	2.5	2.5	5	39.2	10	5	2.5
Tromsø harbour (st. 43B2)	9431-5	2.5	2.5	2.5	5	24.4	10	5	2.5
Tromsø harbour (st. 43B2)	9431-6		2.5		5		10		2.5

General, large scale

The discharges from land-based industries to water varied between 1.6 tonn phenols in 2002 to 4.7 tonn phenols in 2008 in the period 2002-2013 (*Figure 43*).

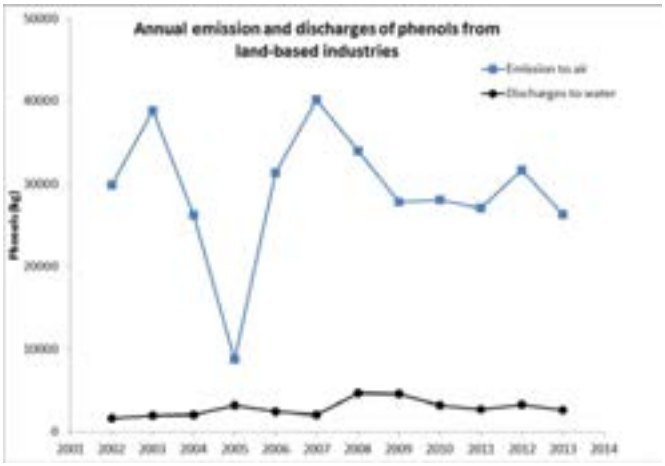


Figure 43. Annual emissions of phenols to air and discharges to water from land-based industries in the period 2002-2013 (data from www.norskeutslipp.no). Note that this category excludes emissions and discharges from municipal treatment plants, land runoff, transportation and offshore industry.

3.4 Biological effects methods for cod in the Inner Oslofjord

Biological effect parameters (BEM) are included in the monitoring program to assess the potential pollution effects on organisms. This cannot be done solely on the basis of tissue concentrations of chemicals. There are five BEM methods used (including analyses of degradation products of PAH in bile). Each method is in theory specific for individual or groups of chemicals. One of the advantages of these methods used at the individual level is the ability to integrate biological and chemical endpoints, since both approaches are performed on the same individuals. The results can be seen in relation to newly established reference values (e.g. ICES 2011).

3.4.1 OH-pyrene metabolites in bile

Analysis of OH-pyrene in bile is not a measurement of biological effects, per se. It is included here, however, since it is a result of biological transformation (biotransformation) of PAHs, and is thus a marker of exposure. Detection methods for OH-pyrene have been improved two times since the initiation of these analyses in the CEMP programme. In 1998, the wavelength for measurement of light absorbance of the support/normalisation parameter biliverdine was changed to 380 nm. In 2000, the use of single-wavelength fluorescence for quantification of OH-pyrene was replaced with HPLC separation proceeding fluorescence detection. The single wavelength fluorescence method is much less specific than the HPLC method. Although there is a good correlation between results from the two methods, they cannot be compared directly.

PAH compounds are effectively metabolized in vertebrates. As such, when fish are exposed to and take up PAHs, the compounds is biotransformed into polar metabolites which enhances the efficiency of excretion. It is therefore not suitable to analyse fish tissues for PAH parent compounds as a measure of exposure. However, since the bile is a dominant excretion route of PAH metabolites, and since the metabolites are stored for some time in the gall bladder, the bile is regarded as a suitable matrix for analyses of PAH metabolites as a measure of PAH exposure.

In 2013 the median concentration of OH-pyrene metabolites in bile from cod in the Inner Oslofjord (st. 30B) were about 21 % lower than the 2012-concentration and 41 % lower than the 2011-concentration. However, no significant temporal trend could be observed over the last 10 years (Appendix F). Median OH-pyrene bile concentration in 2013 was above the ICES/OSPAR assessment criterion (background assessment criteria, BAC) in this area as well as in the Inner Sørfjord (st. 53B), Farsund area (st. 13B) and Bømlo north on the West coast (st. 23B, reference station). Note that the unit of the assessment criterion is ng/ml, without normalization to absorbance at 380nm.

3.4.2 ALA-D in blood cells

Inhibited activity of ALA-D indicates the influence of lead contamination. Although ALA-D inhibition is lead-specific, it is not possible to rule out interference by other metals or organic contaminants.

In 2013, ALA-D activities in the blood of cod from the Inner Oslofjord (st. 30B) fell between the activities observed in 2011 and 2012 (activities in 2012 were about one third the activity measured in 2011). No significant temporal trends could be observed over the last 10 years (Appendix F). The median concentration of lead in cod liver was relatively stable through the last three years, however, a significant downward trend was observed for the last ten years.

Most years up to 2011 the activity of ALA-D in cod was somewhat inhibited in the Inner Oslofjord (st. 30B), compared to reference stations, i.e. Outer Oslofjord (st. 36B; only data to 2001), Bømlo north in the Bømlo-Sotra area (st. 23B), and Varangerfjord (st. 10B; only data to 2001, not shown) (Green *et al.* 2012a). No reference stations were monitored in 2012 but the activity at Bømlo north in 2013 was higher than both the Inner Oslofjord and the Inner Sørfjord (st. 53B). The lower activities of ALA-D in cod from the Inner Oslofjord and Inner Sørfjord compared to the reference station (basis for comparison prior to 2007, 2009-2011 and 2013) indicate the contamination of lead. The higher concentrations of lead in cod liver are generally observed in the Inner Oslofjord and Inner Sørfjord compared to Bømlo north, though with a relatively large individual variation.

3.4.3 EROD-activity and amount of CYP1A protein in liver

High activity of hepatic cytochrome P4501A activity (EROD-activity) normally occurs as a response to the contaminants indicated in *Table 5*. It was expected that higher activity would be found at the stations that were presumed to be most impacted by planar PCBs, PCNs, PAHs or dioxins such as the Inner Oslofjord (st. 30B). In 2013, median EROD-activity in liver of cod from the Inner Oslofjord (30B) fell between the activities observed in 2011 and 2012 (activities in 2012 were about one third the activity measured in 2011). Since 2000, the median EROD-activity was higher in the Inner Oslofjord compared to the reference station on the west coast (Bømlo north, st. 23B). No significant temporal trends could be observed for EROD in cod liver, and median EROD-activities were below the ICES/OSPAR assessment criterion (background assessment criteria, BAC).

No adjustment for water temperature has been made. Fish are sampled at the same time of year (September-November) when differences between the sexes should be at a minimum. Statistical analyses indicate no clear difference in activity between the sexes (Ruus *et al.* 2003). It has been shown that generally higher activity occurs at more contaminated stations (Ruus *et al.* 2003). However, the response is inconsistent (cf. Appendix F), perhaps due to sampling of populations with variable exposure history. Besides, there is evidence from other fish species that continuous exposure to e.g. PCBs may cause adaptation, i.e. decreased EROD-activity response.

CYP1A protein levels in 2013 in the Inner Oslofjord were higher than the level in 2012, as was observed for the EROD activities. No significant long-term or short-term (last ten years) temporal trends in CYP1A protein content or EROD activities could be observed. CYP1A protein levels (as EROD) were higher in the Inner Oslofjord, compared to the Sørfjord and Bømlo north, with the possible explanation that the exposure to PCBs was higher in the Inner Oslofjord than in the Sørfjord and Bømlo north. It was earlier also observed, however, that EROD activities apparently were not significantly influenced by a substantial increase in cod liver PCB content (Ruus *et al.* 2006). Berge *et al.* (2012) also found higher values in the Inner Oslofjord compared to the Outer Oslofjord. An explanation (besides the adaptation hypothesis) may be that the inducing effect of specific contaminants may be inhibited by other contaminants present (e.g. dioxins or PAHs).

3.5 Monitoring of contaminants with passive samplers

Sampling rates for samplers deployed until July-August 2014 were low, particularly considering the surface area of the samplers (1000 cm^2). However sampling rates were extremely similar to those obtained in 2013. The standard errors on the estimation of sampling rates were ~ 10 % (*Table 28*). Sampling rates were lowest for samplers deployed in Hvaler and highest in Ålesund. Sampling rates ranged from 2.0 L d^{-1} for the least hydrophobic substances (e.g. 4-t-octylphenol) to 0.24 L d^{-1} for the most hydrophobic substances (e.g BDE209). These sampling rates are lower than those obtained with the same type of silicone rubber samplers as part of the Tilførselprogrammet (Allan *et al.* 2011; Allan *et al.* 2012).

The extraction and analysis of one QA spiked sampler together with this batch of exposed passive samplers resulted in contaminant amounts per samplers close to those determined in the initial batch of six QA spiked samplers (Appendix G).

Table 28. Estimated sampling rates, R_s for AlteSil silicone rubber samplers (1000 cm^2, 30 g) deployed at three sites for > 300 days.

	Site					
	Hvaler		Oslofjord		Ålesund harbour	
	Replicate 1	Replicate 2	Replicate 1	Replicate 2	Replicate 1	Replicate 2
R_s* for 2013	0.45	0.58	0.30	0.43	1.41	1.36
+/-	0.04	0.04	0.01	0.01	0.07	0.03
R_s* for 2014	0.53	0.50	0.75	0.68	1.26	1.26
+/-	0.05	0.05	0.07	0.07	0.10	0.15

* Rs (L d^{-1}) at $logK_{sw}$ = 5

As shown in *Table 29* most compounds were below limits of detection. In the case of 4-t-OP, 4-t-NP, and BDE209, non-negligible amounts of these substances were measured in field control samplers (and/or in solvent blanks). This affected limits of detection for these compounds. Overall limits of detection depend on the quality of sampler preparation, contamination during sampler extraction and analysis, and instrumental limits of detection.

Significant absorption of para-t-nonylphenol (4-t-NP in the table) could be observed for samplers from Oslofjord and Ålesund. Freely dissolved concentration of 1.6 and 6.05 ng L^{-1}, respectively were estimated. These concentrations are in a similar range as those measured in 2013 in the Oslofjord (10 ng L^{-1}). These values are well below the WFD EQS level (2013/39/EU, Appendix G) of 0.3 μg L^{-1} for nonylphenol. All other alkyphenols were below limits of detection with these ranging from 0.6 to 1.3 ng L^{-1} for para-t-octylphenol and para-t-nonylphenol and 0.02-0.1 ng L^{-1} for para-n-octylphenol and para-n-nonylphenol, respectively. No other alkylphenol measurements have been undertaken using silicone rubber samplers until now. Sack and Lohmann (2011) used LDPE to sample these substances and were able to measure freely dissolved concentrations of t-octylphenol in the low ng L^{-1} range (3-11 ng L^{-1}) in Narragansett Bay, a small and heavily urbanized bay (US) with a surrounding population of two million inhabitants.

The technical mixture of HBCD is mainly composed of the γ-isomer (80-85 %), while α-HBCD and β-HBCD account for 8 and 6 % of the mixture, respectively. The concentration of β- and γ-HBCD were below limits of detection (with these in the range 9-20 pg L^{-1}). A freely dissolved concentrations of the α-isomer of HBCD of 14 pg L^{-1} was estimated for the Oslofjord. This is in a very similar range to the data from the 2012 investigation (Green *et al.* 2013). Freely dissolved concentrations appear to be well below WFD EQS values for HBCD published in 2013.

GC-MS analysis of extracts (sum of all isomers) from silicone samplers exposed at Jan Mayen (Allan *et al.* 2012) as part of the *Tilførselsprogrammet* showed that concentrations of HBCD in these samplers were below limits of detection. While passive air sampling of HBCD has been undertaken, passive sampling in water has not been reported (to the author's knowledge).

Most PBDEs were found below limits of detection. The exposure of samplers for almost a year (2013-2014) resulted in the accumulation of significant amounts of many different brominated substances rendering the quantification of specific PBDEs challenging. A freely dissolved concentration of 18 pg L^{-1} for BDE47 was

estimated for the Oslofjord (data not corrected for temperature or salinity). This value is in agreement with 2013 data. This value is higher than those obtained for silicone rubber samplers exposed at Andøya (4.8 pg L^{-1}), Bjørnøya (6-7 pg L^{-1}) or Jan Mayen (0.27 pg L^{-1}) during the Tilførselsprogrammet (Allan *et al.* 2011; Allan *et al.* 2012). Freely dissolved concentrations of PBDE congeners measured during the RiverPOP programme (2008-2011) were generally in the low pg L^{-1} range or below for rivers such as the Drammenselva and Glomma (Allan *et al.* 2009; Allan *et al.* 2010; Allan *et al.* 2011) and generally an order of magnitude below the estimate for the Oslofjord.

Table 29. Freely dissolved concentrations measured with silicone rubber samplers exposed at three sites.

Substances		**Freely dissolved contaminant concentrations**		
Sites	**Unit**	**Hvaler**	**Oslofjord**	**Ålesund harbour**
Alkylphenols				
4-t-OP	ng L^{-1}	< 0.6[a]	< 0.6[a]	< 0.6[a]
4-t-NP	ng L^{-1}	< 1.3[a]	**1.61** (12)[b]	**6.05** (19)[b]
4-n-OP	ng L^{-1}	< 0.1	< 0.06	< 0.25
4-n-NP	ng L^{-1}	< 0.02	< 0.03	< 0.02
HBCD				
α-HBCD	pg L^{-1}	< 20	**14.3** (5)[b]	< 9
β-HBCD	pg L^{-1}	< 20	< 13	< 9
γ-HBCD	pg L^{-1}	< 21	< 14	< 9
PBDEs				
BDE47	pg L^{-1}	< 34	**18.4** (35)[b]	< 38
BDE99	pg L^{-1}	< 9	< 6	< 4
BDE100	pg L^{-1}	< 9	< 6	< 4
BDE126	pg L^{-1}	< 9	< 6	< 4
BDE153	pg L^{-1}	< 10	< 6	< 5
BDE154	pg L^{-1}	< 10	< 6	< 5
BDE183	pg L^{-1}	< 11	< 7	< 5
BDE196	pg L^{-1}	< 12	< 8	< 5
BDE209	pg L^{-1}	< 60[a]	< 40[a]	< 25[a]

[a]Limit of detection calculated from 3 times the average of amounts found in the field controls (n = 3) and sampler-specific sampling rates.
[b]Relative percent difference of replicate measurements (%) given in brackets
[c]Amounts found in exposed samplers higher than 3 times the amounts found in field controls

3.6 Analysis of stable isotopes

Stable isotopes of Carbon and nitrogen are useful indicators of food origin and trophic levels. $\delta^{13}C$ gives an indication of carbon source in the diet or a food web. For instance, it is in principle possible to detect differences in the importance of autochthonous (native marine) and allochthonous (watershed/origin on land) carbon sources in the food web, since the $\delta^{13}C$ signature of the land-based energy sources is lower (greater negative number). Also $\delta^{15}N$ (although to a lesser extent than δ13C) may be lower in allochthonous as compared to autochthonous organic matter (Helland *et al.* 2002), but more important, it increases in organisms with higher trophic level because of a greater retention of the heavier isotope (15N). The relative increase of 15N over 14N (δ15N) is 3-5‰ per trophic level (Layman *et al.* 2012; Post 2002). It thus offers a continuous descriptor of trophic position. As such, it is also the basis for Trophic Magnification Factors (TMFs). TMFs give the factor of increase in concentrations of contaminants per trophic level. If the concentration increase per trophic level can be expressed as:

Log Concentration = $a + b$Trophic Level

Then:

TMF = 10^b

The trophic magnification factor has recently been amended to Annex XIII of the European Community Regulation on chemicals and their safe use (REACH) for possible use in weight of evidence assessments of the bioaccumulative potential of chemicals as contaminants of concern.

In the present report, the stable isotope data have merely been reviewed to indicate any possibilities that spatial differences in contaminant concentrations may partially be attributed to different energy sources between locations, or that the same species may inhabit different trophic levels on different locations (*Table 30*). It is anticipated that statistical temporal analyses may be applied to perform more "refined" assessments, when the "MILKYS" stable isotope database is further expanded. The δ15N data (Atlantic cod) is also assessed in relation to concentrations of selected contaminants. As fish grow, they feed on larger prey organisms, thus a small increase in trophic level is likely to occur. It is of interest to assess whether concentrations of specific contaminants correlate with δ15N, since this will warrant further scrutiny of the contaminant's potential to biomagnify.

For MCCP, $\delta^{15}N$ has been plotted against concentration to examine potential increase in concentration of the specific contaminants with increasing $\delta^{15}N$. Such correlation will give reason for future examination of the potential of the contaminant to increase in concentration with higher level in the food chain (biomagnification). It is previously shown that e.g. the concentration of mercury increase with $\delta^{15}N$ among individuals of the same species (more specifically tusk; *Brosme brosme*) in the Sørfjord (Ruus *et al.* 2013b). For that reason, also concentrations of mercury, as well as CB153 (another compound with known biomagnifying properties), is plotted against δ15N in cod. The data material for Hg and CB153 is larger (more individuals analysed per station), than for MCCP. For BPA, most concentrations fell below the limit of detection, thus a similar exercise was not performed for this compound (as it was in 2012).

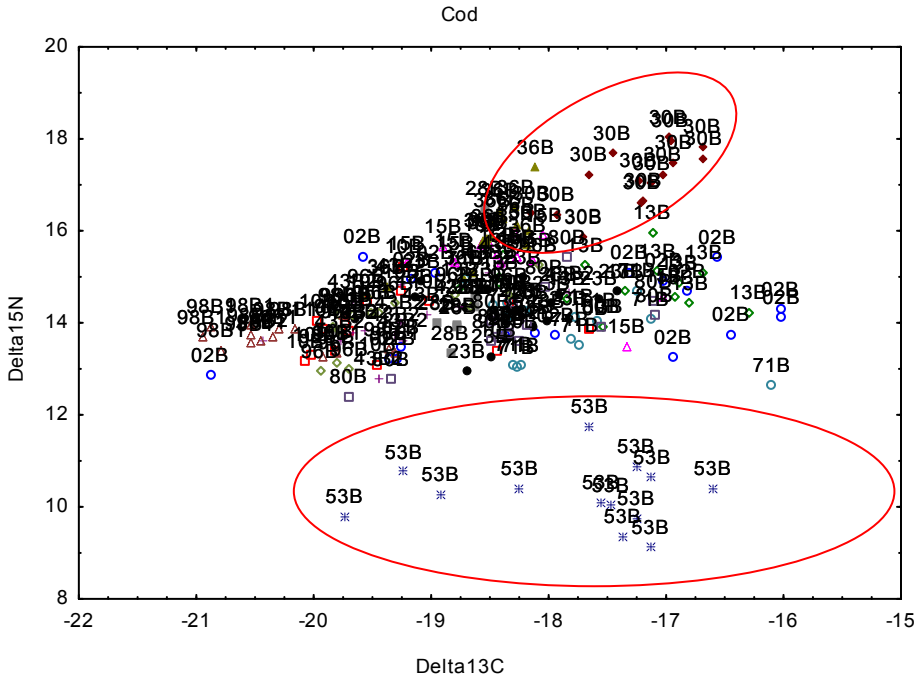
There were no great differences in $\delta^{13}C$ between mussels or fish from the different areas. Furthermore, there were no major differences in $\delta^{15}N$ between cod from different locations, with some exceptions, indicating that the different populations surveyed can be placed on approximately the same trophic level. As mentioned, an increase in $\delta^{15}N$ of 3 to 5 ‰ represent a step of one full trophic level, while the differences observed were generally lower. It is therefore reasonable to assume that any differences in the concentrations of pollutants between areas are due to differences in exposure (either from local sources or through long-range transport). It can be noted, however, that differences in e.g. mercury content in tusk from Sørfjord area could be partly attributed to small differences in trophic position/$\delta^{15}N$ (less than one full trophic level) (Ruus *et al.* 2013b).

Table 30. Summary of analyses of stable isotopes: $\delta^{13}C$ and $\delta^{15}N$ and C:N ratio, in blue mussel and cod, 2013. Statistics shown are count (n), mean and standard deviation.

	Blue mussel									Atlantic Cod								
	$d^{13}C_{VPDB}$			$d^{15}N_{AIR}$			W% C/N			$\delta^{13}C_{VPDB}$			$\delta^{15}N_{AIR}$			W% C/N		
Station ID	n	mean	st.dev.	n	mean	st.dev.	n	mean	st.dev.	n	mean	st.dev.	n	mean	st.dev.	n	mean	st.dev.
presumed more impacted, summary >>	**3**	**-20.57**	**0.18**	**3**	**6.51**	**0.19**	**3**	**3.59**	**0.19**	**14**	**-18.19**	**0.75**	**14**	**13.66**	**0.73**	**14**	**2.58**	**0.05**
Hvaler (st. 02B)										18	-18.00	1.43	18	14.17	0.84	18	2.61	0.03
Kristiansand harbour (st. 13B)										15	-17.48	0.75	15	14.85	0.51	15	2.62	0.02
Måløy (st. 26A2)	3	-20.99	0.37	3	5.50	0.04	3	3.77	0.15									
Ålesund area (st. 28B)										7	-18.74	0.14	7	14.38	1.01	7	2.56	0.04
Gressholmen (st. 30A)	3	-20.36	0.21	3	7.31	0.12	3	3.42	0.20									
Mølen (st. 35A)	3	-20.50	0.02	3	8.08	0.06	3	3.34	0.15									
Tromsø harbour (st. 43B2)										15	-19.21	0.64	15	14.12	0.66	15	2.54	0.13
Byrkjenes (st. 51A)	3	-20.30	0.34	3	3.82	0.38	3	4.25	0.52									
Inner Sørfjord (st. 53B)										13	-17.81	0.94	13	10.25	0.69	13	2.57	0.04
Kvalnes (st. 56A)	3	-19.86	0.29	3	2.99	0.17	3	3.64	0.13									
Bjørkøya (st. 71A)	3	-20.22	0.10	3	6.98	0.05	3	3.21	0.15									
Grenslandsfjord (st. 71B)										15	-17.89	0.67	15	13.88	0.68	15	2.61	0.05
Inner Trondheimsfjord (st. 80B)										15	-18.24	0.70	15	13.92	0.74	15	2.56	0.03
Bodø harbour (st. 97A2)	3	-22.02	0.06	3	7.02	0.22	3	3.90	0.21									
Singlekalven (st. I023)	3	-20.98	0.17	3	8.27	0.22	3	3.32	0.04									
Gåsøya (st. I304)	3	-19.86	0.07	3	7.66	0.33	3	3.88	0.25									
Croftholmen (st. I712)	2	-20.62	0.17	2	7.42	0.33	2	3.20	0.09									
presumed less impacted, summary >>	**3**	**-21.98**	**0.15**	**3**	**6.86**	**0.09**	**3**	**3.54**	**0.19**	**15**	**-18.76**	**0.53**	**15**	**14.91**	**0.57**	**15**	**2.58**	**0.06**
Varangerfjord (st. 10B)										15	-19.35	0.71	15	13.95	0.62	15	2.45	0.13
Brashavn (st. 11X)	3	-23.04	0.13	3	6.56	0.12	3	3.70	0.28									
Gåsøy (st. 15A)	3	-21.56	0.14	3	7.87	0.01	3	3.36	0.17									
Farsund area (st. 15B)										15	-18.33	0.56	15	15.33	0.60	15	2.60	0.04
Espevær (st. 22A)	3	-21.60	0.35	3	6.55	0.17	3	3.43	0.41									
Bømlo north (st. 23B)										18	-18.34	0.57	18	14.24	0.54	18	2.59	0.05
Inner Oslofjord (st. 30B)										15	-17.26	0.43	15	17.14	0.65	15	2.67	0.09
Færder area (st. 36B)										15	-18.48	0.31	15	15.92	0.65	15	2.64	0.02
Outer Trondheimsfjord (st. 91A2)	3	-20.60	0.09	3	6.56	0.10	3	3.63	0.06									
Helgeland (st. 96B)										15	-19.35	0.59	15	14.10	0.65	15	2.54	0.03
Lofoten, Svolvær (st. 98A2)	3	-23.09	0.02	3	6.77	0.06	3	3.58	0.01									
Lofoten, Skrova (st. 98B1)										15	-20.24	0.51	15	13.65	0.27	15	2.54	0.09
Grand Total	**44**	**-21.05**	**1.03**	**44**	**6.61**	**1.48**	**44**	**3.58**	**0.34**	**206**	**-18.47**	**1.07**	**206**	**14.31**	**1.55**	**206**	**2.58**	**0.08**

Although there were generally no major differences in $\delta^{15}N$ between cod from different locations, cod from the Sørfjord (station 53B) stand out with particularly low $\delta^{15}N$ signature. The same is shown for mussels from the same area (stations 51A and 56 A), indicating that the $\delta^{15}N$ -baseline of the food web in the Sørfjord is lower. The reason for this is unknown, but a higher influence of allochthonous nitrogen is possible. Likewise, isotope signatures of both fish and mussels from the Oslofjord are among the highest observed (*Figure 44*) indicating a high baseline (and not a higher trophic position of the Oslofjord cod). Furthermore, this was also shown in 2012. In fact the stations show very similar patterns from 2012 to 2013 in terms of isotopic signatures, suggesting that this is a spatial trend more than a temporal trend.

a



b

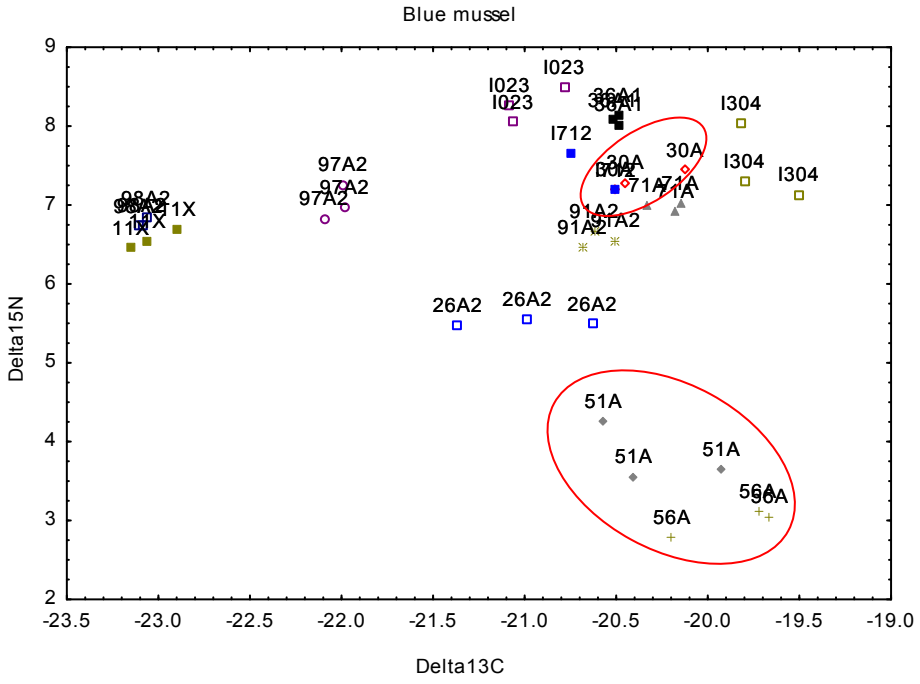


Figure 44. $\delta^{13}C$ plotted against $\delta^{15}N$ in for cod (a) and blue mussel (b). Station codes are superimposed. Red ellipses indicate cod and blue mussel from the Inner Oslofjord and the Sørfjord, respectively.

Plotting δ^{15}N against the concentration of Hg in cod could suggest higher concentrations in individuals with higher δ^{15}N (significant linear regression between δ^{15}N and Log[Hg], with very poor goodness-of-fit; R^2=0,025; P=0,013; ***Figure 45***), However, this is likely partly a result of different exposure, as well as difference in isotopic signature (baseline) among stations (high Hg-exposure as well as high δ^{15}N in cod from 30B, and low δ^{15}N baseline at 53B). But a linear regression excluding stations 53B and 30B also produced significant result (R^2=0,113; P=0,000002). However, from ***Figure 45***, there are some indications of increasing Hg-concentrations with increasing δ^{15}N within stations. Linear regressions isolated for each station produced significant positive linear relationships between δ^{15}N and Log[Hg] for stations 02B, 10B, 15B, 23B, 28B, 71B, 80B, 96B and 98B1.

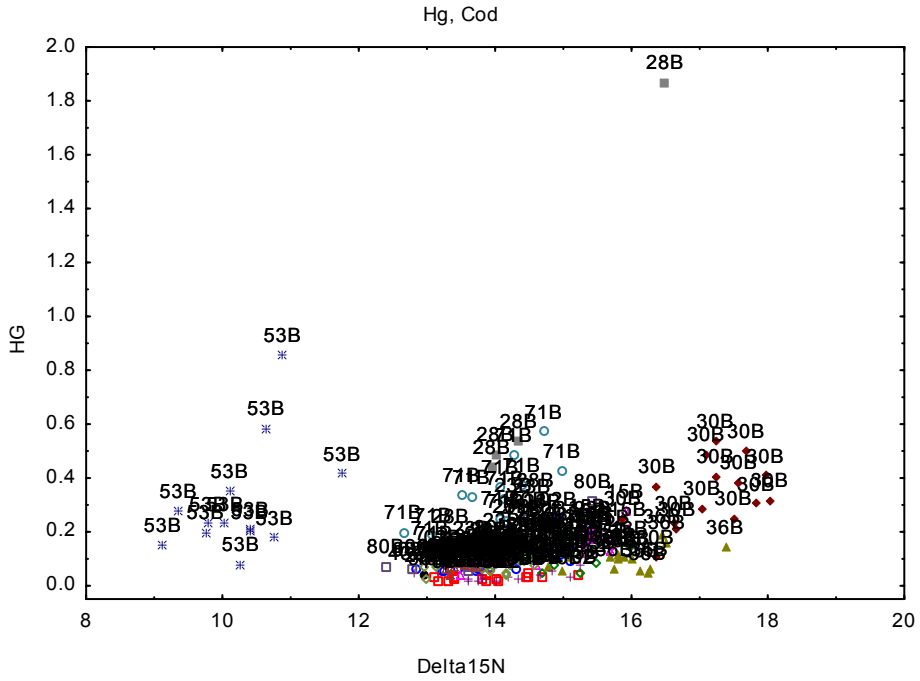


Figure 45. δ^{15}N plotted against the concentration of Hg in cod. Station codes are superimposed.

Plotting δ^{15}N against the concentration of CB153 in cod could suggest higher concentrations in individuals with higher δ^{15}N (significant linear regression between δ^{15}N and Log[CB153]; R^2=0,41; P=0,000000; ***Figure 46***), However, this is most likely partly a result of different exposure, as well as difference in isotopic signature (baseline) among stations (high CB153-exposure as well as high δ^{15}N in cod from 30B, and low CB153 exposure as well as low δ^{15}N baseline at 53B). A linear regression excluding stations 53B and 30B still produced significant result (R^2=0,24; P=0,000000). Linear regressions isolated for each station produced significant positive linear relationships between δ^{15}N and Log[CB153] for stations 10B, 15B, 28B and 43B2.

