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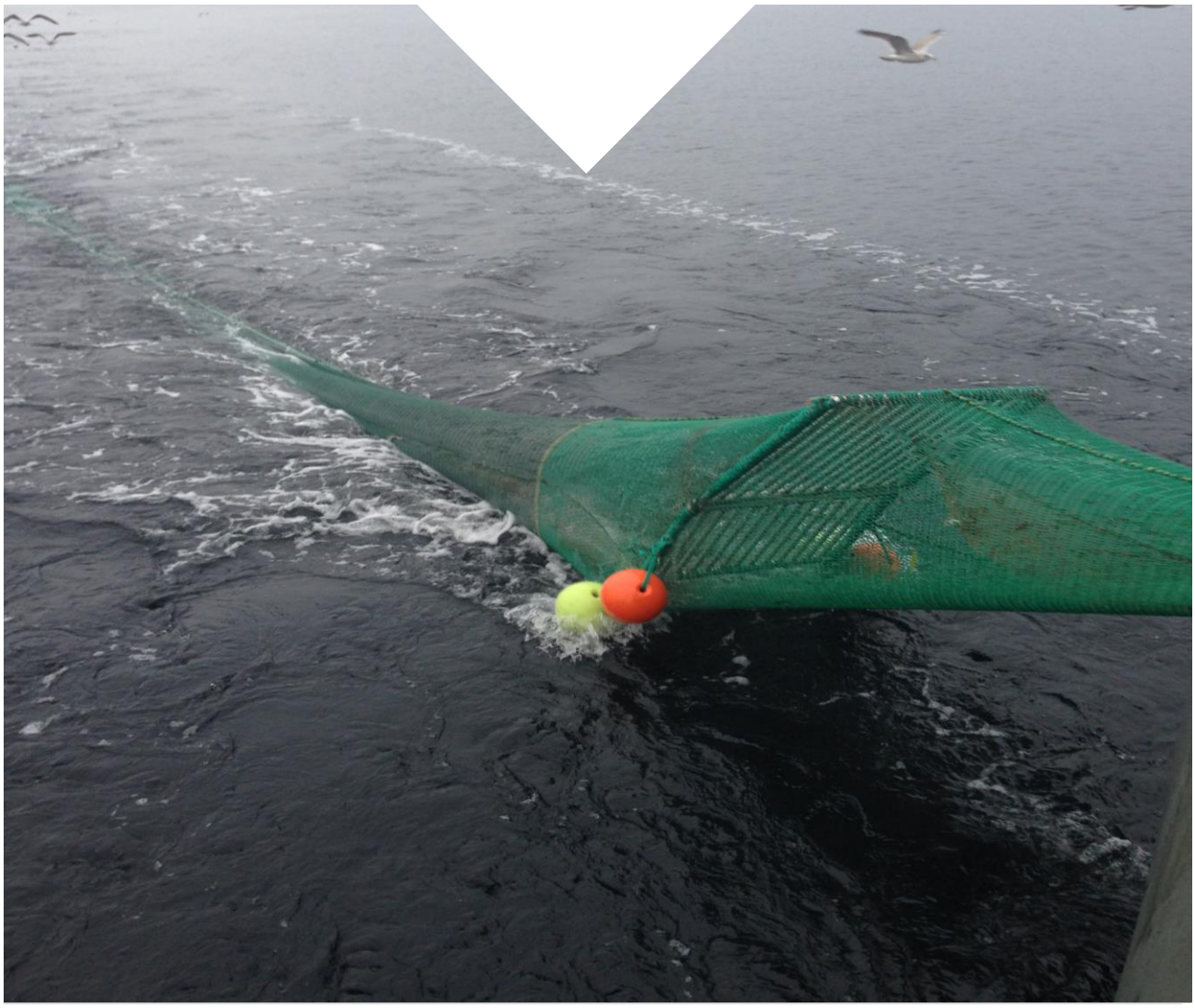
Contaminants in coastal waters of Norway 2015

Miljøgifter i norske kystområder 2015



Foreword

This report presents the investigations of contaminants in coastal waters of Norway 2015 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 concentration 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 2015 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). Coordinator at the Norwegian Environment Agency is Bård Nordbø and the project manager at NIVA is Norman W. Green.

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Oslo, 31 October 2016.

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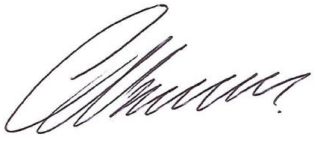
Abstract
This programme examines the levels, trends and effects of contaminants in biota along the coast of Norway. The 2015-investigation included analyses of 108 different contaminants or biological effect parameters in five types of samples (blue mussel, dog whelk, common periwinkle, cod and passive samplers). The contaminants include metals (Ag, As, Hg, Cd, Co, Cr, Cu, Ni, Pb and Zn), tributyltin (TBT), organochlorines (e.g. PCBs, DDT), PAHs, polybrominated diphenyl ethers (PBDEs), perfluorinated alkylated substances (PFAS) as well as contaminants that have recently received much attention such as hexabromocyclododecane (HBCDs), chlorinated paraffins (SCCP, MCCP), phosphorus flame retardants (PFRs), bisphenol A (BPA), tetrabrombisphenol A (TBBPA) and alkyphenols. Biological effects parameters included VDSI, OH-pyrene metabolites, ALA-D and EROD. In the report, 30 representative substances or parameters were chosen for analyses of 829 time series (last 10 years). Of these there were statistically significant trends in 98 cases: 81 were downwards and 17 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 829 cases, 431 could be classified by the environmental classification system used by the Norwegian Environment Agency. 378 were classified as insignificantly polluted, 48 as moderately polluted, four as markedly polluted and one as severely 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. High concentrations of DDE in mussels from the Sørfjord were related to earlier use of DDT as pesticide in orchards along the fjord. The relation of fish length on contaminant concentration was examined. Application of quality standards in biota were discussed.

4 keywords, Norwegian	4 keywords, English
1. Miljøgifter	1. Contaminants
2. Biologiske effekter	2. Biological effects
3. Marin	3. Marine
4. Norge	4. Norway



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English summary

This programme examines the levels, trends and effects of contaminants along the coast of Norway from the Oslofjord and Hvaler region in the southeast to the Varangerfjord in the northeast. The programme provides a basis for assessing the state of the environment for the coastal waters.

The main conclusion is that most trends of contaminant concentrations in marine organisms collected at stations in the Norwegian coastal water were downwards. The Inner Oslofjord seems to be the area where contaminants tend to appear in relatively high concentrations and hence warrant special concern. For example, the investigation found an upward trend for mercury (Hg) in cod fillet and high concentrations of lead (Pb), polychlorinated biphenyls (PCB), polybrominated diphenyl ethers (PBDEs), perfluorinated alkylated substances (PFAS) and alpha-hexabromocyclododecane (α–HBCD) in cod liver. The upwards trend for Hg was also significant after correction for increasing fish size over the last years.

Monitoring contaminants and associated parameters along the Norwegian coast contributes to OSPAR's Coordinated Environmental Monitoring Programme (CEMP). The 2015-investigation monitored blue mussel at 36 stations, dog whelk at 8 stations, common periwinkle at 1 station, cod at 16 stations and seawater using passive sampling at 3 stations. 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 with presumed low exposure to pollution. The programme for 2015 included analyses of mercury (Hg), cadmium (Cd), lead (Pb), copper (Cu), zinc (Zn), silver (Ag), arsenic (As), nickel (Ni), chromium (Cr), cobalt (Co), polychlorinated biphenyls (PCBs), pesticides (DDE), polycyclic aromatic hydrocarbons (PAHs), polybromated diphenyl ethers (PBDEs), perfluorinated alkylated substances (PFAS), hexabromocyclododecanes (HBCD), short and medium chained chlorinated paraffins (SCCP and MCCP), organophosphorus flame retardants (PFRs), bisphenol A (BPA), tetrabrombisphenol A (TBBPA), alkylphenols as well as biological effects parameters.

The results from 2015 (exclusive passive sampling) supplied data for a total of 2506 data sets (contaminant-station-species) on 108 different contaminants. Thirty representative contaminants and biological effect parameters were chosen for presentation in this report. This selection had 829 time series of which there were statistically significant time (2006-2015) related trends in 98 cases: 81 were downwards and 17 upwards. The downward trends were largely associated with concentrations of metals (44 %) and to a lesser degree tributyltin (TBT) and effect of TBT (VDSI - *vas deferens sequence index*). The dominance of downward trends indicated that contamination was decreasing. The upward trends were also associated with metals (82 %), primarily mercury.

Of the 431 cases that could be classified by the system of the Norwegian Environment Agency, 378 were classified as insignificantly polluted (Class I), 48 as moderately polluted (Class II), 4 as markedly polluted (Class III), one as severely polluted (Class IV) and none as extremely polluted (Class V). Even though most concentrations observed can be considered moderately polluted or better, the cases that were worse represent risk of toxic effects and cannot be disregarded. For example, the blue mussel in the Mid Sørfjord is severely polluted with pesticides (DDE).

Passive samplers were deployed at three sites (Inner Oslofjord, Hvaler and Ålesund harbour) and included investigations of alkylphenols, HBCD and PBDEs. The results were mostly below limits of detection. Only BDE47, α-HBCD and beta-HBCD could be measured in waters of Inner Oslofjord. Concentrations were similar to concentrations reported previously in this programme.

Concentrations of contaminants in fish

Cod fillet from the Inner Oslofjord was moderately polluted by mercury, and a significant upward trend was found for the period 1984-2015 using the OSPAR method which targets specific length-groups. Upward trends were also found for mercury in cod fillet from Færder, Farsund and Bømlo using the OSPAR method for the period 2006-2015. At Bømlo, an upward trend for mercury in cod fillet was also found for the period 1990-2015.

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

PBDEs have been investigated in cod liver for several fjords since 2005. In 2015, the concentration of sum PBDEs was highest in the Inner Oslofjord and lowest at Bømlo. BDE47 was the dominant congener in all samples. As for PCB, the high concentrations of PBDEs are probably related to urban activities and water exchange conditions.

PFAS has been investigated in cod liver for several fjords since 2005. PFOS, an abundant PFAS-compound, was highest in cod from the Inner Oslofjord and lowest in the Bergen harbour. PFOSA, also an abundant PFAS-compound, was highest in the Inner Oslofjord and lowest in Tromsø. The differences between the stations are not fully understood, but it appears likely that as for PCBs and PBDEs a combination of urban sources and restricted water exchange provide the highest concentrations in the Inner Oslofjord.

Of the hexabromocyclododecanes, α–HBCD was the most abundant component. Cod liver from the 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.

Concentrations of short chain chlorinated paraffins (SCCP) in cod liver were significantly higher in cod from Bergen harbour compared to the other stations. Medium chlorinated paraffins (MCCP) in cod liver was highest in Ålesund.

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

Bisphenol A, TBBPA and alkylphenols were generally not detected in cod, and no conclusion can be drawn regarding possible differences between stations. There is an indication that of the four alkylphenols that were analysed, 4-t-nonylphenol and 4-n-octylphenol, were the most dominant compounds in cod.

Concentrations of contaminants in blue mussel

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

Blue mussel at Måløy in the Outer Sognefjord was markedly polluted with arsenic. Concentrations of PBDEs, α-HBCD and SCCP in mussels were highest at Nordnes in Bergen harbour area. SCCP and MCCP in blue mussel was highest in the Outer Oslofjord (Tjøme and Færder). These results contrast with what was found for cod. Mussels filter surface waters, whereas cod are generally exposed to deeper water masses, hence concentrations in these two organisms are not always comparable.

The specific sources of the SCCP and MCCP are unknown, but could be the result of industrial activity in these fairly enclosed areas. Further investigations are warranted.

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

Bisphenol A, TBBPA and alkylphenols were generally not detected in blue mussel, and no conclusion can be drawn regarding possible differences between stations. There is an indication that of the four alkylphenols included, 4-t-nonylphenol and 4-n-octylphenol, were the most dominant compounds in blue mussel.

Biological effects

The ICES/OSPARs assessment criterion[1] (background assessment criteria, BAC) for OH-pyrene in cod bile was exceeded at all stations investigated (Inner Oslofjord, Farsund area, Inner Sørfjord), except for at the reference station (Bømlo-Sotra area) in 2015 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 (st. 30B) was about twice as high as in 2014, i.e. at approximately the same level as prior to 2012.

The ALA-D activity in the Inner Oslofjord and the Inner Sørfjord in 2015 showed lower activity than at Bømlo. Reduced activities of ALA-D reflect higher exposure to lead.

The median EROD activity in the Inner Oslofjord was similar to that observed in 2013 (i.e. approximately twice as high as in 2012 and 2014). The concentration was still below the ICES/OSPARs BAC. Concentrations over BAC would indicate possible impact by planar PCBs, PCNs, PAHs or dioxins.

The effects of TBT on dog whelk were relatively low (VDSI<0.828) at all eight stations. There were significant downward trends for all stations, except for Brashavn in the Varangerfjord 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.

Stable isotopes

The stabile isotope $\delta^{15}N$ is analysed as a measure of trophic position. Results showed very similar isotopic signatures in 2012, 2013, 2014 and 2015, suggesting a persistent spatial trend more than a temporal trend. In other words, there are geographical differences in the baseline isotopic signatures, that must be taken into consideration when interpreting accumulation of contaminants in relation to trophic position. The $\delta^{15}N$ data in cod is assessed in relation to concentrations of selected contaminants. Generally, as fish grow through their lifetimes, 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.

Time trends for contaminants in cod taking length into account

The statistical analyses of time trends (increase/decrease) of contaminant concentrations in cod uses the median value (for each contaminant and station), and does not take into account length of the sampled cod. Potentially, this could lead to incorrect conclusions if contaminant

[1] 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.

concentration is correlated with size of the fish (e.g., accumulation) and if the average length of the sampled cod changes over time. We have earlier found this to be the case with regard to Hg in the inner Oslofjord. However, a more extensive analysis shows that in the majority of cases, the statistical conclusions regarding time trends of contaminants would not change if length of the sampled cod was taken into account. This was also the case for Hg in Inner Oslofjord including this year's data. For a minority of time series, downward trends in median values may to some degree be explained by changes in median length of the sampled cod. In a smaller subset of samples, there was no trend in the median values, but a downward trend was found if effects of length were taken into account. In only two cases, length-adjusted concentrations had an upward trend.

Note on application of quality standards

The current risk-based system and the older classification system based on presumed background levels have been compared. The risk-based environmental quality standards need to be improved to be more operational. In this regard it is suggested that both systems be applied to assess the results from monitoring of hazardous substances.

Sammendrag

Denne undersøkelsen omhandler nivåer, trender og effekter av miljøgifter langs norskekysten. I tillegg til en mer langsiktig overvåking er det også gjort analyser av enkelte nyere miljøgifter som har fått større oppmerksomhet de senere årene. Undersøkelsen gir grunnlag for vurdering av miljøstatus for miljøgifter langs kysten.

Resultatene viser at det hovedsakelig var nedadgående trender for forekomst av de undersøkte miljøgiftene. Indre Oslofjord er et område med forhøyede miljøgiftkonsentrasjoner som gir grunnlag for bekymring og behov for nærmere undersøkelser. For eksempel observeres oppadgående trend for kvikksølv (Hg) i torskefilet og høye konsentrasjoner av bly (Pb), polyklorerte bifenyler (PCB), polybromerte difenyletere (PBDE), perfluorerte alkylstoffer (PFAS) og alfa-heksabromsyklododekan (α–HBCD) i torskelever.

Undersøkelsen inngår som en del av OSPARs koordinerte miljøovervåkingsprogram Coordinated Environmental Monitoring Programme *(CEMP). I 2015 omfattet overvåkingen miljøgifter i blåskjell (36 stasjoner), purpursnegl (8 stasjoner), strandsnegl (én stasjon), torsk (16 stasjoner) og sjøvann (bruk av passive prøvetakere på tre 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 for tilførsler av miljøgifter, i områder med diffus tilførsel av miljøgifter slik som byens havneområder, og i fjerntliggende områder med antatt lav eksponering for miljøgifter. Undersøkelsen omfatter overvåking av metaller [kvikksølv (Hg), kadmium (Cd), bly (Pb), kobber (Cu), sink (Zn), sølv (Ag), arsen (As), nikkel (Ni), krom (Cr) og kobolt (Co)], tributyltinn, PCBer, pestisider (DDE), PBDEer, PFAS, heksabromsyklododekan (HBCD), korte- og mellomkjedete klorparafiner (SCCP og MCCP), fosfororganiske flammehemmere (PFRer), bisfenol A (BPA), tetrabrombisfenol A (TBBPA), alkyfenoler, samt biologiske effekt parametre.*

2015-resultatene (eksklusive passive prøvetakere) omfatter totalt 2506 datasett (miljøgifter-stasjoner-arter) for 108 forskjellige miljøgifter. Et utvalg på 30 representative miljøgifter og biologiske parametere presenteres i denne rapporten. Dette utvalget består av 829 tidsserier hvorav 98 viste statistisk signifikante trender for perioden 2006 til 2015: 81 var nedadgående og 17 var oppadgående. De nedadgående trendene omfattet metaller (44 %) og i noe mindre grad også tributyltinn (TBT) og effekt av TBT (VDSI – sædlederindeks). Dominansen av nedadgående trender indikerer avtagende nivåer av miljøgifter. De oppadgående trendene var i hovedsak også metaller (82 %), og da primært kvikksølv.

Av de 431 tidsseriene som kunne klassifiseres i henhold til Miljødirektoratets klassifiseringssystem, var 378 klassifisert som ubetydelig-lite forurenset (klasse I), 48 som moderat forurenset (klasse II), fire som markert forurenset (klasse III), én som sterkt forurenset (klasse IV) og ingen som meget sterkt forurenset (klasse V). Selv om de fleste observerte nivåene kan betraktes som moderat forurenset eller bedre, så viste noen en sterkere grad av forurensing. Et eksempel på dette er blåskjell i Sørfjorden som var sterkt forurenset av DDE.

Passive prøvetakere ble utplassert på tre steder (Hvaler, Oslofjorden og Ålesund havn) for å beregne konsentrasjon i vann av alkylfenoler, HBCD og PBDEer. Resultatene var stort sett under deteksjonsgrensene (særlig for prøver fra Hvaler og Ålesund). Bare fra indre Oslofjord ble det for stoffene BDE47, α-HBCD, para-t-octylfenol og para-t-nonylfenol påvist konsentrasjoner over deteksjonsgrensene. De påviste konsentrasjonene samsvarer med tidligere rapporterte data.

Konsentrasjoner av miljøgifter i fisk
Torskefilet fra indre Oslofjord var moderat forurenset av kvikksølv og det var en signifikant oppadgående trend for perioden 1984-2015. Trendberegningene er gjort etter en OSPAR-metode basert på spesifikke lengde-grupper av fisk. Oppadgående trender for kvikksølv ble registrert i torskefilet fra Færder, Farsund og Bømlo ved bruk av OSPAR-metoden for perioden 2006-2015. Ved Bømlo var det også oppadgående trend kvikksølv i torskefilet for perioden 1990-2015.

Torskelever fra indre Oslofjord var markert forurenset av PCBer. Torsk fra andre områder var ellers generelt lite forurenset (ubetydelig eller moderat forurenset) av disse forbindelsene. De høye konsentrasjonene av PCBer som ble observert i torskelever fra indre Oslofjord har trolig sammenheng med urban påvirkning i kombinasjon med lav vannutskifting med ytre fjord.

PBDEer er undersøkt i torskelever fra flere fjorder siden 2005. I 2015 var konsentrasjonen av sum PBDEer høyest i torsk fra indre Oslofjord og lavest ved Bømlo. BDE47 var den dominerende PBDE-forbindelsen i alle prøvene. Som for PCBer, er urban påvirkning og vannutskiftingsforhold trolig årsaker til de høye nivåene.

Perfluorerte alkylerte forbindelser (PFAS) har blitt undersøkt i torskelever siden 2005. PFOS, en PFAS-forbindelse, var høyest i torskelever fra indre Oslofjord og lavest i Bergen. PFOSA, også en PFAS-forbindelse, var høyest i indre Oslofjord og lavest i Tromsø havn. 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 resultatene var for PCBer og PBDEer.

Av heksabromsyklododekaner var α-HBCD den mest dominerende diastereomeren. Torskelever fra indre Oslofjord hadde den høyeste median-konsentrasjonen av HBCD. De høye HBCD-konsentrasjonene er sannsynligvis relatert til urban påvirkning, samt lav vannutskifting med ytre fjord.

Det var signifikant høyere nivå av kortkjedete klorerte parafiner (SCCP) i torsk fra Bergen havn sammenlignet med de andre stasjonene. Det var høyest nivå av mellomkjedete klorparafiner (MCCP) i torskelever fra Ålesund.

De aller fleste konsentrasjonene av fosfororganiske flammehemmere (PFRer) var under deteksjonsgrensene for torsk. Nivåene anses derfor som generelt lave, men ingen konklusjoner kan trekkes når det gjelder forskjeller mellom stasjonene.

Bisfenol A, TBBPA og alkylfenol ble i hovedsak ikke påvist i torsk.

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

Blåskjell fra Måløy ytterst i Sognefjorden var markert forurenset av arsen. Konsentrasjoner av PBDEer, α-HBCD og SCCP var høyest i blåskjell fra Nordnes i Bergen havneområde. Konsentrasjonen av MCCP og SCCP i blåskjell var høyest i ytre Oslofjord (Tjøme og Færder). Disse resultatene står i kontrast til resultatene for torsk. Blåskjell filtrerer overflatevann, mens torsk generelt er eksponert for dypere vannmasser og de byttedyr som opptrer der, derfor vil eksponeringen kunne være forskjellig og en kan ikke vente at konsentrasjonene i disse to

organismene gir samme relative bilde av forurensningsnivå. De spesifikke kildene til SCCP og MCCP er ukjent, men kan være et resultat av industriell aktivitet i disse relativt lukkede områdene. Dette bør undersøkes nærmere.

De aller fleste konsentrasjonene av fosfororganiske flammehemmere (PFRer) var under deteksjonsgrensene i blåskjell. Nivåene anses derfor som generelt lave, men ingen konklusjoner kan trekkes når det gjelder forskjeller mellom stasjonene.

Bisfenol A, TBBPA og alkylfenol ble i hovedsak ikke påvist i blåskjell. Nivåene anses derfor som generelt lave, men ingen konklusjon kan trekkes vedrørende mulige forskjeller mellom stasjonene. Resultatene tyder på at av de undersøkte alkyfenolene, var 4-t-nonylfenol og 4-n-oktylfenol de mest dominerende.

Biologiske effekter

ICES/OSPARs vurderingskriterium for bakgrunnsnivå[1] («background assessment criteria»*, BAC) for OH-pyren i torskegalle ble overskredet på alle undersøkte stasjoner (indre Oslofjord, Farsund området og indre Sørfjord), unntatt referansestasjonen (Bømlo-Sotra området) i 2015, og dette viser at fisken har vært eksponert for PAH. Median-konsentrasjonen av OH-pyren metabolitter i torskegalle fra indre Oslofjord var omtrent dobbelt så høy som i 2014. Med andre ord var det en tilsynelatende økt PAH-eksponering. Det må imidlertid påpekes at median-konsentrasjonen i 2014 var 10 % lavere enn i 2013 og 30 % lavere enn i 2012.*

ALA-D aktivitet i indre Oslofjord og indre Sørfjorden i 2015 var lavere enn på Bømlo. Redusert aktivitet av ALA-D tyder på høyere eksponering for bly.

Median EROD-aktivitet i indre Oslofjord var omtrent på samme nivå som observert i 2013 (altså omtrent det dobbelte av i 2012 og 2014). Konsentrasjonen var fortsatt under ICES/OSPARs BAC. Konsentrasjoner over BAC indikerer mulig effekt av plane PCBer, PCNer, PAHer eller dioksiner.

Effektene av TBT på purpursnegl var relativt lave (VDSI <0.828) på alle de åtte stasjonene. Det var signifikant nedadgående trender på alle stasjonene bortsett fra ved Brashavn i Varangerfjorden der ingen signifikant trend kunne ses og tidligere VDSI-nivåer har vært lave. Resultatene indikerer at forbudet mot bruk av TBT har vært effektivt.

Stabile isotoper

Stabile isotoper av nitrogen (uttrykt som $\delta^{15}N$) er analysert for å tolke en organismes posisjon i næringskjeden. Resultatene viste veldig like isotop-signaturer i 2012, 2013, 2014 og 2015. Data for stabile isotoper ($\delta^{15}N$) i torsk er vurdert i sammenheng med konsentrasjoner av utvalgte miljøgifter. I hovedsak spiser fisk 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.

Tidstrender for miljøgifter i torsk og betrakninger i forhold til fiskelengde

I de statistiske analysene av tidstrender (økning/nedgang) for konsentrasjoner av miljøgifter er det brukt medianverdier (for hver miljøgift og stasjon), og det er ikke tatt hensyn til lengden av den undersøkte torsken. Dette kan potensielt føre til misvisende konklusjoner dersom konsentrasjonen av miljøgiften er korrelert med størrelsen på fisken, og dersom

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

gjennomsnittslengden på de undersøkte torskene endres over tid. Det er tidligere funnet at dette har vært tilfellet med hensyn på kvikksølv i torsk fra indre Oslofjord. Imidlertid viser mer grundige analyser at i størstedelen av tilfellene forandres ikke de statistiske konklusjonene med hensyn på tidstrender av miljøgifter når det er korrigert for fiskelengde. Dette var også tilfellet når data for kvikksølv i torsk fra indre Oslofjord i 2015 var inkludert i analysene. For et mindretall av tidstrendene ser det ut til at nedadgående trender i medianverdier til en viss grad kan forklares med endring i medianlengden av torsk. I bare to tilfeller ble det registrert oppadgående trender når det ble korrigert for fiskelengde.

Kommentar angående bruk av kvalitetsstandarder
Det er gjort sammenligninger mellom det nåværende risikobaserte systemet og det eldre klassifiseringssystemet som er basert på antatte bakgrunnsnivåer. De risikobaserte miljøkvalitetsstandardene bør forbedres for å bli mer funksjonelle. Det foreslås at begge systemene bør benyttes for å vurdere resultater for overvåking av miljøgifter.

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. All the results in this report 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 indicators for the quality of coastal water. Many of these substances have a tendency to accumulate in tissues (bioaccumulation) in the organisms, 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 an annual basis.

An overview of MILKYS stations in Norway is shown in maps in Appendix D. The program has included monitoring in sediment (cf. Green *et al*. 2010a) and to a larger degree biota, the main emphasis being:

- Oslofjord-area, including the Hvaler area, Singlefjord and Grenlandsfjord 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. Cod liver in the Inner Oslofjord also revealed the highest median concentration of HBCD in 2014. 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 critea

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. Furthermore, EU Water Framework Directive (WFD) of 2000 (2000/60/EC) entered into Norwegian law in 2005 to which the MILKYS programme has had to take into account and has also assessed the concentrations using EU environmental quality standards.

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 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 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 snails as well as biomarkers in fish. The methods were selected for specificity as to which contaminants impact the parameter 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, snail, 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 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 (e.g. bisphenol A, tetrabrombisphenol A), organophosphorus flame retardants and stabile isotopes. The Norwegian Pollution and Reference Indices (cf. Green *et al*. 2011b, 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 discontinued since 2012. However independent funding from the Norwegian Ministry of Climate and Environment ensured that some of these time series have been maintained after 2012. 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 also ensured that investigation of biological effect in cod from the Inner Sørfjord and from Bømlo 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 approach for 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 through:

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 (OSPAR 2014) including OSPAR priority substances (OSPAR 2007). 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) to achieve good chemical and ecological status by assessing the results using EU's EQSD. The results from MILKYS 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 36 stations (34 were planned) and these include 8 funded directly by the Ministry of Climate and Environment (see Chapter 1.1), dog whelk at 8 stations (nine were planned), periwinkle at one station and cod at 16 stations. 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, 2012)[1]. The data was screened and submitted to ICES by agreed procedures (ICES 1996). Blue mussel, snails (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 widely distributed and commercially important fish species. It is a predator and, as such, will for hydrophobic compounds mainly 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 Green *et al.* (2008a).

[1] See also http://www.ospar.org/work-areas/hasec

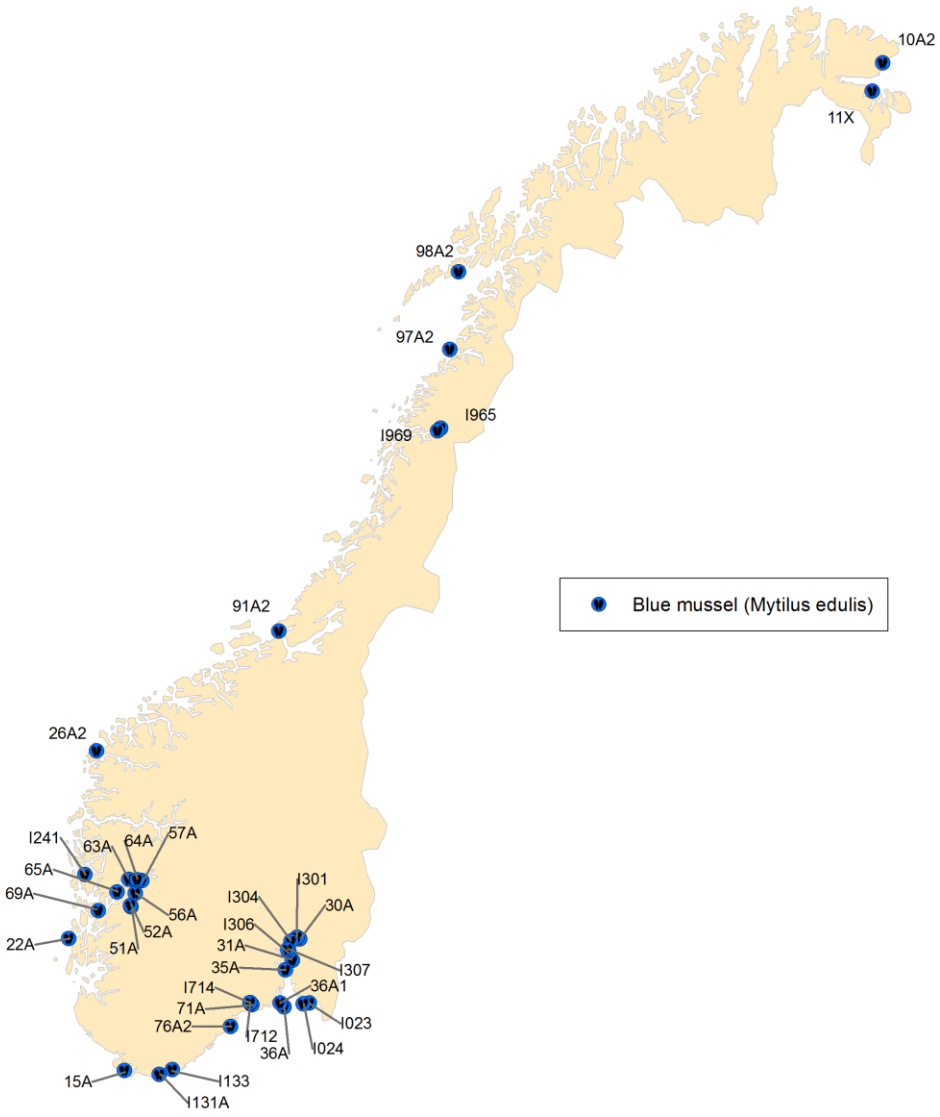


***Figure 1**. Stations where blue mussel were sampled in 2015. See also station information in detailed maps in Appendix D.*

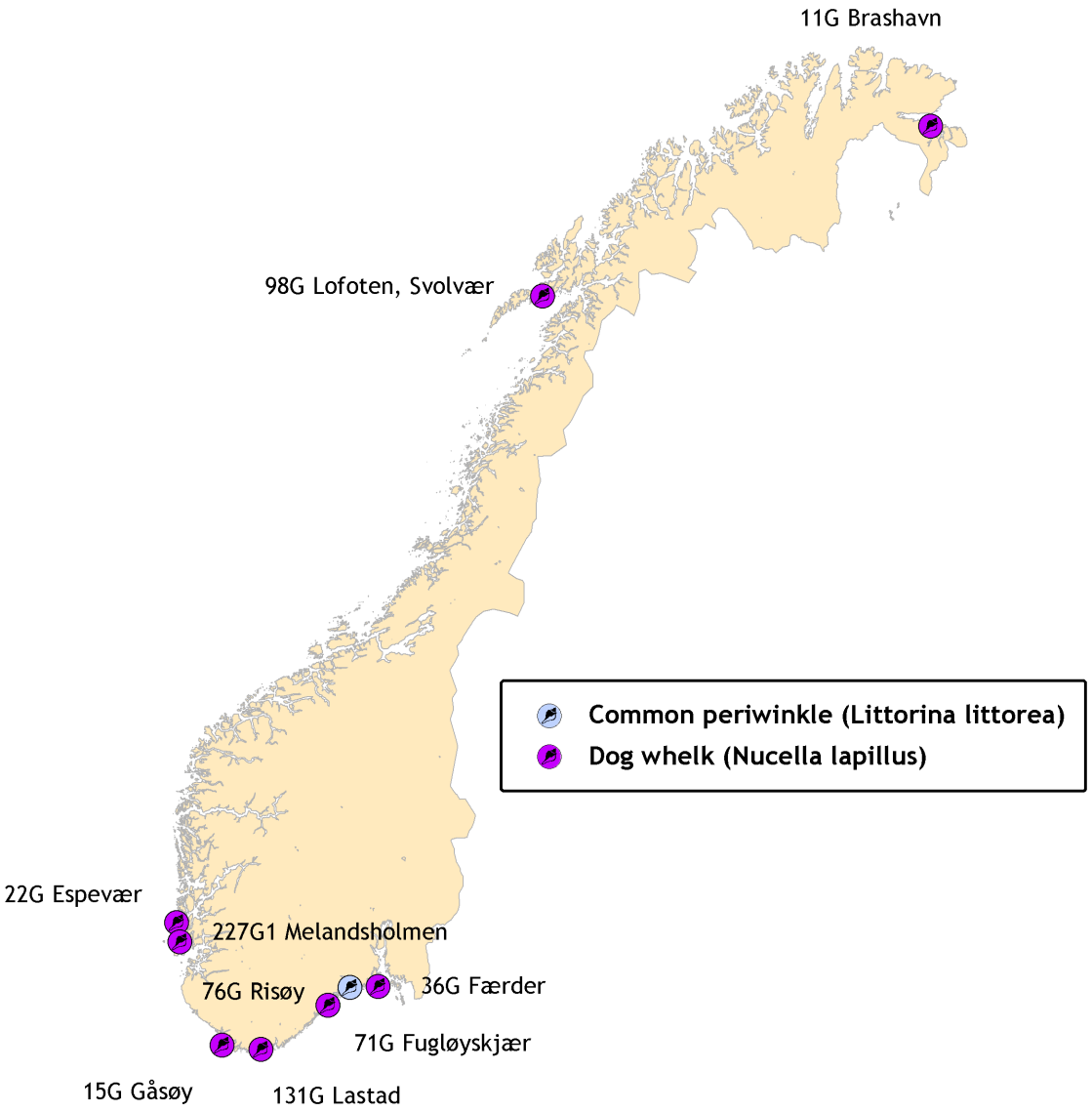


***Figure 2**. Stations where dog whelk and periwinkle were sampled in 2015. See also station information in detailed maps in Appendix D.*