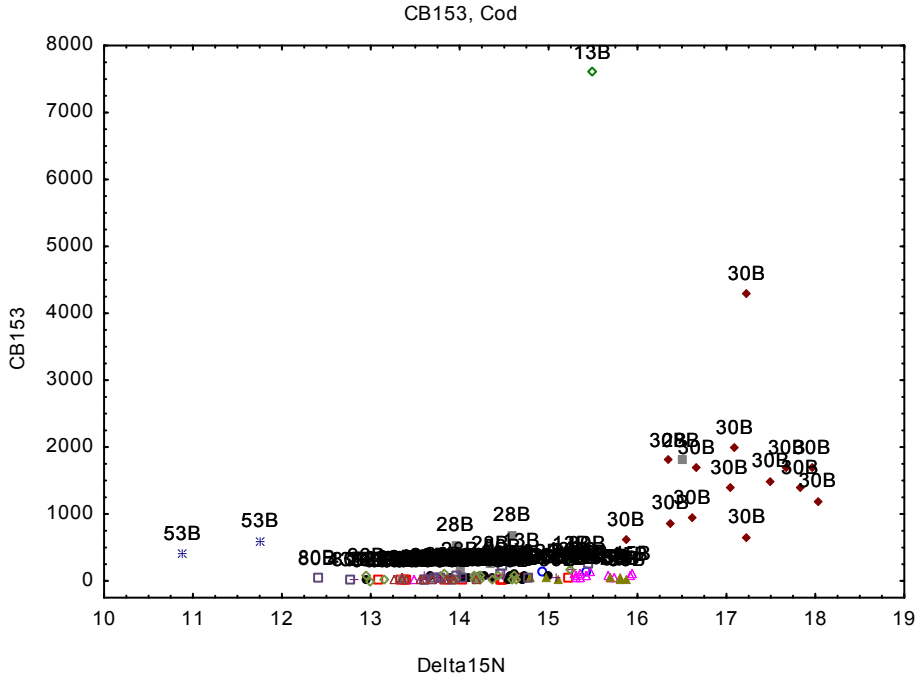


Figure 46. δ^{15}N plotted against the concentration of CB153 in cod. Station codes are superimposed.

Plotting $\delta^{15}N$ against the concentration of MCCP in cod gives no indication of higher concentrations in individuals with higher $\delta^{15}N$, but merely indicates stations with the highest exposure (especially 80B), as well as the above mentioned difference in isotopic signature among stations (*Figure 47*). In 2012, the highest MCCP concentrations were also found at station 80BHB, in addition to station 53B.

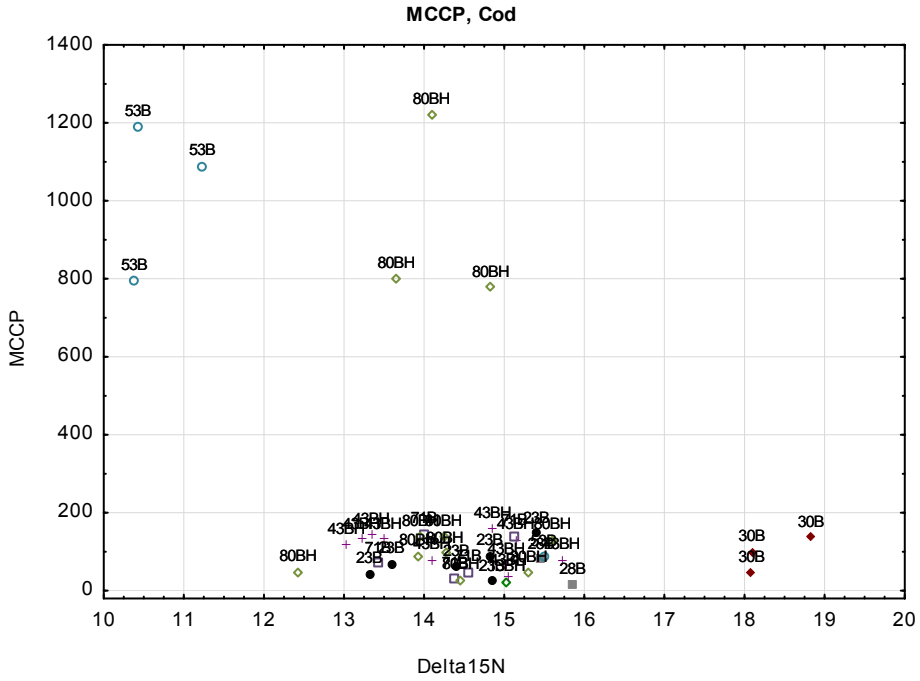


Figure 47. $\delta^{15}N$ plotted against the concentration of MCCP in cod. Station codes are superimposed.

3.7 Effects of the use of pooled samples on statistical results

3.7.1 Background

The costs of laboratory analyses are often the largest cost in contaminant monitoring programmes. Since the costs to a large extent are determined by the number of samples that are sent to analysis, an apparently effective way to decrease costs is to pool the samples from two or more individuals into one sample, which is homogenised and sent to the laboratory. Currently, the MILKYS programme is not pooling the samples from cod (though exceptions are made in order to achieve a minimum of material necessary for analyses). However, pooling the samples physically will result in larger uncertainty in the estimated levels and trends of contaminants, and may also result in biased estimates if the concentrations are not normally distributed among individuals within a site (Nicholson & Fryer 1996). The effect of pooling on uncertainty and bias can be determined theoretically (Nicholson & Fryer 1996), but the results of course depends on the statistical properties of the data.

However, physically pooling and homogenising the tissue samples from several individuals is equivalent to taking the arithmetic mean of the contaminant concentrations of the individual samples. In other words, we can mimic the results of the physical pooling by pooling the concentrations mathematically. Here, we use the existing historical data on contaminants in cod, taken from the MILKYS database, to simulate mathematically how the pooling of samples affects the estimated contaminant levels and trends.

3.7.2 Methods

The data that is the basis of the present analysis is concentrations of environmental contaminants in cod liver and muscle. The database contains 172181 concentrations of 198 different contaminants measured in 26 stations from 1981 to 2012. We define a *time series* as a combination of contaminant, tissue (liver or muscle), and station. For the present analysis, we used only the time series that contained at least 7 years and that had at least 25 samples/year. This resulted in 170 time series, covering 24 contaminants and 8 stations (*Table 31, Table 32, Table 33*). The number of samples (170) is less than 24 x 8 because we did not have time series of all contaminants for all stations). These 170 time series made up 56% of the measurements in the data set.

Table 31. Data used in the analysis. The number of measurements of each contaminant in liver and muscle, respectively.

Component	Liver	Fillet
Hg	0	4640
CD	4098	0
PB	3944	0
ZN	3948	0
CU	3946	0
HCHA	3995	0
HCHG	4232	0
HCB	4345	0
OCS	3530	0
QCB	3450	0
CB28	3719	0
CB52	3708	0
CB101	4083	0
CB105	3792	0
CB118	4171	0
CB138	4170	0
CB153	4169	0
CB156	3787	0
CB180	4170	0
CB209	3994	0
DDEPP	4390	0
TDEPP	3837	0
DDTPP	550	0

Table 32. Data used in the analysis. The number of measurements at each station.

Station		N
10B	**Varangerfjorden**	8112
15B	**Gåsøy (Ullerø)**	12360
23B	**Bømlo north**	12368
30B	**Inner Oslofjord**	15307
36B	**Færder**	14278
53B	**Inner Sørfjord**	12613
67B	**Strandebarm**	8600
98B1	**Lofoten, Skrova**	9561

Table 33. Data used in the analysis. The number of measurements for each station/year combination.

Year	10B	15B	23B	30B	36B	53B	67B	98B1
1981	0	0	0	0	30	0	0	0
1982	0	0	0	0	106	0	0	0
1983	0	0	0	0	115	0	0	0
1984	0	0	0	145	120	0	0	0
1985	0	0	0	125	70	0	0	0
1986	0	0	0	250	258	0	0	0
1987	0	0	0	250	245	73	132	0
1988	0	0	0	250	250	9	9	0
1989	0	0	0	425	409	181	308	0
1990	0	500	498	500	480	499	98	0
1991	0	472	395	465	575	445	362	0
1992	0	529	575	417	568	505	152	575
1993	0	557	575	552	575	575	228	410
1994	399	528	571	575	569	573	342	575
1995	475	552	574	575	575	573	475	552
1996	475	575	575	935	576	860	387	575
1997	437	575	573	935	575	528	265	521
1998	475	557	558	1142	575	648	471	575
1999	475	575	575	578	568	523	443	575
2000	475	575	574	575	529	467	460	0
2001	385	575	521	575	575	575	475	0
2002	474	574	535	566	559	534	474	575
2003	418	574	573	550	563	483	475	483
2004	472	572	570	575	575	565	475	560
2005	475	574	575	587	592	535	473	570
2006	167	554	575	575	600	575	473	557
2007	475	575	563	592	599	552	475	177
2008	475	575	553	599	600	575	376	575
2009	475	551	565	600	504	410	468	575
2010	475	483	549	599	596	559	266	556
2011	475	563	551	600	588	571	38	575
2012	135	195	195	195	159	220	0	0

It was not possible to make an adequate assessment for all pooling strategies noting that for the 2013 investigations, for example, pools consisted of 2-8 individuals (*Table 16*, Appendix F). Hence, we simulated that samples of 5 individuals, where available, were pooled to a single sample. This was done by dividing the total sample (one contaminant, station and year) into groups of 5 individuals, and then take the mean of the measured concentrations for each group of 5 individuals. If the total sample size could not be divided by 5, the last pooled sample was smaller than 5. For instance, if we had 23 individuals from a given station, we numbered the measurements randomly with numbers 1-23, and calculated the arithmetic mean concentrations for 5 pooled samples (fish 1-5, 6-10, 11-15, 16-20, and 21-23). This corresponds to making 5 pooled tissue samples based on the original 23 tissue samples.

The goal of contaminant monitoring programmes is to both assess current conditions, typically based on last year's data, and to detect trends in concentrations over time. We therefore calculated the following single-year statistics and time trend statistics, using both the original sample measurements as well as the pooled samples:

1) **Mean values for a single year, with 95% confidence interval and median.** We used 2011 (as some data were lacking for 2012). The concentrations were mostly close to log-normally distributed with a long right tail (i.e., a few extraordinarily large values), so the means and confidence intervals were calculated for log-transformed values and then back-transformed.

2) **The existence of a statistically significant trend in time**. Here we tested each time series and recorded whether there was a statistically significant trend (P <= 0.05) towards higher or lower concentrations.

3) **The number of years needed to detect a trend.** Here we first picked the time series which had a trend that was statistically significant after the first 18 years of the time series, using the original (unpooled) data. We then picked time series of increasing length (picking the first 2,3,4, etc. years of the time series) and tested, for each length, whether there was a statistically significant trend. This was done both for the original data and for the pooled samples.

For 2) and 3), we also used log-transformed data, and we used time series starting in 1990, as time trends did not appear credible if we used data from 1989 or before. For each of these three types of statistic, we compared the results from the original data with the results from the pooled samples.

3.7.3 Results

How pooling affects single-year statistics (concentrations in 2011)

When the mean and confidence interval for 2011 is plotted for each station x contaminant, there is not a striking difference between the results based on the original samples and the pooled-sample results (*Figure 48*). As expected, the confidence intervals are somewhat broader for the pooled samples, on average about 20% (*Figure 49*).

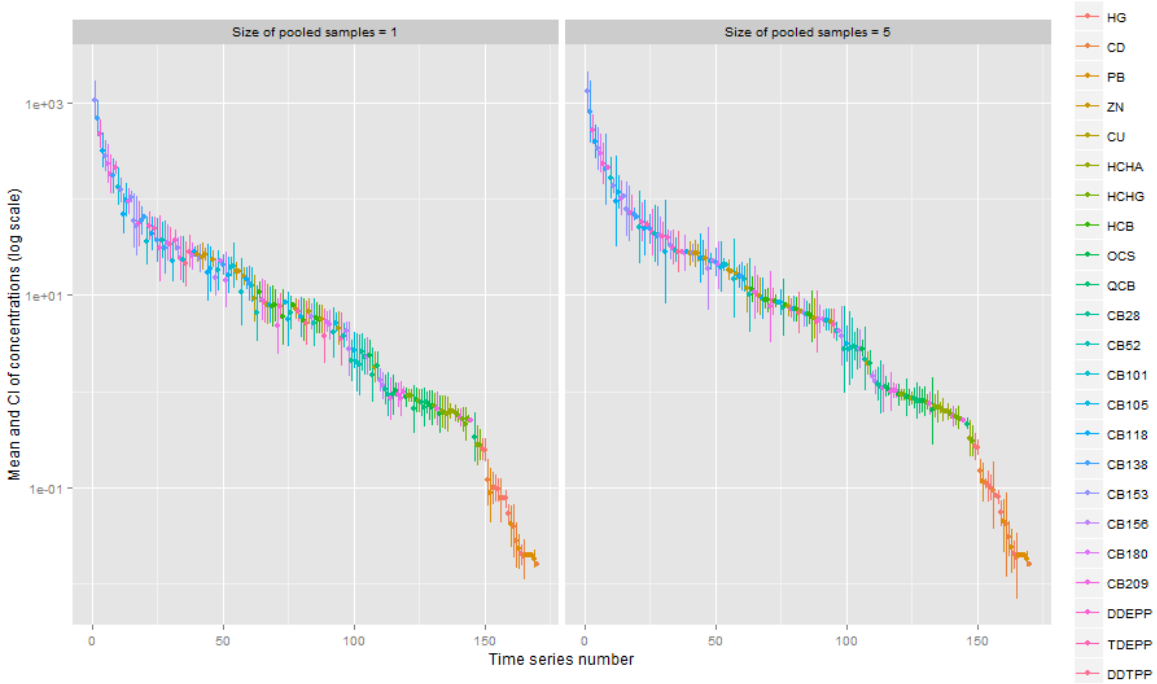


Figure 48. Mean (points) and 95% confidence intervals (lines) for each combination of station and contaminant in 2011, based on the original samples (left) and the pooled samples based on up to 5 individuals (right). Colours show the contaminants. In both plots, the contaminants x stations are sorted according to the mean value in the original data (i.e., the left plot).

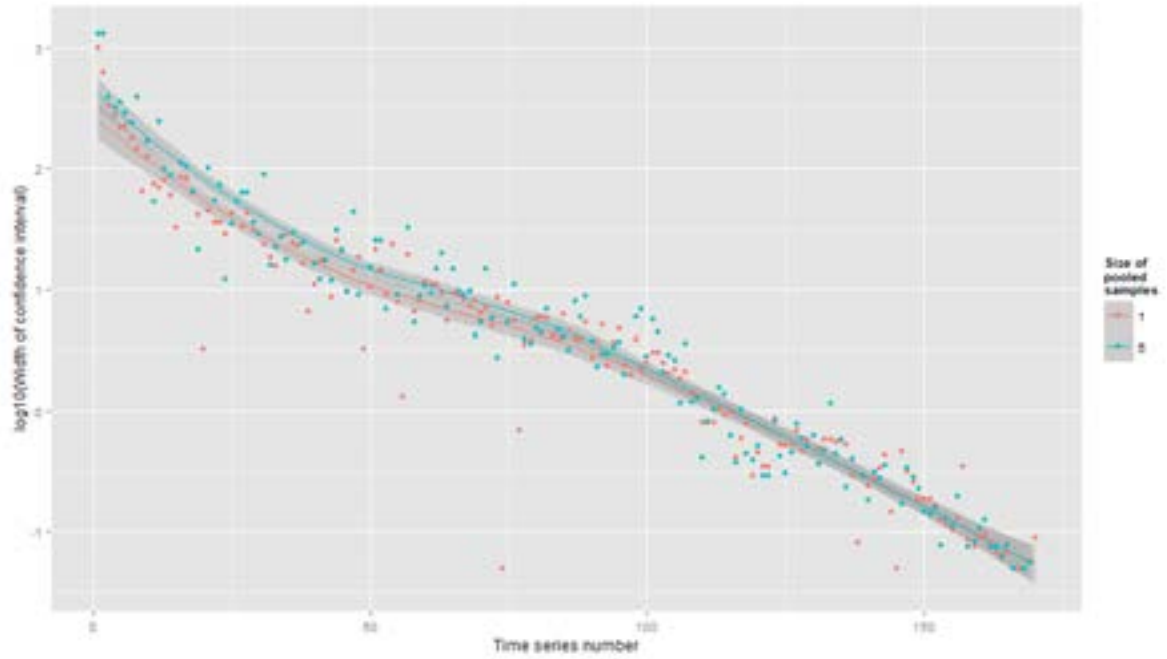


Figure 49. Width of the confidence intervals (log-transformed), both for original data (red) and the pooled samples (blue). The order of the station/contaminants (x-axis) is as in Figure 48, i.e. from high to low mean values.

Further scrutiny of the mean values reveals that the mean values (means of the log-transformed concentrations) of the pooled samples are higher than the mean values based on individual-level data (*Figure 50*). Thus, pooling the samples leads to a bias in the mean values (Nicholson & Fryer 1997). The result is largely similar if we use medians (*Figure 51*). Most of the means based on pooled samples are typically 5-40% higher than the means based on the original data; in some cases the difference is above 40% (*Figure 52*). The bias is slightly smaller for median values; here, the bias is between 0 and 30% in most cases (*Figure 53*). As for different types of contaminants, the bias is clearly smallest for the metals, except copper, and higher for organic compounds (*Figure 54*). The bias was highest for PCB52, which has 4 chlorine atoms, while the bias decreases when the number of chlorine atoms becomes lower or higher than 4.

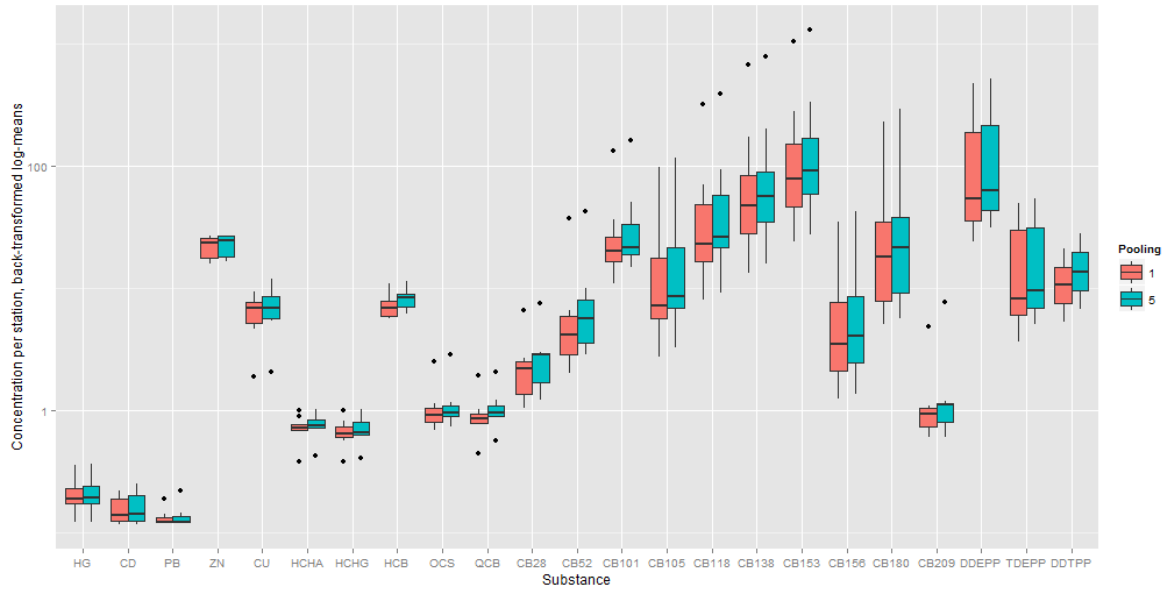


Figure 50. 2011 mean concentrations for each contaminant, showing the spread among means among stations as a boxplot (note that the y axis is log-transformed). Red boxplots are from the original data, blue boxplots are from the pooled samples. The means are calculated based on log-transformed data and then back-transformed.

Figure 51. As Figure 50, but based on median concentrations in 2011, not mean concentrations.

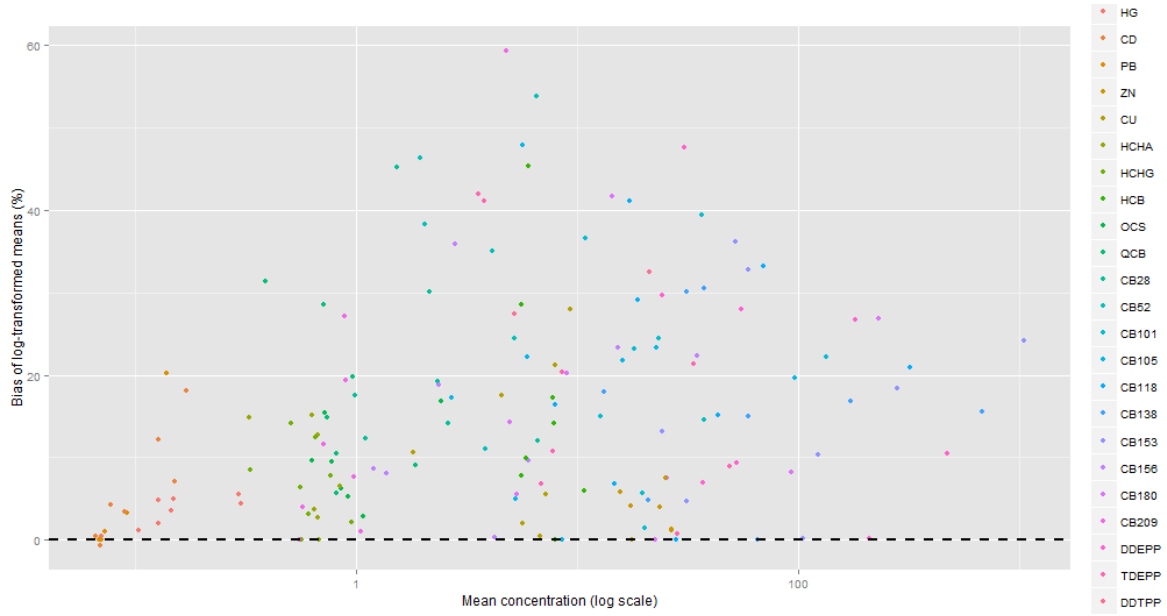


Figure 52. Bias of mean values for 2011. The y axis shows the difference between means based on pooled samples and means based on the original data. The difference is given as the percentage of the original-sample mean, and the x axis is the original-sample mean. Positive values on the y axis indicate that pooled-sample means were higher. In all cases, the means are calculated from log-transformed concentrations and then back-transformed.

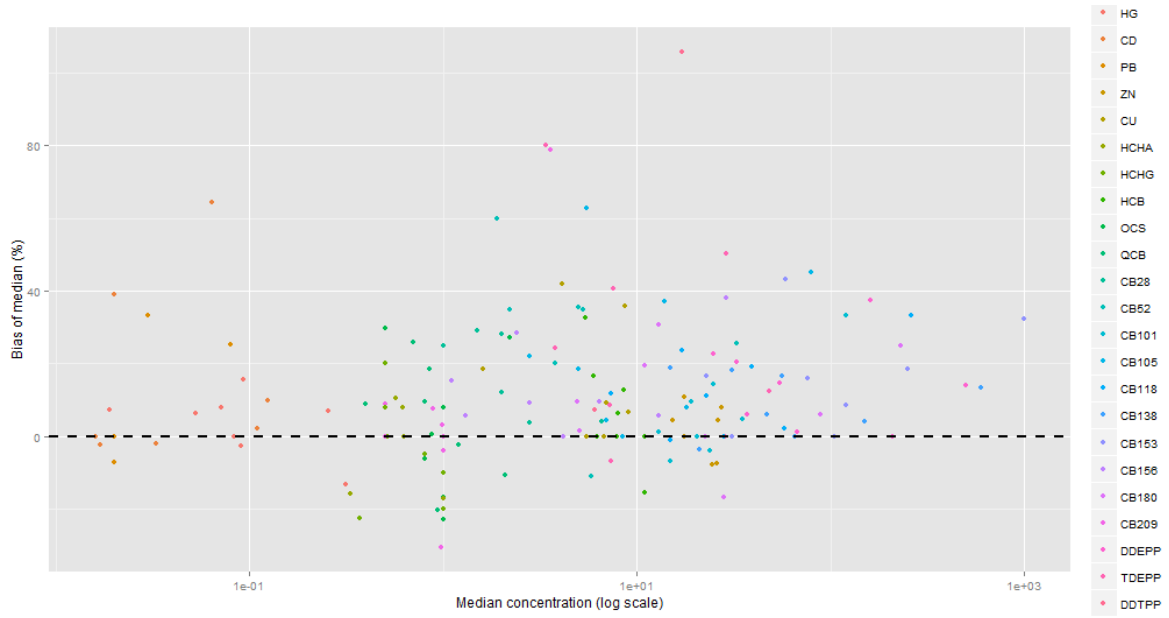


Figure 53. As Figure 52, but based on medians instead of means of log-transformed values.

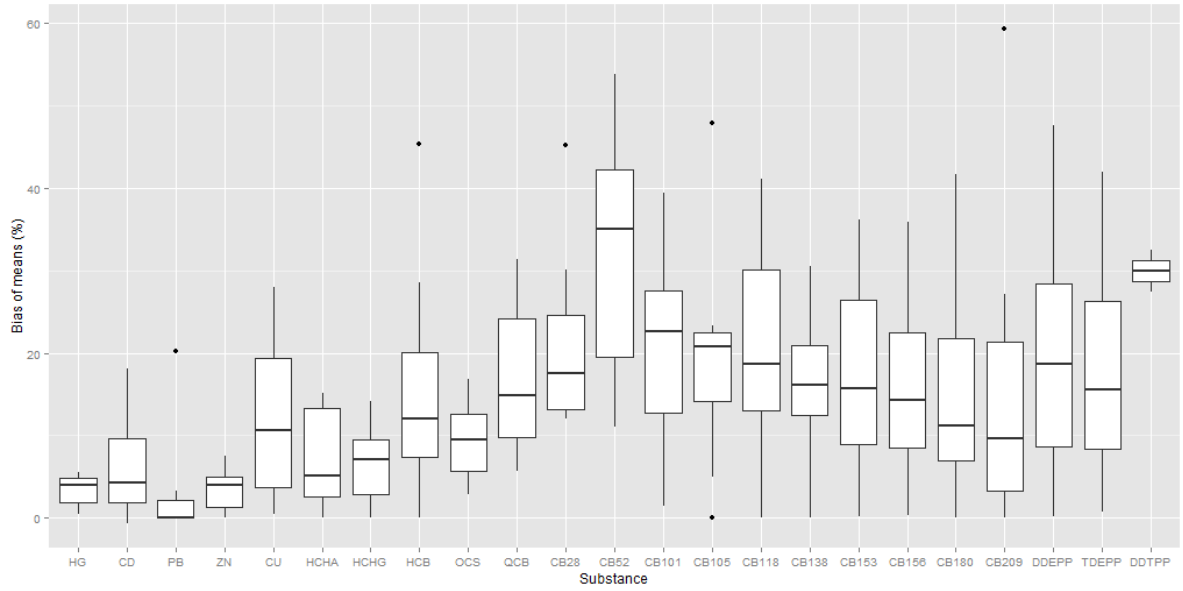


Figure 54. Bias of mean values for 2011. As Figure 52, the y-axis shows the bias (in percent), but the values are sorted by contaminant on the x-axis (showing variation in bias among stations as a boxplot).

How pooling affects the number of significant time trends

Analysis of the time trends in the original data showed that almost all time series displayed a statistically significant trend over time, either up or down, with a clear majority of the latter (*Figure 55*). The uncertainty of the magnitude of time trends increased substantially when pooled data was used (*Figure 55*). The width of the confidence intervals of the slope (change per year) increased on average 53%.

As a result of the increased uncertainty of time trends, fewer of the pooled-data time series show significant trends (*Table 34*). However, the difference was small, as most time series had highly significant time trends (P much smaller than 0.05) in the original data. The difference was greatest for mercury (Hg), where 50% of the stations showed a significant increase using the original data, while the increase was significant in only 37.5% of the cases using pooled data (*Table 35*).

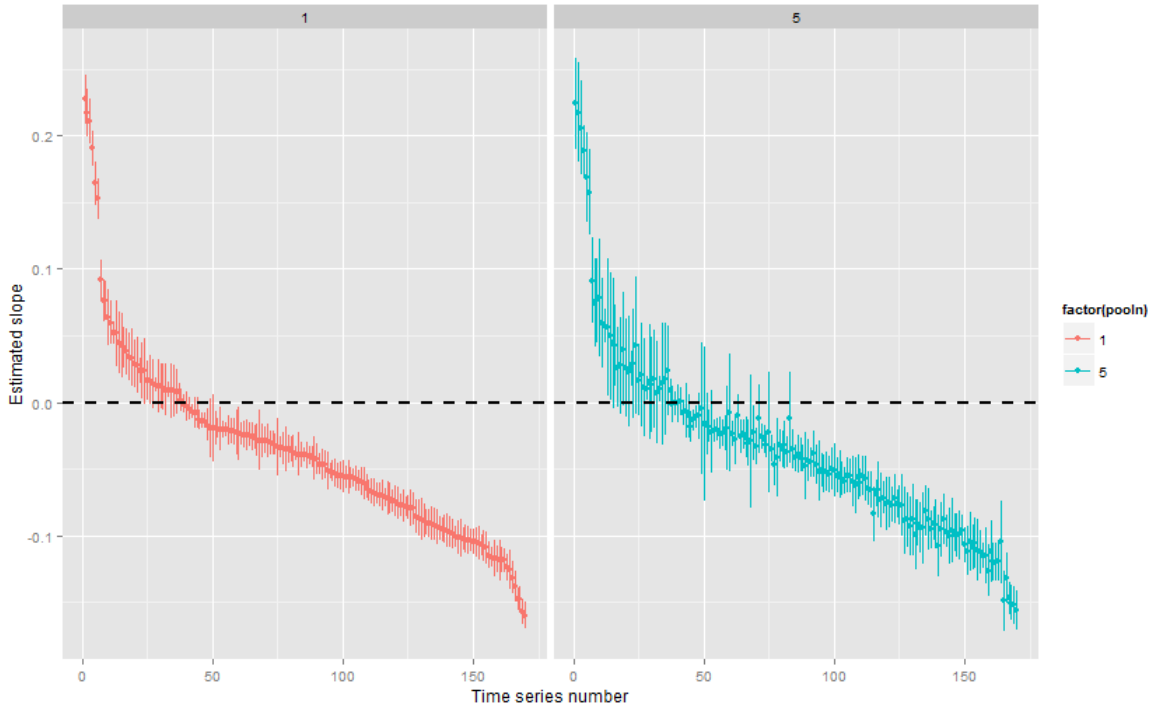


Figure 55. Magnitude of time trends. The y axis shows the time trend (point, i.e., the slope of the year effect) for each time series, with its 95% confidence interval (vertical lines). E.g., a value of 0.1 means that the concentrations increase by 0.1 per year. If a vertical line does not overlap with zero (dashed line) it indicates a significant trend. Negative values (under the dashed line) indicate a decrease. Trends have been calculated based on original data (left) or pooled data (right).

Table 34. The percentage of time series that showed statistically significant (P<0.05) increase or decrease over time, both based on the original data and based on the pooled data.

Original	data	Pooled	data
Increase	Decrease	Increase	Decrease
7.1%	84.1%	5.9%	81.2%

Table 35. The percentage of time series that showed statistically significant (P<0.05) increase or decrease over time, for each contaminant.