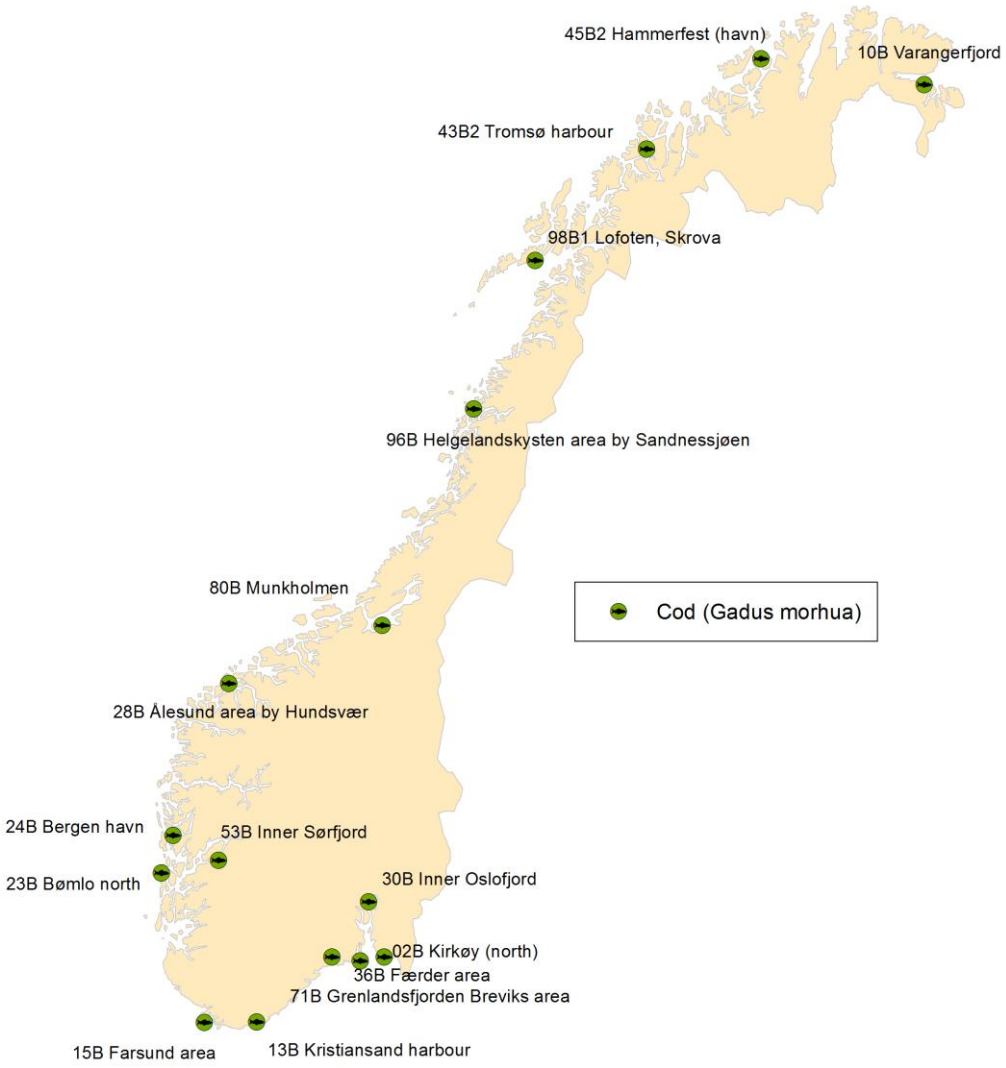


***Figure 3**. Stations where cod were sampled in 2015. Note that biological effects methods were applied to cod samples from the Inner Oslofjord. See also station information in detailed maps in Appendix D.*

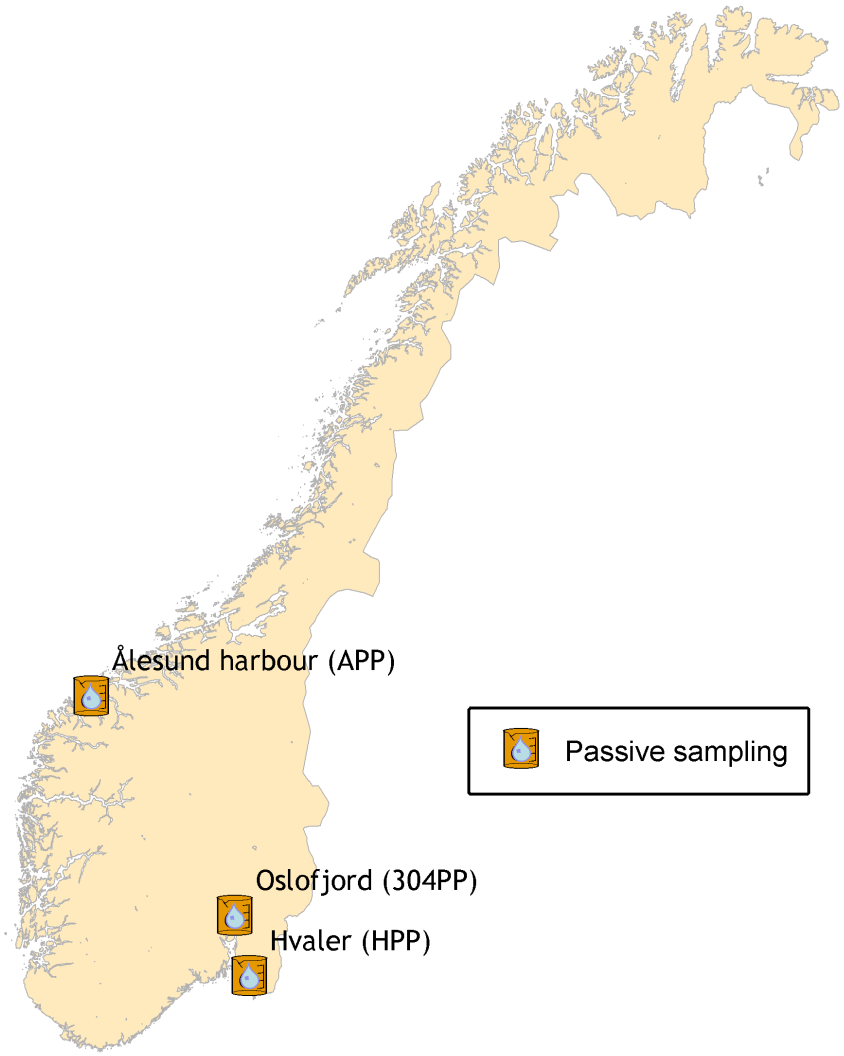


***Figure 4**. Stations where passive sampling was employed in 2015-2016.*

2.1.2 Blue mussel

A sufficient number of blue mussel (*Mytilus edulis*) were found at 35 of the 36 stations (34 stations were 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 individuals are not all necessarily *Mytilus edulis* (Brooks & Farmen 2013), but may be other *Mytilus* species (*M. trossulus*, and *M. galloprovincialis*). Possible differences in contaminant uptake were assumed to be small and not taken into account in the interpretations of the results for this investigation.

The blue mussel samples were collected from September to November 2015.

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 mussels were collected by NIVA except for the blue mussels collected in the Ranfjord, Lofoten and Varangerfjord, which were collected by local contacts.

Three pooled samples of 20 individuals (size range of 3-5 cm) were collected at each station and kept frozen until later treatment. 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. Mussel samples were frozen (-20°C) for later analyses.

For certain stations and prior to the 2012-investigations the intestinal canal was emptied (depuration) in mussels following OSPAR guidelines (OSPAR 2012, cf. Green *et al.* 2012a). 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, Green *et al.* 2001). This practice was discontinued in 2012.

2.1.3 Dog whelk and periwinkle

Concentrations and effects of organotin on dog whelk (*Nucella lapillus*) were investigated at eight stations and one station for periwinkle (*Littorina littorea*) (***Figure 2***, see also maps in Appendix D). TBT-induced development of male sex-characters in female dog whelks, 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, ICES 1999) and concentrations of organotin in dog whelk 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 7 September to 19 October 2015.

2.1.4 Atlantic cod

Fifteen individuals of Atlantic cod (*Gadus morhua)* were to be sampled for each station. This was accomplished at 14 stations, whereas at Hvaler (st. 02B) and Ålesund harbour (28B) (***Figure 3***) only 14 and 8 individuals were caught, respectively.

The cod were sampled from September 2015 to January 2016. 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. Instructions were given to the fisherman to catch coastal cod. Coastal cod is more attached to one place than open ocean cod which migrate considerably farther than coastal cod. Some spot checks were taken using otoliths which confirmed, at least for these samples, that only coastal cod were caught. The otoliths are stored for further verification if necessary. 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 (see Appendix E). The Ullerø area, Hammerfest harbour, Inner Trondheimsfjord and Sandnessjøen area were the four stations where all 15 individuals had sufficient liver size to complete all of the intended analyses. The general lack of material was partially compensated for by making pooled samples of livers. These are noted in the tables below. The concerns using pooled samples or small sample size in cod are discussed in an earlier report (Green *et al*. 2015).

The age of the fish was determined by noting the number opaque and hyaline zones in otoliths.

2.2 Chemical analyses of biological samples

2.2.1 Choice of chemical analyses and target species/tissues

An overview of chemical analyses performed on 2015-samples is shown in ***Table 2***. Note that the table also includes an overview of some supplementary investigations funded by the Ministry of Climate and Environment that are relevant to this report.

Table 2. *Analyses and target organisms of 2015. 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*. (See also Appendix B for complete list of chemical codes.)*

Parameter	Blue mussel	Dog whelk	Common periwinkle	Cod liver	Cod fillet	Passive samplers
Metals	33 (8)			13		
Cadmium (Cd), copper (Cu), lead (Pb), zinc (Zn), silver (Ag), arsenic (As), chrome (Cr), nickel (Ni), cobalt (Co) and tin (Sn)						
Mercury (Hg)	34 (8)				16	
Total-Hg						
Organotin	8(8)	8	1			
monobutyltin (MBT), dibutyltin (DBT), tributyltin (TBT), trifenyltin (TPT)						
PCB-7	33 (8)			13		
PCB-28, 52, 101, 118, 138, 153, and 180						
HCB, OCS, 5CS	0 (20)			0 (7)		
∑DDT	21 (15)			7 (6)		
p-p`-DDT, p-p`-DDE, p-p`-DDD						
PAH-16	11					
Polybrominated diphenyl ethers (PBDEs)	11			8		3
BDE28, 47, 99, 100, 126, 153, 154, 183, 196 and 209						
Hexabromocyclododecane (HBCDs)	10			10		3
α, ß, γ-HBCD						
Perfluorinated alkylated substances (PFAS)				8		
PFNA, PFOA, PFHpA, PFHxA, PFHXS, PFOS, PFBS, PFOSA						
Chlorinated paraffins	10			10		
SCCP (C10-C13) and MCCP (C14-C17)						
Phosphorus flame retardants (PFRs)	12			12		
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)						

Parameter	Blue mussel	Dog whelk	Common periwinkle	Cod liver	Cod fillet	Passive samplers
dibutylphenylphosphate (DBPhP)						
butyldiphenylphosphate (BdPhP)						
tris(2-ethylhexyl)phosphate (TEHP)						
tris-o-cresylphosphate (ToCrP)						
tricresylphosphate (TCrP)						
Alkylphenol	12			9		3
Octylphenol, nonylphenol						
Tetrabrombisphenol A (TBBPA)	11			9		
Bisphenol A (BPA)	12			9		

*) 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.

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 (see «count» for the relevant tables, e.g. ***Table 13)***. 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 quantification (LOQ, usually taken at three times the standard deviation) is indicated. See 2.2.2 for description of the labs used for the different analysis.*

Name	[CAS-number]	Lab.	LOQ	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
PCB-52	35693-99-3	**NIVA/EFM**	0.05 µg/kg low fat. 1 µg/kg high fat	30 %	Internal method	ISO 17025
PCB-101	37680-73-2	**NIVA/EFM**	0.05 µg/kg low fat. 1 µg/kg high fat	40 %	Internal method	ISO 17025
PCB-118	31508-00-6	**NIVA/EFM**	0.05 µg/kg low fat. 1 µg/kg high fat	30 %	Internal method	ISO 17025
PCB-138	35065-28-2	**NIVA/EFM**	0.05 µg/kg low fat. 1 µg/kg high fat	30 %	Internal method	ISO 17025
PCB-153	35065-27-1	**NIVA/EFM**	0.05 µg/kg low fat. 1 µg/kg high fat	40 %	Internal method	ISO 17025
PCB-180	35065-29-3	**NIVA/EFM**	0.05 µg/kg low fat. 1 µg/kg high fat	40 %	Internal method	ISO 17025
p-p`-DDT	50-29-3	**NIVA/EFM**	0.2 µg/kg low fat. 4 µg/kg high fat	60 %	Internal method	ISO 17025
p-p`-DDE	82413-20-5	**NIVA/EFM**	0.05 µg/kg low fat. 1 µg/kg high fat	40 %	Internal method	ISO 17025
p-p`-DDD	72-54-8	**NIVA/EFM**	0.1 µg/kg low fat. 2 µg/kg high fat	50 %	Internal method	ISO 17025
PBDEs						
BDE47	5436-43-1	**NIVA/EFM**	0.005 µg/kg mussels. 0.1 µg/kg high fat	30 %	Internal method	ISO 17025
BDE99	60348-60-9	**NIVA/EFM**	0.01 µg/kg mussels. 0.1 µg/kg high fat	40 %	Internal method	ISO 17025
BDE100	189084-64- 8	**NIVA/EFM**	0.01 µg/kg mussels. 0.1 µg/kg high fat	40 %	Internal method	ISO 17025
BDE126*	366791-32-4	**NIVA/EFM**	0.01 µg/kg mussels	50 %	Internal method	ISO 17025
BDE153	68631-49-2	**NIVA/EFM**	0.02 µg/kg mussels. 0.1 µg/kg high fat	40 %	Internal method	ISO 17025
BDE154	207122-15-4	**NIVA/EFM**	0.02 µg/kg mussels. 0.1 µg/kg high fat	40 %	Internal method	ISO 17025
BDE183	207122-16-5	**NIVA/EFM**	0.03 µg/kg mussels. 0.3 µg/kg high fat	40 %	Internal method	ISO 17025
BDE196	32536-52-0	**NIVA/EFM**	0.05 µg/kg mussels. 0.3 µg/kg high fat	40 %	Internal method	ISO 17025
BDE209	1163-19-5	**NIVA/EFM**	0.5 µg/kg mussels. 0.5 µg/kg high fat	50 %	Internal method	ISO 17025
α, ß, γ-HBCD	134237-50-6 (α isomer), 134237-51-7 (ß isomer), 134237-52-8 (γ isomer)	**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**	0.4 µg/kg	30 %	Internal method, validated	Not accredited but follows the

Name	[CAS-number]	Lab.	LOQ	Est. uncertainty	Standard or internal method	Accreditation status
						routines and systems of ISO 17025
PFOA	335-67-1	**NIVA**	0.4 µg/kg	40 %	Internal method, validated	Not accredited but follows the routines and systems of ISO 17025
PFHpA	375-85-9	**NIVA**	0.4 µg/kg	30 %	Internal method, validated	Not accredited but follows the routines and systems of ISO 17025
PFHxA	307-24-4	**NIVA**	0.4 µg/kg	30 %	Internal method, validated	Not accredited but follows the routines and systems of ISO 17025
PFOS	1763-23-1	**NIVA**	0.1 µg/kg	25 %	Internal method, validated	Not accredited but follows the routines and systems of ISO 17025
PFBS	29420-49-3	**NIVA**	0.1 µg/kg	30 %	Internal method, validated	Not accredited but follows the routines and systems of ISO 17025
PFOSA	4151-50-2	**NIVA**	0.1 µg/kg	30 %	Internal method, validated	Not accredited but follows the routines and systems of ISO 17025
S/MCCP			0.4 µg/kg			
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**	20-200 ng/1 g fat	40 %	Internal method, under development	ISO 17025
tributylphosphate (TBP)	126-73-8	**EF-GFA**	20-200 ng/1 g fat	40 %	Internal method, under development	ISO 17025
tri(2-chlorethyl)phosphate (TCEP)	115-96-8	**EF-GFA**	20-200 ng/1 g fat	40 %	Internal method, under development	ISO 17025
tri(1-chlor-2-propyl) phosphate (TCPP)	13674-84-5	**EF-GFA**	20-200 ng/1 g fat	40 %	Internal method, under development	ISO 17025
tri(1,3-dichlor-2-propyl) phosphate (TDCP)	13674-87-8	**EF-GFA**	20-200 ng/1 g fat	40 %	Internal method, under development	ISO 17025
tri(2-butoxyethyl) phosphate (TBEP)	78-51-3	**EF-GFA**	20-200 ng/1 g fat	40 %	Internal method, under development	ISO 17025
triphenylphosphate (TPhP)	115-86-6	**EF-GFA**	20-200 ng/1 g fat	40 %	Internal method, under development	ISO 17025
2-ethylhexsyl-di-phenylphosphate (EHDPP)*	1241-94-7	**EF-GFA**	20-200 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

Name	[CAS-number]	Lab.	LOQ	Est. uncertainty	Standard or internal method	Accreditation status
tris(2-etylheksyl)phosphate (TEHP)*	78-42-2	**EF-GFA**	20-200 ng/1 g fat	40 %	Internal method, under development	ISO 17025
tris-o-kresylphosphate (ToCrP)*	78-30-8	**EF-GFA**	20-200 ng/1 g fat	40 %	Internal method, under development	ISO 17025
trikresylphosphate (TCrP)	1330-78-5	**EF-GFA**	200-1000 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
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
Triclosan	9012-63-9	**ALS**	10 µg/kg	40 %	Internal method, under development?	Accredited
Diuron	330-54-1	**NIVA/EFM**	10 µg/kg	50 %	Internal method	Accredited
Irgarol	28159-98-0	**NIVA/EFM**	10 µg/kg	50 %	LE / cleanup / LC/MS/MS	Accredited
BEM						
VDSI		**NIVA**		10-20%	ICES 1999	Not accredited
EROD		**NIVA**		10-20%	ICES 1991	Not accredited
CYP1A		**NIVA**		10-20%	ICES 1998	Not accredited
ALA-D		**NIVA**		20 %	ICES 2004	Not accredited

2.2.2 Laboratories and brief method descriptions

The 2015 samples were largely analysed by Eurofins Moss (EFM) and by one of the Eurofins laboratories in Germany (GFA) (see **Table 3**). 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[1] (***Table 4***).