Contaminant	Original data		Pooled data	
	Increase	Decrease	Increase	Decrease
Hg	50.0	50.0	37.5	50.0
Cd	28.6	42.9	28.6	28.6
Pb	0.0	71.4	0.0	71.4
Zn	28.6	42.9	28.6	42.9
Cu	14.3	57.1	14.3	57.1
HCHA	0.0	100.0	0.0	100.0
HCHG	0.0	100.0	0.0	100.0
HCB	0.0	100.0	0.0	100.0
OCS	0.0	100.0	0.0	100.0
QCB	0.0	100.0	0.0	100.0
CB28	0.0	100.0	0.0	100.0
CB52	0.0	100.0	0.0	85.7
CB101	0.0	100.0	0.0	87.5
CB105	0.0	87.5	0.0	87.5
CB118	0.0	87.5	0.0	87.5
CB138	12.5	75.0	12.5	75.0
CB153	12.5	75.0	12.5	75.0
CB156	0.0	100.0	0.0	87.5
CB180	12.5	75.0	0.0	75.0
CB209	0.0	87.5	0.0	87.5
DDEPP	0.0	100.0	0.0	87.5
TDEPP	0.0	100.0	0.0	100.0
DDTPP	0.0	50.0	0.0	50.0

How pooling affects the number of years needed to detect trends

In this analysis, we picked time series which had a statistically significant time trend - either significantly declining or increasing – when analysed after 18 years using the original data. There were only 10 increasing time series, and there was a modest difference between the original data and the pooled data (*Figure 56*). For the much larger number of time series with declining concentrations (134 series), there is an especially large difference on the scale of 4-7 years (*Figure 57*). A negative trend can be detected (with p>0.05) in 40% of the time series if the original data is used, while if pooled data is used, 8 years is needed in order to detect the trend in the same number of time series. For short (2-3 year) and long (10-18 years) time series, there is little difference between the original data and the pooled samples

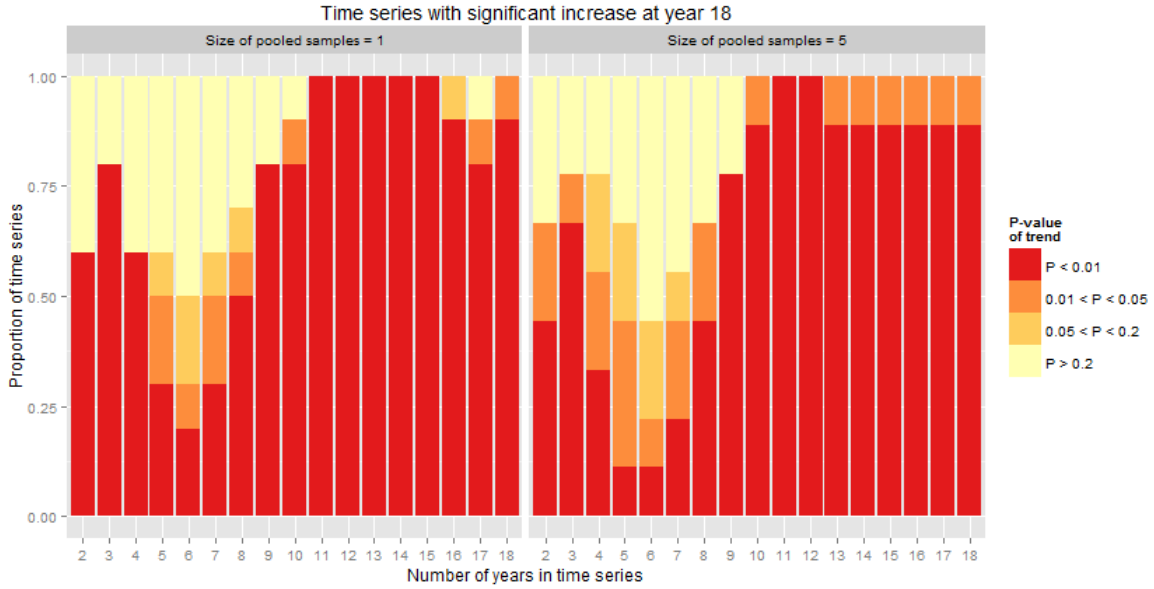


Figure 56. The number of years needed in order to detect a time trend; time series with increasing concentrations (P < 0.05) over time (N=10). Original data to the left, simulated pooled samples to the right. Trends in the "wrong" (decreasing) direction were counted as P > 0.2.

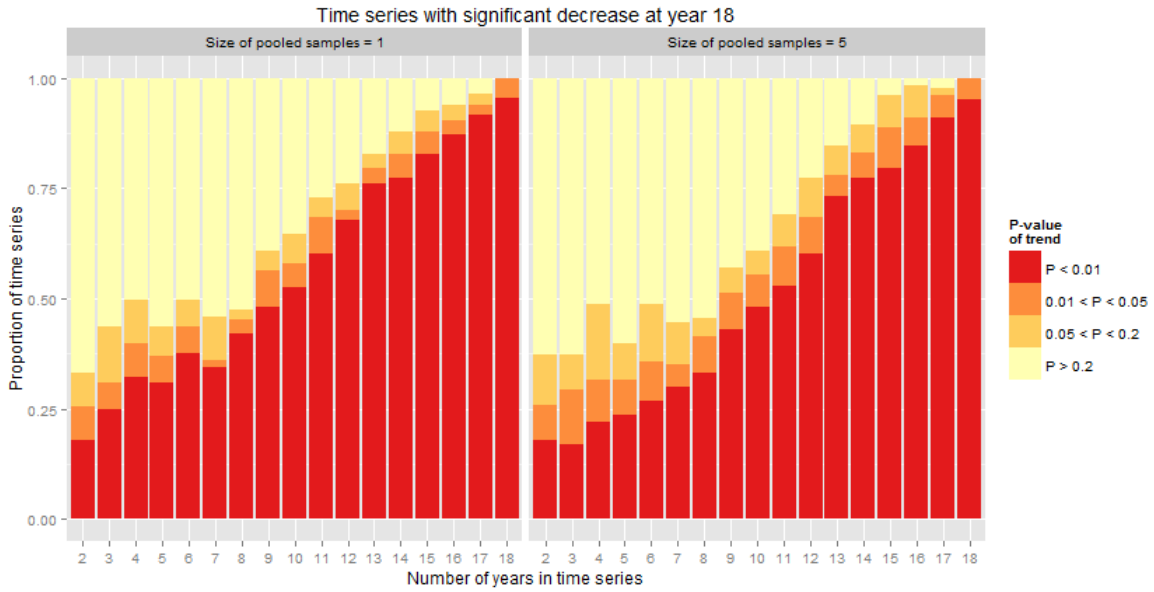


Figure 57. As Figure 56, but for time series with decreasing concentrations (P < 0.05) over time (N=134).

3.7.4 Discussion and conclusion

Using pooled samples results in an upward bias when current concentrations are assessed. The bias is modest (ca. 20%) and on the conservative (precautionary) side. The higher variance will make it more uncertain whether a concentration is above or below a set limit (this has not been specifically explored in this analysis). The increased variance also makes time trends more uncertain. This is of little significance when looking at long time series, as long-term trends are likely to be detected anyway. However, for shorter time series (or when a short part of a time series is assessed), a substantially longer time may be needed to detect a trend for a given contaminant and station. For our particular data, an 8-year series of pooled data had about the same "quality" as a 4-year series of unpooled data (*Figure 57*), in the sense that the same number of trends were picked up. In our case, this was evident for data with a negative trend, but we expect the same to happen if most trends were positive. The extra 4 years may be of some significance practically and politically. It should be emphasized that other data – with different strength of trends and different distribution of the data – would give results that differ from our results quantitatively (for instance, that the effect of pooling was highest on a 4-8 year time scale). However, we expect the qualitative results to be similar.

4. Conclusions

This programme examines long-term changes for legacy contaminants in biota along the coast of Norway in both polluted and in areas remote from point sources. In addition, the programme includes supplementary analyses of some emerging contaminants. As such, the programme provides a basis for assessing the state of the environment for the coastal waters with respect to contaminants and changes over time. The main conclusions were:

- Most temporal trends are downwards, predominantly for metals, including TBT and its effect, but also PCBs.
- The decrease in TBT can be related to legislation banning the use of this substance.
- Significant increase in mercury was found in cod from the Inner Oslofjord. The reasons for this upward trend are not clear.
- PBDEs, predominantly BDE47, were highest in the Inner Oslofjord.
- Blue mussel from one station in the Sørfjord was extremely polluted with DDE, presumably related to the earlier use of DDT as pesticide in this orchard district.
- Cod from the Inner Oslofjord had significant higher levels of PFOS, PFOSA and PFDcS in liver than all other stations.
- Significant downward short-term trends at six of the eight stations were identified for PFOS in cod liver.
- The dominant hexabromcyclododecane (α–HBCD) in cod liver was highest in the Inner Oslofjord, probably related to urban activities.
- Medium chain-chlorinated paraffins (MCCP) were significantly higher in blue mussel from the Inner Oslofjord compared to other mussel-stations.
- The median concentrations of flame retardants (PFRs) were below the detection limit.
- The median concentrations of bisphenol A were below the detection limit or low (cod from Bømlo north) and no conclusions could be drawn.
- Concentrations of PCBs in liver were well correlated with concentrations in fillet. Concentrations in liver were a factor of 3.3 higher than fillet on a lipid basis.
- Concentrations of SCCP and MCCP were higher in liver than fillet (by a factor of 3.9 and 4.5, respectively).
- Due to dominance of values below the detection limit, especially in fillet no strong conclusions could be drawn for liver-fillet correlations for α–HBCD, PFR, PBDE or bisphenol A.
- The ICES/OSPAR Background Assessment Criteria (BAC) for OH-pyrene in cod bile was exceeded at all four stations investigated.
- Inhibited ALA-D activity in cod liver from the Inner Oslofjord and Inner Sørfjord indicated exposure to lead.
- EROD activities and CYP1A protein levels in cod liver from the Inner Oslofjord indicated exposure to contaminants.
- The Inner Oslofjord seems all together to be an area where contaminants tend to appear in high concentrations. This is probably caused by a dens population, a multitude of urban activities and former and present use of products containing contaminants. A reduced water exchange with the outer fjord might also be part of the explanation.
- Freely dissolved contaminant concentrations measured with passive sampling are mostly close to or below limits of detection in the low pg/L range.
- Results from stabile isotopes indicate that the stations show very similar patterns from 2012 to 2013 in terms of isotopic signatures, suggesting that this is a spatial trend more than a temporal trend.
- Pooling samples from 1 to 5 individuals increases the uncertainty of time trends (change per year) by approximately 50%, resulting in perhaps twice as long to detect a trend.

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Appendix A
Quality assurance programme

Information on Quality Assurance

The chemical laboratories (NIVA and subcontractor Eurofins) and the biological laboratory (NIVA) have participated in the QUASIMEME international intercalibration exercises and other SLPs relevant to chemical and imposex analyses. The QUASIMEME exercises included nearly all the contaminants as well as imposex analysed in this programme.

For chemical analyses, these include Round 73 of October 2013 to January 2014, which apply to the 2013 samples. The quality assurance programme is corresponding to the 2012 programme (cf. Green *et al.* 2013).

NIVA participated in the last round of QUASIMEME Laboratory Performance Studies "imposex and intersex in Marine Snails BE1" in June-August 2012. Shell height, penis-length-male, penis-length-female, average-shell-height and female-male-ratio were measured. NIVA got the score satisfactory for all parameters except number of females for one sample, which got the score questionable. The score for VDSI was satisfactory for both samples tested.

In addition to the QUASIMEME exercises, certified reference materials (CRM) and in-house reference materials are analysed routinely with the MILKYS samples. It should be noted that for biota, the type of tissue used in the CRMs does not always match the target tissue for analysis. Uncertain values identified by the analytical laboratory or the reporting institute are flagged in the database. The results are also "screened" during the import to the database at NIVA and ICES.

Accreditation
The laboratories used for the chemical testing are accredited according to ISO 17025:2005.

Summary of quality control results
Standard Reference Materials (SRM) as well as in-house reference materials were analysed regularly (*Table 36*). Fish protein (DORM-4) or dogfish liver (DOLT-4) was used as SRM for the control of the determination of metals. The SRM for determination of BDEs in blue mussel was Folkehelsa reference material Halibut 2012. For determination of PCBs, DDTs, PAHs and chlorinated paraffines in blue mussel and liver, as well as BDEs in liver, Quasimeme biota samples with known true value was applied. The HBCDDs were determined using Folkehelsa reference material Salmon 2011. For TBBPA, spiked fish oil was used for quality assurance, for bisphenol-A and octyl/nonylphenols spiked fish meal was used. For organophosphorous flame retardants, spiked internal reference material was used.

The results for QUASIMEME-Round 73 apply to the 2013 samples. The results are acceptable for all parameters.

Table 36. Summary of the quality control of results for the 2013 biota samples analysed in 2013-2014. The Standard Reference Materials (SRM) were DOLT-4 (dogfish liver) for fish liver, DORM-4* (fish protein) for blue mussel and fish fillet.* Folkehelsa RM Halibut 2012** *and* Folkehelsa RM Salmon 2011** *were used for blue mussel and fish liver. The in-house reference materials were QUASIMEME samples QOR110BT (mussel tissue), QBC032BT and QOR108BT (fish liver) and QPH065BT (shellfish tissue). In addition, spiked fish oil, spiked fish meal and spiked internal reference material were analysed. The SRMs and in-house reference materials and quality assurance standards were analysed in series with the MILKYS samples, and measured several times (N) over a number of weeks (W). The values are reported in the following units: metals (mg/kg), BDE (pg/g mussel in soft body, µg/kg in liver), PCB (µg/kg), DDTs (µg/kg), HBCDDs (pg/g), PAH (µg/kg), TBBPA (ng/sample), BPA (ng/sample), SCCP/MCCP (µg/g), octyl/nonylphenol (ng/sample), organophosporous flame retardants (pg/sample) and PFCs (% recovery). Tissue types were: mussel soft body (SB), fish liver (LI) and fish fillet (MU).*

Code	Contaminant	Tissue type	SRM type	SRM value confidence interval	N	W	Mean value	Standard deviation
Ag	Silver	LI	DOLT-4	0.93 ± 0.07	33	30	0.8	0.11
As	Arsenic	LI	DOLT-4	9.66 ± 0.62	33	30	8.5	0.72
Cd	Cadmium	LI	DOLT-4	24.3 ± 0.8	33	30	23.8	2.4
Co	Cobalt	LI	DOLT-4	0.25[1)]	42	30	0.22	0.02
Cr	Chromium	LI	DOLT-4	1.4[1)]	33	30	1.39	0.22
Cu	Copper	LI	DOLT-4	31.2 ± 1.1	33	30	29.9	3.4
Ni	Nickel	LI	DOLT-4	0.97 ± 0.11	33	30	1.09	0.16
Pb	Lead	LI	DOLT-4	0.16 ± 0.04	33	30	0.14	0.04
Sn	Tin	LI	DOLT-4	0.17[1)]	42	30	0.19	0.06
Zn	Zinc	LI	DOLT-4	116 ± 6	42	30	122	11.5
As	Arsenic	SB	DORM-4	6.80 ± 0.64	35	30	6.26	0.5
Cd	Cadmium	SB	DORM-4	0.306 ± 0.015	35	30	0.29	0.022
Cr	Chromium	SB	DORM-4	1.87 ± 0.16	35	30	1.90	0.36
Co	Cobalt	SB	DORM-4	m	35	30	0.23	0.019
Cu	Copper	SB	DORM-4	15.9 ± 0.9	35	30	13.96	0.92
Hg	Mercury	MU	DORM-4	0.410 ± 0.055	36	30	0.37	0.036
Ni	Nickel	SB	DORM-4	1.36 ± 0.22	35	30	1.32	0.22
Pb	Lead	SB	DORM-4	0.416 ± 0.053	35	30	0.40	0.034
Zn	Zinc	SB	DORM-4	52.2 ± 3.2	35	30	49.8	3.9
BDE28	2,2,4' Tribromodiphenylether	LI	QBC032BT	0.39	17	4	0.34	0.14
BDE100	2,2',4,4',6-Pentabromodiphenylether	LI	QBC032BT	6.91	17	4	5.75	2.26
BDE153	2,2',4,4'5,5'-Hexabromodiphenylether	LI	QBC032BT	0.86[1)]	17	4	0.613	0.118
BDE154	2,2',4,4',5,6'-Hexabromodiphenylether	LI	QBC032BT	1.68	17	4	1.15	0.62
BDE47	2,2',4,4',-Tetrabromodiphenylether	LI	QBC032BT	23.2[1)]	17	4	17.7	6.99
BDE99	2,2',4,4',5-Pentabromodiphenylether	LI	QBC032BT	0.01[1)]	17	4	0.0064	0.0022
BDE126		LI	QBC032BT	m	17	4	0.019	0.0095
BDE183	2,2',3,4,4,5',6-Heptabromodiphenylether	LI	QBC032BT	m	17	4	m	m
BDE196		LI		m	17	4	m	m
BDE209	Decabromodiphenylether	LI	QBC032BT	m	17	4	0.0098	0.0064
BDE28	2,2,4' Tribromodiphenylether	LI/SB	Folkehelsa RM Halibut 2012	35 ± 5.6	2	20	34.3	4.6
BDE100	2,2',4,4',6-Pentabromodiphenylether	LI/SB	Folkehelsa RM Halibut 2012	92 ± 12	2	20	87.4	7.3
BDE153	2,2',4,4'5,5'-Hexabromodiphenylether	LI/SB	Folkehelsa RM Halibut 2012	17 ± 3.2	2	20	16.2	2.7
BDE154	2,2',4,4',5,6'-Hexabromodiphenylether	LI/SB	Folkehelsa RM Halibut 2012	86 ± 19	2	20	63.7	7
BDE47	2,2',4,4',-Tetrabromodiphenylether	LI/SB	Folkehelsa RM Halibut 2012	544 ± 94	2	20	519	23
BDE99	2,2',4,4',5-Pentabromodiphenylether	LI/SB	Folkehelsa RM Halibut 2012	26 ± 6.5	2	20	25.9	0.7
BDE126		LI/SB	Folkehelsa RM Halibut 2012	m	2	20	4.2	1.7
BDE183	2,2',3,4,4,5',6-Heptabromodiphenylether	LI/SB	Folkehelsa RM Halibut 2012	0.55 ± 0.31	1	20	1.31	m
BDE196		LI/SB	Folkehelsa RM Halibut 2012	m	m	m	m	m
BDE209	Decabromodiphenylether	LI/SB	Folkehelsa RM Halibut 2012	21 ± 10	1	20	54.9	m
CB101	PCB congener CB-101	SB	QOR110BT	3.25	27	13	3.08	0.306
CB118	PCB congener CB-118	SB	QOR110BT	2.20	27	13	2.105	0.144
CB138	PCB congener CB-138	SB	QOR110BT	7.93	27	13	5.51	0.303
CB153	PCB congener CB-153	SB	QOR110BT	4.46	27	13	8.64	0.557
CB180	PCB congener CB-180	SB	QOR110BT	0.48	27	13	0.586	0.058
CB28	PCB congener CB-28	SB	QOR110BT	0.37	27	13	0.41	0.039
CB52	PCB congener CB-52	SB	QOR110BT	1.11	27	13	1.36	0.123
DDEPP	4.4'-DDE	SB	QOR110BT	1.4	27	13	1.82	0.23

Code	Contaminant	Tissue type	SRM type	SRM value confidence interval	N	W	Mean value	Standard deviation
TDEPP	4.4'-DDD	SB	QOR110BT	0.59	27	13	0.418	0.118
DDTPP	4.4'-DDT	SB	QOR110BT	0.14 [1)]	27	13	0.794	0.997
α-HBCDD	α-Hexabromocyclododecane	LI	Folkehelsa RM Salmon 2011	1970 ± 533	6	3	2188	87
ß-HBCDD	ß- Hexabromocyclododecane	LI	Folkehelsa RM Salmon 2011	41 ± 19	6	3	43	8
γ-HBCDD	γ- Hexabromocyclododecane	LI	Folkehelsa RM Salmon 2011	94 ± 34	6	3	96	11
CB101	PCB congener CB-101	LI	QOR108BT	63.7	55	18	62.9	10.66
CB118	PCB congener CB-118	LI	QOR108BT	69.9	55	18	63.5	11.92
CB138	PCB congener CB-138	LI	QOR108BT	219	55	18	168.5	28.9
CB153	PCB congener CB-153	LI	QOR108BT	204.77	55	18	217.8	36.7
CB180	PCB congener CB-180	LI	QOR108BT	45.5	55	18	50.16	7.9
CB28	PCB congener CB-28	LI	QOR108BT	10.5	55	18	11.29	1.005
CB52	PCB congener CB-52	LI	QOR108BT	23.7	55	18	27.03	1.42
DDEPP	4.4'-DDE	LI	QOR108BT	83.1	55	18	79.72	14.5
DDTPP	4.4'-DDT	LI	QOR108BT	26.7	55	18	20.11	5.76
TDEPP	4.4'-DDD	LI	QOR108BT	0.83[1)]	55	18	m	m
ACNE	Acenaphthene	SB	QPH065BT	0.77	36	14	0.64	0.188
ACNLE	Acenaphthylene	SB	QPH065BT	0.45	36	14	0.94	0.175
ANT	Anthracene	SB	QPH065BT	0.75	36	14	1.99	0.417
BAP	benzo[a]pyrene	SB	QPH065BT	1.50	36	14	1.68	0.29
BBJF	Benzo[b+j]fluoranthene	SB	QPH065BT	4.99	36	14	4.59	0.843
BKF	Benzo[k]fluoranthene	SB	QPH065BT	2.00	36	14	3.09	0.495
BAA	Benzo[a]anthracene	SB	QPH065BT	5.26	36	14	5.18	0.76
CHR	Chrysene	SB	QPH065BT	7.19	36	14	6.52	0.752
DBA3A	Dibenzo[ac,ah]anthracene	SB	QPH065BT	0.43	36	14	0.45	0.092
FLE	Fluorene	SB	QPH065BT	1.59	36	14	0.96	0.301
FLU	Fluoranthene	SB	QPH065BT	13.8	36	14	17.21	2.642
ICDP	Indeno[1,2,3-cd]pyrene	SB	QPH065BT	1.52	36	14	1.02	0.232
NAP	Naphthalene	SB	QPH065BT	5.05	36	14	3.59	1.43
PA	Phenanthrene	SB	QPH065BT	8.18	36	14	8.47	1.121
BGHIP	Benzo(g,h,i)perylene	SB	QPH065BT	2.39	36	14	1.74	0.288
PYR	Pyrene	SB	QPH065BT	11.1	36	14	14.85	2.058
TBBPA	Tetrabromobisphenol-A	LI/SB	Internal RM (spiked fish oil)	m	20	17	1.5	0.09
BPA	Bisphenol-A	LI/SB	Internal RM (spiked fish meal)	m	12	10	38.5	1.3
SCCP	C10-C13 Chlorinated paraffines	LI/SB	Fish extract (proficiency test material)	0.191	3	m	0.143	0.011
MCCP	C13-C17 Chlorinated paraffines	LI/SB	m	m	m	m	m	m
	4-n-nonylphenol	LI/SB	Internal RM (spiked fish meal)	55	18	12	55.4	2
	4-n-octylphenol	LI/SB	Internal RM (spiked fish meal)	55	18	12	52.4	2.9
	4-Nonylphenol	LI/SB	Internal RM (spiked fish meal)	55	18	12	56.3	3.2
	4-tert-octylphenol	LI/SB	Internal RM (spiked fish meal)	55	18	12	64.1	8.3
TIBP	Triisobutylphosphate	LI/SB	Internal RM (spiked)	139130	19	5	133679	27.9
TBP	Tributylphosphate	LI/SB	Internal RM (spiked)	133211	19	5	193075	30.9
TCEP	Tris(2-chloroethyl)phosphate	LI/SB	Internal RM (spiked)	130435	19	5	143502	10.1
TCPP	Tris(2-chloro-isopropyl)phosphate	LI/SB	Internal RM (spiked)	146011	19	5	411918	37,2
TDCP	Tris(1,3-chloro-isopropyl)phosphate	LI/SB	Internal RM (spiked)	130435	19	5	162818	37.2
TBEP	Tris(2-butoxyethyl)phosphate	LI/SB	Internal RM (spiked)	134314	19	5	137900	10.8
TPhP	Triphenylphosphate	LI/SB	Internal RM (spiked)	130435	19	5	208478	38.1
EHDPP	2-Ethylhexyl-diphenylphosphate	LI/SB	Internal RM (spiked)	130435	19	5	188355	43.1
TEHP	Tris(2-ethylhexyl) phosphate	LI/SB	Internal RM (spiked)	197874	19	5	243354	41.6
ToCrP	o-Tricresylphosphate	LI/SB	Internal RM (spiked)	130435	19	5	161031	50.1
TCrP	Tricresylphosphate	LI/SB	Internal RM (spiked)	129130	19	5	161031	38,0
PFBS	Perfluorobutane sulphonate	LI		100 %[2)]	m	m	81	13.2
PFHxA	Perfluorohexane acid	LI		100 %[2)]	m	m	80	7.91
PFHpA	Perfluoroheptane acid	LI		100 %[2)]	m	m	68	14.0
PFOA	Perfluorooctane acid	LI		100 %[2)]	m	m	79	8.89
PFNA	Perfluorononane acid	LI		100 %[2)]	m	m	74	16.8
PFOS	Perfluorooctane sulphonate	LI		100 %[2)]	m	m	96	5.06
PFOSA	Perfluorooctane sulphone amide	LI		100 %[2)]	m	m	86	12.0
PFHxS	Perfluorohexane sulphonate	LI		100 %[2)]	m	m	82	7.81
PFDcA	Perfluorodecanoic acid	LI		100 %[2)]	m	m	78	16.4
PFUdA	Perfluoroundecanoic acid	LI		100 %[2)]	m	m	78	14.9
PFDcS	Perfluorodecanesulphonate	LI		100 %[2)]	m	m	77	4.68

* National Research Council Canada, Division of Chemistry, Marine Analytical Chemistry Standards.

** BCR, Community Bureau of Reference, Commission of the European Communities.

*** National Institute of Standards & Technology (NIST).

**** CIL, US.

1) Not certified value.

2) Calculated from separate values for **Benzo(b)fluoranthene** and **Benzo(j)fluoranthene.**

3) Recovery of spiked control sample

Appendix B
Abbreviations

Abbreviation[1]	English	*Norwegian*	Param. group
ELEMENTS			
Al	aluminium	*aluminium*	I-MET
Ag	Silver	*sølv*	I-MET
As	arsenic	*arsen*	I-MET
Ba	barium	*barium*	I-MET
Cd	cadmium	*kadmium*	I-MET
Ce	cerium	*serium*	I-MET
Co	cobalt	*kobolt*	I-MET
Cr	chromium	*krom*	I-MET
Cu	copper	*kobber*	I-MET
Fe	iron	*jern*	I-MET
Hg	mercury	*kvikksølv*	I-MET
La	lanthanum	*lantan*	I-MET
Li	lithium	*litium*	I-MET
Mn	manganese	*mangan*	I-MET
Mo	molybdenum	*molybden*	I-MET
Nd	neodymium	*neodym*	I-MET
Ni	nickel	*nikkel*	I-MET
Pb	lead	*bly*	I-MET
Pb210	lead-210	*bly-210*	I-RNC
Pr	praseodymium	*praseodym*	I-MET
Se	selenium	*selen*	I-MET
Sn	tin	*tinn*	I-MET
Ti	titanium	*titan*	I-MET
V	vanadium	*vanadium*	I-MET
Zn	zinc	*sink*	I-MET
METAL COMPOUNDS			
TBT	tributyltin (formulation basis =TBTIN*2.44)	*tributyltinn (formula basis =TBTIN*2.44)*	O-MET
MBTIN (MBT)	monobutyltin	*monobutyltinn*	O-MET
MBTIN (MBT)	monobutyltin	*monobutyltinn*	O-MET
MOT	monooctyltin	*monooktyltinn*	O-MET
MPTIN	monophenyltin	*monofenyltinn*	O-MET
DBTIN	dibutyltin (di-n-butyltin)	*dibutyltinn (di-n-butyltinn)*	O-MET
DOT	dioctyltin	*dioktyltinn*	O-MET
DPTIN	diphenyltin	*difenyltinn*	O-MET
TBTIN	tributyltin (=TBT*0.40984)	*tributyltinn (=TBT*0.40984)*	O-MET
TCHT	tricyclohexyl-stannylium	*tricyclohexyl-stannylium*	O-MET
TPTIN (TPhT)	triphenyltin	*trifenyltinn*	O-MET
TTBT	tetrabutyltin	*tetrabutyltinn*	O-MET
PAHs			
PAH	polycyclic aromatic hydrocarbons	*polysykliske aromatiske hydrokarboner*	
ACNE [3]	acenaphthene	*acenaften*	PAH
ACNLE [3]	acenaphthylene	*acenaftylen*	PAH
ANT [3]	anthracene	*antracen*	PAH
BAA [3, 4]	benzo[*a*]anthracene	*benzo[a]antracen*	PAH
BAP [3, 4]	benzo[*a*]pyrene	*benzo[a]pyren*	PAH
BBF [3, 4]	benzo[*b*]fluoranthene	*benzo[b]fluoranten*	PAH
BBJF [3, 4]	benzo[*j*]fluoranthene	*benzo[j]fluoranten*	PAH
BBJKF [3, 4]	benzo[*b,j,k*]fluoranthene	*benzo[b,j,k]fluoranten*	PAH
BBJKF [3, 4]	benzo[b+j,k]fluoranthene	*benzo[b+j,k]fluoranten*	PAH
BBKF [3, 4]	benzo[*b+k*]fluoranthene	*benzo[b+k]fluoranten*	PAH
BEP	benzo[*e*]pyrene	*benzo[e]pyren*	PAH

Abbreviation[1]	English	*Norwegian*	Param. group
BGHIP [3]	benzo[*ghi*]perylene	*benzo[ghi]perylen*	PAH
BIPN [2]	biphenyl	*bifenyl*	PAH
BJKF [3, 4]	benzo[*j,k*]fluoranthene	*benzo[j,k]fluorantren*	PAH
BKF [3, 4]	benzo[*k*]fluoranthene	*benzo[k]fluorantren*	PAH
CHR [3, 4]	chrysene	*chrysen*	PAH
CHRTR [3, 4]	chrysene+triphenylene	*chrysen+trifenylen*	PAH
COR	coronene	*coronen*	PAH
DBAHA [3, 4]	dibenz[*a,h*]anthracene	*dibenz[a,h]anthracen*	PAH
DBA3A [3, 4]	dibenz[*a,c/a,h*]anthracene	*dibenz[a,c/a,h]antracen*	PAH
DBP [4]	dibenzopyrenes	*dibenzopyren*	PAH
DBT	dibenzothiophene	*dibenzothiofen*	PAH
DBTC1	C_1-dibenzothiophenes	*C_1-dibenzotiofen*	PAH
DBTC2	C_2-dibenzothiophenes	*C_2-dibenzotiofen*	PAH
DBTC3	C_3-dibenzothiophenes	*C_3-dibenzotiofen*	PAH
FLE [3]	fluorene	*fluoren*	PAH
FLU [3]	fluoranthene	*fluoranten*	PAH
ICDP [3, 4]	indeno[*1,2,3-cd*]pyrene	*indeno[1,2,3-cd]pyren*	PAH
NAP [2]	naphthalene	*naftalen*	PAH
NAPC1 [2]	C_1-naphthalenes	*C_1-naftalen*	PAH
NAPC2 [2]	C_2-naphthalenes	*C_2-naftalen*	PAH
NAPC3 [2]	C_3-naphthalenes	*C_3-naftalen*	PAH
NAP1M [2]	1-methylnaphthalene	*1-metylnaftalen*	PAH
NAP2M [2]	2-methylnaphthalene	*2-metylnaftalen*	PAH
NAPD2 [2]	1,6-dimethylnaphthalene	*1,6-dimetylnaftalen*	PAH
NAPD3 [2]	1,5-dimethylnaphthalene	*1,5-dimetylnaftalen*	PAH
NAPDI [2]	2,6-dimethylnaphthalene	*2,6-dimetylnaftalen*	PAH
NAPT2 [2]	2,3,6-trimethylnaphthalene	*2,3,6-trimetylnaftalen*	PAH
NAPT3 [2]	1,2,4-trimethylnaphthalene	*1,2,4-trimetylnaftalen*	PAH
NAPT4 [2]	1,2,3-trimethylnaphthalene	*1,2,3-trimetylnaftalen*	PAH
NAPTM [2]	2,3,5-trimethylnaphthalene	*2,3,5-trimetylnaftalen*	PAH
NPD	collective term for naphthalenes, phenanthrenes and dibenzothiophenes	*sammebetegnelse for naftalen, fenantren og dibenzotiofens*	PAH
PA [3]	phenanthrene	*fenantren*	PAH
PAC1	C_1-phenanthrenes	*C_1-fenantren*	PAH
PAC2	C_2-phenanthrenes	*C_2-fenantren*	PAH
PAC3	C_3-phenanthrenes	*C_3-fenantren*	PAH
PAM1	1-methylphenanthrene	*1-metylfenantren*	PAH
PAM2	2-methylphenanthrene	*2-metylfenantren*	PAH
PADM1	3,6-dimethylphenanthrene	*3,6-dimetylfenantren*	PAH
PADM2	9,10-dimethylphenanthrene	*9,10-dimetylfenantren*	PAH
PER	perylene	*perylen*	PAH
PYR [3]	pyrene	*pyren*	PAH
DI-Σn	sum of "n" dicyclic "PAH"s (footnote 2)	*sum "n" disykliske "PAH" (fotnote 2)*	
P-Σn/P_S	sum "n" PAH (DI-Σn not included, footnote 3)	*sum "n" PAH (DI-Σn ikke inkludert, fotnot 3)*	
PK-Σn/PK_S	sum carcinogen PAHs (footnote 4)	*sum kreftfremkallende PAH (fotnote 4)*	
PAHΣΣ	dI-Σn + P-Σn etc.	*dI-Σn + P-Σn mm.*	
SPAH	"total" PAH, specific compounds not quantified (outdated analytical method)	*"total" PAH, spesifikk forbindelser ikke kvantifisert (foreldret metode)*	
BAP_P	% BAP of PAHΣΣ	*% BAP av PAHΣΣ*	
BAPPP	% BAP of P-Σn	*% BAP av P-Σn*	

Abbreviation[1]	English	*Norwegian*	Param. group
BPK_P	% BAP of PK_Sn	*% BAP av PK_Sn*	
PKn_P	% PK_Sn of PAHΣΣ	*% PK_Sn av PAHΣΣ*	
PKnPP	% PK_Sn of P-Σn	*% PK_Sn av P-Σn*	
PCBs			
PCB	**polychlorinated biphenyls**	*polyklorerte bifenyler*	
CB	individual chlorobiphenyls (CB)	*enkelte klorobifenyl*	
CB28	CB28 (IUPAC)	*CB28 (IUPAC)*	OC-CB
CB31	CB31 (IUPAC)	*CB31 (IUPAC)*	OC-CB
CB44	CB44 (IUPAC)	*CB44 (IUPAC)*	OC-CB
CB52	CB52 (IUPAC)	*CB52 (IUPAC)*	OC-CB
CB77 [5]	CB77 (IUPAC)	*CB77 (IUPAC)*	OC-CB
CB81 [5]	CB81 (IUPAC)	*CB81 (IUPAC)*	OC-CB
CB95	CB95 (IUPAC)	*CB95 (IUPAC)*	OC-CB
CB101	CB101 (IUPAC)	*CB101 (IUPAC)*	OC-CB
CB105	CB105 (IUPAC)	*CB105 (IUPAC)*	OC-CB
CB110	CB110 (IUPAC)	*CB110 (IUPAC)*	OC-CB
CB118	CB118 (IUPAC)	*CB118 (IUPAC)*	OC-CB
CB126 [5]	CB126 (IUPAC)	*CB126 (IUPAC)*	OC-CB
CB128	CB128 (IUPAC)	*CB128 (IUPAC)*	OC-CB
CB138	CB138 (IUPAC)	*CB138 (IUPAC)*	OC-CB
CB149	CB149 (IUPAC)	*CB149 (IUPAC)*	OC-CB
CB153	CB153 (IUPAC)	*CB153 (IUPAC)*	OC-CB
CB156	CB156 (IUPAC)	*CB156 (IUPAC)*	OC-CB
CB169 [5]	CB169 (IUPAC)	*CB169 (IUPAC)*	OC-CB
CB170	CB170 (IUPAC)	*CB170 (IUPAC)*	OC-CB
CB180	CB180 (IUPAC)	*CB180 (IUPAC)*	OC-CB
CB194	CB194 (IUPAC)	*CB194 (IUPAC)*	OC-CB
CB209	CB209 (IUPAC)	*CB209 (IUPAC)*	OC-CB
CB-Σ7	CB: 28+52+101+118+138+153+180	*CB: 28+52+101+118+138+153+180*	
CB-ΣΣ	sum of CBs, includes CB-Σ7	*sum CBer, inkluderer CB-Σ7*	
TECBW	sum of CB-toxicity equivalents after WHO model, see **TEQ**	*sum CB- toksitets ekvivalenter etter WHO modell, se TEQ*	
TECBS	sum of CB-toxicity equivalents after SAFE model, see **TEQ**	*sum CB-toksitets ekvivalenter etter SAFE modell, se TEQ*	
PCN	polychlorinated naphthalenes	*polyklorerte naftalen*	
DIOXINs			
TCDD	2, 3, 7, 8-tetrachloro-dibenzo dioxin	*2, 3, 7, 8-tetrakloro-dibenzo dioksin*	OC-DX
CDDST	sum of tetrachloro-dibenzo dioxins	*sum tetrakloro-dibenzo dioksiner*	
CDD1N	1, 2, 3, 7, 8-pentachloro-dibenzo dioxin	*1, 2, 3, 7, 8-pentakloro-dibenzo dioksin*	OC-DX
CDDSN	sum of pentachloro-dibenzo dioxins	*sum pentakloro-dibenzo dioksiner*	
CDD4X	1, 2, 3, 4, 7, 8-hexachloro-dibenzo dioxin	*1, 2, 3, 4, 7, 8-heksakloro-dibenzo dioksin*	OC-DX
CDD6X	1, 2, 3, 6, 7, 8-hexachloro-dibenzo dioxin	*1, 2, 3, 6, 7, 8-heksakloro-dibenzo dioksin*	OC-DX
CDD9X	1, 2, 3, 7, 8, 9-hexachloro-dibenzo dioxin	*1, 2, 3, 7, 8, 9-heksakloro-dibenzo dioksin*	OC-DX
CDDSX	sum of hexachloro-dibenzo dioxins	*sum heksakloro-dibenzo dioksiner*	
CDD6P	1, 2, 3, 4, 6, 7, 8-heptachloro-dibenzo dioxin	*1, 2, 3, 4, 6, 7, 8-heptakloro-dibenzo dioksin*	OC-DX
CDDSP	sum of heptachloro-dibenzo dioxins	*sum heptakloro-dibenzo dioksiner*	

Abbreviation[1]	English	*Norwegian*	Param. group
CDDO	Octachloro-dibenzo dioxin	*Oktakloro-dibenzo dioksin*	OC-DX
PCDD	sum of polychlorinated dibenzo-p-dioxins	*sum polyklorinaterte-dibenzo-p-dioksiner*	
CDF2T	2, 3, 7, 8-tetrachloro-dibenzofuran	*2, 3, 7, 8-tetrakloro-dibenzofuran*	OC-DX
CDFST	sum of tetrachloro-dibenzofurans	*sum tetrakloro-dibenzofuraner*	
CDFDN	1, 2, 3, 7, 8/1, 2, 3, 4, 8-pentachloro-dibenzofuran	*1, 2, 3, 7, 8/1, 2, 3, 4, 8-pentakloro-dibenzofuran*	OC-DX
CDF2N	2, 3, 4, 7, 8-pentachloro-dibenzofuran	*2, 3, 4, 7, 8-pentakloro-dibenzofuran*	OC-DX
CDFSN	sum of pentachloro-dibenzofurans	*sum pentakloro-dibenzofuraner*	
CDFDX	1, 2, 3, 4, 7, 8/1, 2, 3, 4, 7, 9-hexachloro-dibenzofuran	*1, 2, 3, 4, 7, 8/1, 2, 3, 4, 7, 9-heksakloro-dibenzofuran*	OC-DX
CDF6X	1, 2, 3, 6, 7, 8-hexachloro-dibenzofuran	*1, 2, 3, 6, 7, 8-heksakloro-dibenzofuran*	OC-DX
CDF9X	1, 2, 3, 7, 8, 9-hexachloro-dibenzofuran	*1, 2, 3, 7, 8, 9-heksakloro-dibenzofuran*	OC-DX
CDF4X	2, 3, 4, 6, 7, 8-hexachloro-dibenzofuran	*2, 3, 4, 6, 7, 8-heksakloro-dibenzofuran*	OC-DX
CDFSX	sum of hexachloro-dibenzofurans	*sum heksakloro-dibenzofuraner*	
CDF6P	1, 2, 3, 4, 6, 7, 8-heptachloro-dibenzofuran	*1, 2, 3, 4, 6, 7, 8-heptakloro-dibenzofuran*	OC-DX
CDF9P	1, 2, 3, 4, 7, 8, 9-heptachloro-dibenzofuran	*1, 2, 3, 4, 7, 8, 9-heptakloro-dibenzofuran*	OC-DX
CDFSP	sum of heptachloro-dibenzofurans	*sum heptakloro-dibenzofuraner*	OC-DX
CDFO	octachloro-dibenzofurans	*octakloro-dibenzofuran*	OC-DX
PCDF	sum of polychlorinated dibenzo-furans	*sum polyklorinated dibenzo-furaner*	
CDDFS	sum of PCDD and PCDF	*sum PCDD og PCDF*	
TCDDN	sum of TCDD-toxicity equivalents after Nordic model, see **TEQ**	*sum TCDD- toksitets ekvivalenter etter Nordisk modell, se TEQ*	
TCDDI	sum of TCDD-toxicity equivalents after international model, see **TEQ**	*sum TCDD-toksitets ekvivalenter etter internasjonale modell, se TEQ*	
PESTICIDES			
ALD	aldrin	*aldrin*	OC-DN
DIELD	dieldrin	*dieldrin*	OC-DN
ENDA	endrin	*endrin*	OC-DN
CCDAN	cis-chlordane (=α-chlordane)	*cis-klordan (=α-klordan)*	OC-DN
TCDAN	trans-chlordane (=γ-chlordane)	*trans-klordan (=γ-klordan)*	OC-DN
OCDAN	oxy-chlordane	*oksy-klordan*	OC-DN
TNONC	trans-nonachlor	*trans-nonaklor*	OC-DN
TCDAN	trans-chlordane	*trans-klordan*	OC-DN
OCS	octachlorostyrene	*oktaklorstyren*	OC-CL
QCB	pentachlorobenzene	*pentaklorbenzen*	OC-CL
DDD	dichlorodiphenyldichloroethane 1,1-dichloro-2,2-bis-(4-chlorophenyl)ethane	*diklordifenyldikloretan* *1,1-dikloro-2,2-bis-(4-klorofenyl)etan*	OC-DD
DDE	dichlorodiphenyldichloroethylene (principle metabolite of DDT) 1,1-*bis*-(4-chlorophenyl)-2,2-dichloroethene*	*diklordifenyldikloretylen (hovedmetabolitt av DDT)* *1,1-bis-(4-klorofenyl)-2,2-dikloroeten*	OC-DD
DDT	dichlorodiphenyltrichloroethane 1,1,1-trichloro-2,2-bis-(4-chlorophenyl)ethane	*diklordifenyltrikloretan* *1,1,1-trikloro-2,2-bis-(4-klorofenyl)etan*	OC-DD
DDEOP	o,p'-DDE	*o,p'-DDE*	OC-DD
DDEPP	p,p'-DDE	*p,p'-DDE*	OC-DD
DDTOP	o,p'-DDT	*o,p'-DDT*	OC-DD

Abbreviation[1]	English	*Norwegian*	Param. group
DDTPP	p,p'-DDT	*p,p'-DDT*	OC-DD
TDEPP	p,p'-DDD	*p,p'-DDD*	OC-DD
DDTEP	p,p'-DDE + p,p'-DDT	*p,p'-DDE + p,p'-DDT*	OC-DD
DD-nΣ	sum of DDT and metabolites, n = number of compounds	*sum DDT og metabolitter, n = antall forbindelser*	OC-DD
HCB	hexachlorobenzene	*heksaklorbenzen*	OC-CL
HCHG	Lindane γ HCH = gamma hexachlorocyclohexane (γ BHC = gamma benzenehexachloride, outdated synonym)	*Lindan* *γ HCH = gamma heksaklorsykloheksan* *(γ BHC = gamma benzenheksaklorid, foreldret betegnelse)*	OC-HC
HCHA	α HCH = alpha HCH	*α HCH = alpha HCH*	OC-HC
HCHB	β HCH = beta HCH	*β HCH = beta HCH*	OC-HC
HC-nΣ	sum of HCHs, n = count	*sum av HCHs, n = antall*	
EOCl	extractable organically bound chlorine	*ekstraherbart organisk bundet klor*	OC-CL
EPOCl	extractable persistent organically bound chlorine	*ekstraherbart persistent organisk bundet klor*	OC-CL
PBDEs			
PBDE	**polybrominated diphenyl ethers**	*polybromerte difenyletere*	OC-BR
BDE	brominated diphenyl ethers		OC-BR
BDE28	2,4,4'-tribromodiphenyl ether	*2,4,4'-tribromdifenyleter*	OC-BR
BDE47	2,2',4,4'-tetrabromodiphenyl ether	*2,2',4,4'-tetrabromdifenyleter*	OC-BR
BDE49*	2,2',4,5'- tetrabromodiphenyl ether	*2,2',4,5'- tetrabromdifenyleter*	OC-BR
BDE66*	2,3',4',6- tetrabromodiphenyl ether	*2,3',4',6- tetrabromdifenyleter*	OC-BR
BDE71*	2,3',4',6- tetrabromodiphenyl ether	*2,3',4',6- tetrabromdifenyleter*	OC-BR
BDE77	3,3',4,4'-tetrabromodiphenyl ether	*3,3',4,4'-tetrabromdifenyleter*	OC-BR
BDE85	2,2',3,4,4'-pentabromodiphenyl ether	*2,2',3,4,4'-pentabromdifenyleter*	OC-BR
BDE99	2,2',4,4',5-pentabromodiphenyl ether	*2,2',4,4',5-pentabromdifenyleter*	OC-BR
BDE100	2,2',4,4',6-pentabromodiphenyl ether	*2,2',4,4',6-pentabromdifenyleter*	OC-BR
BDE119	2,3',4,4',6-pentabromodiphenyl ether	*2,3',4,4',6-pentabromdifenyleter*	OC-BR
BDE138	2,2',3,4,4',5'-hexabromodiphenyl ether	*2,2',3,4,4',5'-heksabromdifenyleter*	OC-BR
BDE153	2,2',4,4',5,5'-hexabromodiphenyl ether	*2,2',4,4',5,5'-heksabromdifenyleter*	OC-BR
BDE154	2,2',4,4',5,6'-hexabromodiphenyl ether	*2,2',4,4',5,6'-heksabromdifenyleter*	OC-BR
BDE183	2,2',3,4,4',5',6-heptabromodiphenyl ether	*2,2',3,4,4',5',6-heptabromdifenyleter*	OC-BR
BDE196	2,2',3,3',4,4',5',6-octabromodiphenyl ether	*2,2',3,3',4,4',5',6-octabromdifenyleter*	OC-BR
BDE205	2,2',3,3',4,4',5,5',6'-nonabromodiphenyl ether	*2,2',3,3',4,4',5,5',6'-nonabromdifenyleter*	OC-BR
BDE209	decabromodiphenyl ether	*Dekabromdifenyleter*	OC-BR
BDE5S	sum of BDE -85, -99, -100, -119	*sum av BDE -85, -99, -100, -119*	OC-BR
BDESS	sum of all BDEs	*sum av alle BDEer*	OC-BR

Abbreviation[1]	English	*Norwegian*	Param. group
HBCDD	hexabromocyclododecane (1 2 5 6 9 10 hexabromocyclododecane)	*heksabromsyklododekan (1 2 5 6 9 10 heksabromsyklododekan)*	OC-BR
HBCDA	α–hexabromocyclododecane	*α–heksabromsyklododekan*	OC-BR
HBCDB	β-hexabromocyclododecane	*β-heksabromsyklododekan*	OC-BR
HBCDG	γ-hexabromocyclododecane	*γ-heksabromsyklododekan*	OC-BR
TBBPA	tetrabrombisphenol A	*tetrabrombisfenol A*	OC-CP
BPA	bisphenol A	*bisfenol A*	OC-CP
PFAS	**perfluorinated alkylated substances**	*perfluoralkylertestoffer*	
PFBS	perfluorobutane sulfonate	*perfluorbutan sulfonat*	PFAS
PFDCA	perfluorodecanoic acid	*perfluordekansyre*	PFAS
PFDCS	ammonium henicosafluorodecanesulphonate	*ammonium henikosafluordekansulfonat*	PFAS
PFHxA	perfluorohexanoic acid	*perfluorhexansyre*	PFAS
PFHpA	perfluoroheptanoic acid	*perfluorheptansyre*	PFAS
PFOA	perfluorooctanoic acid	*perfluoroktansyre*	PFAS
PFNA	perfluorononanoic acid	*perfluornonansyre*	PFAS
PFOS	perfluoroctanoic sulfonate	*perfluoroktansulfonat*	PFAS
PFOSA	perfluoroctanesulfonic amide	*perfluoroktansulfonamid*	PFAS
PFUDA	perfluoroundecanoic acid	*perfluorundekansyre*	PFAS
SCCP	short chain chlorinated paraffins, C_{10-13}	*kortkjedete klorerte parafiner, C_{10-13}*	
MCCP	medium chain chlorinated, C_{14-17} paraffins	*mediumkjedete klorerte parafiner, C_{14-17}*	
Akylphenols	**phenols/chlorophenols**	*fenoler/klorfenoler*	
4-n-NP	4-n-nonylphenol	*4-n-nonylfenol*	
4-n-OP	4-n-octylphenol	*4-n-oktylfenol*	
4-t-NP	4-tert-nonylphenol	*4-tert-nonylfenol*	
4-t-OP	4-tert-octylphenol	*4-tert-oktylfenol*	
PFR	**Phosphorus Flame Retardants**	*Fosforflammehemmera*	
TIBP	tri-*iso*-butylphosphate	*tri-iso-butylfosfat*	
TBP	tributylphosphate	*tributylfosfat*	
TCEP	tri(2-chloroethyl)phosphate	*tri(2-kloretyl)fosfat*	
TCPP	tri(1-chloro-2-propyl)phosphate	*tri(1-klor-2-propyl)fosfat*	
TDCP	tri(1,3-dichloro-2-propyl)phosphate	*tri(1,3-diklor-2-propyl)fosfat*	
TBEP	tri(2-butoxyethyl)phosphate	*tri(2-butokysetyl)fosfat*	
TPhP	triphenylphosphate	*trifenylfosfat*	
EHDPP	2-ethylhexyl-di-phenylphosphate	*2-etylheksyl-difenylfosfat*	
V6	tetrekis(2-chlorethyl)dichloroisopentyldiphosphate	*tetrakis-(2-kloroetyl)diklorisopentyldifosfat*	
DBPhP	dibutylphenylphosphate	*dibutylfenylfosfat*	
BdPhP	butyldiphenylphosphate	*butyldifenylfosfat*	
TEHP	tris(2-etylhexyl)phosphate	*tris(2-etylheksyl)fosfat*	
ToCrP	tris-o-cresylphosphate	*tris-o-kresylfosfat*	
TCrP	tricresyl phosphate	*trikresylfosfat*	
	stable isotopes	*stabile isotoper*	
C/N	$\delta^{13}C$ /$\delta^{15}N$	*$\delta^{13}C$ /$\delta^{15}N$*	
Delta15N	$\delta^{15}N$	*$\delta^{15}N$*	
Delta13C	$\delta^{13}C$	*$\delta^{13}C$*	
	phthalates/organic esters	*phtalater/organiske estere*	
DBP	dibutylphthalate	*dibutylftalat*	

Abbreviation[1]	English	*Norwegian*	Param. group
DBPA	dibutyladipat	*dibutyladipat*	
DEHA	diethylhexcyladipate	*dietylheksyladipat*	
DEHP	di(2-ethylhexyl)-phthalate	*di(2-etylhexyl)-ftalate*	
DEP	dietylphthale	*dietylftalat*	
DEPA	diethyladipat	*dietyladipat*	
BBP	benzylbutylphthalate	*benzylbutylftalat*	
DIBP	diisobutylphthalate	*diisobutylftalat*	
DIDP	diisodectylyphthalate	*diisodekylftalat*	
DIHP	diisoheptylphthalate	*diisoheptylftalat*	
DINCH	1,2-Cyclohexane dicarboxylic acid diisononyl ester	*1,2-sykloheksan dikarboksylik syre diisononyl ester*	
DIPA	diisobutyl adipate	*diisobutyladipat*	
DMP	dimethylphthalate	*dimetylftalat*	
DNOP	di-n-octylphthalte	*di-n-oktylftalt*	
DPF	diphenylphthalate	*difenylftalat*	
SDD	dinonylphthalte+diisononylphthalate	*dinonylftalat+diisononylftalat*	
TOA	tributyl-o-acetylcitrate	*tributyl-o-acetylcitrate*	
[not defined]	trichlosan	*triklosan*	
[not defined]	dodecylfenol	*dodecylfenol*	
[not defined]	Duiron	*Durion*	
[not defined]	Irgarol	*Irgarol*	
NTOT	total organic nitrogen	*total organisk nitrogen*	I-NUT
CTOT	total organic carbon	*total organisk karbon*	O-MAJ
CORG	organic carbon	*organisk karbon*	O-MAJ
GSAMT	grain size	*kornfordeling*	P-PHY
MOCON	moisture content	*vanninnhold*	P-PHY
Specific biological effects methods			
ALAD	δ-aminolevulinic acid dehydrase inhibition	*δ-aminolevulinsyre dehydrase*	BEM
CYP1A	cytochrome P450 1A-protein	*cytokrom P450 1A-protein*	BEM
EROD-activity	Cytochrome P4501A-activity (CYP1A/P4501A1, EROD)	*cytokrom P450 1A-aktivitet*	BEM
OH-pyrene	Pyrene metabolite	*pyren metabolitt*	BEM
VSDI	Vas Deferens Sequence Index		BEM
INSTITUTES			
EFDH	Eurofins [DK]	*Eurofins [DK]*	
EFNO	Eurofins [N, Moss]	*Eurofins [N, Moss]*	
EFGFA	Eurofins [DE, GFA]	*Eurofins [DE, GFA]*	
EFSofia	Eurofins [DE, Sofia]	*Eurofins [DE, Sofia]*	
FIER	Institute for Nutrition, Fisheries Directorate	*Fiskeridirektoratets Ernæringsinstitutt*	
FORC	FORCE Institutes, Div. for Isotope Technique and Analysis [DK]	*FORCE Institutterne, Div. for Isotopteknik og Analyse [DK]*	
GALG	GALAB Laboratories Gmbh [D]	*GALAB Laboratories Gmbh [D]*	
IFEN	Institute for Energy Technology	*Institutt for energiteknikk*	
IMRN	Institute of Marine Research (IMR)	*Havforskningsinstituttet*	
NACE	Nordic Analytical Center	*Nordisk Analyse Center*	
NILU	Norwegian Institute for Air Research	*Norsk institutt forluftforskning*	
NIVA	Norwegian Institute for Water Research	*Norsk institutt for vannforskning*	
SERI	Swedish Environmental Research Institute	*Institutionen för vatten- och luftvårdsforskning*	

Abbreviation[1]	English	*Norwegian*	Param. group
SIIF	Fondation for Scientific and Industrial Research at the Norwegian Institute of Technology-SINTEF (a division, previously: Center for Industrial Research SI)	*Stiftelsen for industriell og teknisk forskning ved Norges tekniske høgskole- SINTEF (en avdeling, tidligere: Senter for industriforskning SI)*	
VETN	Norwegian Veterinary Institute	*Veterinærinstituttet*	
VKID	Water Quality Institute [DK]	*Vannkvalitetsintitutt [DK]*	

[1]) After: ICES Environmental Data Reporting Formats. International Council for the Exploration of the Sea. July 1996 and supplementary codes related to non-ortho and mono-ortho PCBs and “dioxins” (ICES pers. comm.)

[2]) Indicates "PAH" compounds that are dicyclic and not truly PAHs typically identified during the analyses of PAH, include naphthalenes and "biphenyls".

[3]) Indicates the sum of tri- to hexacyclic PAH compounds named in EPA protocol 8310 minus naphthalene (dicyclic), so that the Klif classification system can be applied

[4]) Indicates PAH compounds potentially cancerogenic for humans according to IARC (1987, updated 14.August 2007 at http://monographs.iarc.fr/ENG/Classification/crthgr01.php), i.e., categories 1, 2A, and 2B (are, possibly and probably carcinogenic). NB.: the update includes Chrysene as cancerogenic and hence, KPAH with Chrysene should not be used in Klif's classification system for this sum-variable (Molvær *et al.* 1997).

[5]) Indicates non ortho- co-planer PCB compounds i.e., those that lack Cl in positions 1, 1', 5, and 5'

*) The Pesticide Index, second edition. The Royal Society of Chemistry, 1991.

Other abbreviations *andre forkortelser*

	English	*Norwegian*
TEQ	"Toxicity equivalency factors" for the most toxic compounds within the following groups:	*"Toxisitetsekvivalentfaktorer" for de giftigste forbindelsene innen følgende grupper.*
	• polychlorinated dibenzo-p-dioxins and dibenzofurans (**PCDD/PCDFs**). Equivalents calculated after Nordic model (Ahlborg 1989) [1] or international model (Int./EPA, cf. Van den Berg *et al.* 1998) [2]	• *polyklorerte dibenzo-p-dioksiner og dibenzofuraner (**PCDD/PCDF**). Ekvivalentberegning etter nordisk modell (Ahlborg 1989) [1] eller etter internasjonal modell (Int./EPA, cf. Van den Berg et al. 1998) [2]*
	• non-ortho and mono-ortho substituted chlorobiphenyls after WHO model (Ahlborg *et al.* 1994) [3] or Safe (1994, cf. NILU pers. comm.)	• *non-orto og mono-orto substituerte klorobifenyler etter WHO modell (Ahlborg et al. 1994) [3] eller Safe (1994, cf. NILU pers. medd.)*
ppm	parts per million, mg/kg	*deler pr. milliondeler, mg/kg*
ppb	parts per billion, μg/kg	*deler pr. milliarddeler, μg/kg*
ppp	parts per trillion, ng/kg	*deler pr. tusen-milliarddeler, ng/kg*
d.w.	dry weight basis	*tørrvekt basis*
w.w.	wet weight or fresh weight basis	*våtvekt eller friskvekt basis*

[1]) Ahlborg, U.G., 1989. Nordic risk assessment of PCDDs and PCDFs. Chemosphere 19:603-608.

[2]) Van den Berg, Birnbaum, L, Bosveld, A. T. C. and co-workers, 1998. Toxic equivalency factors (TEFs) for PCBs, PCDDs, PCDFs for humans and wildlife. Environ Hlth. Perspect. 106:775-792.

[3]) Ahlborg, U.G., Becking G.B., Birnbaum, L.S., Brouwer, A, Derks, H.J.G.M., Feely, M., Golor, G., Hanberg, A., Larsen, J.C., J.C., Liem, A.K.G., Safe, S.H., Schlatter, C., Wärn, F., Younes, M., Yrjänheikki, E., 1994. Toxic equivalency factors for dioxin-like PCBs. Report on a WHO-ECEH and IPSC consultation, December 1993. Chemosphere 28:1049-1067.

Appendix C
Classification of environmental quality

Table 37. Norwegian Environment Agency classification system of contaminants in blue mussel and fish (Molvær et al. 1997) and proposed revisions (shaded) for Class I concentrations (Knutzen & Green 2001) used in this report.

Contaminant			**Classification (upper limit for Classes I-IV)** *Degree of pollution*				
			I *Insignificant*	**II** *Moderate*	**III** *Marked*	**IV** *Severe*	**V** *Extreme*
Blue mussel							
Arsenic (As)	mg/kg	w.w. [2)]	10	30	70	140	>140
	mg/kg	d.w.	50	150	350	700	>700
Cadmium (Cd)	mg/kg	w.w. [2)]	0.4	1	4	8	>8
	mg/kg	d.w.	2	5	20	40	>40
Copper (Cu)	mg/kg	w.w. [2)]	2	6	20	40	>40
	mg/kg	d.w.	10	30	100	200	>200
Chromium (Cr)	mg/kg	w.w. [2)]	0.2	1	3	10	>10
	mg/kg	d.w.	1	5	15	50	>50
Lead (Pb)	mg/kg	w.w. [2)]	0.6	3	8	20	>20
	mg/kg	d.w.	3	15	40	100	>100
Mercury (Hg)	mg/kg	w.w. [2)]	0.04	0.1	0.3	0.8	>0.8
	mg/kg	d.w.	0.2	0.5	1.5	4	>4
Nickel (Ni)	mg/kg	w.w. [2)]	1	5	10	20	>20
	mg/kg	d.w.	5	25	50	100	>100
Silver (Ag)	mg/kg	d.w.	0.3	1	2	5	>5
Zinc (Zn)	mg/kg	w.w. [2)]	40	80	200	500	>500
	mg/kg	d.w.	200	400	1000	2500	>2500
TBT [1)]	mg/kg	d.w.	0.1	0.5	2	5	>5
∑PCB-7	µg/kg	w.w.	3 [5)]	15	40	100	>100
		d.w. [2)]	15 [2)]	75	200	500	>500
∑DDT [11)]	µg/kg	w.w.	2	5	10	30	>30
		d.w. [2)]	10	25	50	150	>150
∑HCH [12)]	µg/kg	w.w.	1	3	10	30	>30
		d.w. [2)]	5	15	50	150	>150
HCB	µg/kg	w.w.	0.1	0.3	1	5	>5
		d.w. [2)]	0.5	1.5	5	25	>25
∑PAH [13)]	µg/kg	w.w.	50	200	2000	5000	>5000
		d.w. [2)]	250	1000	10000	25000	>25000
∑KPAH	µg/kg	w.w.	10	30	100	300	>300
		d.w. [2)]	50	150	500	1500	>1500
B[*a*]P	µg/kg	w.w.	1	3	10	30	>30
		d.w. [2)]	5	15	50	150	>150
$TE_{PCDF/D}$ [3)]	µg/t [4)]	w.w.	0.2	0.5	1.5	3	>3
Cod, fillet							
Mercury (Hg)	mg/kg	w.w.	0.1	0.3	0.5	1	>1
∑PCB-7	µg/kg	w.w.	3 [6)]	20	50	150	>150
∑DDT [11)]	µg/kg	w.w.	1	3	10	25	>25
∑HCH [12]	µg/kg	w.w.	0.3 [7)]	2	5	15	>15
HCB	µg/kg	w.w.	0.2	0.5	2	5	>5
$TE_{PCDF/D}$	ng/kg	w.w.	< 0.1	0.3	1	2	> 2
Cod, liver							
∑PCB-7	µg/kg	w.w.	500	1500	4000	10000	>10000
∑DDT [11)]	µg/kg	w.w.	200 [8)]	500	1500	3000	>3000
∑HCH [12)]	µg/kg	w.w.	30 [9)]	200	500	1000	>1000
HCB	µg/kg	w.w.	20	50	200	400	>400
$TE_{PCDF/D}$ [3)]	µg/t [4)]	w.w.	10 [10)]	40	100	300	>300
Flounder, fillet							
∑PCB-7	µg/kg	w.w.	<5	20	50	150	>150
∑DDT [11)]	µg/kg	w.w.	<2	4	15	40	>40
∑HCH [12)]	µg/kg	w.w.	<1	3	10	30	>30
HCB	µg/kg	w.w.	<0.2	0.5	2	5	>5
$TE_{PCDF/D}$	ng/kg	w.w.	<0.1	0.3	1	3	>3

[1)] Tributyltin on a formula basis

[2]) Conversion assuming 20% dry weight

[3]) TCDDN (Appendix B)

[4]) µg/t = µg/ton = g/1000 kg (Appendix B)

[5]) Blue mussel-ΣPCB7: Decrease limit from 4 to 3

[6]) Cod fillet-ΣPCB7: Decrease limit from 5 to 3

[7]) Cod fillet-ΣHCH: Decrease limit from 0.5 to 0.3

[8]) Cod liver-ΣDDT: Proposal to either increase limit from 200 to 300 or, preferably, replace ΣDDT with p,p'-DDE and keep the limit (Knutzen & Green 2001)

[9]) Cod liver-ΣHCH: Decrease limit from 50 to 30

[10]) Cod liver: TEPCDD/PCDF: Decrease limit from 15 to 10

[11]) Used in this investigation also for ppDDE

[12]) Used in this investigation also for γ-HCH (lindane)

[13]) The sum of tri- to hexacyclic PAH compounds named in EPA protocol 8310 minus naphthalene (dicyclic)-totalling 15 compounds, so that the Klif classification system can be applied

Table 38. Provisional "high background levels" of selected contaminants, in mg/kg dry weight (blue mussel) and mg/kg wet weight (blue mussel and fish) used in this report. The respective "high background" limits are from Knutzen & Skei (1990) with mostly minor adjustments (Knutzen & Green 1995, 2001; Molvær et al. 1997, Green & Knutzen 2003), except for dab where the suggested limit is based on CEMP-data (Knutzen & Green 1995) and PFOS, PFOSA and S_BDE (Green et al. 2009 and Bakke et et al. 2008, see footnote). Especially uncertain values are marked with "?".