Table 4. *Suggested PCB-congeners (PCB-7), 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. For this report the total is 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 (see Appendix B).

Organic tin compounds were analysed at Eurofins GFA in 2015/2016 using GC-MS quantification.

Analyses of polybrominated diphenylether (PBDE) in cod liver were done at Eurofins Moss in 2015/2016. Results are given based on the total extractable fat content of the target tissue using a GC-Negative Chemical Ionization (NCI)-MS.

Analysis of perfluorinated alkylated substances (PFAS) in cod liver 2015 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. The limit of quantification has improved for analyses of the 2015-samples primarily due to a slight modification in the method and better access to internal standards.

[1] Several marine conventions (e.g. OSPAR and HELCOM[1]) use ΣPCB-7 to provide a common basis for PCB assessment.

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 retardants (PFRs) 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, β, γ-HBCD) were determined by LC-MS-MS also by Eurofins GFA.

For fish, the target tissues for quantification of hazardous substances were; liver and fillet (***Table 2***), whereas for the biological effects methods (BEM) liver; blood and bile were used (cf. *Table 5*). In addition, the age, sex, and visual pathological state for each individual were 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).

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[1], see ***Table 3***).

2.3 Biological effects analysis

Five biological effects methods (BEM) are assessed using methods described by ICES (see***Table 3***) and includes the measurement of OH-pyrene have been applied on an annual basis for this investigation. Each method is in theory 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.

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/Intersex	whole body[1]	organotin

[1] This is the ICES tissue designation Vas Deferens Sequence Index is determined

BEM-sampling requires that the target fish is kept alive until just prior to tissue or blood 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 then collected and stored in liquid nitrogen. Analyses of a metabolite of pyrene (OH-pyrene) were done on bile samples stored at -20°C.

The effect of TBT for Imposex (on dog whelk) or Intersex (on the common periwinkle) usually on fresh samples unless for practicle purposes the samples had to be frozen until anaysis.

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. There have been some modifications since then in accordance to the ICES guidelines (cf. ***Table 3***). 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.

The MILKYS programme for 2015 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, b, Allan *et al*. 2010, Allan *et al*. 2011). At equilibrium, the mass of a chemical absorbed in the sampling device can be used to calculate the freely dissolved contaminant concentration in the water that the device was exposed to through K_{sw}, the sampler-

water partition coefficient. Passive sampling techniques that allow to derive freely dissolved contaminant concentrations have been the subject of much development over the last two decades (Vrana *et al.* 2005). For hydrophobic contaminants with a log octanol-water partition coefficient ($logK_{ow}$)> 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 to monitor a range of contaminants at Andøya, Bjørnøya and Jan Mayen (*Tilførselprogrammet* 2009-2013). Deployments were in most cases at least 200 days. For the riverine input and discharge programme since 2013, silicone rubber passive samplers have also been chosen (Skarbøvik *et al.* 2015). 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 polybrominated 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 about 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 and Polar Chemical Integrative Samplers (POCIS). Samplers are stored frozen and can be used to analyse for new and emerging chemicals of interest in the future. Only the silicone rubber passive samplers were analysed for this investigation.

Samplers made of AlteSil™ silicone rubber (nominal size of 1000 cm^2 and 30 g, strips 100 cm long and 2.5 cm wide, two strips per sampler) 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). 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 metalholders. 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 sampling stations and deployment duration are shown in **Table 6**. Samplers were deployed for 339 to 386-0 days at all three stations depending on the station.

***Table 6**. Sampling stations, deployment and retrieval dates, and exposure times for silicone rubber and POCIS samplers deployed at the three stations.*

Sampling station	Coordinates	Deployment date	Retrieval date	Exposure time (d)
Oslofjord (*304PP*)	N59.85527 E10.59527	09.06.2015	13.05.2016	339
Hvaler (*HPP*)	N59.09655 E11.05073	25.06.2015	15.07.2016	386
Ålesund harbour (*APP*)	N62.46322 E06.22077	01.07.2015	11.07.2016	376

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

There was a problem with the QA sampler extract in the laboratory and no data could be obtained. We have participated in QUASIMEME intercomparison exercises on passive sampling with AlteSil™ silicone rubber in 2014 and 2015 and obtained excellent results.

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 $\log K_{sw}$ or molecular weight (Booij and 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 needed). 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 $\log K_{sw}$ values with hexadecane-water partition coefficients (from Cosmotherm software), $\log K_{hdw}$ were used to estimate $\log K_{sw}$ 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. Freely dissolved concentrations ($C_{w,free}$) were calculated using the following equation:

$$C_{w,free} = \frac{n_{acc}}{K_{sw} m_{sil} (1 - e^{-\frac{R_s t}{K_{sw} m_{sil}}})}$$

where n_{acc} is the amount of chemical absorbed into the sampler during deployment (ng), m_{sil} is the mass of the silicone rubber sampler (g), t the deployment time (d) and R_s the sampling rate (L d^{-1}). Analytical limits of quantification where transformed into field limits of quantification using the equation above. No data corrections for temperature or salinity were made here.

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, round 2015-2, FAPAS 202015 05100F and FAPAS 1264 apply to the 2015-samples. The results are acceptable. These QUASIMEME exercises included nearly all the contaminants as well as imposex analysed in this programme. The quality assurance programme is corresponding to the analyses of the 2014 samples (cf. Green *et al*. 2015).

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.

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 17025:2005, except for the PFCs.

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 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.

Recently a risk-based approach has been introduced to assess environmental quality. This has been implemented through EU directives which have defined Environmental Quality Standards (EQS, 2013/39/EU). Exceedances of EQS are interpreted as potentially harmful to the environment and remedial action should be implemented. Norway used this approach and developed their own quality standards for biota for substances not otherwise accounted for by the EU directives (Arp *et al*. 2014, Miljødirektoratet 2016). This is discussed in more detail in Chapter 3.7.

Assessing the risk to human consumption that elevated concentrations of contaminants in seafood has not been the task of this programme and hence, the EU foodstuff limits have not been applied. However, it should be noted that the background dossiers for the EQS (2013/39/EU) as well as the national quality standards (Arp *et al*. 2014, Miljødirektoratet 2016[1]) applied risk to human health standards if these are lower than the limits found by assessing risk of secondary poisoning or marine organisms.

Focus for the 2015-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, EQS and supplementary national quality standards (see above) for biota are considered (***Table 7***, ***Table 11***). 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 trend analyses 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.

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, the system of the Norwegian Environment Agency provides the primary assessment criteria.

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.

[1] This report summarises Arp *et al*. 2014, with only a few modifications. It was published too late to incorporate entirely in this report other than in Chapter 3.7.

***Table 7**. The Water Framework Directive (WFD) Environmental Quality Standards (EQS) for "biota" [1)] (in black) (cf. Environmental Quality Standard Directive-2013/39/EU), national quality standards[1] (in blue bold type, Norwegian Environment Agency (NEA, Miljødirektoratet 2016)) and the Class I and V (upper limit to insignificant and extreme degree of pollution, respectively) in the environmental classification system of the NEA (Molvær et al. 1997). Concentrations are given in µg/kg wet weight. The concentration interval shown under "Class I-V" indicates the upper limit to Class I to the lower limit to Class V (see details for classes and "assumed upper limit to background in Appendix C). Note: EQS used for assessing water with passive sampling are treated separately (see Appendix G, Table 32).*

Hazardous substance	EQS biota [1)]	NEA - blue mussel Class I - V	NEA - cod-liver Class I - V	NEA - cod-fillet Class I - V	Cod liver - assumed upper limit to background
Brominated diphenylether [2)]	0.0085				50
C10-C13 Chloroalkanes (SCCP)	**6000**				
C14-C17 Chloroalkanes (MCCP)	**170**				
DDT, total [3)]	**610**	2 - 30	200	1 - 25	
Dicofol	33				
Dioxins and dioxin-like compounds	0.0065 [4)]	0.0002 - 0.003		0.0001 - 0.002	
Heptachlor and heptachlorexpoxide	0.0067				
Hexabromocyclododecane (HBCD)	167				
Hexachlorobenzene (HCB)	10	0.1 - 5	20	0.2 - 5	
Hexachlorcyclohexane (HCH) [5)]	**61**	1 - 30	300	0.3 - 15	
Hexachlorobutadiene (HCBD)	55				
Mercury and its compounds	20	40 - 800 [6)]		100 - 1000	
Nonylphenol	**3000**				
Octylphenol	**0.004**				
Pentachlorobenzene (QCB)	**50**				
Perflurooctanoic acid (PFOA)	**91**				
Perfluorooctane sulfonic acid and its derivatives (PFOS)	9.1				50
Polyaromatic hydrocarbons (PAH) [7)]		50 - 5000			
Anthracene	**2400**				
Benzo(a)anthracene	**304**				
Benzo(a)pyrene	5 [8)]	1 - 30			
Benzo(b)fluoranthene	[8)]				
Benzo(g,h,i)perylene	[8)]				
Benzo(k)fluoranthene	[8)]				
Fluoranthene	30 [8)]				
Indeno(1,2,3-cd)-pyrene	[8)]				
Polychlorinated biphenyls (PCB) [9)]	**1**	4 - 100	500	3 - 150	
Tributyltinn compounds (TBT)	**150**	20 - 1000			

1) Quality Standard. Compounds in black text are Environmental Quality Standards (EQS) as derived from 2013/39/EU and compounds in blue bold type are national quality standards as derived from Arp *et al.* 2014 and modified by NEA (Miljødirektoratet 2016) concern 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) For this study the same limit were applied to p,p DDE.
4) Sum of PCDD+PCSF+PCB-DL TEQ.
5) For this study the same limit were applied to γ-HCH.
6) Conversion assuming 20% dry weight.
7) 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.
8) Crustaceans and molluscs. (Monitoring of these PAHs not appropriate for fish). Benzp(a)pyrene is considered a marker for other PAHs (2013/39/EU).
9) Sum of PCB congeners 28, 52, 101, 118, 138, 153, 180.

[1] The contaminants for which the national quality standards apply are termed in the EU system as "river basin specific".

The NEA-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 MILKYS. 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[1] polluted.

A classfication system based on background levels should be periodically reviewed 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.

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 2016 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 11***). 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.

Proposed background assessment criteria (BAC) for EROD and OH-pyrene and VDSI (OSPAR 2013) 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) (OSPAR 2013). 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	0.7*	-	ng/ml; HPLC-F
VDSI	dog whelk	0.3	2	

*) 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 BAC from 21 to 0.7 ng/ml or by a factor of about 30.

[1] In this context the term has no statistical implications

2.7 Statistical time trend analysis

2.7.1 Treatment of values below the quantification limit

Values below the limit of quantification 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. PCB-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 quantification and is assigned the median value prefixed with a "<" sign in Appendix F. When such values are presented in tables of the main text, then the cells are shaded and the half value is shown. It should be noted that the quantification limit can vary within and among sets of samples and comparisons of quantification limits should be made with caution.

Dominance of values below the limit of quantification could invalidate the statistical assumption behind the trend analysis (Rob Fryer, pers. comm.).In calculating trends for this report, 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.

2.7.2 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 5***. It should be noted that this robust method has been developed so that it could provide a rough guide to possible trends in the OSPAR region. Further investigation is necessary to better understand the factors affecting a particular trend. This may lead to different conclusions. As an exercise in this respect the times series for mercury in cod filet from the Inner Oslofjord was examined more closely (see Green *et al*. 2015).

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 the smoothed annual concentration at the beginning of the time series compared the smoothed annual concentration at the end of the time series. This report presents an assessment in line with the current OSPAR approach. The smoothed values were determined for the whole time series. The whole time series is termed in this report as a long-term trend. The smooth values were also used as a basis for assessing the trend for the last 10 years of the series, which is referred to in this report as short-term or recent trend. Be aware that a series may have gaps and recent trend may not necessarily include data for 2015.

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.

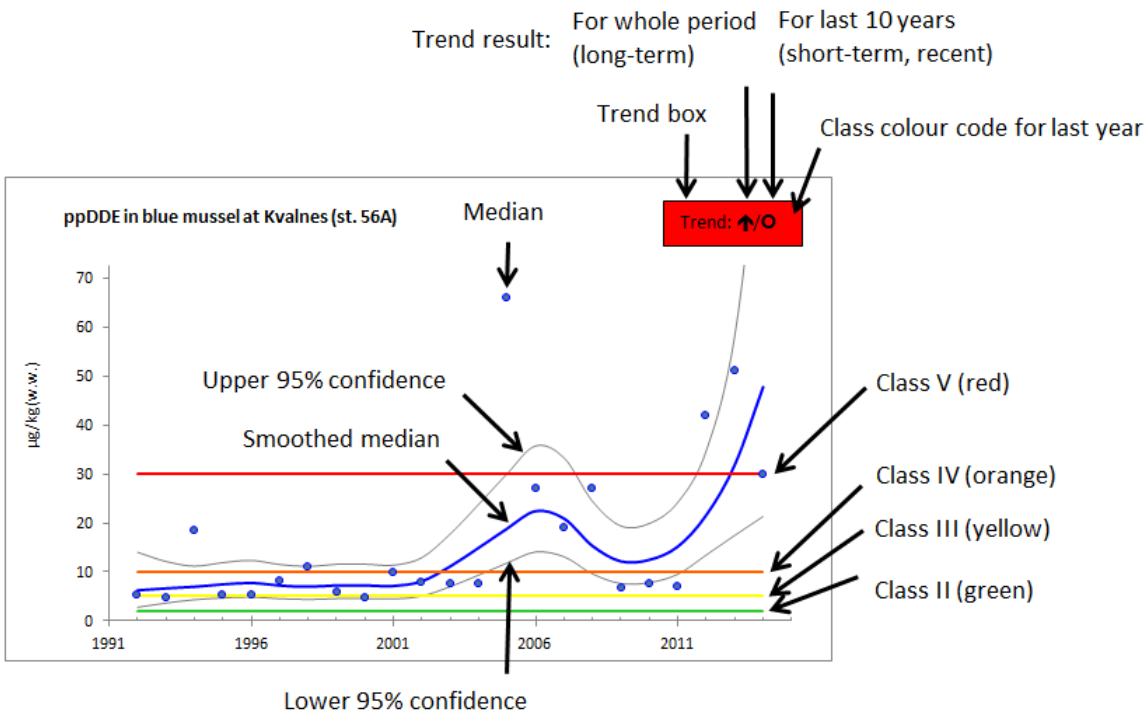


***Figure 5**. Example of time series that show the median concentration (blue dots), running mean of median values (Loess smoother - blue line) and 95 % confidence intervals (grey lines). The horizontal lines indicate the lower boundaries to the classes of pollution in the system of the Norwegian Environment Agency : Class II (green line, moderate=upper boundary to Class I (insignificantly polluted, also herein termed as "acceptable")), Class III (yellow line, marked), Class IV (orange line, severe) and Class V (red line, extreme) (cf. **Table 29**), 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 2006-2015 (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.*

2.8 Note on presentation of contaminant tables

Summaries of the results for some organic contaminants are presented in **Table 13** to **Table 20**. These provide some extensive detail and warrant explanation. The added details is largely because the sample sizes are not uniform in the process explained above to obtain enough material for all analyses. Some of the analyses, especially of the "New" contaminants, revealed a vast number below the limit of quantificatio (LOQ) resulting in a number of median values below the LOQ. It was considered added-value to convey some information about the concentrations that were quantifiably. This was done by introducing the *Detactable data information* (D.d.i) which showed the count of concentrations above the LOQ and the minimum and maximum of these values.

An extract from **Table 13** is shown in below in **Table 9**. With respect to "Count" the first number indicates the number of individuals or pooled samples that were analysed. For example for blue mussel from Tjøme there were three samples analysed and all three were pooled samples and the maximum number of individual mussels that went into the pooled sample was 50. For cod liver from the Inner Oslofjord there were 12 samples whereof 11 were pooled with a maximum of 3 fish livers in each pool. This means that one individual (12-11=1) was analysed on its own. Note that the values for median ("Med.") and standard deviation ("S.d.") are rounded, and for example "0.000" represents a number greater than zero but less than 0.0005. The "D.d.i." for blue mussel from Tjøme indicates that none of the three values were above LOQ, whereas for cod liver from Færder seven of the 15 samples had concentrations of BDE28 above LOQ and these ranged from 0.1 to 0.91 µg/kg w.w. All values were above LOQ for blue mussel from Croftholmen and cod liver from the Inner Oslofjord. Note that when a dataset contains values below LOQ the median takes these as half the LOQ (see chapter 2.7.1). For example for Færder the three values were <0.0079, <0.0083 and <0.0084 µg/kg w.w. and the median and standard deviation are determined from half these values, i.e. 0.00395, 0.00415 and 0.0042 µg/kg w.w. Hence, the median was 0.00415 and the standard deviation was 0.0001323, which were rounded to 0.004 and 0.000, respectively. Also note that when there are only three samples the median can be the minimum or maximum of this range shown by the "D.d.i.".