Cont.	Blue mussel [1]		Cod [1]	
			liver	fillet
	mg/kg d.w.	mg/kg w.w.	mg/kg w.w.	mg/kg w.w.
Lead	3.0 [2]	0.6 [3]	0.1	
Cadmium	2.0 [2]	0.4 [3]	0.3	
Copper	10 [2]	2 [3]	20	
Mercury	0.2 [2]	0.04 [3]		0.1 [2]
Zinc	200 [2]	40 [3]	30	
∑PCB-7 [8]	0.015[3,9]	0.003[2 9]	0.50 [2]	0.003[9]
ppDDE	0.010 [3]	0.002 [6]	0.2 [9]	
γ HCH	0.005 [3]	0.001 [6]	0.03 [9]	0.0003[9]
HCB	0.0005 [3]	0.0001 [2]	0.02 [2]	
TCDDN	0.000001 [3]		0.00001 [9]	
	0.0000002 [2]			
PFOS [10]			0.05	
PFOSA [11]			0.01	
S_BDE [12]			0.05	

[1]) Respectively: *Mytilus edulis, Gadus morhua, Platichthys flesus* and *Limanda limanda*

[2]) From the Norwegian Environment Agency Class I ("good") (Molvær *et al*. 1997)

[3]) Conversion assuming 20% dry weight

[4]) Approximately 25% of ΣPCB-7 (Knutzen & Green 1995)

[5]) 1.5-2 times 75% quartile (cf. Annex B in Knutzen & Green 1995)

[6]) Assumed equal to limit for ΣDDT or ΣHCH, respectively, from the Norwegian Pollution Control Authority Environmental Class I ("good") (Molvær *et al*. 1997). Hence, limits for ppDDE and γHCH are probably too high (lacking sufficient and reliable reference values)

[7]) Mean plus 2 times standard deviation (cf. Annex B in Knutzen & Green 1995)

[8]) Estimated as sum of 7 individual PCB compounds (CB-28, -52, -101, -118, -138, -153 and -180) and assumed to be ca. 50% and 70% of total PCB for blue mussel and cod/flatfish, respectively

[9]) Flounder liver: Decrease limit from 5 to 3 and from 2 to 1 for ΣPCB7 and p,p-DDE, respectively, with regard to revisions suggested by Knutzen & Green (2001) and Green & Knutzen (2003)

[10]) PFOS in cod liver. Background: West coast, Lofoten: 1-49 µg/kg w.w. (Green *et al*. 2009), Barentshav: 3 – 8 µg/kg w.w. (Bakke *et al*. 2008). Conclusion: 50 µg/kg w.w.

[11]) PFOSA in cod liver. Background: West coast, Lofoten: 1.9-6.1 µg/kg w.w. (Green *et al*. 2009), Barentshav: 3 – 8 µg/kg w.w. (Bakke *et al*. 2008). Conclusion: 10 µg/kg w.w.

[12]) Sum_BDE in cod liver. Background: Norwegian coast, exposed and remote from heavily populated areas: average 12-36 µg/kg w.w. (Green *et al*. 2009). Conclusion: 50 µg/kg w.w.

Appendix D
Map of stations

Nominel station positions 1981-2013
(cf. Appendix E)

Appendix D (cont.) Map of stations

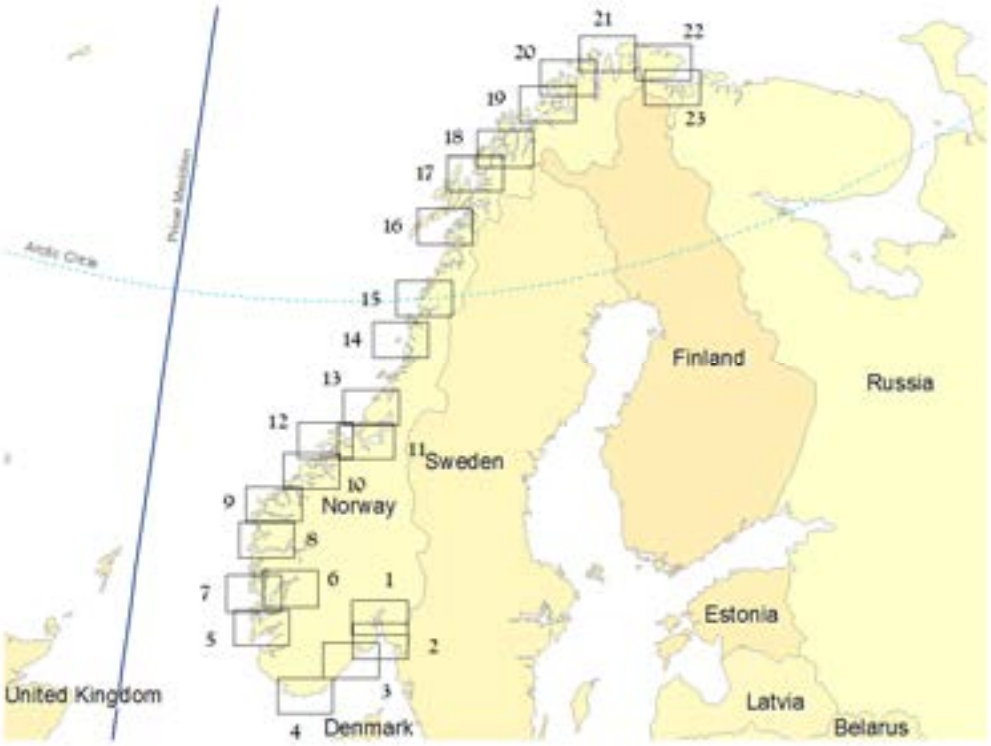
NOTES

The station's nominal position is plotted, and not the specific positions that may have differed from one year to another. The maps are generated using ArcGIS version 9.1.

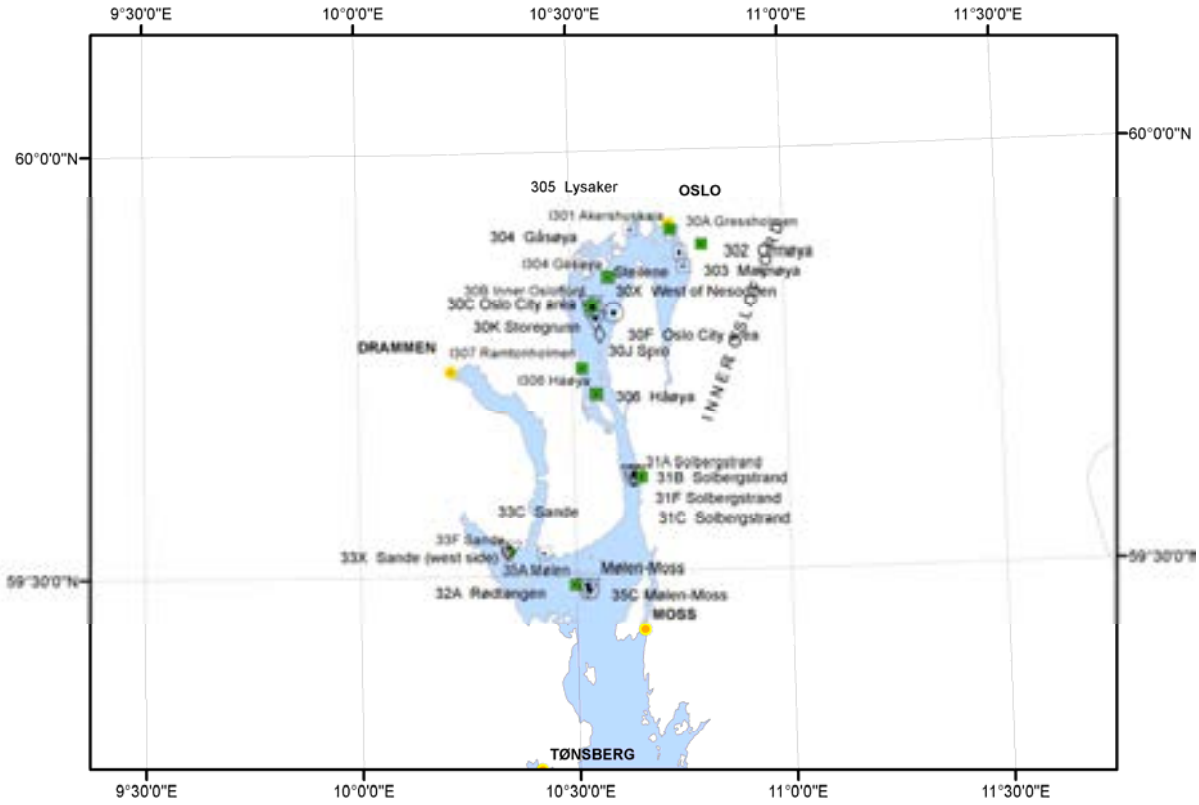
The following symbols and codes apply:

All years	2013	Explanation	Station code
		Sediment	<number>S
		Blue mussel	<number>A
		Blue mussel	I<number/letter> [1)]
		Blue mussel	R<number/letter> [1)]
		Dog whelk	<number>F
		Prawn	<number>C
		Atlantic cod	<number>A
		Flatfish	<number>D/E
		Other round fish	
		Town or city	

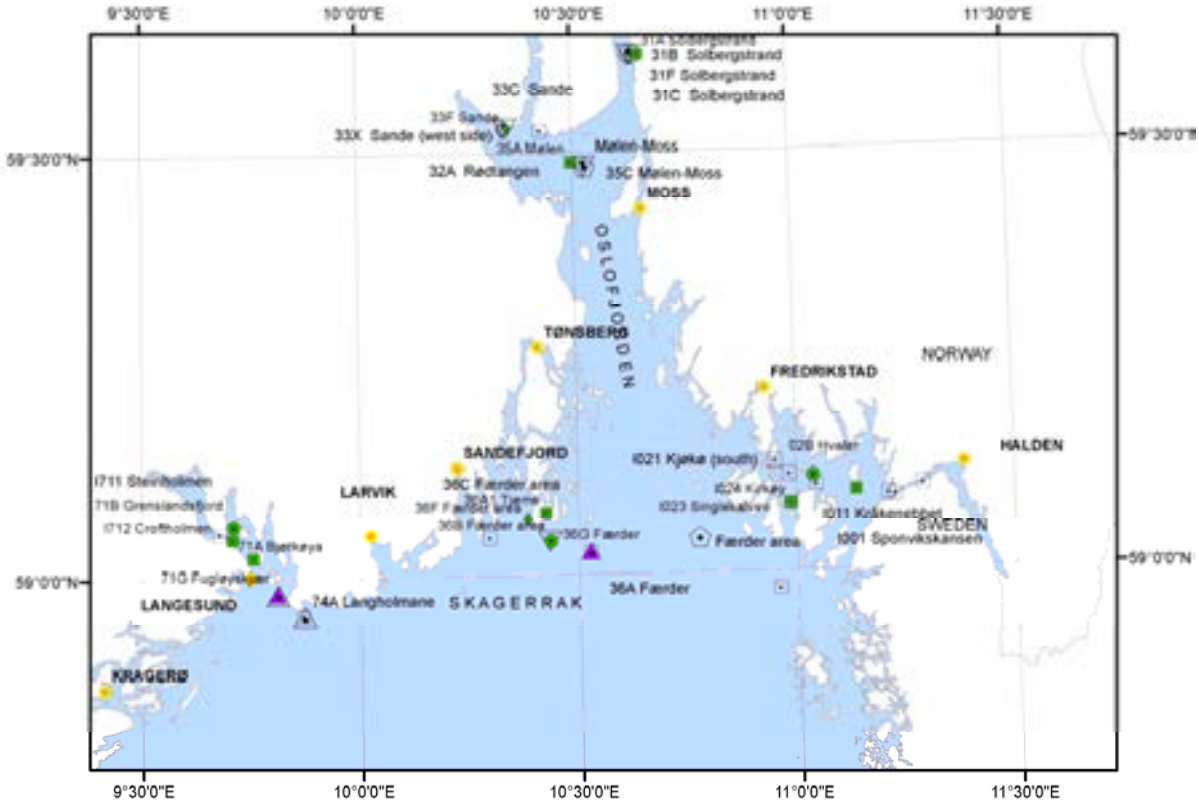
1) Supplementary station used in the blue mussel pollution (I) or reference (R) index of the Norwegian Environment Agency (cf. Green *et al.* 2011).



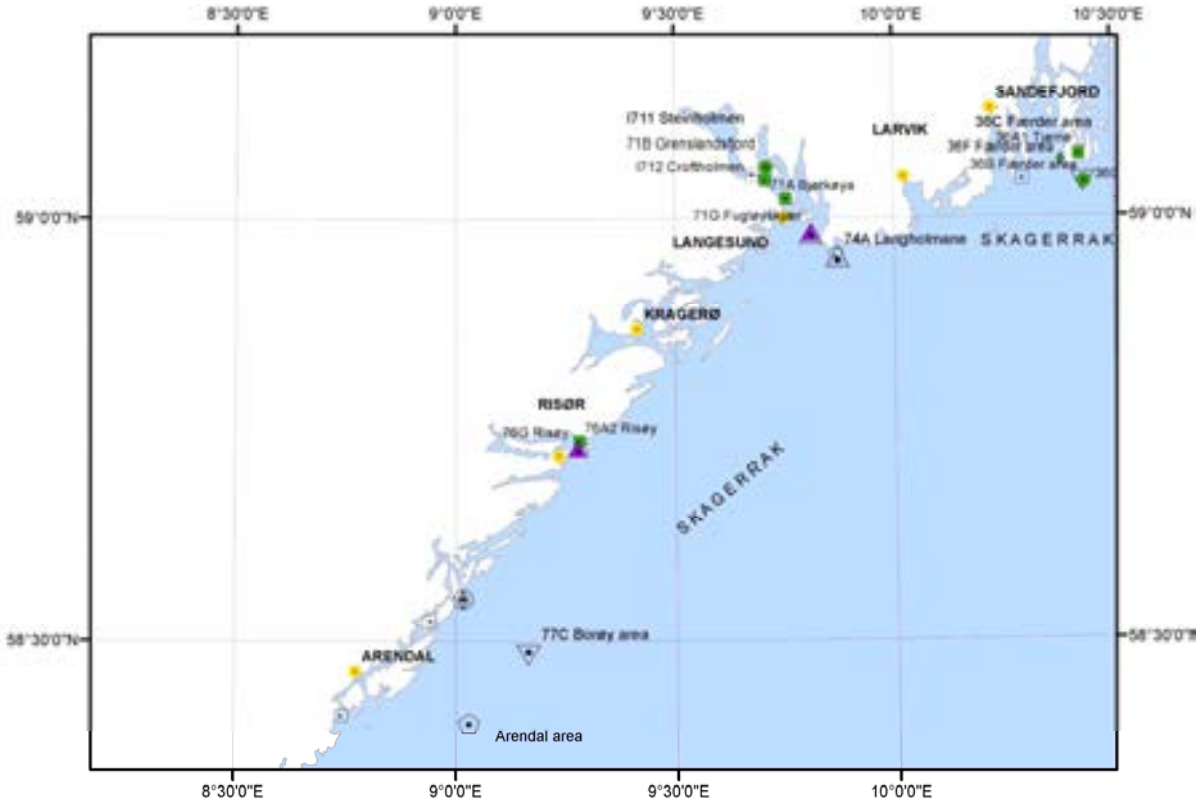
MILKYS stations Norway. Numbers indicate map references that follow.
Note: distance between two lines of latitude is 15 nautical miles (= 27.8 km).


9°30'0"E
10°0'0"E
10°30'0"E
11°0'0"E
11°30'0"E
60°0'0"N
59°30'0"N
305 Lysaker
OSLO
304 Gåsøya
302 Ormøya
303 Malmøya
30K West of Nesodden
30C Oslo City area
30K Storegrunn
30F Oslo City area
30J Spro
DRAMMEN
306 Håøya
INNER OSLOFJORD
31A Solbergstrand
31B Solbergstrand
31F Solbergstrand
31C Solbergstrand
33C Sande
33X Sande (west side)
35A Moss
Moss-Moss
32A Rødtangen
35C Moss-Moss
MOSS
TØNSBERG

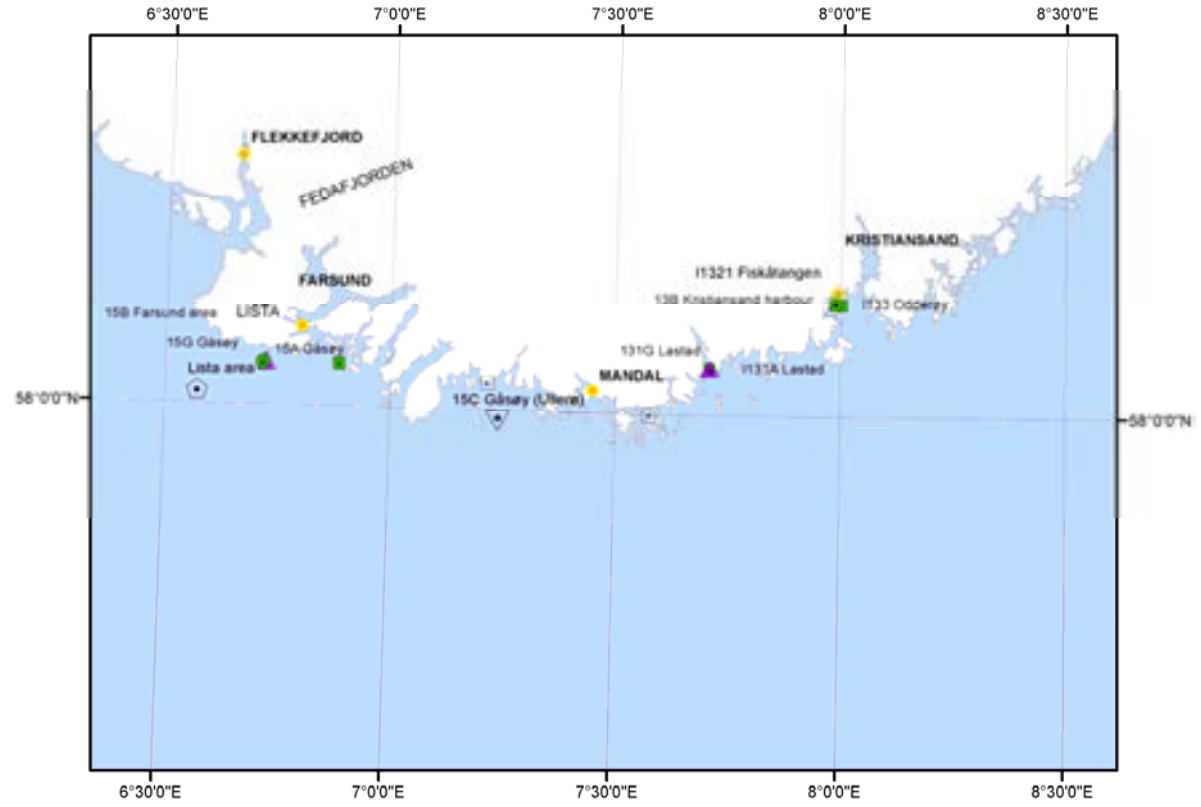
MAP 1


9°30'0"E
10°0'0"E
10°30'0"E
11°0'0"E
11°30'0"E
59°30'0"N
59°0'0"N
31B Solbergstrand
31F Solbergstrand
31C Solbergstrand
33C Sande
33X Sande (west side)
35A Moss
Moss-Moss
32A Rødtangen
35C Moss-Moss
MOSS
OSLOFJORDEN
TØNSBERG
NORWAY
FREDRIKSTAD
HALDEN
SANDEFJORD
LARVIK
36C Færder area
36G Færder
Færder area
36A Færder
SWEDEN
SKAGERRAK
LANGESUND
KRAGERØ

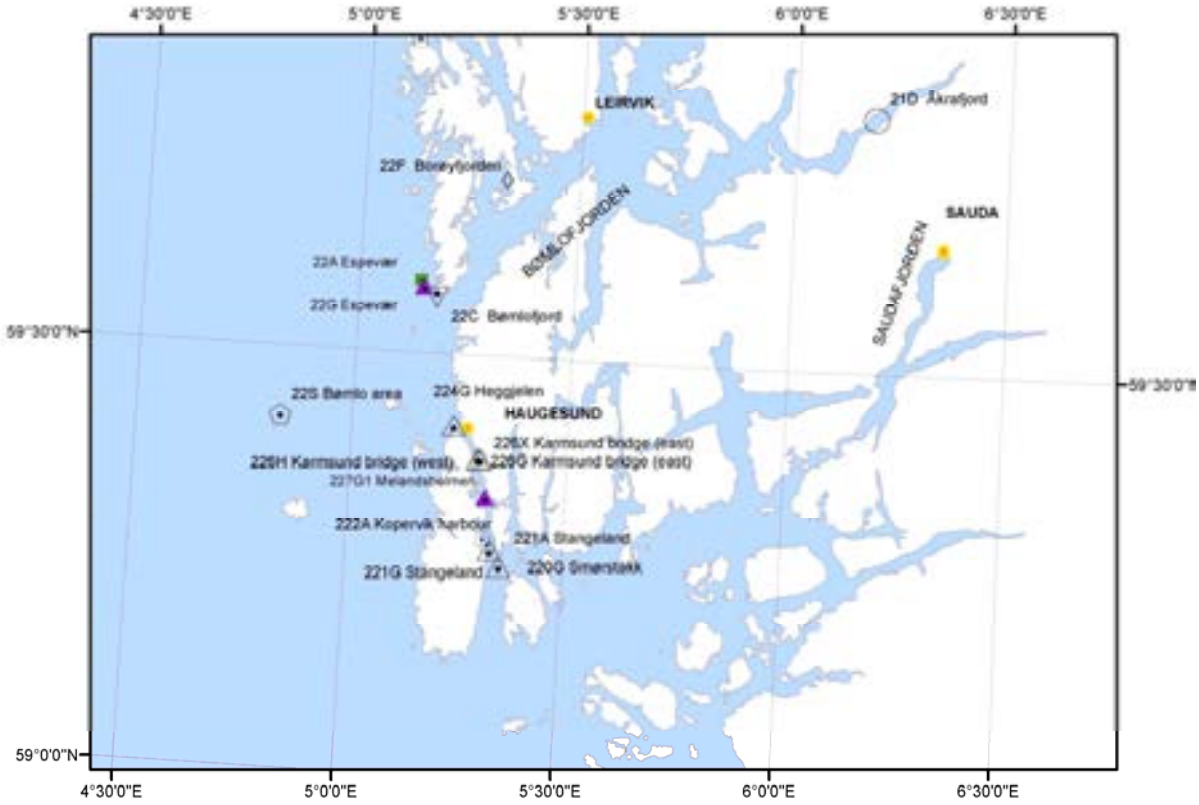
MAP 2


8°30'0"E
9°0'0"E
9°30'0"E
10°0'0"E
10°30'0"E
59°0'0"N
58°30'0"N
SANDEFJORD
LARVIK
LANGESUND
SKAGERRAK
KRAGERØ
RISØR
ARENDAL
77C Boray area
Arendal area

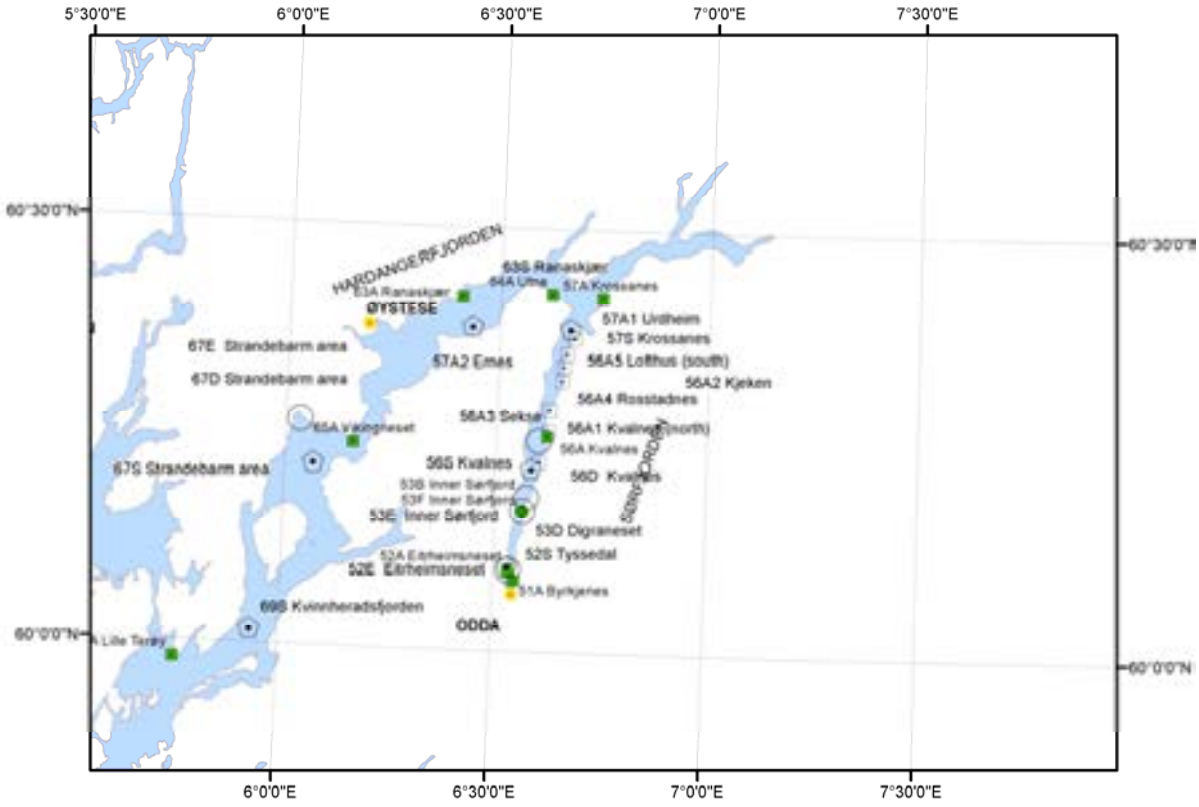
MAP 3


6°30'0"E
7°0'0"E
7°30'0"E
8°0'0"E
8°30'0"E
58°0'0"N
FLEKKEFJORD
FEDAFJORDEN
FARSUND
LISTA
KRISTIANSAND
MANDAL
Lista area
15C Gåsøy (Ullerø)

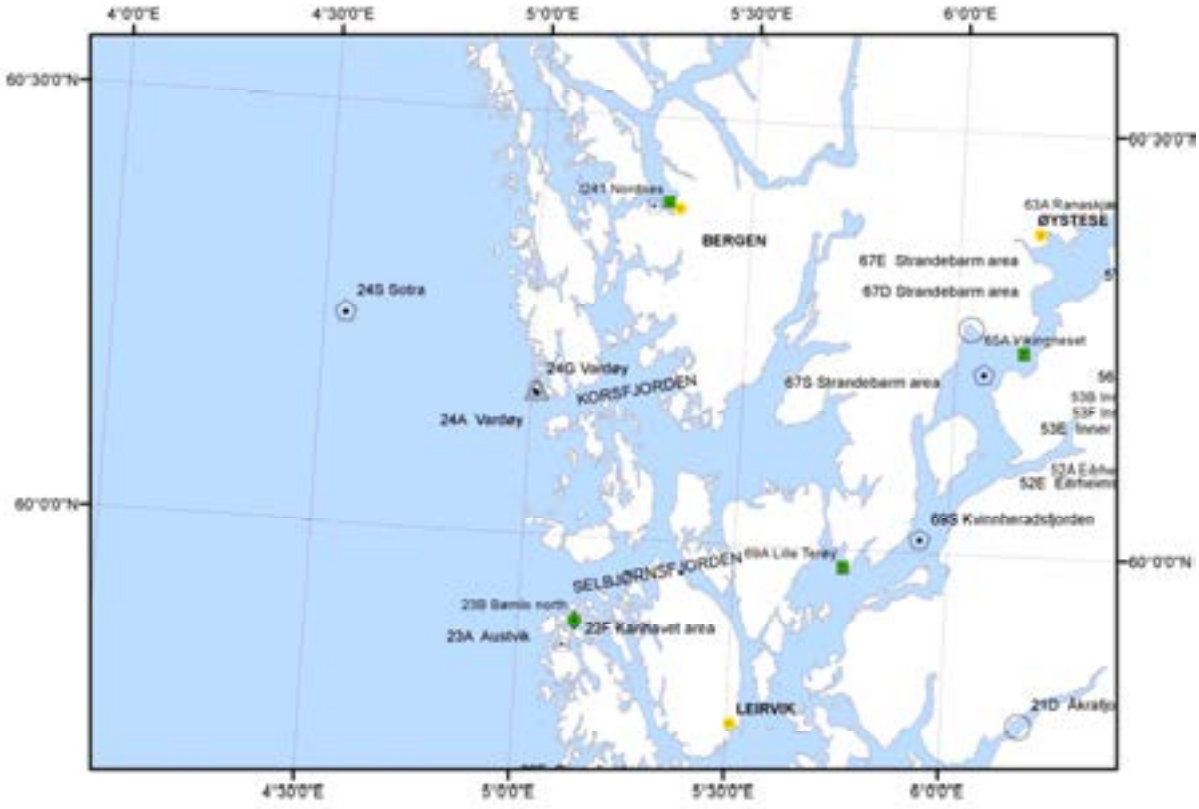
MAP 4


4°30'0"E
5°0'0"E
5°30'0"E
6°0'0"E
6°30'0"E
59°30'0"N
59°0'0"N
LEIRVIK
21D Åkrafjord
22F Boknafjorden
BOKNAFJORDEN
SAUDA
SAUDAFJORDEN
22A Espevær
22G Espevær
22C Bømlofjord
22S Bømlo area
224G Heggjelen
HAUGESUND
226X Karmsund bridge (east)
226H Karmsund bridge (west)
226G Karmsund bridge (east)
227G1 Melandsholmen
222A Kopervik harbour
221A Stangeland
221G Stangeland
220G Smørstakk