***Table 9**. Example table – extract from **Table 13**. 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 the maximum number of individuals used in any one of the pooled samples. Shaded cells indicate that the median (Med.) was the limit of quantification (LOQ) and value shown in these cells is one half of this limit. The standard deviation (S.d.) is based on all values and where values below the LOQ are taken as half. Detectable data information (D.d.i.) indicates the number of data above the LOQ (if any) and the numbers within the square brackets indicate the minimum and maximum values in this category. (See text for more detail.)*

Component	Count	BDE28		
Species and sampling locality	2015	Med.	S.d.	D.d.i
Blue mussel				
Tjøme (st. 36A1)	3(3-50)	0.004	0.000	
Croftholmen (st. I712)	3(3-80)	0.002	0.000	3[0.002 - 0.003]
Lofoten, Svolvær (st. 98A2)	3(3-120)	0.000	0.000	1[0.001]
Cod, liver				
Inner Oslofjord (st. 30B)	12(11-3)	0.230	0.101	11[0.11 - 0.42]
Færder area (st. 36B)	15(9-2)	0.050	0.209	7[0.1 - 0.91]

3. Results and discussion

3.1 General information on measurements

A summary of the levels and trends of contaminants or their effects in Atlantic cod, blue mussel, dog whelk and periwinkle along the coast of Norway in 2015 is shown in ***Table 11***. More details on trend analyses for the entire monitored period that include results from either 2014 or 2015 are shown in Appendix F. The results from 2015 present data for a total of 2506 data sets (contaminant[1]-station-species-tissue) on 108 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. 2006-2015 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 2015 and totalled 829 data series[2] (***Table 10***). Of the 829 cases 52% could be classified and there were 59 cases where 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"). Of the 829 data series recent and significant trends were registered in 98 cases: 81 (9.8%) were downwards trends and 17 (2.1 %) were upwards (***Figure 6A***). Of the 431 cases that could be classified by the system of the Norwegian Environment Agency, 378 (87.7 %) were classified as insignificantly polluted (Class I), 48 (11.1 %) as moderately polluted (Class II), 4 (0.9 %) as markedly polluted (Class III), 1 (0.2 %) as severely polluted (Class IV) and none as extremely polluted (Class V, ***Figure 6B***). The downward trends were primarily associated with metals (44.4 %), tributyltin (TBT, 8.6 %) and Vas Deferens Sequence Index (VDSI) (the effect of TBT) (3.3 %) (***Figure 7A***). The upward trends were also mainly associated with metals (82.4 %), primarily Hg (29.4 %). There were five cases classified higher than Class II (***Figure 7B***). In Class III there was one case for arsenic and PCB, two cases for DDT metabolite. In Class IV there was also one case for the metabolite. The results are discussed in more detail below.

Primary focus were on those cases where median concentrations in 2015 were over presumed high backgrounds level (>Class I, insignificantly polluted, acceptable levels) and where significant upward trends were found, and to a lesser degree where no significant trends or significant downward trends were found. The evaluation focused secondarily on cases where median concentrations in 2015 were below presumed high background level (<Class I, insignificantly polluted) in combination with significant upward trends. An overview of trends, classifications and median concentrations is presented in Appendix F. The results are presented by classes and with results for observed trend analyses. The results were also assessed against quality standards (2013/39/EU, Arp *et al.* 2014).

It should be noted that in the previous report (Green *et al.* 2015) the classification for arsenic, chromium and nickel on a wet weight basis in blue mussel was erroneously based on limits 25 times higher than they should have been. Without the corrections, all 2014-concentrations were in Class I, but with the corrections, 13 median concentrations be in Class II; nine for arsenic, three for chromium and one for nickel. Also in this previous report PCBs in blue mussel were assessed assuming an upper limit to Class I is 4 µg/kg weight (as noted by Molvær *et al.* 1997) instead of 3

[1] In this regard «contaminants» include *inter alia* results from biological effects methods, stable isotopes and some biological co-variables.

[2] Consisting of one or more annual medians contrasting earlier reports which tallied only datasets of five or more annual medians

µg/kg weight wet as suggested by Knutzen and Green (2001, see Appendix C). With the correction, one more median concentration would be in Class II for 2014. The limits were corrected for the 2015 investigations.

***Table 10**. 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 11**.*

Contaminant /BEM	Description	Blue mussel	Dog whelk, periwinkle	Cod, liver	Cod fillet	TOTAL
Ag	Silver	33*		16		**49**
As	Arsenic	33*		16		**49**
Cd	Cadmium	33*		16		**49**
Co	Cobalt	33*		16		**49**
Cr	Chromium	33*		16		**49**
Cu	Copper	33*		16		**49**
Hg	Mercury	34*			16	**50**
Ni	Nickel	33*		16		**49**
Pb	Lead	33*		16		**49**
Zn	Zinc	33*		16		**49**
PCB-7 (CB_S7)	sum of PCB congeners 28+52+101+118+138+153+180	33*		15		**48**
ppDDE (DDEpp)	p,p'-DDE (a DDT metabolite)	21*		7*		**28**
HBCDa	α—hexabromocyclododecane	10		12		**22**
SCCP	short chain chlorinated paraffin (C10-C13)	12		12		**24**
MCCP	medium chain chlorinated paraffin (C14-C17)	12		12		**24**
BDE47	Tetrabromdiphenylether	11		10		**21**
BDE100	Pentabromdiphenylether	11		10		**21**
BDE209	Decabromdiphenylether	11		10		**21**
PAHs (P_S)	sum nondicyclic PAHs	11				**11**
KPAHs (PK_S)	sum carcinogen PAHs	11				**11**
BKF	benzo[k]fluoranthene	11				**11**
B[ghi]P	benzo[ghi]perylene	11				**11**
ICDP	Indeno[1,2,3-cd]pyrene	11				**11**
B[a]P	benzo[a]pyrene	11				**11**
FLU	Fluoranthene	11				**11**
PFOS	perfluorooctanoic sulfonate			9		**9**
PFOSA	perfluorooctylsulfonate acid amide			9		**9**
PFBS	Potassium perfluorobutanesulfonat			9		**9**
TBT	tributyltin (formulation basis)	8*	9			**17**
VDSI	Vas Deferens Sequence Index		8			**8**
TOTAL		**537**	**17**	**259**	**16**	**829**

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.

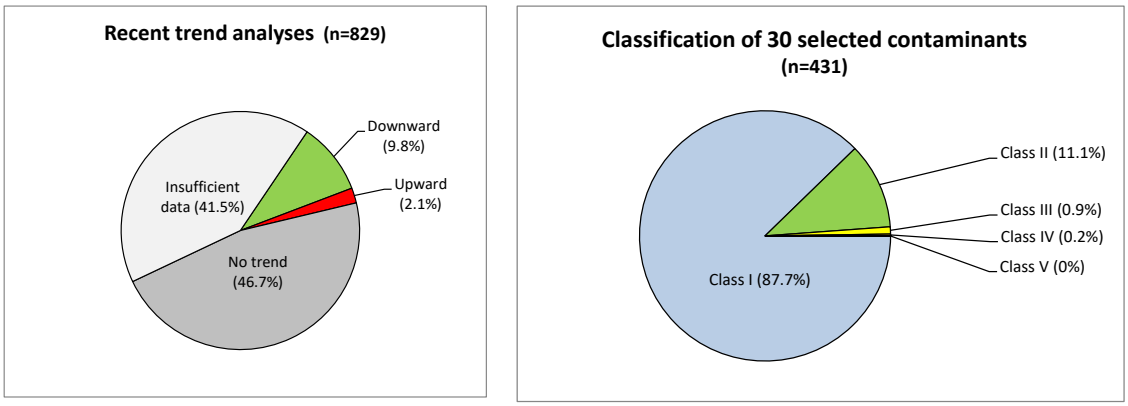


Figure 6. *Summary of the results from short-term trend analyses (**A**) and classification in Norwegian Environment Agency system (B) for 30 selected contaminants (cf. **Table 10**). Colour coding in Figure B refers to classification colours (cf. **Table 29**).*

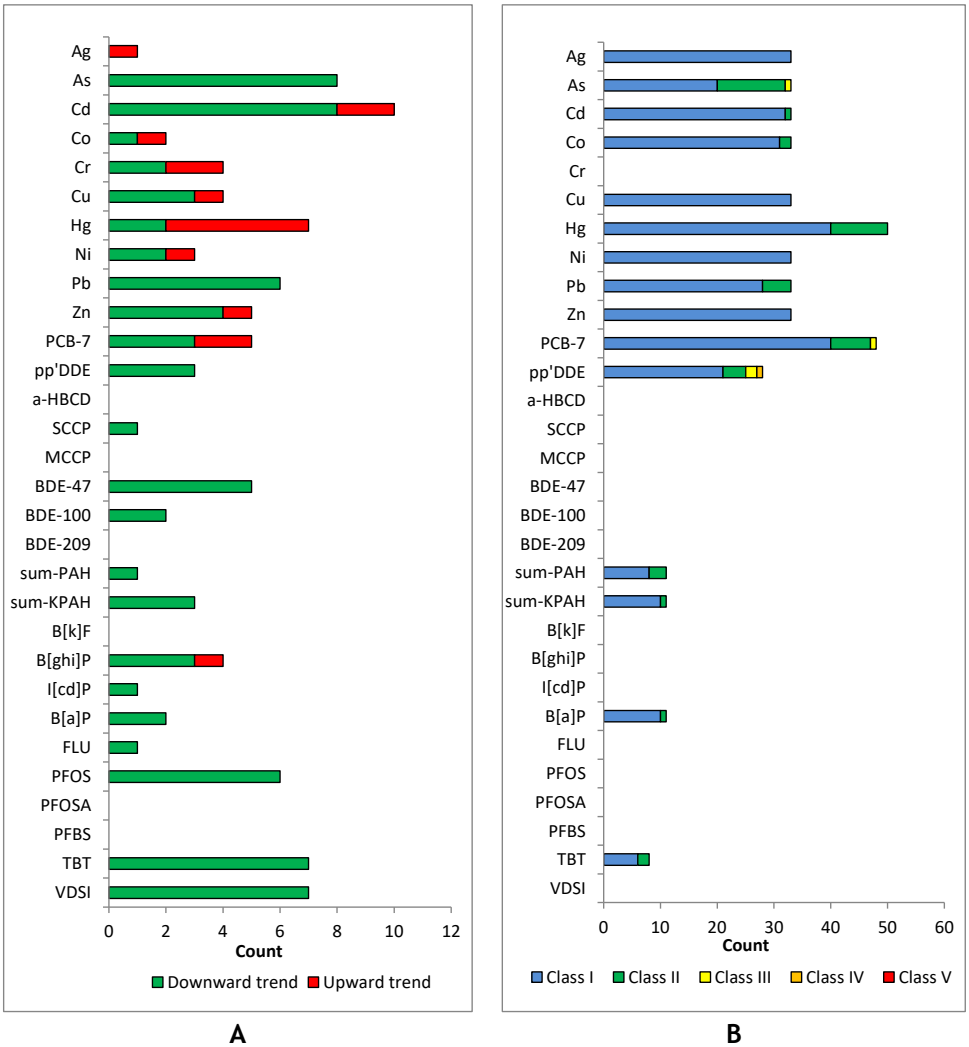


Figure 7. *Summary of short-term trends (**A**) and classification in Norwegian Environment Agency system (B) for each of the 30 selected contaminants (cf. **Table 10**, (see Appendix B for description of chemical codes). Colour coding in Figure B refers to classification colours (cf. **Table 29**).*

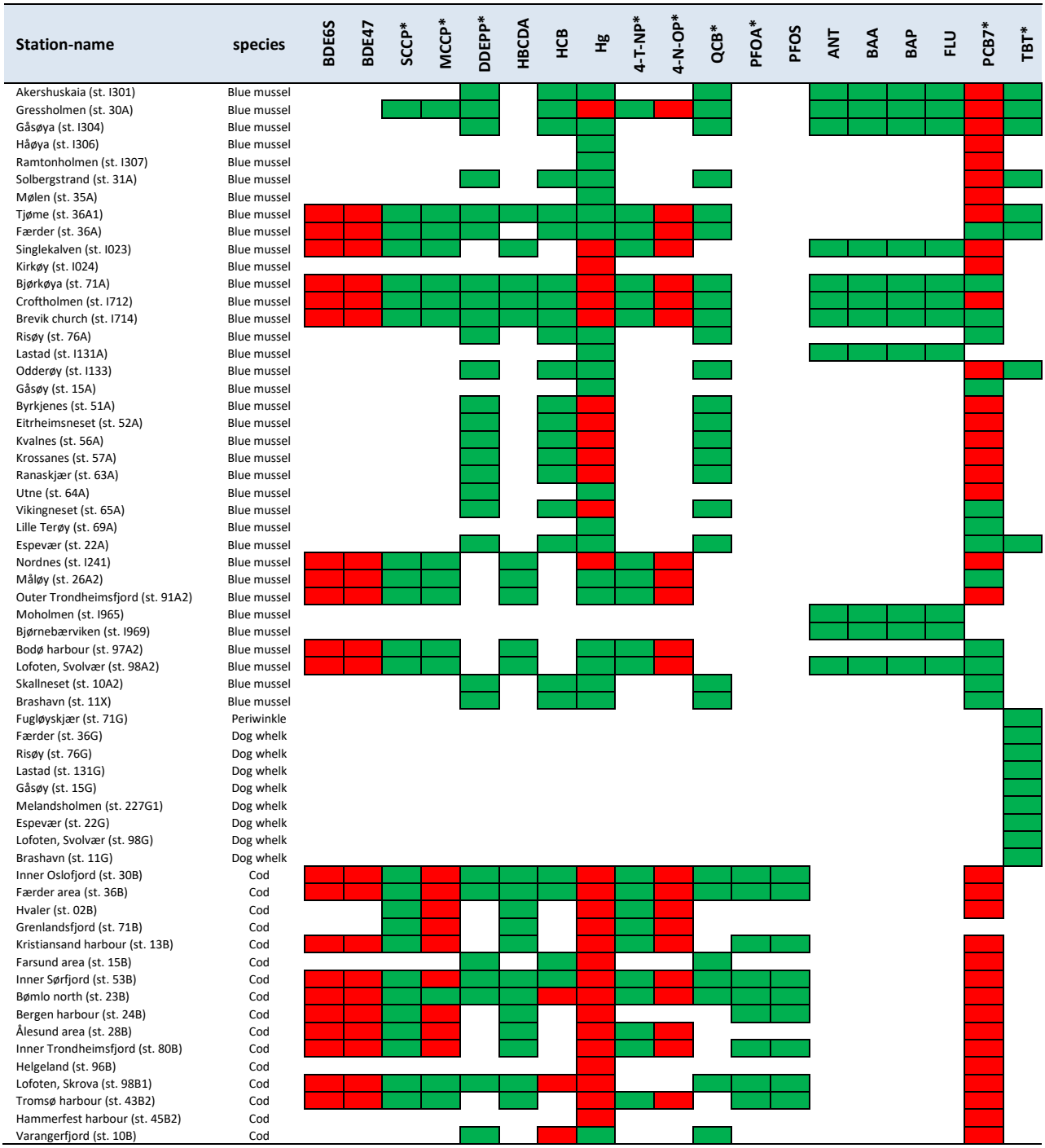
***Table 11**. Overview of samples collected in 2015 with indication of levels and trends in concentrations of contaminants monitored. Classification is based on observed concentrations in cod, blue mussel, dog whelk and periwinkle. Tissues: soft body (SB), muscle (MU, fillet), liver (LI) and whole organism (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 C). For biota, trend analyses were done on time series with data from five or more years. An upward (↑) or downward (↓) arrow indicates statistically significant trends, whereas a zero (O) indicates no trend. A small filled square (▪) indicates that chemical analysis was performed but the results were insufficient to do a trend analysis. Results marked with a star (★) indicate that there is insufficient data above the quantification limit to perform a trend analysis. The result from the trend analysis for the entire time series (long-term) is shown before the slash "/", and the result for the last 10 years (short-term) is shown after the slash. 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. (See Appendix B for description of chemical codes.). The asterisk after the station name indicates those stations considered less impacted by contamination (see **Table 26**).*