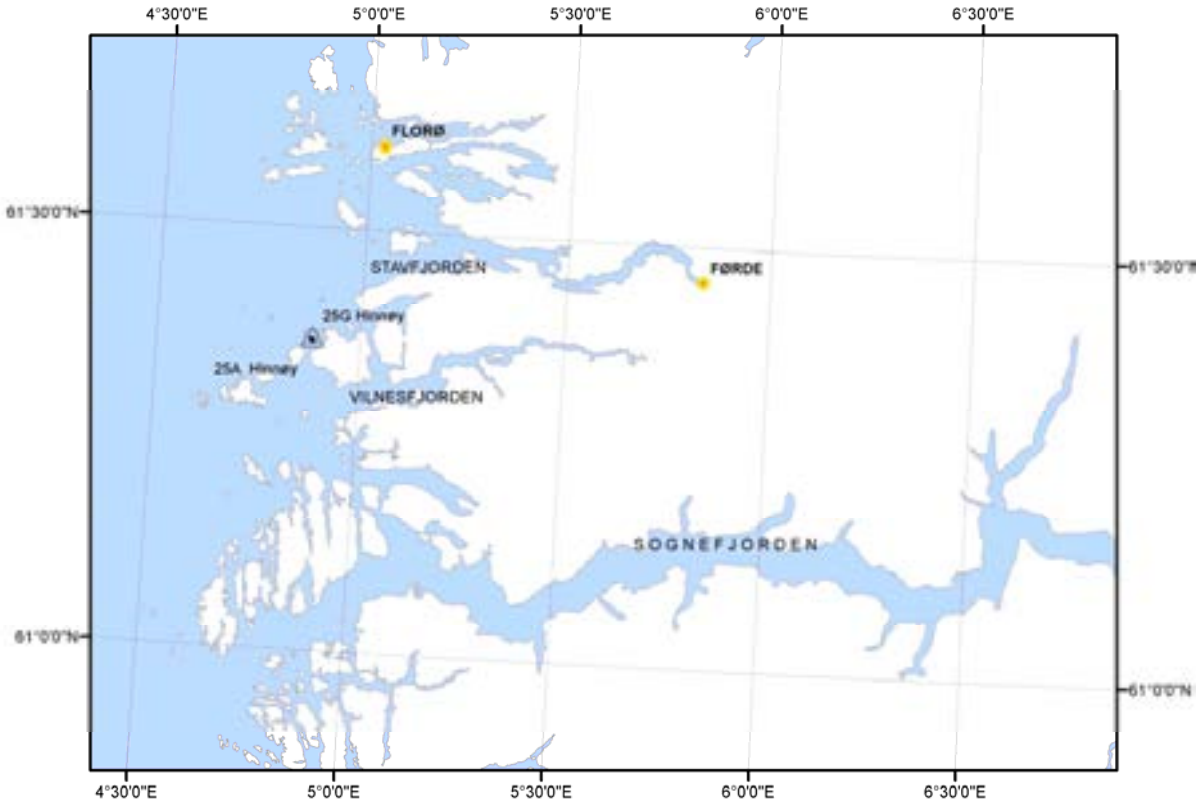
MAP 5


5°30'0"E
6°0'0"E
6°30'0"E
7°0'0"E
7°30'0"E
60°30'0"N
60°0'0"N
HARDANGERFJORDEN
63S Ranaskjær
64A Urna
57A Krossanes
ØYSTESE
57A1 Urdheim
57S Krossanes
67E Strandebarm area
67D Strandebarm area
57A2 Emas
56A5 Lofthus (south)
56A2 Kjeken
56A4 Rosstadnes
56A3 Seksa
56A1 Kvalnes (north)
56A Kvalnes
67S Strandebarm area
56S Kvalnes
56D Kvalnes
53B Inner Sørfjord
53F Inner Sørfjord
53E Inner Sørfjord
SØRFJORDEN
53D Digraneset
52A Eitheimsneset
52S Tyssedal
52E Eitheimsneset
51A Byrkjenes
69S Kvinnheradsfjorden
ODDA

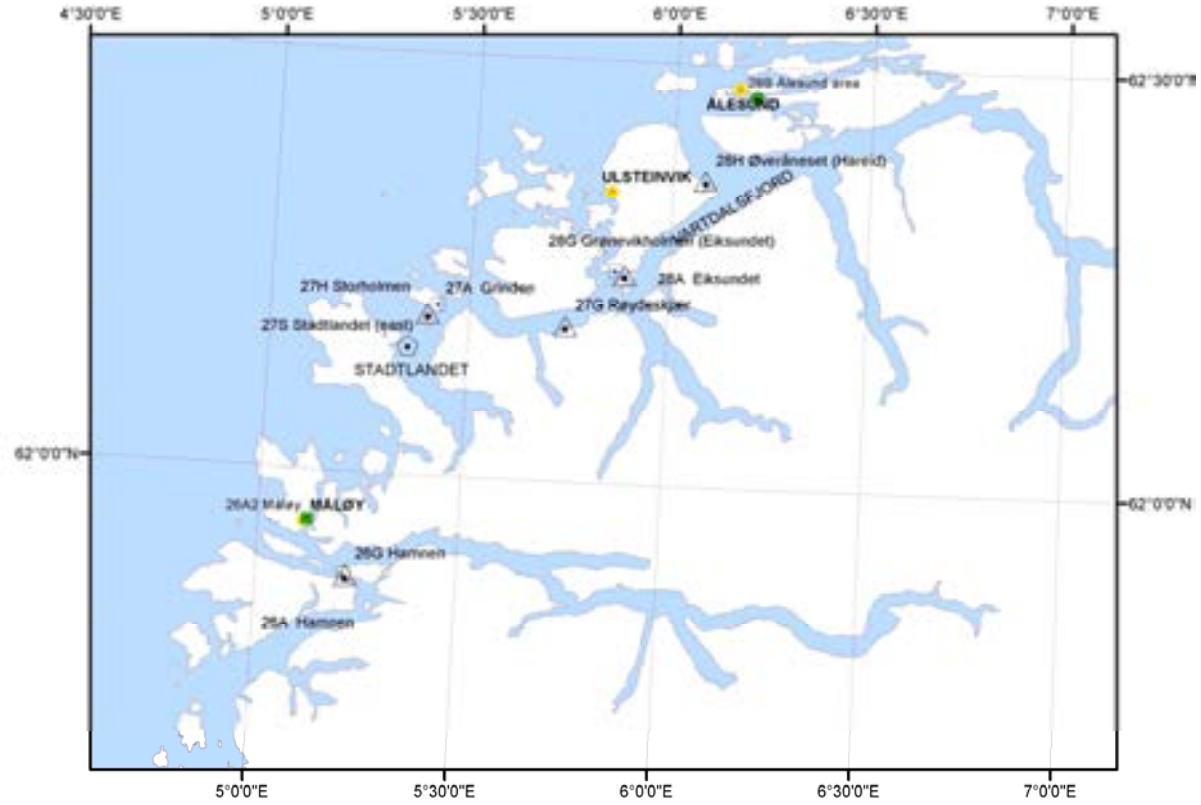
MAP 6


4°0'0"E
4°30'0"E
5°0'0"E
5°30'0"E
6°0'0"E
60°30'0"N
60°0'0"N
BERGEN
ØYSTESE
67E Strandebarm area
67D Strandebarm area
24S Sotra
24G Vardøy
24A Vardøy
KORSFJORDEN
67S Strandebarm area
53E Inner
69S Kvinnheradsfjorden
SELBJØRNSFJORDEN
69A Lille Terøy
23A Austvik
23F Karihavet area
LEIRVIK

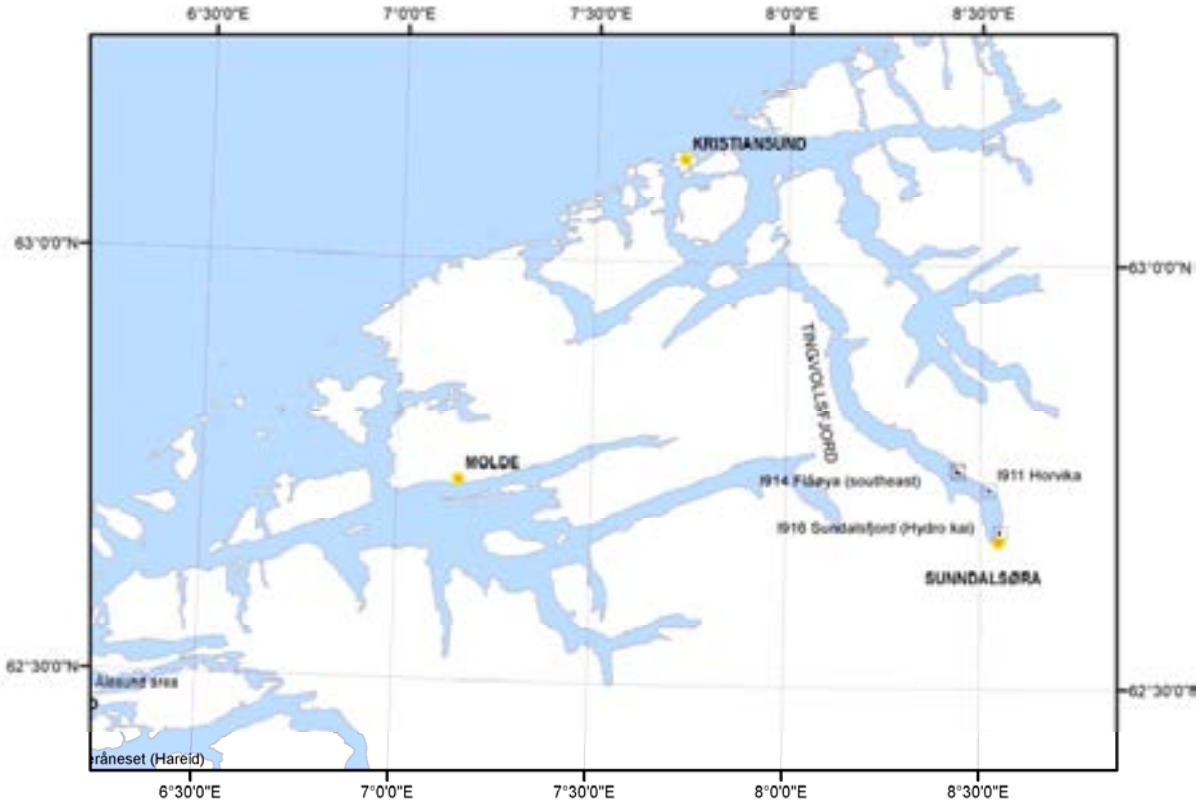
MAP 7


4°30'0"E
5°0'0"E
5°30'0"E
6°0'0"E
6°30'0"E
61°30'0"N
61°0'0"N
FLORØ
STAVFJORDEN
FØRDE
25G Hinnøy
25A Hinnøy
VILNESFJORDEN
SOGNEFJORDEN

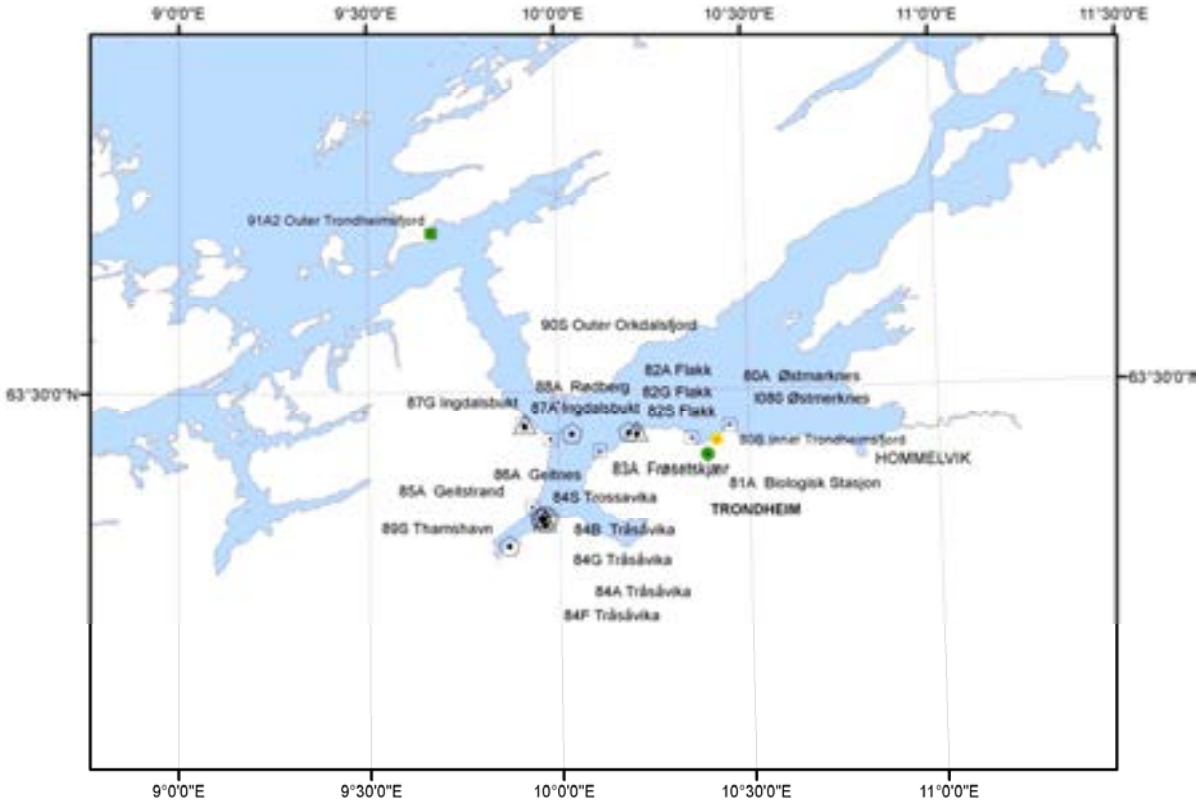
MAP 8


4°30'0"E
5°0'0"E
5°30'0"E
6°0'0"E
6°30'0"E
7°0'0"E
62°30'0"N
62°0'0"N
ALESUND
ULSTEINVIK
28H Øveråneset (Hareid)
HARTDALSFJORD
28A Eiksundet
27H Storholmen
27A Grivider
27G Røydeskjær
27S Stadtlander (east)
STADTLANDET
MALØY
28G Hamnen
28A Hamnen
5°0'0"E
5°30'0"E
6°0'0"E
6°30'0"E
7°0'0"E

MAP 9


6°30'0"E
7°0'0"E
7°30'0"E
8°0'0"E
8°30'0"E
63°0'0"N
62°30'0"N
KRISTIANSUND
TINGVOLLSFJORD
MOLDE
I914 Flåøya (southeast)
I911 Horvika
I916 Sundalsfjord (Hydro kai)
SUNNDALSØRA
Ålesund area
råneset (Hareid)

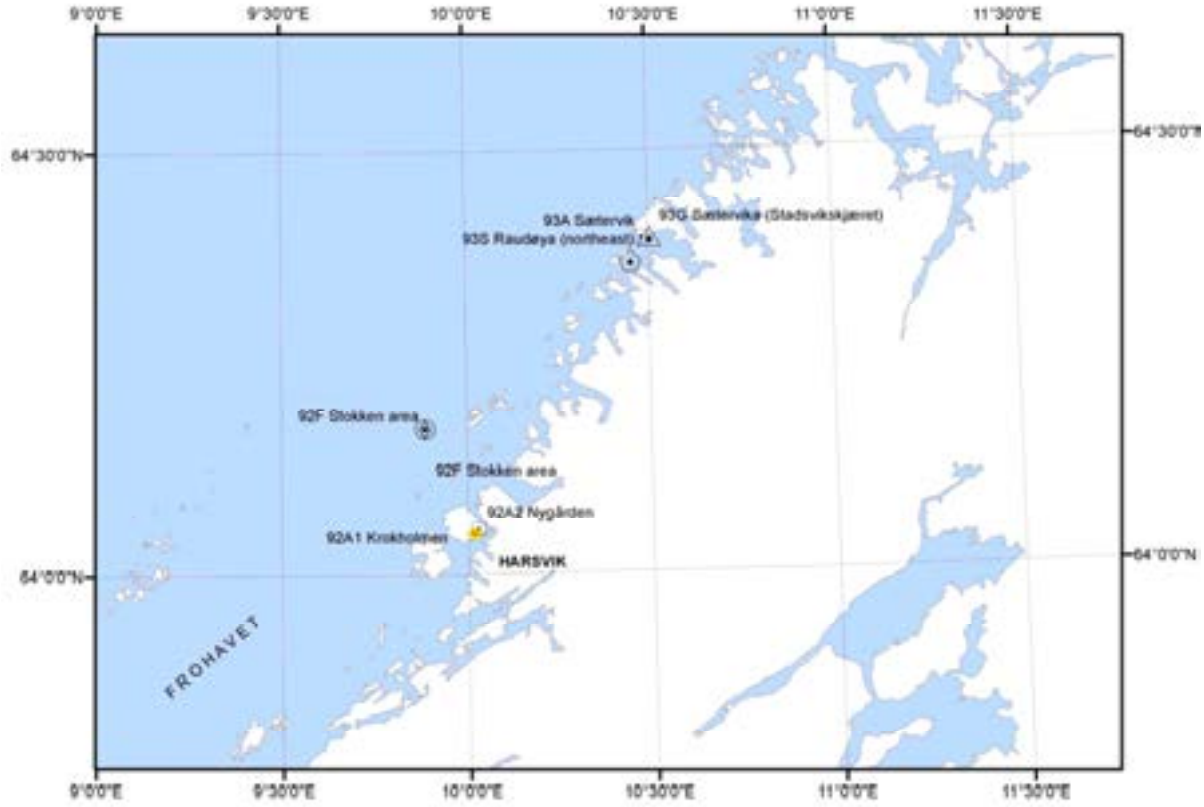
MAP 10


9°0'0"E
9°30'0"E
10°0'0"E
10°30'0"E
11°0'0"E
11°30'0"E
63°30'0"N
91A2 Outer Trondheimsfjord
90S Outer Orkdalsfjord
82A Flakk
82G Flakk
82S Flakk
88A Rødberg
87G Ingdalsbukt
87A Ingdalsbukt
80A Østmarkneset
80G Østmarkneset
80S Inner Trondheimsfjord
HOMMELVIK
83A Frøsettkjær
81A Biologisk Stasjon
86A Geitnes
85A Geitstrand
84S Trossavika
TRONDHEIM
89G Thamshavn
84B Tråsåvika
84G Tråsåvika
84A Tråsåvika
84F Tråsåvika

MAP 11


7°0'0"E
7°30'0"E
8°0'0"E
8°30'0"E
9°0'0"E
9°30'0"E
63°30'0"N
91A2 Outer Trondhe
HITRA
TRONDHEIMSLEIA
SMØLA
91A Nordvika
KRISTIANSUND

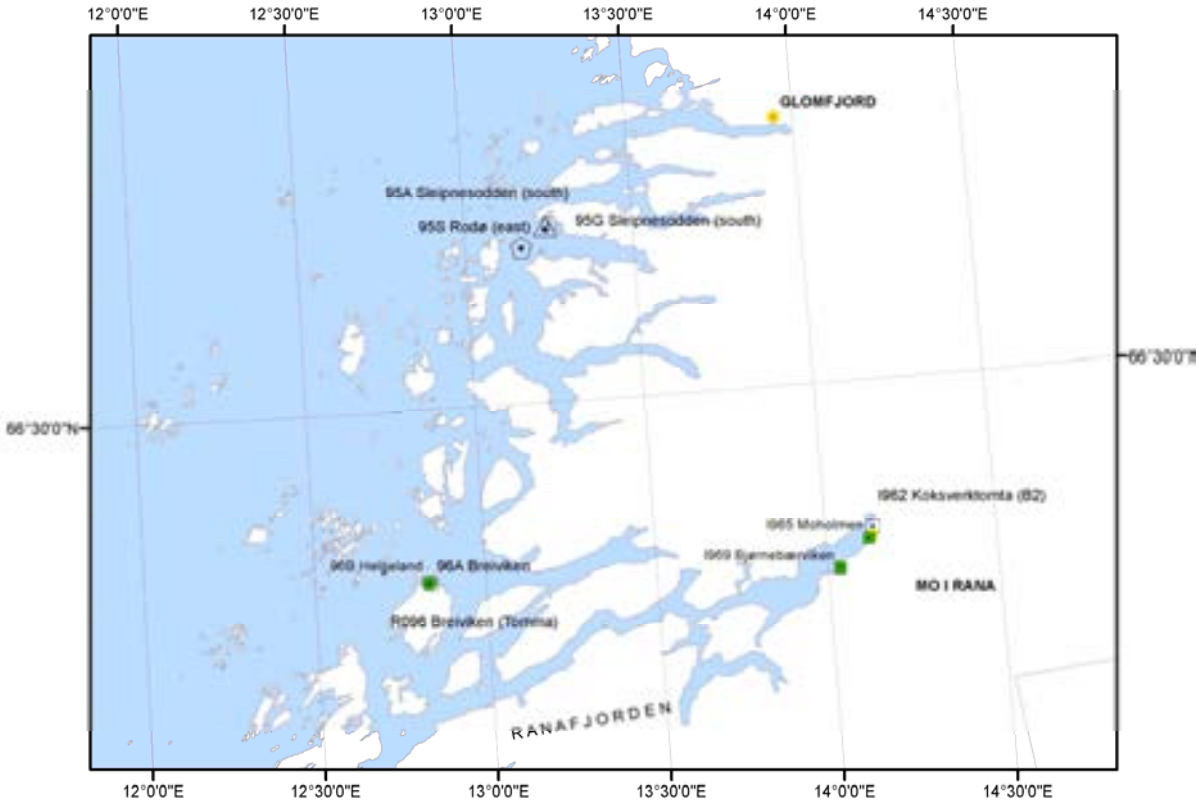
MAP 12


9°0'0"E
9°30'0"E
10°0'0"E
10°30'0"E
11°0'0"E
11°30'0"E
64°30'0"N
64°0'0"N
93A Sætervik
93S Raudøya (northeast)
92F Stokken area
92F Stokken area
92A2 Nygården
92A1 Krokholmen
HARSVIK
FROHAVET

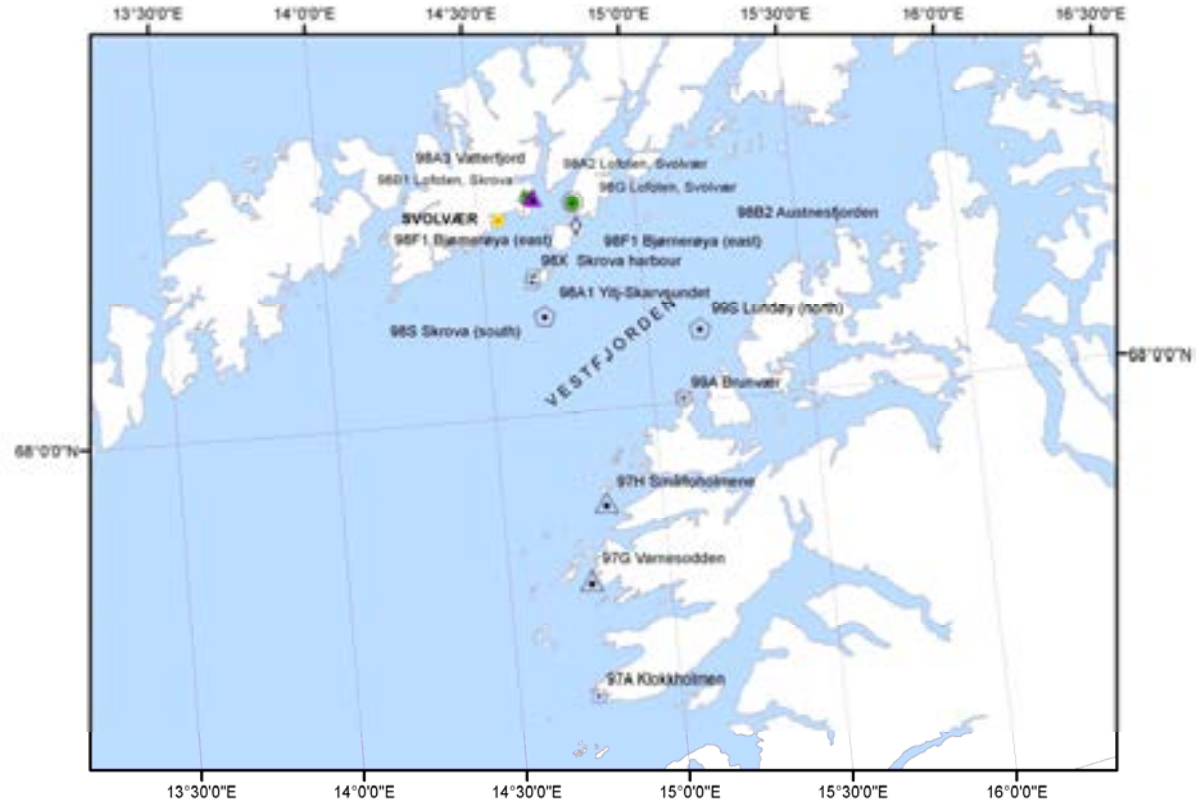
MAP 13


11°0'0"E
11°30'0"E
12°0'0"E
12°30'0"E
13°0'0"E
13°30'0"E
66°0'0"N
65°30'0"N
VEFSNFJORD
94G Steinskjær (Landfast)
94A Landfast
BRØNØYSUND

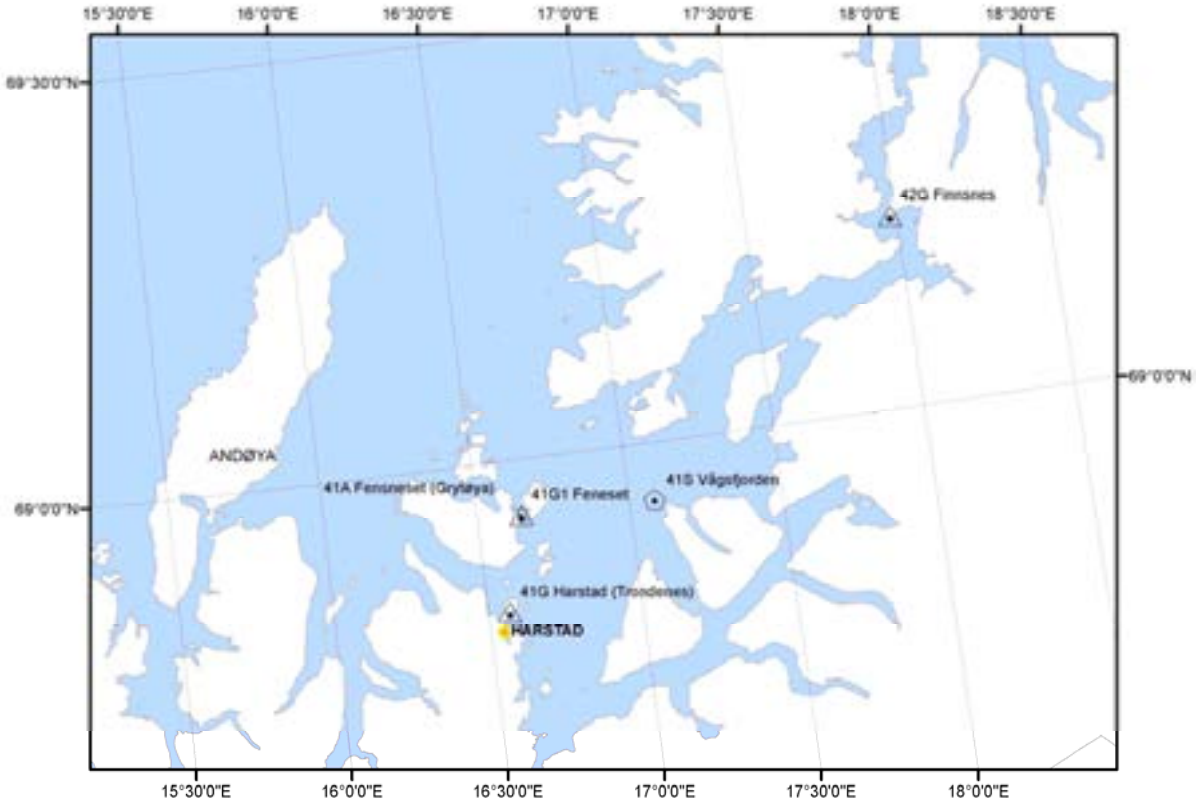
MAP 14


12°0'0"E
12°30'0"E
13°0'0"E
13°30'0"E
14°0'0"E
14°30'0"E
66°30'0"N
GLOMFJORD
95A Sleipnesodden (south)
95S Rodø (east)
95G Sleipnesodden (south)
I962 Koksverktomta (B2)
I965 Moholmen
I969 Bjørnebærviken
MO I RANA
96G Helgeland
96A Brønviken
R096 Brønviken (Tomma)
RANAFJORDEN