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
I301	Akershuskaia	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				↓/↓	
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				↓/↓	
I304	Gåsøya	Blue mussel	SB	★/★	O/O	O/O	↑/↑	O/O	O/O	↑/↑	O/O	O/O	↓/O	↓/↓	O/O							O/O	O/O	★/★	★/★	★/★	★/★	O/O				▪/▪	
I306	Håøya	Blue mussel	SB	★/★	O/O	O/O	O/O	O/O	O/O	O/↑	O/O	O/O	O/O	↓/O																			
I307	Ramtonholmen	Blue mussel	SB	★/★	O/O	O/O	O/O	O/O	↓/↓	O/O	O/O	O/O	O/O	↓/O																			
31A	Solbergstrand*	Blue mussel	SB	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	↓/O																			
36A1	Tjøme*	Blue mussel	SB	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪												▪/▪	
36A	Færder*	Blue mussel	SB							★/O				↓/O	O/O		▪/▪	▪/▪	▪/▪	▪/▪	▪/▪												↓/O	
I023	Singlekalven*	Blue mussel	SB	★/★	O/O	O/O	O/O	O/O	O/O	O/O	O/O	O/O	O/O	↓/O		▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	★/★	★/★	▪/▪	★/★	▪/▪					
I024	Kirkøy	Blue mussel	SB	★/★	O/O	O/O	O/↑	O/O	O/O	O/O	O/O	O/O	O/O	↓/O																			
71A	Bjørkøya*	Blue mussel	SB	★/★	↓/↓	O/O	↓/O	O/O	O/↓	↓/O	O/O	O/O	↓/O	↓/O	O/O	▪/▪	▪/▪	▪/▪	↓/↓	O/O	★/★	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪					
I712	Croftholmen	Blue mussel	SB	★/★	O/O	O/O	O/O	O/O	O/O	O/O	O/O	O/O	O/O	↓/O	O/O	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪					
I714	Brevik church	Blue mussel	SB	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪					
76A	Risøy*	Blue mussel	SB	★/★	↓/↓	↓/↓	O/O	O/O	↓/↓	O/O	↓/↓	O/O	↓/↓	↓/O	↓/O																		
I131A	Lastad	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					
I133	Odderøy	Blue mussel	SB	★/★	O/O	O/O	O/O	O/O	O/O	O/O	O/O	O/O	O/O	↓/↑	O/O																	↓/↓	
15A	Gåsøy*	Blue mussel	SB	O/O	↓/↓	O/O	O/O	O/O	O/O	O/O	O/O	O/O	O/O	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	O/O																		
56A	Kvalnes	Blue mussel	SB							↓/O				O/O	O/O																		
57A	Krossanes*	Blue mussel	SB	O/O	O/O	O/O	↓/↓	O/O	O/O	↓/O	O/O	↓/↓	↓/O	↓/O	O/O																		
63A	Ranaskjær*	Blue mussel	SB	★/★	O/O	↓/O	↓/↓	O/O	O/O	O/O	O/O	↓/O	↓/O	↓/↑	O/O																		
64A	Utne*	Blue mussel	SB	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪																		
65A	Vikingneset*	Blue mussel	SB	★/★	O/O	O/O	↓/↓	O/O	O/O	O/O	O/O	↓/O	↓/O	↓/O	O/O																		
69A	Lille Terøy*	Blue mussel	SB	O/O	O/O	O/O	↓/↓	O/O	O/O	O/O	O/O	↓/↓	↓/↓	O/O																			
22A	Espevær*	Blue mussel	SB	★/★	O/O	O/O	O/O	O/O	O/O	O/↓	O/O	↓/↓	↓/O	↓/O	O/O																	↓/↓	
I241	Nordnes	Blue mussel	SB	★/★	O/O	O/O	↓/↓	O/O	O/O	O/O	O/O	↓/↓	O/O	O/O		▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪											
26A2	Måløy*	Blue mussel	SB	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪		▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪												
91A2	Outer Trondheimsfj.*	Blue mussel	SB	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪		▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	★/★												
I965	Moholmen	Blue mussel	SB	★/★	↓/↓	O/O	↓/↓	↓/O	O/O		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
I969	Bjørnebærviken*	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					
97A2	Bodø harbour	Blue mussel	SB	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪		▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	★/★													
98A2	Lofoten, Svolvær*	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					
10A2	Skallneset*	Blue mussel	SB	O/O	↓/↓	O/O	O/O	O/O	↓/O	↓/O	O/O	O/O	O/O	↓/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																		
30B	Inner Oslo fjord	Cod	LI	O/O	O/O	O/O	↑/O	★/★	O/O		O/O	O/O	O/O	O/O	↓/O	O/O	↓/↓	▪/▪	↓/↓	↓/↓	★/★								O/↓	O/O	★/★		
36B	Færder area*	Cod	LI	O/O	O/O	O/O	O/O	★/★	↓/O		O/O	★/★	↓/O	O/↓	↓/O	O/O	O/O	▪/▪	↓/O	O/O	★/★								↓/↓	O/O	★/★		
02B	Kirkøy (north)	Cod	LI	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪		▪/▪	▪/▪	▪/▪	▪/▪		▪/▪	▪/▪	▪/▪															
71B	Breviks area	Cod	LI	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪		▪/▪	★/★	▪/▪			▪/▪	▪/▪	▪/▪															
13B	Kristiansand harbour	Cod	LI	O/O	O/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	↓/↓																		
53B	Inner Sørfjord	Cod	LI	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	★/★								↓/↓	★/★	★/★		
23B	Bømlo north*	Cod	LI	O/O	O/O	O/O	O/O	★/★	O/O		★/★	★/★	O/O	↓/O	↓/↓	▪/▪	O/O	O/O	↓/↓	↓/O	★/★								O/↓	★/★	★/★		
24B	Bergen harbour	Cod	LI	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪		▪/▪	▪/▪	▪/▪	▪/▪		▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪								▪/▪	▪/▪	▪/▪		
28B	Ålesund area	Cod	LI	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪		▪/▪	▪/▪	▪/▪	▪/▪		▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪												
80B	Munkholmen	Cod	LI	O/O	O/O	O/O	O/O	★/★	O/O		★/★	★/★	O/O	↓/↓		▪/▪	▪/▪	▪/▪	O/O	O/O	★/★								O/O	O/O	★/★		
96B	Helgeland coast*	Cod	LI	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪		▪/▪	▪/▪	▪/▪	▪/▪																			
98B1	Lofoten, Skrova*	Cod	LI	O/O	O/O	O/O	O/O	★/★	O/O		O/O	★/★	O/O	O/O	O/O	▪/▪	▪/▪	▪/▪	O/O	O/O	★/★								O/O	★/★	★/★		
43B2	Tromsø harbour	Cod	LI	↑/↑	↓/↓	O/O	O/O	★/★	O/O		O/O	★/★	O/O	O/O		▪/▪	▪/▪	▪/▪	↓/↓	O/O	★/★								↓/↓	★/★	★/★		
45B2	Hammerfest	Cod	LI	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪		▪/▪	★/★	▪/▪	▪/▪																			
10B	Varangerfjord*	Cod	LI	O/O	O/O	O/O	↓/O	★/★	↓/O		★/★	★/★	↓/O	↓/O	↓/↓																		
30B	Inner Oslo fjord	Cod	MU							↑/O																							
36B	Færder area	Cod	MU							O/↑																							
02B	Kirkøy (north)	Cod	MU							▪/▪																							
71B	Breviks area	Cod	MU							▪/▪																							
13B	Kristiansand harbour	Cod	MU							O/O																							
15B	Farsund area	Cod	MU							O/↑																							
53B	Inner Sørfjord	Cod	MU							O/O																							
23B	Bømlo north	Cod	MU							↑/↑																							
24B	Bergen harbour	Cod	MU							▪/▪																							
28B	Ålesund area	Cod	MU							▪/▪																							
80B	Munkholmen	Cod	MU							O/O																							
96B	area by Sandnessjøen	Cod	MU							▪/▪																							
98B1	Lofoten, Skrova	Cod	MU							O/O																							
43B2	Tromsø harbour	Cod	MU							O/O																							
45B2	Hammerfest	Cod	MU							▪/▪																							
10B	Varangerfjord	Cod	MU							↓/O																							
71G	Fugløyskjær	Periwinkle	SB																												O/O		
36G	Færder	Dog Whelk	SB																												↓/↓	↓/↓	
76G	Risøy	Dog Whelk	SB																												★/★	↓/↓	
131G	Lastad	Dog Whelk	SB																												★/★	↓/↓	
15G	Gåsøy	Dog Whelk	SB																												★/★	↓/↓	
227G1	Melandsholmen	Dog Whelk	SB																												↓/↓	↓/↓	
22G	Espevær	Dog Whelk	SB																												↓/↓	↓/↓	
98G	Svolvær area	Dog Whelk	SB																												★/★	↓/↓	
11G	Brasharbour	Dog Whelk	SB																												★/★	O/O	

A summary of the result when assessed by EU's EQS (2013/39/EU) and supplmented with national quality standards (Arp *et al*. 2014, Miljødirektoratet 2016) is presented in (**Table 12**). These standards are discussed in comparison to the five-class system in more detail in Chapter 3.7.

***Table 12**. Assessment of median consentrations of contamaninants with respect to quality standards from the Water Framework Directive (WFD) (cf. Environmental Quality Standard Directive-2013/39/EU) or national quality standards (*) by Norwegian Environment Agency (NEA, Miljødirektoratet 2016)) for hazardous substances in "biota" 1). Green boxes indicate no exceedences and red boxes indicate exceedences of standard. (See also **Table 7**).*



3.2 Levels and trends in contaminants

The term “common” as used here has no specific definition but is a generic term for contaminants that have been monitored generally annually over ten years.

The highest classes of contaminants were found in blue mussel at Kvalnes (st. 56A) in the Mid Sørfjord. The mussels were severely (Class IV) polluted with ppDDE at this station. Blue mussel were markedly (Class III) polluted with ppDDE at Krossanes (st. 57A) and Utne (st. 64A) which are located on either side in the Outer Sørfjord. Mussels at Måløy (st. 26A2) in the Outer Sognefjord were markedly polluted with As. Cod fillet from the Inner Oslofjord (st. 30B) was markedly polluted with PCB-7. All other blue mussel or cod were within insignificant (Class I) or moderately (Class II) polluted.

3.2.1 Mercury (Hg)

Mercury (Hg) was analysed in cod fillet at 16 stations and in blue mussel at 34 stations.

Important levels exceeding Class I

Cod fillet were moderately polluted (Class II) with Hg in the Inner Oslofjord (st. 30B), Færder (st. 36B), Hvaler (st. 02B), Grenlandsfjord (st. 71B), the Inner Sørfjord (st. 53B), Bømlo (st. 23B), Bergen harbour (st. 24B), Ålesund harbour (st. 28B) and Lofoten (st. 98B1). Blue mussel at Byrkjenes (st. 51A) in the Inner Sørfjord was also moderately polluted with Hg. All other cod and blue mussel showed background levels (Class I) of Hg.

Class increased since 2014

The concentration of Hg in cod fillet from Lofoten (st. 98B1) had increased from being insignificantly polluted (Class I, 0.089 mg/kg w.w.) in 2014 to being moderately polluted (Class II, 0.103 mg/kg w.w.) in 2015.

Upward trends

Cod fillet from the Inner Oslofjord (st. 30B) was moderately polluted (Class II) with Hg and showed significant upward long-term trend (***Table 11***, ***Figure 8***). The median concentration had increased from 0.207 mg/kg w.w. in 2014 to 0.227 mg/kg w.w. in 2015. In 2014, a significant upward short-term trend was found. In 2015, no significant short-term trend was found.

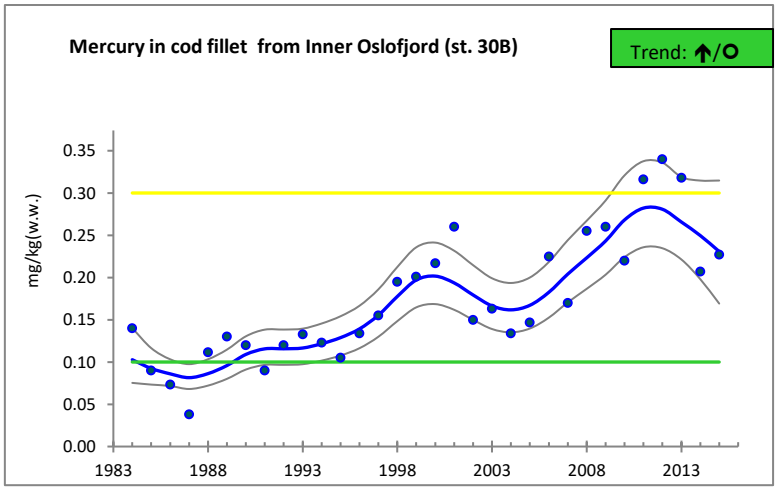


Figure 8. *Median concentrations (mg/kg w.w.) of mercury (Hg) in cod fillet from 1984 to 2015 in the Inner Oslofjord (st. 30B).*

Cod fillet from Bømlo (st. 23B) was also moderately polluted (Class II) with Hg and showed both significant upward long-term and short-term trends. Cod fillet from Færder (st. 36B) was also moderately polluted (Class II) with Hg and showed significant upward short-term trend. Cod fillet from Farsund area (st. 15B) was insignificantly polluted (Class I) with Hg and showed significant upward short-term trend.

Mussels in the Inner Oslofjord at Gåsøya (st. I304) showed significant upward long-term and short-term trends but within background levels (Class I). Blue mussel at Håøya (st. I306) had also background levels (Class I), and a significant upward short-term trend was observed.

Class decreased since 2014

Hg-concentrations in cod fillet from Farsund (st. 30B) had decreased from being moderately polluted (Class II, 0.131 mg/kg w.w.) in 2014, to being insignificantly polluted (Class I, 0.088 mg/kg w.w.) in 2015.

Downward trends/low levels

There was a significant downward long-term trend in cod fillet from the Varangerfjord (st. 10B) in 2015 and the concentration was at background levels (Class I).

Significant downward long-term trends within background levels were observed in mussel from the Oslofjord at Solbergstrand (st. 31A), in the Grenlandsfjord at Bjørkøya (st. 71A) ***(Table 11, Figure 9)***, in the Sørfjord at Eitrheimsneset (st. 52A), Kvalnes (st. 56A) and Krossanes (st. 57A), and in the Varangerfjord at Skallneset (st. 10A2).

Significant downward short-term trends were found in mussels at Solbergstrand (st. 31A) and at Espevær (st. 22A).

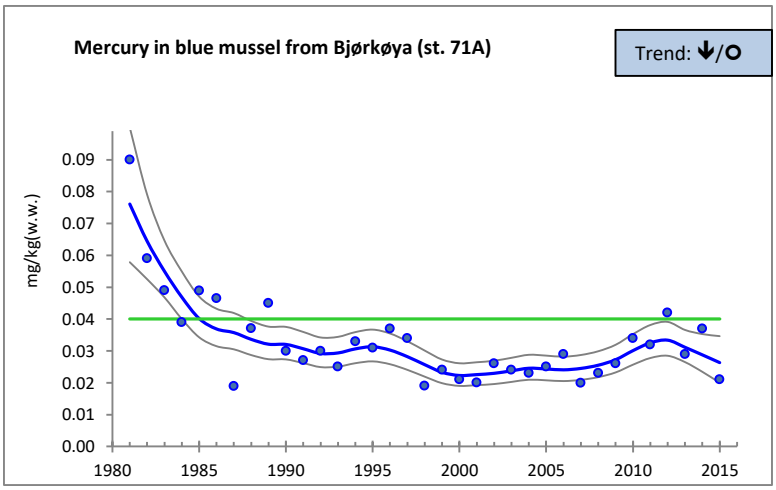


Figure 9. *Median concentrations (mg/kg w.w.) of mercury (Hg) in blue mussel from 1981 to 2015 at Bjørkøya (st. 71A) in the Grenlandsfjord area.*

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. This reduction is not so evident for the Norwegian discharges. For MILKYS long-term trends, there is some evidence of downward trends. Seven downward long-term trends and one long-term upward trend were found in blue mussel. However, three long-term trends were found in cod fillet; upwards in the Inner Oslofjord and at Bømlo, and downwards in the Varangerfjord.

Total riverine input of Hg in Norway has been 259 kg in 2014 (Skarbøvik *et al.* 2015). The total riverine inputs of Hg were 99 kg to Skagerrak, 69 kg to the North sea, and 90.5 kg to the Norwegian and Barents sea, indicating higher input in the southern part of Norway. There was a decrease for total riverine inputs in the period 1990-2014. Total Hg load dropped 62 % to 259 tonnes in 2014 compared to the mean for the period 1990-2013 (421 tonnes). In addition to riverine inputs was the contribution by direct discharges from sewage and industrial effluents amounting to 18 kg or about 7 % of the total (276 kg).

When considering the total of 39 recent short-term (2006-2015) trends for both cod and blue mussel, significant trends are limited to upwards at 10 stations and downwards at 5 stations (***Table 11***, ***Figure 10***).

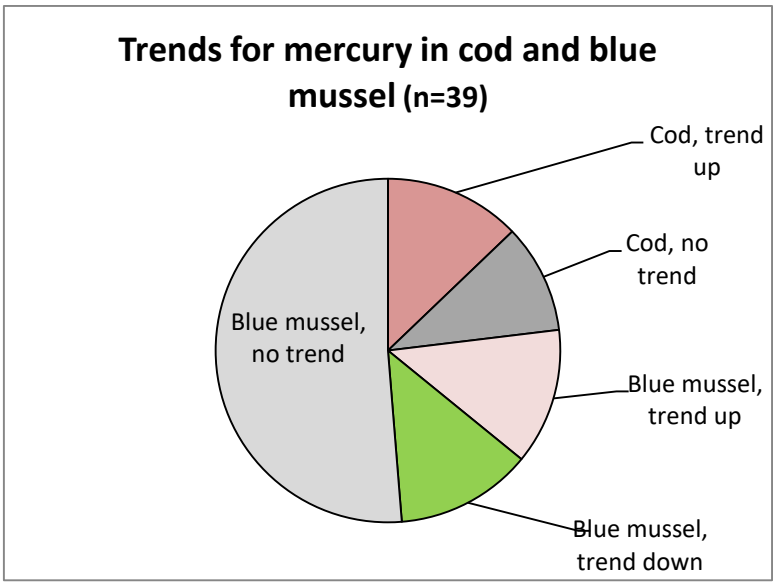


Figure 10. *Frequency of short-term (recent) trends (2006-2015) for Hg in cod fillet and blue mussel.*

Emissions of Hg to air from land-based industries showed essentially a decrease from 2002 (257 kg Hg/year) to 2009 (104 kg Hg/year), and the emission was 91 kg Hg/year in 2015 (***Figure 11***). The emissions to air varied between 260 kg Hg/year in 2004 to 91 kg Hg/year in 2015 for the period 2002-2015.

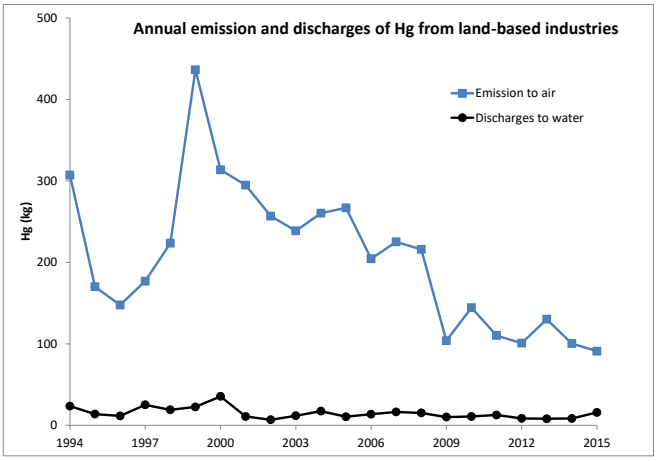


Figure 11. *Annual emissions of Hg to air and discharges to water from land-based industries for the period 1994-2015 (data from www.norskeutslipp.no, 27 October 2016). Note that emissions and discharges from municipal treatment plants, land runoff, transportation and offshore industry are not accounted for in the figure. New calculation methods for data of emissions and discharges might lead to changes in calculations of present and previous data.*

There is some indication that Norwegian atmospheric deposition in southern Norway is decreasing for the period 1995-2006, but this was not statistically confirmed (Wängberg *et al.* 2010). Still we see upward short-term and long-term trends in cod fillet from Bømlo and long-term trend in cod

fillet from Inner Oslo fjord. Furthermore, an upward short-term trend at Færder and Farsund were registered. Possible explanations of increasing trends could be related to factors such as; climate change, more favourable conditions for methyl mercury formation, increased bioavailability of Hg stored in the sediments, increased access of cod to contaminated feeding areas due to improved oxygen levels in deep water, changes in what the cod eat, etc. It has also been speculated in that the increasing trend in Inner Oslofjord might be a result of sediment remediation works in Oslo harbour in 2006-2008. Neither explanation can be ruled out based on existing knowledge, but the monitoring designed to reveal spreading of mercury during the dredging operations (Berge 2014) gave little evidence to support the latter hypotheses. Neither can it explain why Hg is the only contaminant, with the exception Cd for upward long term trend in cod liver, showing an upward long term trend in the in cod from the Inner Oslofjord. Before speculating too much in potential causes, the nature of the trend data will be further investigated below.

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). Bjerkeng *et al*. (2009) found that more than 60 % of the Hg input to Bunnefjord 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*. 2013b). The riverine input to the Inner Oslofjord from Alna river was 0.089 kg Hg (upper average) in 2014 (Skarbøvik *et al*. 2015). VEAS sewage treatment plant reported a discharge of 0.37 kg Hg in 2015 to the Inner Oslofjord (VEAS 2016).

Other studies

Blue mussel at Gåsøya and Håøya in the Inner Oslofjord showed significant upward short-term trends of Hg, but within background levels (Class I) in 2015, as in 2014. Mussel at Gåsøya also showed significant upward long-term trend. Blue mussel at Frognerkilen, the mouth of Alna and Bekkelaget were also at background levels for Hg in 2014 (Ruus *et al*. 2015) and 2013 (Ruus *et al*. 2014). Other investigations in the Inner Oslofjord also found insignificantly polluted (Class I) blue mussel (Berge 2014).

Cod fillet from the Inner Oslofjord had concentration (0.227 mg/kg Hg w.w.) almost at the same level (0.2994 mg/kg Hg w.w.) as in a comparable study in the Inner Oslofjord in 2015 (Ruus *et al*. 2016b). Cod fillet from Bekkelaget and Frognerkilen was also moderately polluted in 2010 and 2013 (Berge 2014).

Blue mussel from Langøya in the Holmestrandfjord in 2015 was at background levels (Class I) for Hg at four of five stations (Gitmark *et al*. 2016). 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 have decreased significantly during the last 25 years due to remedial actions performed by the local industry (Ruus *et al*. 2013b).

Concentrations of Hg in cod from the Barents sea collected in 1976, 1995 and 2000 did not seem to have increased in the period of 25 years (Ervik *et al*. 2003).

Most of the Hg-pollution in Norwegian lakes is now due to atmospherically deposited Hg originating from other parts of the world (Fjeld *et al*. 2016). The concentration of Hg in trout from Mjøsa showed a decreasing trend in the period 1980-2005, and showed more or less unchanged concentrations during the period 2006-2014 (Løvik *et al*. 2016). Surveys from 2008 suggests that the

length adjusted average Hg-concentrations in ten perch populations from forest lakes, increased with 63 % since the early 1990s (Fjeld & Rognerud 2009).

The influence of fish length on trend-assessments, which was shown to affect the analyses (Green *et al*. 2015), can't be disregarded. The OSPAR-method, which uses target specific length-groups, is a robust method. A more rigorous approach indicated that results had been biased by increased length of the fish in the analysed samples over the years. This was caused by poor fish recruitment in recent years and a need for larger fish to comply with need for more liver tissue for the request analyses. Using the more rigorous trend analysis which took into account fish size, no significant trend was detected for the entire period.

Environmental Quality Standards (EQS) for EU-priority substances

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) for blue mussel (0.04 mg/kg w.w.). Applying this EQS for blue mussel (see **Table 12**), concentrations of Hg were above or at the EQS applied for biota at Gressholmen (st. 30A, 0.02 mg/kg w.w.) in the Inner Oslofjord and at Singlekalven (st. I023, 0.022 mg/kg w.w.) and Kirkøy (st. I024, 0.026 mg/kg w.w.) in the Hvaler area. This was also the result at Bjørkøya (st. 71A, 0.021 mg/kg w.w.), Brevik (st. I714, 0.029 mg/kg w.w.) and Croftholmen (st. I712, 0.034 mg/kg w.w.) in the Grenlandsfjord-area. This was also the case at Byrkjenes (st. 51A, 0.068 mg/kg w.w.), Eitrheimsneset (st. 52A, 0.037 mg/kg w.w.), Kvalnes (st. 56A, 0.039 mg/kg w.w.) and Krossanes (st. 57A, 0.026 mg/kg w.w.) in the Sørfjord, and in the Hardangerfjord at Ranaskjær (st. 63A, 0.025 mg/kg w.w.) and Vikingneset (st. 65A, 0.022 mg/kg w.w.). This was also the result at Nordnes (st. I241, 0.021 mg/kg w.w.) in Bergen.

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. Using fillet probably represents an overestimate of the whole fish concentration because Hg accumulates more in the fillet than in other tissues (Kwasniak & Falkowska 2012). If it is assumed, for this exercise, that the same concentration is found in all fish tissue types, then the results of Hg (in cod fillet) would have exceeded the EQS (0.020 mg/kg w.w.) for all 2015-samples (except for the Varangerfjord st. 10B where the concentration was 0.018 mg/kg w.w., see **Table 12**).

Another recent surveys actuated due to operational monitoring in compliance with the EU Water Framework Directive showed that blue mussel had concentrations below EQS for Hg at Toraneskaia, Bjørnebærviken and Moholmen in the Ranfjord in 2015 (Øxnevad *et al*. 2016). Blue mussel concentration of mercury was also below EQS at Svensholmen in the Kristiansandsfjord (Håvardstun and Næs 2016).

If the EQS was applied to all the blue mussel and cod fillet data, including historical data, from stations presumed to be less impacted by contamination, over 35 % of the medians would have exceeded the limit compared to <5 % that would have exceeded Class II (see Chapter 3.7, ***Figure 51***).

3.2.2 Cadmium (Cd)

Cadmium (Cd) was analysed in cod liver at 16 stations and in blue mussel at 33 stations.

Levels exceeding Class I

Blue mussel at Eitrheimsneset (st. 52A) in the Inner Sørfjord was moderately polluted (Class II) with Cd. All other blue mussels were insignificantly polluted (Class I), and all cod liver was at background levels and in 2015, as in 2014.

Upward trends

For cod liver, there was significant upward long-term trend in the Inner Oslofjord (st. 30B) (***Table 11***), as in 2014.

There were both significant upward long-term and short-term trends in blue mussel at Gåsøya (st. I304) and a short-term upward trend in blue mussel at Kirkøy (st. I024) in the Hvaler area, as in 2014.

Class increased since 2014

Blue mussel at Eitrheimsneset (st. 52A) in the Inner Sørfjord was moderately (Class II) polluted with Cd in 2015, but at background levels in 2014.

Downward trends/low levels

In blue mussel, there were significant downward long-term and short-term trends at Solbergstrand (st. 31A) in the Mid Oslofjord and at Krossanes (st. 57A) in the Outer Sørfjord. This was also the result at Ranaskjær (st. 63A), Vikingneset (st. 65A) and Lille Terøy (st. 69A) in the Hardangerfjord, at Nordnes (st. I241) close to Bergen and at Moholmen (st. I965) in the Ranfjord. There were significant downward long-term trends for blue mussel at Mølen (st. 35A) in the Mid Oslofjord, at Bjørkøya (st. 71A) in the Grenlandsfjord and at Eitrheimsneset (st. 52A) in the Inner Sørfjord. There was significant downward short-term trend for blue mussel at Gressholmen (st. 30A) in the Inner Oslofjord.

There was a significant long-term downward trend in cod liver from the Varangerfjord (st. 10B).

Other studies

Blue mussel at Frognerkilen, the mouth of Alna and Bekkelaget were also at background levels for Cd in 2014 (Ruus *et al.* 2015) and 2013 (Ruus *et al.* 2014). Other reports have also shown blue mussel insignificantly polluted with Cd in the Inner Oslofjord 2006-2013 (Berge 2014).

Cod liver from the Inner Oslofjord had concentration (0.18 mg/kg Cd w.w.) almost at the same level (0.110 mg/kg Cd w.w.) as in a comparable study in the Inner Oslofjord in 2015 (Ruus *et al.* 2016b).

Mussels were, however, up to moderately polluted with Cd at one of five stations at Langøya in the Holmestrandfjord in 2015 (Gitmark *et al.* 2016). Blue mussel at all seven stations in the Kristiansandsfjord was at background levels in the period 2010 to 2013 (Schøyen *et al.* 2014).

General, large scale trends

Discharges of Cd to water from land-based industries showed a decrease from 2000 (1734 kg Cd/year) to 2015 (115 kg Cd/year) (***Figure 12***). The emission of Cd to air showed a gradually decrease from 1999 (560 kg Cd/year) to 2015 (79 kg Cd/year).

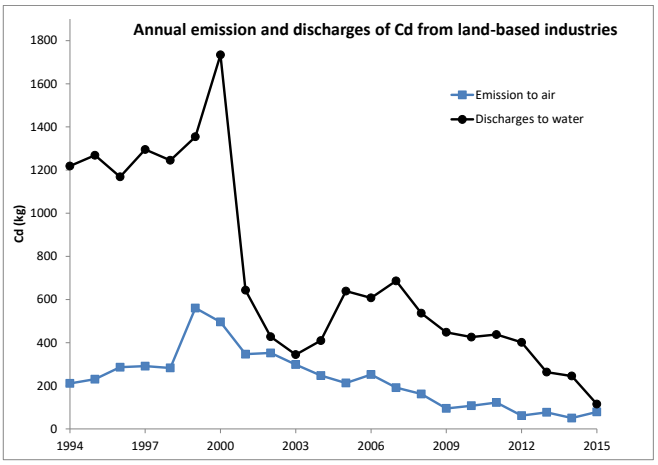


Figure 12. *Annual emissions of Cd to air and discharges to water from land-based industries in the period 1994-2015 (data from www.norskeutslipp.no, 27 October 2016). Note that emissions and discharges from municipal treatment plants, land runoff, transportation and offshore industry are not accounted for in the figure. New calculation methods for data of emissions and discharges might lead to changes in calculations of present and previous data.*

The discharge of Cd to water from local industry in Skien has decreased from 0.12 kg/year in 2014 to 0.05 kg/year in 2015 (www.norskeutslipp.no). The discharge of Cd to water from local industry in Odda in the Inner Sørfjord has increased from 31.2 kg/year in 2014 to 46.8 kg/year in 2015 (www.norskeutslipp.no). This might be the reason for the increase of Cd at Eitrheimsneset where mussels were at background levels in 2014, while they were moderately polluted in 2015.

Total riverine input of Cd in Norway has been 2.6 tonnes in 2014 (Skarbøvik *et al*. 2015). Total riverine inputs of Cd were 1.5 tonnes to Skagerrak, 0.6 tonnes to the North sea and 0.5 tonnes to the Norwegian and Barents sea, indicating higher input in the southern part of Norway. There was a decrease for total riverine inputs in the period 1990-2014. Total Cd load dropped 50 % to 2.6 tonnes in 2014 compared to the mean for the period 1990-2013 (5.2 tonnes). In addition to riverine inputs, direct discharges from sewage and industrial effluents contribute, amounting to 0.11 tonnes or about 3.6 % of the total (3 tonnes). The riverine input to the Inner Oslofjord from Alna river was 0.004 kg Cd (upper average) in 2014. VEAS sewage treatment plant reported a discharge of 5.8 kg Cd to the Inner Oslofjord in 2015 (VEAS 2016).

3.2.3 Lead (Pb)

Lead (Pb) was analysed in cod liver at 16 stations and in blue mussel at 33 stations.

Important levels exceeding background levels

Cod liver from the Inner Oslofjord (st. 30B) exceeded background levels of Pb.

Important levels exceeding Class I

The presence of Pb in blue mussel exceeded Class I (insignificantly polluted) at five of the blue mussel stations (***Table 11***). The highest levels (1.1 mg Pb/kg w.w.) were found in blue mussel from Eitrheimsneset (st. 52A) in the Inner Sørfjord and Moholmen (st. I965) in the Ranfjord, and they were moderately polluted (Class II). Blue mussel at Gressholmen (st. 30A) in the Oslofjord, Odderøy (st. I133) in the Kristiansandsfjord, Krossanes (st. 57A) in the Outer Sørfjord and Moholmen (st. I965) in the Ranfjord were also moderately polluted (Class II) with Pb.

There were both significant downward long-term and short-term trends at Krossanes and Moholmen. At Eitrheimsneset, there was a significant downward long-term trend in 2015. In 2014, no significant trends were found at this location.

Class increased since 2014

Blue mussel at Gressholmen in the Inner Oslofjord was at background levels in 2014, but was moderately polluted in 2015.

Downward trends/low levels

Observed concentrations of Pb in cod liver were at background level at all stations, except for the Inner Oslofjord (st. 30B) where background level was exceeded (***Table 11***). No significant trends were found in cod liver from the Inner Oslofjord. At 10 stations, data was inadequate for trend analysis in cod liver due to concerns about the limit of quantifications.

Of the trend analysis performed for blue mussel, 12 revealed significant downward long-term trends. Both significant downward long-term and short-term trends were observed for mussel at Krossanes (st. 57A) in the Outer Sørfjord and Moholmen (st. I965) in the Ranfjord, and both were moderately polluted (Class II). Both significant downward long-term and short-term trends were also observed for mussel at Lille Terøy (st. 69A) in the Hardangerfjord, at Espevær (st. 22A) on the west coast, at Nordnes (st. I241) close to Bergen and at Bjørnebærviken (st. I969) in the Ranfjord, all within background levels (Class I). Significant downward long-term trends were observed in blue mussel at Akershuskaia (st. I301) in the Inner Oslofjord, at Solbergstrand (st. 31A) and Mølen (st. 35A) in the Mid Oslofjord, and at Ranaskjær (st. 63A) and Vikingneset (st. 65A) in the Hardangerfjord, all within background concentrations.

Other studies

Blue mussel at Frognerkilen, the mouth of Alna and Bekkelaget were markedly polluted (Class III) with Pb in 2014 (Ruus *et al*. 2015) and at background levels (Class I) in 2013 (Ruus *et al*. 2014). Monitoring of mussels in the Inner Oslofjord in 2006 to 2013 showed that mussels were up to moderately polluted (Class II) with Pb (Berge 2014). Blue mussel was up to moderately polluted at one of five blue mussel stations at Langøya in the Holmestrandfjord in 2015 (Gitmark *et al*. 2016).

Blue mussel from Hanneviksbukta and Odderøy in the Kristiansandsfjord were markedly polluted with Pb in 2015 (Schøyen *et al*. 2016).

Cod liver from the Inner Oslofjord showed higher concentration (0.235 mg/kg Pb w.w.) than observed in a comparable study (0.071 mg/kg Pb w.w.) in the Inner Oslofjord in 2015 (Ruus et *al*. 2016b).

General, large scale trends

There were low levels of Pb in cod liver 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. Total riverine input of Pb in Norway has been 49 tonnes in 2014 (Skarbøvik *et al*. 2015). Total riverine inputs of Pb were 35 tonnes to Skagerrak, 10 tonnes to the North sea and 3.7 tonnes to the Norwegian and Barents sea, indicating higher input in the southern part of Norway. There was a decrease for total riverine inputs in the period 1990-2014. Total Pb load dropped 11 % to 49 tonnes in 2014 compared to the mean for the period 1990-2013 (55 tonnes). In addition to riverine inputs, comes the contribution by direct discharges from sewage and industrial effluents amounting to 1.64 tonnes or about 3 % of the total (50 tonnes). The riverine input to the Inner Oslofjord from Alna river was 0.052 kg Pb (upper average) in 2014. VEAS sewage treatment plant reported a discharge of 82 kg Pb in 2015 (VEAS 2016).

Discharges of Pb to water from land-based industries showed a decrease from 2010 (6841 kg Pb/year) to 2015 (1199 kg Pb/year) (***Figure 13***).

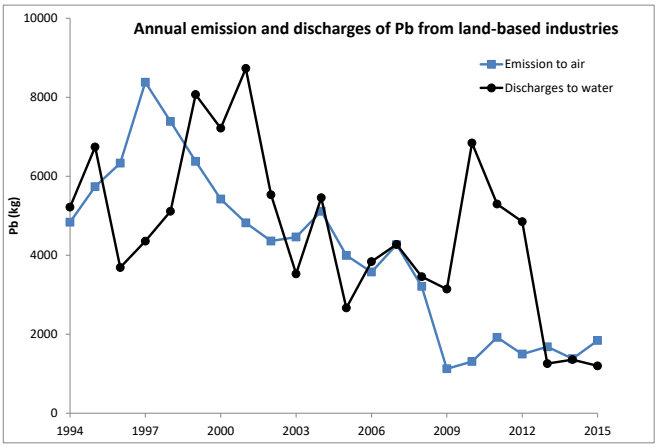


Figure 13. *Annual emissions of Pb to air and discharges to water from land-based industries in the period 1994-2015 (data from www.norskeutslipp.no, 27 October 2016). Note that emissions and discharges from municipal treatment plants, land runoff, transportation and offshore industry are not accounted for in the figure. New calculation methods for data of emissions and discharges might lead to changes in calculations of present and previous data.*

3.2.4 Copper (Cu)

Copper (Cu) was analysed in cod liver at 16 stations and in blue mussel at 33 stations.