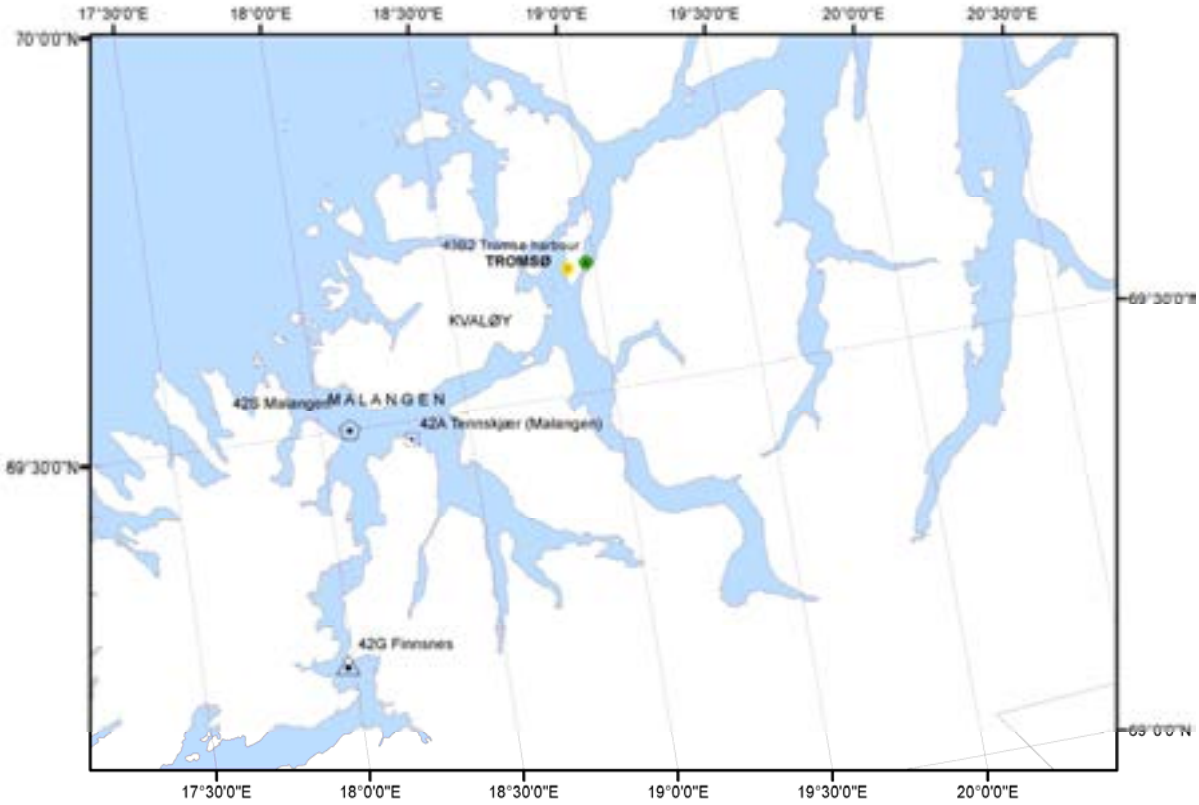
MAP 15


13°30'0"E
14°0'0"E
14°30'0"E
15°0'0"E
15°30'0"E
16°0'0"E
16°30'0"E
68°0'0"N
98A3 Vatterfjord
98D1 Lofoten, Skrova
98A2 Lofoten, Svolvær
98G Lofoten, Svolvær
SVOLVÆR
98B2 Austnesfjorden
98F1 Bjørnerøya (east)
98X Skrova harbour
98A1 Ytlg-Skarvsundet
98G Lundøy (north)
98S Skrova (south)
VESTFJORDEN
98A Brunvatn
97H Småfiskholmene
97G Varnesodden
97A Klokkholmen

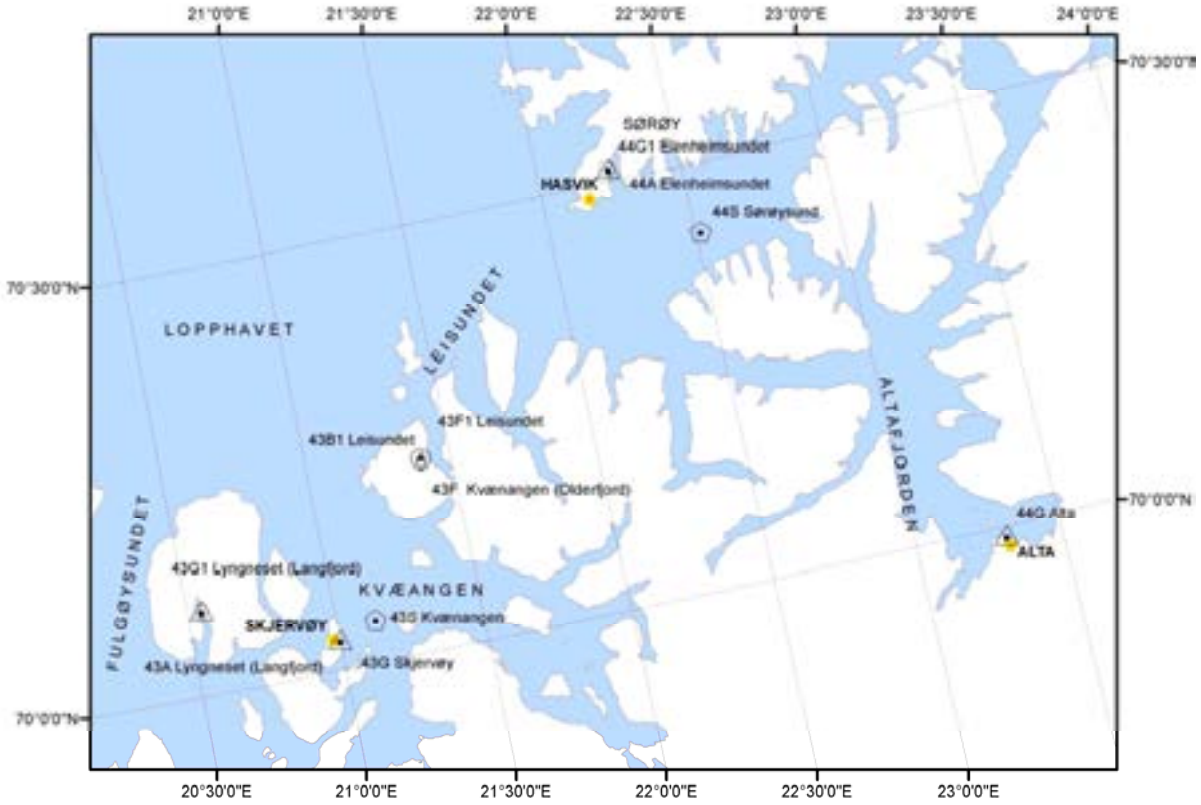
MAP 16


15°30'0"E
16°0'0"E
16°30'0"E
17°0'0"E
17°30'0"E
18°0'0"E
18°30'0"E
69°30'0"N
69°0'0"N
42G Finnsnes
ANDØYA
41A Fensneset (Grytøya)
41G1 Feneset
41G Vågsfjorden
41G Harstad (Trondenes)
HARSTAD

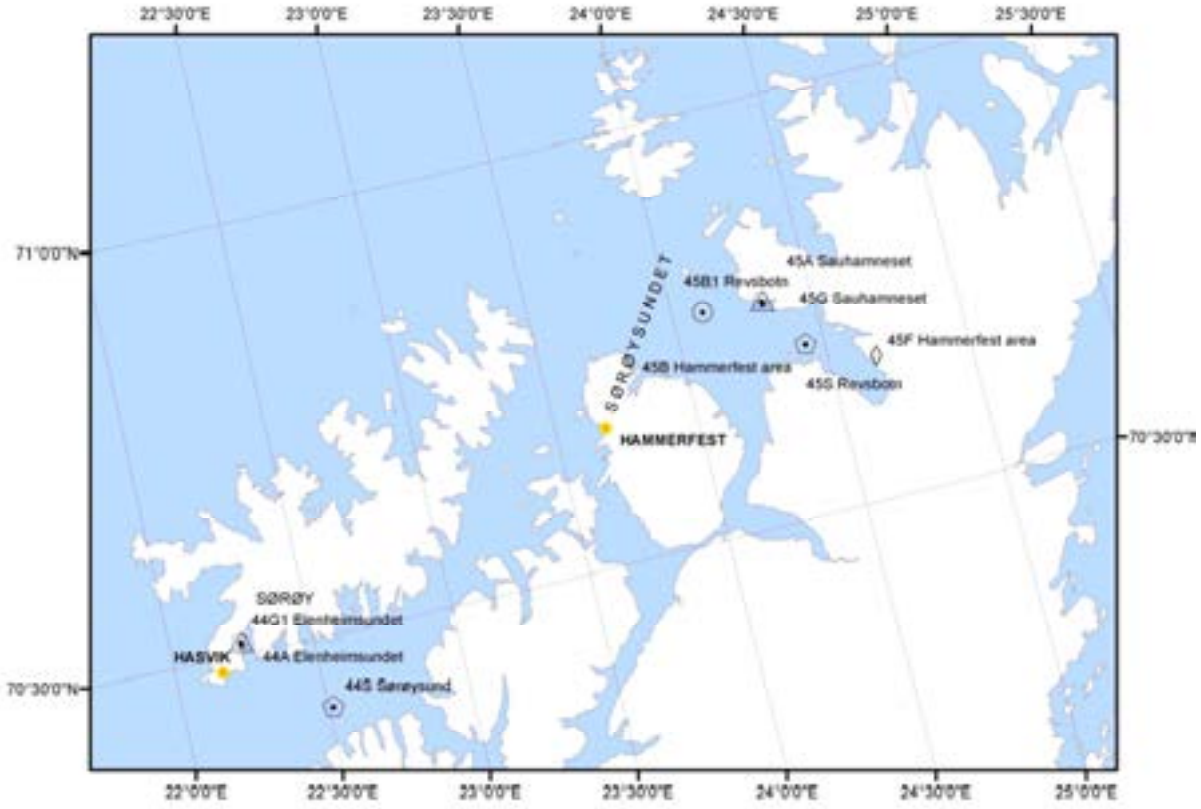
MAP 17


17°30'0"E
18°0'0"E
18°30'0"E
19°0'0"E
19°30'0"E
20°0'0"E
20°30'0"E
70°0'0"N
69°30'0"N
TROMSØ
KVALØY
M A L A N G E N
42A Tennskjær (Malangen)
42G Finnsnes

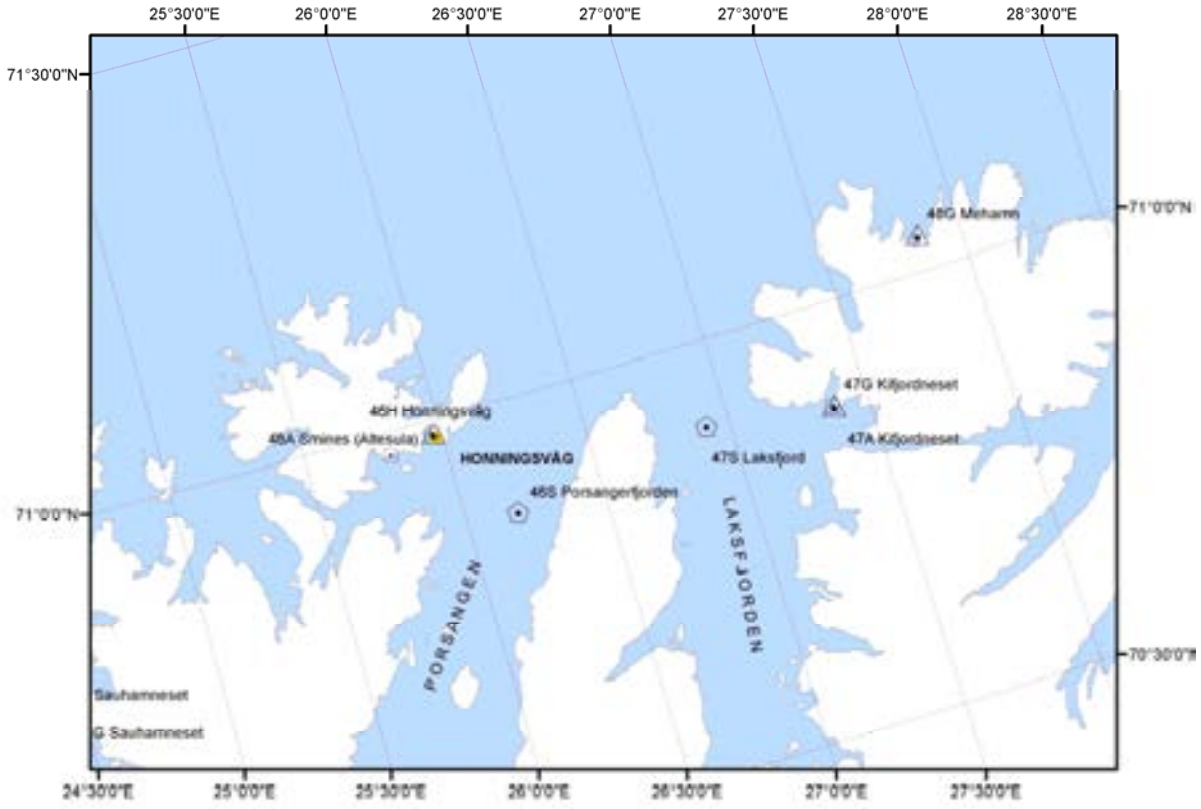
MAP 18


21°0'0"E
21°30'0"E
22°0'0"E
22°30'0"E
23°0'0"E
23°30'0"E
24°0'0"E
70°30'0"N
70°0'0"N
20°30'0"E
21°0'0"E
21°30'0"E
22°0'0"E
22°30'0"E
23°0'0"E
SØRØY
44G1 Elenheimsundet
HASVIK
44A Elenheimsundet
44S Sørøysund
LOPPHAVET
LEISUNDET
43F1 Leisundet
43B1 Leisundet
43F Kvænangen (Olderfjord)
ALTAFJORDEN
44G Alta
ALTA
FULGØYSUNDET
43G1 Lyngneset (Langfjord)
KVÆANGEN
43G Kvænangen
SKJERVØY
43A Lyngneset (Langfjord)
43G Skjervøy

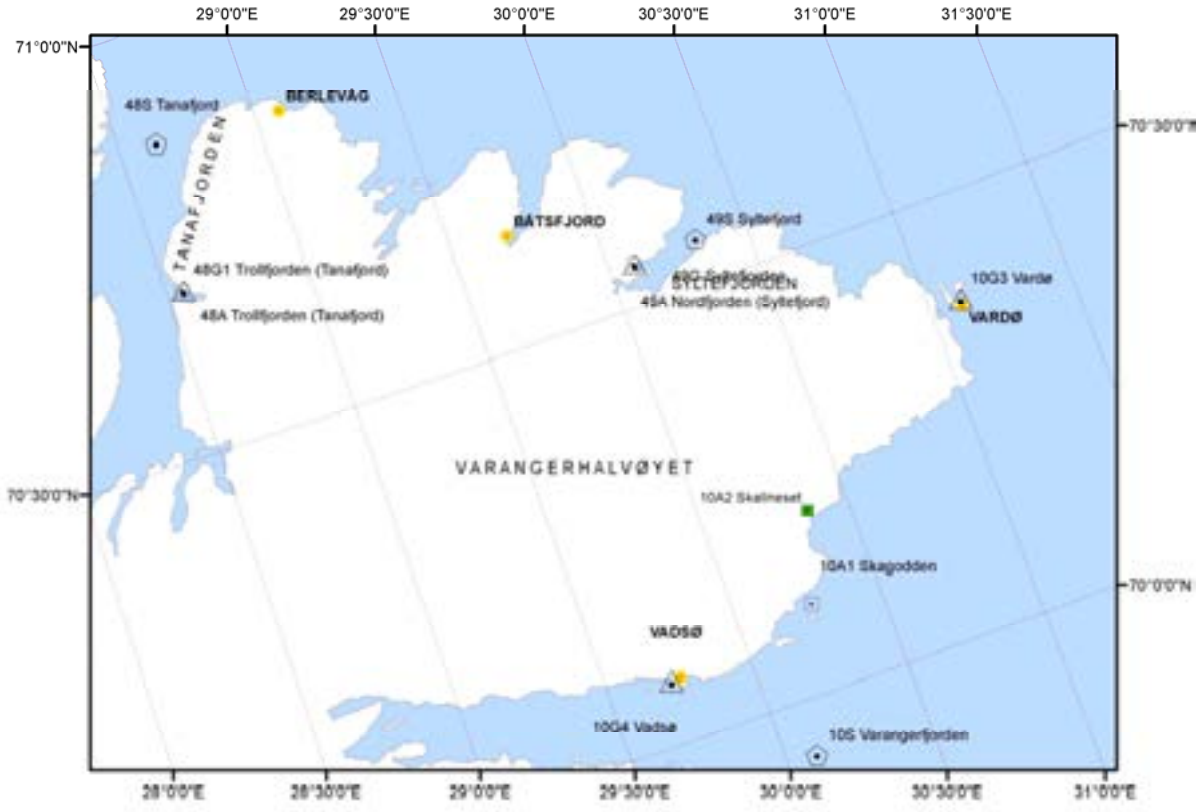
MAP 19


22°30'0"E
23°0'0"E
23°30'0"E
24°0'0"E
24°30'0"E
25°0'0"E
25°30'0"E
71°0'0"N
70°30'0"N
22°0'0"E
22°30'0"E
23°0'0"E
23°30'0"E
24°0'0"E
24°30'0"E
25°0'0"E
45A Sauhamneset
45B1 Revsbotn
45G Sauhamneset
45F Hammerfest area
45B Hammerfest area
45S Revsbotn
SØRØYSUNDET
HAMMERFEST
SØRØY
44G1 Elenheimsundet
HASVIK
44A Elenheimsundet
44S Sørøysund

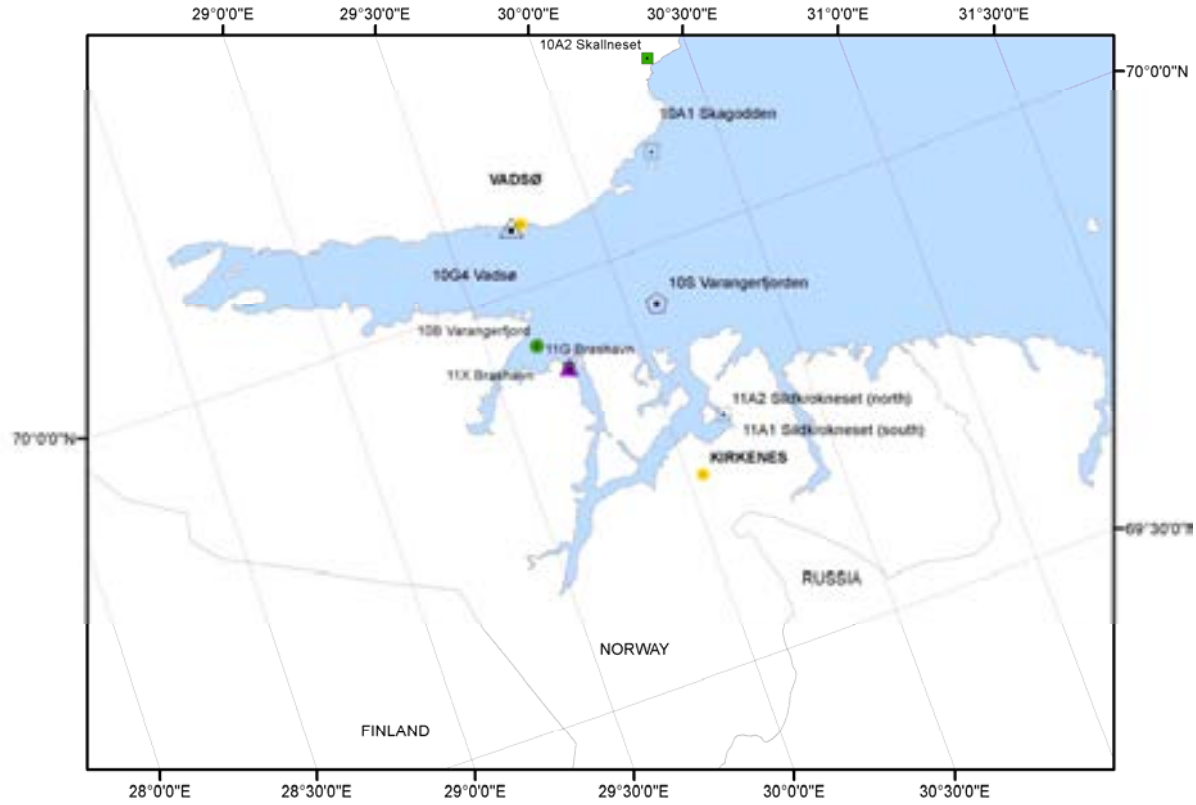
MAP 20


25°30'0"E
26°0'0"E
26°30'0"E
27°0'0"E
27°30'0"E
28°0'0"E
28°30'0"E
71°30'0"N
71°0'0"N
70°30'0"N
48G Meharm
47G Kiljordneset
47A Kiljordneset
46H Honningsvåg
46A Smines (Altesula)
HONNINGSVÅG
47S Laksfjord
46S Porsangerfjorden
PORSANGEN
LAKSFJORDEN
Sauhamneset
G Sauhamneset
24°30'0"E
25°0'0"E
25°30'0"E
26°0'0"E
26°30'0"E
27°0'0"E
27°30'0"E

MAP 21


29°0'0"E
29°30'0"E
30°0'0"E
30°30'0"E
31°0'0"E
31°30'0"E
71°0'0"N
70°30'0"N
70°0'0"N
48S Tanafjord
BERLEVÅG
TANAFJORDEN
BÅTSFJORD
49S Syltefjord
48G1 Trollfjorden (Tanafjord)
48A Trollfjorden (Tanafjord)
48A Nordfjorden (Syltefjord)
10G3 Vardø
VARDØ
VARANGERHALVØYET
10A2 Skallneset
10A1 Skagodden
VADSØ
10G4 Vadsø
10S Varangerfjorden
28°0'0"E
28°30'0"E
29°0'0"E
29°30'0"E
30°0'0"E
30°30'0"E
31°0'0"E

MAP 22


29°0'0"E
29°30'0"E
30°0'0"E
30°30'0"E
31°0'0"E
31°30'0"E
10A2 Skallneset
70°0'0"N
10A1 Skagodden
VADSØ
10G4 Vadsø
10S Varangerfjorden
10B Varangerfjord
11G Brashavn
11X Brashavn
11A2 Sildkrokneset (north)
11A1 Sildkrokneset (south)
KIRKENES
69°30'0"N
RUSSIA
NORWAY
FINLAND
28°0'0"E
28°30'0"E
29°0'0"E
29°30'0"E
30°0'0"E
30°30'0"E

MAP 23

Appendix E
Overview of materials and analyses 2012-2013

Nominal station positions are shown on maps in Appendix D

Year:
2012t - samples taken in 2012
2013p – samples planned in 2013
2013t – samples taken in 2013

Species:
Atlantic cod (*Gadus morhua***)**
Blue Mussel (*Mytilus edulis***)**
Dog whelk (*Nucella lapillus***)**
Periwinkle (*Littorina littorea)*

Tissue:
SB-Soft body tissue
LI-Liver tissue, in fish
MU-Muscle tissue, in fish
BL-Blood, in fish
BI-Bile, fish

Red numbers indicate supplementary investigations funded by the Ministry of Climate and Environment and these involved additional analyses on samples from blue mussel stations 30A, I301, I304, 31A, 36A1, 71A, I712, 51A, 56A, 65A, 22A, 10A2 and 11X; cod stations 30B, 36B, 15B, 53B, 23B, 98B1 and 10B; as well as all analyses for blue mussel stations: 52A, 57A, 63A, 69A, I133, I306, I307

Overview follows on next page

Parameter-group codes (See Appendix B for descriptions of codes) 2013:

code	Description	Me-SB	NI/LI-SB	Gm-BI	Gm-BL	Gm-LI	Gm-MU
I-MET	metals [1)]	x				x	
I-MET	Hg	x					x
ISOTO	$\delta^{15}N$ and $\delta^{13}C$	x					x
O-BR	PBDE [2)]	x				x	x
OC-CB	PCBs [3)]	x				x	
OC-CL	HCB	x				x	x
OC-CP	SCCP, MCCP	x				x	
OC-DD	DDT, DDE, DDD	x				x	
OC-HC	α-, γ-HCH	x				x	
O-FL	PFAS [4)]					x	
O-PAH	PAHs [5)]	x				x	
O-MET	TBT [6)]	x	x				
O-FTA	Phthalates [7)]					x	
O-PHE	Phenols [8)]	x				x	x
PFR	PFRs [9)]	x	x			x	x
PHC	PHCs [10)]	x	x			x	x
BE	Biological effects met.[11)]		Impo-sex	OH-pyrene	ALA-D	EROD-activity, CYP1A [12)]	

[1)] Cadmium (Cd), copper (Cu), lead (Pb), zinc (Zn), silver (Ag), arsenic (As), chrome (Cr), nickel (Ni), cobalt (Co) and tin (Sn)

[2)] Polybrominated diphenyl ethers (PBDE), including brominated flame retardants and includes a selection of: BDE28, BDE47, BDE49, BDE66, BDE71, BDE77, BDE85, BDE99, BDE100, BDE119, BDE138, BDE153, BDE154, BDE183, BDE205, HBCD,

[3)] Includes a selection of the congeners: CB-28,-52,-101,-105,-118,-138,-153,-156,-180, 209, 5-CB, OCS and, when dioxins are analysed, the non-orto-PCBs, i.e. CB-77, -81, -126, -169

[4)] Includes: PFNA, PFOA, PFHpA, PFHxA, PFOS, PFBS, PFOSA

[5)] Includes (with NPDs): ACNE, ACNLE, ANT, BAP, BBJF, BEP, BGHIP, BKF. BAA. CHR, DBA3A, DBT, DBTC1, DBTC2, DBTC3, FLE, FLU, ICDP, NAP, NAPC1, NAPC2, NAPC3, PA, PAC1, PAC2, PAC3, PER, PYR.

[6)] Includes: DBTIN, DPTIN, MBTIN, MPTIN, TBTIN, TPTIN

[7)] O-FTA Phtalates, includes: BBP, DBPA, DEHA, DEHP, DEP, DEPA, DIBP, DIDP, DIHP, DINCH, DIPA, DMP, DNOP, DPF

[8)] O-PHE phenols (octa non), includes: 4-n-NP, 4-n-OP, 4-t-NP, 4-t-OP

[9)] PFR – Phosphorus Flame Retardants and includes a selection of: TIBP, TBP, TCEP, TCPP, TDCP, TBEP, TPhP, EHDPP, V6, DBPhP, BdPhP, TEHP, ToCrP, TCrP

[10)] PHC – phenols including BPA, TBBPA

[11)] Biological effects methods

[12)] Cod only

Appendix E. Sampling and analyses for 2012-2013 –biota.

Year	Station	Station name	Latitude	Longitude	Species	Tissue	Count	I-MET*	ISOTO	O-BR	OC-CB	OC-CL	OC-CP	OC-DD	OC-HC	O-FL	O-PAH	O-MET	BE	O-FTA	O-PHE	PFR	PHC
2012t	23B	Bømlo north area	59.9000	5.1333	GADU MOR	BI	15												0				
2013p	23B	Bømlo north area	59.9000	5.1333	GADU MOR	BI	15												15				
2013t	23B	Bømlo north area	59.9000	5.1333	GADU MOR	BI	15												15				
2012t	30B	Inner Oslofjord (Oslo City area)	59.8167	10.5500	GADU MOR	BI	15												15				
2013p	30B	Inner Oslofjord (Oslo City area)	59.8167	10.5500	GADU MOR	BI	15												15				
2013t	30B	Inner Oslofjord (Oslo City area)	59.8167	10.5500	GADU MOR	BI	15												14				
2012t	53B	Inner Sørfjord	60.1667	6.5667	GADU MOR	BI	15												0				
2013p	53B	Inner Sørfjord	60.1667	6.5667	GADU MOR	BI	15												15				
2013t	53B	Inner Sørfjord	60.1667	6.5667	GADU MOR	BI	15												15				
2012t	23B	Bømlo north area	59.9000	5.1333	GADU MOR	BL	15												0				
2013p	23B	Bømlo north area	59.9000	5.1333	GADU MOR	BL	15												15				
2013t	23B	Bømlo north area	59.9000	5.1333	GADU MOR	BL	15												15				
2012t	30B	Inner Oslofjord (Oslo City area)	59.8167	10.5500	GADU MOR	BL	15												15				
2013p	30B	Inner Oslofjord (Oslo City area)	59.8167	10.5500	GADU MOR	BL	15												15				
2013t	30B	Inner Oslofjord (Oslo City area)	59.8167	10.5500	GADU MOR	BL	15												15				
2012t	53B	Inner Sørfjord	60.1667	6.5667	GADU MOR	BL	15												0				
2013p	53B	Inner Sørfjord	60.1667	6.5667	GADU MOR	BL	15												15				
2013t	53B	Inner Sørfjord	60.1667	6.5667	GADU MOR	BL	15												15				
2012t	02B	Hvalerbassenget, Kirkøy North	59.1125	11.0388	GADU MOR	LI	17	6		2	6		2								2	2	2
2013p	02B	Hvalerbassenget, Kirkøy North	59.1125	11.0388	GADU MOR	LI	15	15		15	15		15								15	15	15
2013t	02B	Hvalerbassenget, Kirkøy North	59.1125	11.0388	GADU MOR	LI	32	4		2	4		2								2	2	2
2012t	10B	Varangerfjord	69.9333	29.6667	GADU MOR	LI	15	15			15	0		0	0		3			3		3	
2013p	10B	Varangerfjord	69.9333	29.6667	GADU MOR	LI	15	15			15	15		15	15								
2013t	10B	Varangerfjord	69.9333	29.6667	GADU MOR	LI	17	13			13	13		13	13								
2012t	13B	Kristiansand harbour	58.1328	7.9885	GADU MOR	LI	17	11		11	11		4			7					4	4	4
2013p	13B	Kristiansand harbour	58.1328	7.9885	GADU MOR	LI	15	15		15	15		15			15					15	15	15
2013t	13B	Kristiansand harbour	58.1328	7.9885	GADU MOR	LI	36	10		10	10		6			10					6	6	6
2012t	15B	Farsund area	58.0500	6.7167	GADU MOR	LI	15	15			15	0		0	0		5			5		5	
2013p	15B	Farsund area	58.0500	6.7167	GADU MOR	LI	15	15			15	15		15	15								
2013t	15B	Farsund area	58.0500	6.7167	GADU MOR	LI	15	15			15	15		15	15								
2012t	23B	Bømlo north area	59.9000	5.1333	GADU MOR	LI	15	15		15	15	0	6	0	0	11			0		6	6	6
2013p	23B	Bømlo north area	59.9000	5.1333	GADU MOR	LI	15	15		15	15	15	15	15	15	15			15		15	15	15

Year	Station	Station name	Latitude	Longitude	Species	Tissue	Count	I-MET*	ISOTO	O-BR	OC-CB	OC-CL	OC-CP	OC-DD	OC-HC	O-FL	O-PAH	O-MET	BE	O-FTA	O-PHE	PFR	PHC
2013t	23B	Bømlo north area	59.9000	5.1333	GADU MOR	LI	35	16		19	16	**16**	9	**16**	**16**	16			**15**		9	9	8
2012t	28B	Ålesund, Hundsvær area	62.2517	5.8640	GADU MOR	LI	4	4		4	4		2								2	2	2
2013p	28B	Ålesund, Hundsvær area	62.2517	5.8640	GADU MOR	LI	15	15		15	15		15								15	15	15
2013t	28B	Ålesund, Hundsvær area	62.2517	5.8640	GADU MOR	LI	6	6		6	6		4								4	4	4
2012t	30B	Oslo City area	59.8167	10.5500	GADU MOR	LI	15	15		15	15	**0**	5	**0**	**0**	13	5		15	5	5	9	5
2013p	30B	Oslo City area	59.8167	10.5500	GADU MOR	LI	15	15		15	15	**15**	15	**15**	**15**	15			15		15	15	15
2013t	30B	Oslo City area	59.8167	10.5500	GADU MOR	LI	19	16		18	16	**16**	10	**16**	**16**	16			15		10	10	10
2012t	36B	Færder area	59.0405	10.4358	GADU MOR	LI	17	12		12	12	**0**	2	**0**	**0**	11					2	2	2
2013p	36B	Færder area	59.0405	10.4358	GADU MOR	LI	15	15		15	15	**15**	15	**15**	**15**	15					15	15	15
2013t	36B	Færder area	59.0405	10.4358	GADU MOR	LI	32	10		10	10	**10**	3	**10**	**10**	10					3	3	3
2012t	43B2	Tromsø harbour	70.3020	21.4268	GADU MOR	LI	15	15		15	15		10			15					10	10	10
2013p	43B2	Tromsø harbour	70.3020	21.4268	GADU MOR	LI	15	15		15	15		15			15					15	15	15
2013t	43B2	Tromsø harbour	70.3020	21.4268	GADU MOR	LI	33	15		15	15		15			15					15	15	15
2012t	45B2	Hammerfest area	70.7000	24.4833	GADU MOR	LI	0	0			0												
2013p	45B2	Hammerfest area	70.7000	24.4833	GADU MOR	LI	15	15			15												
2013t	45B2	Hammerfest area	70.7000	24.4833	GADU MOR	LI	0	0			0												
2012t	53B	Inner Sørfjord	60.1667	6.5667	GADU MOR	LI	15	15		15	15	**0**	4	15	**0**	14	3		**0**	3	4	5	4
2013p	53B	Inner Sørfjord	60.1667	6.5667	GADU MOR	LI	15			15	15	**15**	15	15	**15**	15			**15**		15	15	15
2013t	53B	Inner Sørfjord	60.1667	6.5667	GADU MOR	LI	34			6	6	**6**	6	6	**6**	6			**15**		6	6	5
2012t	71B	Grenlandsfjord, Brevik area	59.0612	9.7097	GADU MOR	LI	16	13		7			7				2			2	7	7	7
2013p	71B	Grenlandsfjord, Brevik area	59.0612	9.7097	GADU MOR	LI	15	15		15			15								15	15	15
2013t	71B	Grenlandsfjord, Brevik area	59.0612	9.7097	GADU MOR	LI	37	15		9			9								9	9	9
2012t	80B	Inner Trondheimsfjord	63.4573	10.4495	GADU MOR	LI	12	12		12	12		11			11					11	11	11
2013p	80B	Inner Trondheimsfjord	63.4573	10.4495	GADU MOR	LI	15	15		15	15		15			15					15	15	15
2013t	80B	Inner Trondheimsfjord	63.4573	10.4495	GADU MOR	LI	15	15		15	15		15			15					15	15	14
2013p	96B	Helgelandskysten, Sandnessjøen area	66.2962	12.8337	GADU MOR	LI	15	15			15												
2013t	96B	Helgelandskysten, Sandnessjøen area	66.2962	12.8337	GADU MOR	LI	15	15			15												
2012t	98B1	Lofoten, Skrova	68.2467	14.8033	GADU MOR	LI	17	11		11	11	**0**	2	**0**	**0**	6						2	
2013p	98B1	Lofoten, Skrova	68.2467	14.8033	GADU MOR	LI	16	15		16	15	**15**	15	**15**	**15**	15						15	
2013t	98B1	Lofoten, Skrova	68.2467	14.8033	GADU MOR	LI	33	15		16	15	**15**	3	**15**	**15**	15						1	
2012t	02B	Hvalerbassenget, Kirkøy North	59.1125	11.0388	GADU MOR	MU	15	15	15														
2013p	02B	Hvalerbassenget, Kirkøy North	59.1125	11.0388	GADU MOR	MU	15	15	15														
2013t	02B	Hvalerbassenget, Kirkøy North	59.1125	11.0388	GADU MOR	MU	18	18	18														

Year	Station	Station name	Latitude	Longitude	Species	Tissue	Count	I-MET*	ISOTO	O-BR	OC-CB	OC-CL	OC-CP	OC-DD	OC-HC	O-FL	O-PAH	O-MET	BE	O-FTA	O-PHE	PFR	PHC
2012t	10B	Varangerfjord	69.9333	29.6667	GADU MOR	MU	15	15	15														
2013p	10B	Varangerfjord	69.9333	29.6667	GADU MOR	MU	15	15	15														
2013t	10B	Varangerfjord	69.9333	29.6667	GADU MOR	MU	15	15	15														
2012t	13B	Kristiansand harbour	58.1328	7.9885	GADU MOR	MU	15	15	15	9	9												
2013p	13B	Kristiansand harbour	58.1328	7.9885	GADU MOR	MU	15	15	15														
2013t	13B	Kristiansand harbour	58.1328	7.9885	GADU MOR	MU	25	15	15														
2012t	15B	Farsund area	58.0500	6.7167	GADU MOR	MU	15	15	15														
2013p	15B	Farsund area	58.0500	6.7167	GADU MOR	MU	15	15	15														
2013t	15B	Farsund area	58.0500	6.7167	GADU MOR	MU	15	15	15														
2012t	23B	Bømlo north area	59.9000	5.1333	GADU MOR	MU	15	15	15	5											5		5
2013p	23B	Bømlo north area	59.9000	5.1333	GADU MOR	MU	15	15	15														
2013t	23B	Bømlo north area	59.9000	5.1333	GADU MOR	MU	30	18	18														
2012t	28B	Ålesund, Hundsvær area	62.2517	5.8640	GADU MOR	MU	4	4	4														
2013p	28B	Ålesund, Hundsvær area	62.2517	5.8640	GADU MOR	MU	15	15	15														
2013t	28B	Ålesund, Hundsvær area	62.2517	5.8640	GADU MOR	MU	7	7	7														
2012t	30B	Oslo City area	59.8167	10.5500	GADU MOR	MU	15	15	15	15	12										3		3
2013p	30B	Oslo City area	59.8167	10.5500	GADU MOR	MU	15	15	15														
2013t	30B	Oslo City area	59.8167	10.5500	GADU MOR	MU	15	15	15														
2012t	36B	Færder area	59.0405	10.4358	GADU MOR	MU	15	15	15	4	4												
2013p	36B	Færder area	59.0405	10.4358	GADU MOR	MU	15	15	15														
2013t	36B	Færder area	59.0405	10.4358	GADU MOR	MU	15	15	15														
2012t	43B2	Tromsø harbour	70.3020	21.4268	GADU MOR	MU	15	15	15				10								6	10	
2013p	43B2	Tromsø harbour	70.3020	21.4268	GADU MOR	MU	15	15	15														
2013t	43B2	Tromsø harbour	70.3020	21.4268	GADU MOR	MU	15	15	15														
2012t	45B2	Hammerfest area	70.7000	24.4833	GADU MOR	MU	0	0	0														
2013p	45B2	Hammerfest area	70.7000	24.4833	GADU MOR	MU	15	15	15														
2013t	45B2	Hammerfest area	70.7000	24.4833	GADU MOR	MU	0	0	0														
2012t	53B	Inner Sørfjord	60.1667	6.5667	GADU MOR	MU	15	15	15														
2013p	53B	Inner Sørfjord	60.1667	6.5667	GADU MOR	MU	15	15	15														
2013t	53B	Inner Sørfjord	60.1667	6.5667	GADU MOR	MU	29	15	13														
2012t	71B	Grenlandsfjord, Brevik area	59.0612	9.7097	GADU MOR	MU	15	15	15	3											3		3
2013p	71B	Grenlandsfjord, Brevik area	59.0612	9.7097	GADU MOR	MU	15	15	15														
2013t	71B	Grenlandsfjord, Brevik area	59.0612	9.7097	GADU MOR	MU	15	15	15														
2012t	80B	Inner Trondheimsfjord	63.4573	10.4495	GADU MOR	MU	12	12	12	4			4								8		4
2013p	80B	Inner Trondheimsfjord	63.4573	10.4495	GADU MOR	MU	15	15	15														

Year	Station	Station name	Latitude	Longitude	Species	Tissue	Count	I-MET*	ISOTO	O-BR	OC-CB	OC-CL	OC-CP	OC-DD	OC-HC	O-FL	O-PAH	O-MET	BE	O-FTA	O-PHE	PFR	PHC
2013t	80B	Inner Trondheimsfjord	63.4573	10.4495	GADU MOR	MU	15	15	15														
2013p	96B	Helgelandskysten, Sandnessjøen area	66.2962	12.8337	GADU MOR	MU	15	15	15														
2013t	96B	Helgelandskysten, Sandnessjøen area	66.2962	12.8337	GADU MOR	MU	15	15	15														
2012t	98B1	Lofoten, Skrova	68.2467	14.8033	GADU MOR	MU	15	15	15														
2013p	98B1	Lofoten, Skrova	68.2467	14.8033	GADU MOR	MU	15	15	15														
2013t	98B1	Lofoten, Skrova	68.2467	14.8033	GADU MOR	MU	15	15	15														
2012t	71G	Fugløyskjær	58.9825	9.8083	LITT LIT	SB	1											1				1	1
2013p	71G	Fugløyskjær	58.9825	9.8083	LITT LIT	SB	1											1				1	1
2013t	71G	Fugløyskjær	58.9825	9.8083	LITT LIT	SB	1											1				1	1
2012t	10A2	Skallneset, Varangerfjord	70.2083	30.3583	MYTI EDU	SB	3	3			3	**0**		**0**									
2013p	10A2	Skallneset, Varangerfjord	70.2083	30.3583	MYTI EDU	SB	3	3			3	**3**		**3**									
2013t	10A2	Skallneset, Varangerfjord	70.2083	30.3583	MYTI EDU	SB	3	3			3	**3**		**3**									
2012t	11X	Brashavn, Varangerfjord	69.8987	29.7442	MYTI EDU	SB	3	3	3		3	**0**		**0**									
2013p	11X	Brashavn, Varangerfjord	69.8987	29.7442	MYTI EDU	SB	3	3	3		3	**3**		**3**	3								
2013t	11X	Brashavn, Varangerfjord	69.8987	29.7442	MYTI EDU	SB	3	3	3		3	**3**		**3**	3								
2012t	15A	Gåsøy (Ullerø), Kristiansand area	58.0512	6.8860	MYTI EDU	SB	3	3	3		3												
2013p	15A	Gåsøy (Ullerø), Kristiansand area	58.0512	6.8860	MYTI EDU	SB	3	3	3		3												
2013t	15A	Gåsøy (Ullerø), Kristiansand area	58.0512	6.8860	MYTI EDU	SB	3	3	3		3												
2012t	22A	Espevær (west), West Coast	59.5867	5.1417	MYTI EDU	SB	3	3	3		3	**0**		**0**				**0**					
2013p	22A	Espevær (west), West Coast	59.5867	5.1417	MYTI EDU	SB	3	3	3		3	**3**		**3**				**3**				3	3
2013t	22A	Espevær (west), West Coast	59.5867	5.1417	MYTI EDU	SB	3	3	3		3	**3**		**3**				**3**				3	3
2012t	26A2	Måløy	61.9405	5.1230	MYTI EDU	SB	3	3	3	3	3		3									3	
2013p	26A2	Måløy	61.9405	5.1230	MYTI EDU	SB	3	3	3	3	3		3								3	3	3
2013t	26A2	Måløy	61.9405	5.1230	MYTI EDU	SB	3	3	3	3	3		3								3	3	3
2012t	30A	Gressholmen	59.8867	10.8097	MYTI EDU	SB	4	3	3	3	4	**0**	3	**0**			3	**0**				3	3
2013p	30A	Gressholmen	59.8867	10.8097	MYTI EDU	SB	3	3	3	3	3	**3**	3	**3**			3	**3**			3	3	3
2013t	30A	Gressholmen	59.8867	10.8097	MYTI EDU	SB	3	3	3	3	3	**3**	3	**3**			3	**3**			3	3	3
2012t	31A	Solbergstrand	59.6150	10.6567	MYTI EDU	SB	3	3			3	**0**		**0**				**0**					
2013p	31A	Solbergstrand	59.6150	10.6567	MYTI EDU	SB	3	**3**			**3**	**3**		**3**				**3**				3	3
2013t	31A	Solbergstrand	59.6150	10.6567	MYTI EDU	SB	3	**3**			**3**	**3**		**3**				**3**				3	3
2012t	35A	Mølen	59.4882	10.4980	MYTI EDU	SB	0	**0**			**0**												

Year	Station	Station name	Latitude	Longitude	Species	Tissue	Count	I-MET*	ISOTO	O-BR	OC-CB	OC-CL	OC-CP	OC-DD	OC-HC	O-FL	O-PAH	O-MET	BE	O-FTA	O-PHE	PFR	PHC
2013p	35A*	Mølen	59.4882	10.4980	MYTI EDU	SB	3	3			3												
2013t	35A*	Mølen	59.4882	10.4980	MYTI EDU	SB	3	3			3												
2012t	36A	Færder	59.0272	10.5255	MYTI EDU	SB																	
2013p	36A	Færder	59.0272	10.5255	MYTI EDU	SB																	
2013t	36A	Færder	59.0272	10.5255	MYTI EDU	SB																	
2012t	36A1	Tjøme	59.0736	10.4252	MYTI EDU	SB						0		0				0					
2013p	36A1	Tjøme	59.0736	10.4252	MYTI EDU	SB	3	3			3	3		3				3					
2013t	36A1	Tjøme	59.0736	10.4252	MYTI EDU	SB	3	3			3	3		3				3					
2012t	51A	Byrkjenes	60.0850	6.5517	MYTI EDU	SB	3	3	3		3	0		3									
2013p	51A	Byrkjenes	60.0850	6.5517	MYTI EDU	SB	3	3	3		3	3		3	3								
2013t	51A	Byrkjenes	60.0850	6.5517	MYTI EDU	SB	3	3	3		3	3		3	3								
2012t	52A*	Eitrheimsneset	60.0967	6.5367	MYTI EDU	SB	0	0			0	0		0									
2013p	52A*	Eitrheimsneset	60.0967	6.5367	MYTI EDU	SB	3	3			3	3		3									
2013t	52A*	Eitrheimsneset	60.0967	6.5367	MYTI EDU	SB	3	3			3	3		3									
2012t	56A	Kvalnes	60.2552	6.6200	MYTI EDU	SB	3	3	3		3	0		3									
2013p	56A	Kvalnes	60.2552	6.6200	MYTI EDU	SB	3	3	3		3	3		3	3								
2013t	56A	Kvalnes	60.2552	6.6200	MYTI EDU	SB	3	3	3		3	3		3	3								
2012t	57A*	Krossanes	60.4208	6.7422	MYTI EDU	SB	0	0			0	0		0									
2013p	57A*	Krossanes	60.4208	6.7422	MYTI EDU	SB	3	3			3	3		3									
2013t	57A*	Krossanes	60.4208	6.7422	MYTI EDU	SB	3	3			3	3		3									
2012t	63A*	Ranaskjær	60.4183	6.4083	MYTI EDU	SB	0	0			0	0		0									
2013p	63A*	Ranaskjær	60.4183	6.4083	MYTI EDU	SB	3	3			3	3		3									
2013t	63A*	Ranaskjær	60.4183	6.4083	MYTI EDU	SB	3	3			3	3		3									
2012t	64A	Utne	60.4237	6.6222	MYTI EDU	SB	3	3			3			3									
2013p	64A	Utne	60.4237	6.6222	MYTI EDU	SB	3	3			3			3									
2013t	64A	Utne	60.4237	6.6222	MYTI EDU	SB	3	3			3			3									
2012t	65A	Vikingneset	60.2417	6.1600	MYTI EDU	SB	3	3			3	0		3									
2013p	65A	Vikingneset	60.2417	6.1600	MYTI EDU	SB	3	3			3	3		3	3								
2013t	65A	Vikingneset	60.2417	6.1600	MYTI EDU	SB	3	3			3	3		3	3								
2012t	69A*	Lille Terøy	59.9798	5.7558	MYTI EDU	SB	0	0			0												
2013p	69A*	Lille Terøy	59.9798	5.7558	MYTI EDU	SB	3	3			3												
2013t	69A*	Lille Terøy	59.9798	5.7558	MYTI EDU	SB	3	3			3												
2012t	71A	Bjørkøya (Risøyodden)	59.0233	9.7537	MYTI EDU	SB	3	3	3	3		0	3	0			3					3	
2013p	71A	Bjørkøya (Risøyodden)	59.0233	9.7537	MYTI EDU	SB	3	3	3	3	3	3	3	3			3				3	3	3
2013t	71A	Bjørkøya (Risøyodden)	59.0233	9.7537	MYTI EDU	SB	3	3	3	3	3	3	3	3			3				3	3	3

Year	Station	Station name	Latitude	Longitude	Species	Tissue	Count	I-MET*	ISOTO	O-BR	OC-CB	OC-CL	OC-CP	OC-DD	OC-HC	O-FL	O-PAH	O-MET	BE	O-FTA	O-PHE	PFR	PHC
2012t	76A	Risøy area	58.7267	9.2833	MYTI EDU	SB	3	3			3												
2013p	76A	Risøy area	58.7267	9.2833	MYTI EDU	SB																	
2013t	76A	Risøy area	58.7267	9.2833	MYTI EDU	SB																	
2012t	76A2	Risør area	58.7372	9.2810	MYTI EDU	SB						**0**		**0**									
2013p	76A2	Risør area	58.7372	9.2810	MYTI EDU	SB	3	3			3	**3**	3	**3**									
2013t	76A2	Risør area	58.7372	9.2810	MYTI EDU	SB	3	3			3	**3**	3	**3**									
2012t	91A2	Ørland	63.6875	9.6678	MYTI EDU	SB	3	3	3	3	3		3									3	1
2013p	91A2	Ørland	63.6875	9.6678	MYTI EDU	SB	3	3	3	3	3		3								3	3	3
2013t	91A2	Ørland	63.6875	9.6678	MYTI EDU	SB	3	3	3	3	3		3								3	3	3
2012t	97A2	Bodø havn	67.2950	14.3880	MYTI EDU	SB	4	3	3	3	4		3									3	3
2013p	97A2	Bodø havn	67.2950	14.3880	MYTI EDU	SB	3	3	3	3	3		3								3	3	3
2013t	97A2	Bodø havn	67.2950	14.3880	MYTI EDU	SB	3	3	3	3	3		3								3	3	3
2012t	98A2	Lofoten, Husvaagen	68.2577	14.6638	MYTI EDU	SB	3	3	3	3	3		3				3				3	3	3
2013p	98A2	Lofoten, Husvaagen	68.2577	14.6638	MYTI EDU	SB	3	3	3	3	3		3				3				3	3	3
2013t	98A2	Lofoten, Husvaagen	68.2577	14.6638	MYTI EDU	SB	3	3	3	3	3		3				3				3	3	3
2012t	I023	Singlekalven (south)	59.0950	11.1367	MYTI EDU	SB	5	3	3	3	5		3				3					3	3
2013p	I023	Singlekalven (south)	59.0950	11.1367	MYTI EDU	SB	3	3	3	3	3		3				3				3	3	3
2013t	I023	Singlekalven (south)	59.0950	11.1367	MYTI EDU	SB	3	3	3	3	3		3				3				3	3	3
2012t	I024	Kirkøy (north west)	59.0800	10.9863	MYTI EDU	SB																	
2013p	I024	Kirkøy (north west)	59.0800	10.9863	MYTI EDU	SB	3	3															
2013t	I024	Kirkøy (north west)	59.0800	10.9863	MYTI EDU	SB	1	1															
2012t	I131A	Lastad	58.0555	7.7087	MYTI EDU	SB	3	3									3						
2013p	I131A	Lastad	58.0555	7.7087	MYTI EDU	SB	3	3									3						
2013t	I131A	Lastad	58.0555	7.7087	MYTI EDU	SB	3	3									3						
2012t	I133*	Odderøy	58.1317	8.0017	MYTI EDU	SB	0	**0**			**0**	**0**		**0**				**0**					
2013p	I133*	Odderøy	58.1317	8.0017	MYTI EDU	SB	3	**3**			**3**	**3**		**3**				**3**				3	3
2013t	I133*	Odderøy	58.1317	8.0017	MYTI EDU	SB	3	**3**			**3**	**3**		**3**				**3**				3	3
2012t	I241	Nordnes	60.4007	5.3017	MYTI EDU	SB																	
2013p	I241	Nordnes	60.4007	5.3017	MYTI EDU	SB	3	3		3	3		3								3	3	3
2013t	I241	Nordnes	60.4007	5.3017	MYTI EDU	SB	2	2		2	2		2								2	2	2
2012t	I301	Akershuskaia	59.9053	10.7363	MYTI EDU	SB	3	3			3			**0**			3	**0**					
2013p	I301	Akershuskaia	59.9053	10.7363	MYTI EDU	SB	3	3			3	3		**3**	3		3	**3**				3	3
2013t	I301	Akershuskaia	59.9053	10.7363	MYTI EDU	SB	3	3			3	3		**3**	3		3	**3**				3	3
2012t	I304	Gåsøya	59.8513	10.5890	MYTI EDU	SB	3	3	3		3			**0**			3	**0**					
2013p	I304	Gåsøya	59.8513	10.5890	MYTI EDU	SB	3	3	3		3	3		**3**	3		3	**3**				3	3

Year	Station	Station name	Latitude	Longitude	Species	Tissue	Count	I-MET*	ISOTO	O-BR	OC-CB	OC-CL	OC-CP	OC-DD	OC-HC	O-FL	O-PAH	O-MET	BE	O-FTA	O-PHE	PFR	PHC
2013t	I304	Gåsøya	59.8513	10.5890	MYTI EDU	SB	3	3	3		3	3		3	3		3	3				3	3
2012t	I306*	Håøya	59.7133	10.5552	MYTI EDU	SB	0	0			0												
2013p	I306*	Håøya	59.7133	10.5552	MYTI EDU	SB	3	3			3												
2013t	I306*	Håøya	59.7133	10.5552	MYTI EDU	SB	3	3			3												
2012t	I307*	Ramtonholmen	59.7445	10.5228	MYTI EDU	SB	0	0			0												
2013p	I307*	Ramtonholmen	59.7445	10.5228	MYTI EDU	SB	3	3			3												
2013t	I307*	Ramtonholmen	59.7445	10.5228	MYTI EDU	SB	3	3			3												
2012t	I712	Croftholmen	59.0453	9.7068	MYTI EDU	SB	3	3	3	3			3				3					3	
2013p	I712	Croftholmen	59.0453	9.7068	MYTI EDU	SB	3	3	3	3	3		3				3				3	3	3
2013t	I712	Croftholmen	59.0453	9.7068	MYTI EDU	SB	2	2	2	2	2		2				2				2	2	2
2012t	I965	Moholmen	66.3120	14.1258	MYTI EDU	SB	3	3									3						
2013p	I965	Moholmen	66.3120	14.1258	MYTI EDU	SB	3	3									3						
2013t	I965	Moholmen	66.3120	14.1258	MYTI EDU	SB	3	3									3						
2012t	I969	Bjørnbærviken	66.2798	14.0355	MYTI EDU	SB	3	3									3						
2013p	I969	Bjørnbærviken	66.2798	14.0355	MYTI EDU	SB	3	3									3						
2013t	I969	Bjørnbærviken	66.2798	14.0355	MYTI EDU	SB	3	3									3						
2012t	11G	Brashavn	69.8987	29.7442	NUCE LAP	SB	1											1	1			1	1
2013p	11G	Brashavn	69.8987	29.7442	NUCE LAP	SB	1											1	1			1	1
2013t	11G	Brashavn	69.8987	29.7442	NUCE LAP	SB	1											1	1			1	1
2012t	131G	Lastad	58.0555	7.7087	NUCE LAP	SB	1											1	1			1	1
2013p	131G	Lastad	58.0555	7.7087	NUCE LAP	SB	1											1	1			1	1
2013t	131G	Lastad	58.0555	7.7087	NUCE LAP	SB	1											1	1			1	1
2012t	15G	Gåsøy (Ullerø)	58.0517	6.7217	NUCE LAP	SB	1											1	1			1	1
2013p	15G	Gåsøy (Ullerø)	58.0517	6.7217	NUCE LAP	SB	1											1	1			1	1
2013t	15G	Gåsøy (Ullerø)	58.0517	6.7217	NUCE LAP	SB	1											1	1			1	1
2012t	227G1	Melandholmen	59.3335	5.3150	NUCE LAP	SB	1											1	1			1	1
2013p	227G1	Melandholmen	59.3335	5.3150	NUCE LAP	SB	1											1	1			1	1
2013t	227G1	Melandholmen	59.3335	5.3150	NUCE LAP	SB	1											1	1			1	1
2012t	22G	Espevær (west)	59.5792	5.1483	NUCE LAP	SB	1											1	1			1	1
2013p	22G	Espevær (west)	59.5792	5.1483	NUCE LAP	SB	1											1	1			1	1
2013t	22G	Espevær (west)	59.5792	5.1483	NUCE LAP	SB	1											1	1			1	1
2012t	36G	Færder	59.0272	10.5255	NUCE LAP	SB	1											1	1			1	1
2013p	36G	Færder	59.0272	10.5255	NUCE LAP	SB	1											1	1			1	1
2013t	36G	Færder	59.0272	10.5255	NUCE LAP	SB	1											1	1			1	1
2012t	76G	Risøy	58.7280	9.2760	NUCE LAP	SB	1											1	1			1	1

Year	Station	Station name	Latitude	Longitude	Species	Tissue	Count	I-MET*	ISOTO	O-BR	OC-CB	OC-CL	OC-CP	OC-DD	OC-HC	O-FL	O-PAH	O-MET	BE	O-FTA	O-PHE	PFR	PHC
2013p	76G	Risøy	58.7280	9.2760	NUCE LAP	SB	1											1	1			1	1
2013t	76G	Risøy	58.7280	9.2760	NUCE LAP	SB	1											1	1			1	1
2012t	98G	Lofoten, Svolvær	68.2567	14.6767	NUCE LAP	SB	1											1	1			1	1
2013p	98G	Lofoten, Svolvær	68.2567	14.6767	NUCE LAP	SB	1											1	1			1	1
2013t	98G	Lofoten, Svolvær	68.2567	14.6767	NUCE LAP	SB	1											1	1			1	1

Appendix F
Temporal trend analyses of contaminants and biomarkers in biota 1981-2013

This Appendix is provided as an EXCEL file separate from this report but described below.

Median concentrations are only shown for those timeseries that include data for either 2012 or 2013.

Code descriptions are given in Appendix B

MYTI EDU-Blue Mussel (*Mytilus edulis***)**
LITT LIT-Common periwinkle (*Littorina littorea***)**
NUCE LAP-Dog whelk (*Nucella lapillus***)**
GADU MOR-Atlantic cod (*Gadus morhua***)**

Tsu -tissue:
SB-Soft body tissue
LI-Liver tissue
MU-Muscle tissue
BL-Blood
BI-Bile

The annual count and standard deviation are shown for 2012 and 2013.

(continues on next page)

OC Overconcentration expressed as quotient of median of last year and upper limit to presumed "high background" ("m" missing background value)

SD Standard deviation (concerns each of the last two years

Power (long) POWER; estimated number of years to detect a hypothetical situation of 10% trend a year with a 90% power – for the entire sampling period.

First Yr (long) First year in time series for entire sampling period

Last Yr (long) Last year in time series for entire sampling period

No.Yrs (long) Number of years in time series for entire sampling period

Power (short) POWER; estimated number of years to detect a hypothetical situation of 10% trend a year with a 90% power – for the entire sampling period.

First Yr (short) First year in time series for the last 10-year-sampling period

Last Yr (short) Last year in time series for the last 10-year-sampling period

No. Yrs (short) Number of years in time series for the last 10-year-sampling period

Trend Indication of levels and trends in concentrations of contaminants monitored. Classification is based on observed median concentrations in cod, flatfish and blue mussel. The classification system of the Norwegian Environment Agency is used for biota (Molvær *et al.* 1997: Classes: I (blue), II (green), III (yellow), IV (orange) and V (red) (see Appendix D). For biota, trend analyses were done on time series with five or more years and the results, before the slash "/"(i.e. long-term trend which means the entire time series), are indicated by an upward (🡅) or downward (🡇) arrow where significant trends were found, or a zero (**O**) if no trend was detected. Where there was sufficient data a time series analysis was performed for the last ten-year period (short-term or recent trend) and the result is shown after the slash. A small filled square (▪) indicates that chemical analysis has been performed, but data either were insufficient to do a trend analysis or was not presented. For all significant trends the statistical significance (p) is given as well as the annual detectable change (%) that can be detected with statistical probability of 90% (Power) in two-sided testing with a 10% significance level (alpha). Dark grey indicates concentrations higher than estimated high background levels. Light grey indicates concentrations lower than high background levels. Note: Class limits for ΣDDT are used for ppDDE, and the Class limits for ΣHCH are used for HCHG.

The time trend analyses are done on wet weight, dry weight and fat weight basis

Note on detection limit in trend analyses: half of the limit is used or null is used if the parameter is included as part of a sum. However, the number of such cases and position in a timesseries may affect whether or not a trendanalyses can be applied.

Appendix G
Passive sampling result-tables

As part of the batch of analysis of samplers from the 2012-2013 survey, two QA spiked samplers were analysed for substances of interest. This will allow us to gauge the performance of the extraction and analysis over time. The table below (*Table 39*) shows the contaminant concentrations measured in two QA spiked samplers. For most substances concentrations measured are very close to the mean concentrations from the six QA spiked samplers analysed previously. This will allow us to build control charts.

Table 39. Comparison of concentrations of substances of interest measured in the two QA spiked samplers with data from the initial evaluation of the QA spiked samplers.

Substance	**Mean concentration in ng g^{-1} (% RSD)** [4]	**QA Spike (ng g^{-1})**
Alkyphenols [1]		
4-t-OP	79 (12)	63.00
4-t-NP	289 (10)	252.3
4-n-OP	72 (18)	67.8
4-n-NP	64 (4)	63.9
HBCD [2]		
α-HBCD	2.5 (11)	2.28
β-HBCD	2.7 (13)	2.72
γ-HBCD	2.3 (21)	2.48
PBDEs [3]		
BDE 47	4.5 (9)	4.17
BDE99	4.4 (12)	4.38
BDE100	3.0 (8)	2.88
BDE126	2.3 (11)	2.12
BDE153	2.2 (14)	1.83
BDE154	2.0 (15)	1.95
BDE183	2.2 (21)	1.81
BDE196	1.7 (20)	2.00
BDE209	4.1 (18)	3.31

1) 4-t-OP: para-t-octylphenol; 4-t-NP : para-t-nonylphenol; 4-n-OP: para-n-octylphenol; 4-n-NP : para-n-nonylphenol
2) HBCD: Hexabromocyclododecane
3) PBDE: Polybrominated diphenyl ether
4) Mean concentration in the first six QA spiked samplers

The table below (*Table 40*) shows Water Framework Directive Environmental Quality Standards for substances of interest for the passive sampling work. These have been set for the "Whole Water" (as opposed to passive samplers measuring the freely dissolved concentration).

Table 40. Annual average and maximum acceptable concentration environmental quality standard set by the European Union's Water Framework Directive (2013/39/EU).

	Water Framework Directive EQS (μg L^{-1})	
	AA-EQS	**MAC-EQS**
Octylphenol*	0.01	Not applicable
Nonylphenol**	0.3	2.0
PBDEs***		0.014
HBCD	0.0008	0.05

*with CAS number 1806-26-4 (including compound with CAS number 140-66-9)
**with CAS number 25154 (including compounds with CAS numbers 104-40-5 and84852-15-3)
***only tetra, penta, hexa and heptabromodiphenyl ether (CAS numbers 40088-47-9, 32534-81-9, 36483-60-0, 68928-80-3)

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The Norwegian Environment Agency's primary tasks are to reduce greenhouse gas emissions, manage Norwegian nature, and prevent pollution.

We are under the Ministry of Climate and Environment and have over 700 employees at our two offices in Trondheim and Oslo and at the Norwegian Nature Inspectorate's more than sixty local offices.

Our principal functions include monitoring the state of the environment, conveying environment-related information, exercising authority, overseeing and guiding regional and municipal authorities, cooperating with relevant industry authorities, acting as an expert advisor, and assisting in international environmental efforts.

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