Upward trends

In cod liver from the Farsund area (st. 15B), a significant upward short-term trend was found.

Downward trends/low levels

There were both significant downward short-term and long-term trends in mussel from Ramtonholmen (st. I307) in the Inner Oslo fjord and at Risøy (st. 76A). There was a significant downward long-term trend at Skallneset (st. 10A2) in the Varangerfjord and a short-term trend at Bjørkøya (st. 71A).

Cod liver from all stations had Cu-concentrations at background levels in 2015, as observed in 2014. Significant downward long-term trends were observed in cod liver from Færder (st. 36B) and Varangerfjord (st. 10B).

Other studies

Blue mussel at Frognerkilen, the mouth of Alna and Bekkelaget were at background levels for Cu in 2014 (Ruus *et al*. 2015) and 2013 (Ruus *et al*. 2014). Blue mussel from the Inner Oslofjord was up to moderately polluted with Cu in 2013 (Berge 2014).

Cod liver from the Inner Oslofjord had concentration (5.6 mg/kg Cu w.w.) almost at the same level (7.706 mg/kg Cu w.w.) as in a comparable study in the Inner Oslofjord in 2015 (Ruus *et al*. 2016b).

All five blue mussel stations at Langøya in the Holmestrandfjord had background concentrations of Cu in 2015 (Gitmark *et al*. 2016). The concentrations of Cu in mussels from one station in the Kristiansandsfjord were markedly polluted in 2015 while four stations in the same fjord were moderately polluted (Schøyen *et al*. 2016).

General, large scale

Discharges of Cu to water from land-based industries showed a gradually decrease from 2005 (90 186 kg Cu/year) to 2015 (5560 kg Cu/year) (***Figure 14***). In 2014, the discharges to water were (42 655 kg Cu/year).

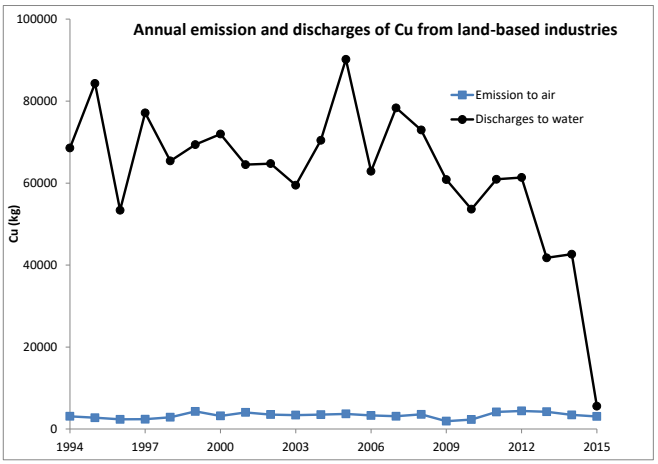


Figure 14. *Annual emissions of Cu to air and discharges to water from land-based industries in the period 1994-2015 (data from www.norskeutslipp.no, 27 October 2016). Note that emissions and discharges from municipal treatment plants, land runoff, transportation and offshore industry are not accounted for in the figure. New calculation methods for data of emissions and discharges might lead to changes in calculations of present and previous data.*

Total riverine input of Cu in Norway has been 171 tonnes in 2014 (Skarbøvik *et al*. 2015). The total riverine inputs of Cu were 90 tonnes to Skagerrak, 23 tonnes to the North sea and 57.8 tonnes to the Norwegian and Barents sea. There was a decrease for total riverine inputs in the period 1990-2014. Total Cu load in Norway decreased 24 % to 171 tonnes in 2014 compared to the mean for the period 1990-2013 (225 tonnes). In addition to riverine inputs, comes the contribution by direct discharges from sewage and industrial effluents and fish farming amounting to 967.7 tonnes or about 85 % of the total (1139 tonnes). The riverine input to the Inner Oslofjord from Alna river was 0.277 kg Cu (upper average) in 2014. VEAS sewage treatment plant reported a discharge of 785 kg Cu in 2015 (VEAS 2016).

3.2.5 Zinc (Zn)

Zinc (Zn) was analysed in cod liver at 16 stations and in blue mussel at 33 stations.

Important levels exceeding background level

Cod liver from Færder (st. 36B), Kristiansand harbour (st. 13B), Bømlo (st. 23B) and Bergen harbour (st. 24B) showed concentrations of Zn that exceeded background levels.

Upward trends

No significant upward trends were found in blue mussel. A significant upward short-term trend was observed in cod liver from Farsund (st. 15B) in 2015, as in 2014.

Class decreased since 2014

Concentrations of Zn in cod liver in the Grenlandsfjord (st. 71B), Farsund (st. 15B) and Lofoten (st. 98B1) exceeded background levels in 2014, but not in 2015.

Downward trends/low levels

Both significant long-term and short-term trends in blue mussel for Zn were found at Solbergstrand (st. 31A) in the Inner Oslo fjord, at Risøy (st. 76A) and at Lille Terøy (st. 69A) in the Hardangerfjord.

Significant downward long-term trends were found in blue mussel from Akershuskaia (st. I301) and Gåsøya (st. I304) in the Inner Oslofjord, and at Bjørkøya (st. 71A) in the Grenlandsfjord. This was also observed at Eitrheimsneset (st. 52A) in the Inner Sørfjord, Krossanes (st. 57A) in the Outer Sørfjord, and at Ranaskjær (st. 63A) and Vikingneset (st. 65A) in the Hardangerfjord. Significant downward long-term trend was also the case for mussels from Espevær (st. 22A) on the west coast.

A significant downward short-term trend was found in blue mussel from Bjørnebærviken (st. I969) in the Ranfjord.

Significant downward long-term trends were found in cod liver at Færder (st. 36B) and in the Varangerfjord (st. 10B).

Other studies

Other studies also documented low levels of Zn in blue mussel. Blue mussel at Frognerkilen, the mouth of Alna and Bekkelaget were at background levels for Zn in 2014 (Ruus *et al.* 2015) and 2013 (Ruus *et al.* 2014).

Cod liver from the Inner Oslofjord had concentration (29.5 mg/kg Zn w.w.) almost at the same level (22.120 mg/kg Zn w.w.) as in a comparable study in the Inner Oslofjord in 2015 (Ruus *et al.* 2016b).

Mussels at five stations at Langøya in the Holmestrandfjord showed background levels (Class I) of Zn in 2015 (Gitmark *et al.* 2016). All five blue mussel stations in the Kristiansandsfjord were insignificantly polluted by Zn in 2015 (Schøyen *et al.* 2016).

General, large scale

Discharges of Zn to water from land-based industries showed a gradually decrease from 2005 (200 785 kg Zn/year) to 2015 (17 849 kg Zn/year) (***Figure 15***). In 2014, the discharges to water were (78 213 kg Zn/year).

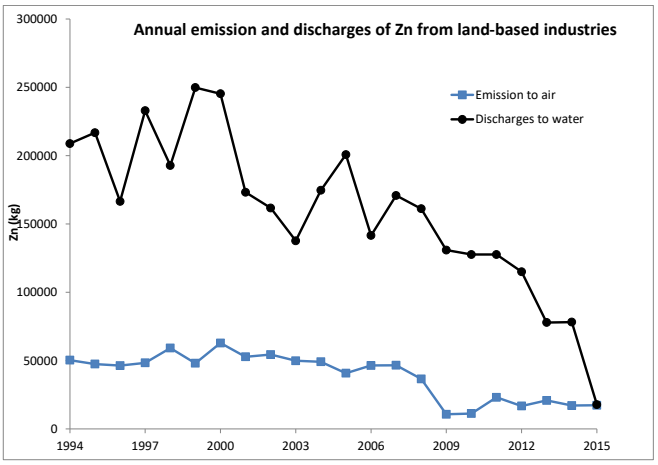


Figure 15. *Annual emissions of Zn to air and discharges to water from land-based industries in the period 1994-2015 (data from www.norskeutslipp.no, 27 October 2016). Note that emissions and discharges from municipal treatment plants, land runoff, transportation and offshore industry are not accounted for in the figure. New calculation methods for data of emissions and discharges might lead to changes in calculations of present and previous data.*

Total riverine input of Zn in Norway has been 764 tonnes in 2014 (Skarbøvik *et al*. 2015). Total riverine inputs of Zn were 571 tonnes to Skagerrak, 103 tonnes to the North sea and 89.7 tonnes to the Norwegian and Barents sea, indicating higher input in the southern part of Norway. There was an increase for total riverine inputs in the period 1990-2014. Total Zn load increased 3 % to 764 tonnes in 2014 compared to the mean for the period 1990-2013 (741 tonnes). In addition to riverine inputs, comes the contribution by direct discharges from sewage and industrial effluents amounting to 30.51 tonnes or about 4 % of the total (795 tonnes). The riverine input to the Inner Oslofjord from Alna river was 1.101 kg Zn (upper average) in 2014. VEAS sewage treatment plant reported a discharge of 2324 kg Zn in 2015 (VEAS 2016).

3.2.6 Silver (Ag)

Silver (Ag) was analysed in cod liver at 16 stations and in blue mussel at 33 stations.

Levels

There were no changes in classes for Ag in blue mussel from 2014 to 2015, and only background levels (Class I) were observed. The environmental classifications system does not include Ag in cod. The highest concentration (6.9 mg/kg w.w.) in cod liver was found in the Inner Oslofjord, as in 2014 (6.7 mg/kg w.w.). The second highest concentration (1.6 mg/kg w.w.) was found in cod liver from Færder (st. 36B). The lowest concentration (0.091 mg/kg w.w.) was found in Ålesund (st. 28B).

Upward trends

There were both significant upward long-term and short-term-trends in cod liver (0.45 mg Ag/kg) from Tromsø harbour (st. 43B2) (***Figure 16***).

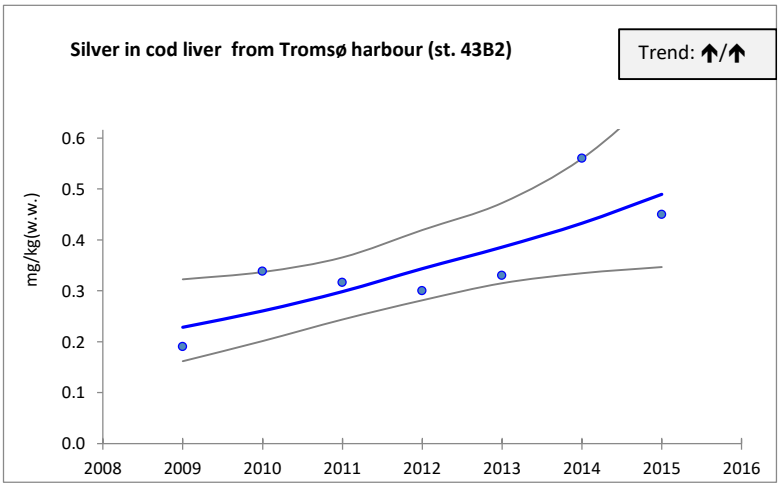


Figure 16. *Median concentrations (mg/kg w.w.) of silver (Ag) in cod liver from 2009 to 2015 in the Tromsø harbour (st. 43B2).*

Other studies

The highest Ag-concentrations were found in cod liver from the Inner Oslofjord in 2015, as in previous years. 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.

Cod liver from the Inner Oslofjord revealed concentration of 6.85 mg/kg Ag (w.w.). Cod liver from a comparable study in Inner Oslofjord in 2015 showed lower concentrations (4.318 mg/kg Ag w.w.) (Ruus *et al.* 2016b).

Blue mussel at Frognerkilen, the mouth of Alna and Bekkelaget in 2014 (Ruus *et al.* 2015) and 2013 (Ruus *et al.* 2014) were all at background levels (Class I). Another investigation showed that blue mussel from seven stations in the Kristiansandsfjord was insignificantly polluted (Class I) with Ag in 2013 (Schøyen *et al.* 2014).

Discharges of wastewater treatment plants and discharges from mine tailings are considered major and important sources for silver to the aquatic environment (Tappin *et al.* 2010). The incorporation of silver nanoparticles into consumer products is important 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 Ag-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 1994 (9.74 kg Ag/year) to 2009 (0.1 kg Ag/year) (***Figure 17***). The discharges to water in 2015 were 0.52 kg Ag).

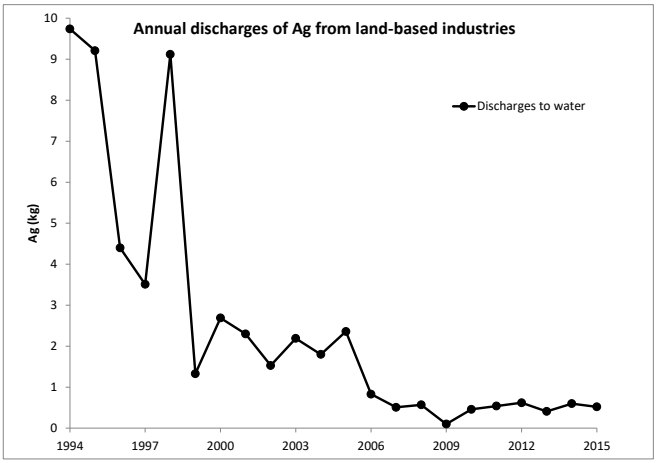


Figure 17. *Annual discharges of Ag to water from land-based industries in the period 1994-2015 (data from www.norskeutslipp.no, 27 October 2016). Note that emissions and discharges from municipal treatment plants, land runoff, transportation and offshore industry are not accounted for in the figure. New calculation methods for data of discharges might lead to changes in calculations of present and previous data.*

Total riverine input of Ag in Norway has been 8 tonnes in 2014. Total riverine inputs of Ag were 4 tonnes to Skagerrak, 2 tonnes to the North sea, 1 tonnes to the Norwegian Sea and 1 tonnes to the Barents sea, indicating higher input in the southern part of Norway. The riverine input to the Inner Oslofjord from Alna river was 0.003 kg Ag (upper average) in 2014.

3.2.7 Arsenic (As)

Arsenic (As) was analysed in cod liver at 16 stations and in blue mussel at 33 stations.

Levels

Note that in the previous report (Green *et al*. 2015) assessment of this contaminant in blue mussel was erroneously based on Class thresholds 25 times higher (see Chapter 3.1).

Blue mussel at Måløy (st. 26A2) was markedly (Class III) polluted by As. Mussel were moderately (Class II) polluted at Brevik (st. I714) in the Grenlandsfjord, at Eitrheimsneset (st. 52A) in the Inner Sørfjord, and at Krossanes (st. 57A) and Utne (st. 64A) in the Outer Sørfjord. This was also the case at Ranaskjær (st. 63A), Vikingneset (st. 65A) and Lille Terøy (st. 69A) in the Hardangerfjord. Moderately (Class II) polluted mussels was also observed at Espevær (st. 22A) on the west coast and Nordnes (st. I241) in Bergen. Mussels were also moderately polluted in the Outer Trondheimsfjord (st. 91A2), Bodø harbour (st. 97A2) and Lofoten (st. 98A2).

Relevant values for background levels of As are not available for cod. The highest concentration was found in cod liver from the Inner Oslofjord (st. 30B) where the concentration had increased to 27 mg As/kg w.w. in 2015 from 11 mg As/kg w.w. in 2014. The lowest concentration in cod liver was found in Helgeland (st. 96B, 2.8 mg As/kg w.w.).

Class increased since 2014

Blue mussel at Eitrheimsneset (st. 52A) in the Inner Sørfjord and at Krossanes (st. 57A) and Utne (st. 64A) in the Outer Sørfjord were at background levels (Class I) in 2014, but were moderately polluted (Class II) in 2015. This was also the result at Ranaskjær (st. 63A) and Lille Terøy (st. 69A) in the Hardangerfjord.

Class decreased since 2014

Blue mussel at Ramtonholmen (st. I307) in the Inner Oslofjord and Solbergstrand (st. 31A) in the Mid Oslofjord were moderately (Class II) polluted in 2014, but at background (Class I) levels in 2015.

Downward trends

In blue mussel, both significant downward long-term and short-term trends were found at Bjørkøya (st. 71A) in the Grenlandsfjord, and at Risøy (st. 76A), Lastad (st. I131) and Gåsøy (st. 15A) in the southern part of Norway. This was also the case at Moholmen (st. I965) in the Ranfjord and at Brashavn (st. 11X) and Skallneset (st. 10A2) in the Varangerfjord.

There were both significant downward long-term and short-term trends in the cod liver from Tromsø harbour (st. 43B2).

Other studies

Blue mussel at Frognerkilen, the mouth of Alna and Bekkelaget were at background levels for As in 2014 (Ruus *et al*. 2015) and 2013 (Ruus *et al*. 2014). Blue mussel in the Inner Oslofjord was up to moderately polluted with As from 2006 to 2013 (Berge 2014). Mussel was insignificantly polluted with As at the five stations at Langøya in the Holmestrandfjord in 2015 (Gitmark *et al*. 2016). Most blue mussel stations in the Kristiansandsfjord were moderately polluted by As in 2015 (Schøyen *et al*. 2016).

Cod liver from the Inner Oslofjord revealed concentration of 27 mg/kg As (w.w.). Cod liver from a comparable study in Inner Oslofjord in 2015 had lower concentrations (23.442 mg/kg As w.w.) (Ruus *et al*. 2016b).

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 from 2013 (1504 kg As/year) to 2015 (1846 kg As/year) (***Figure 18***). Emission to air was 882 kg As/year in 2015.

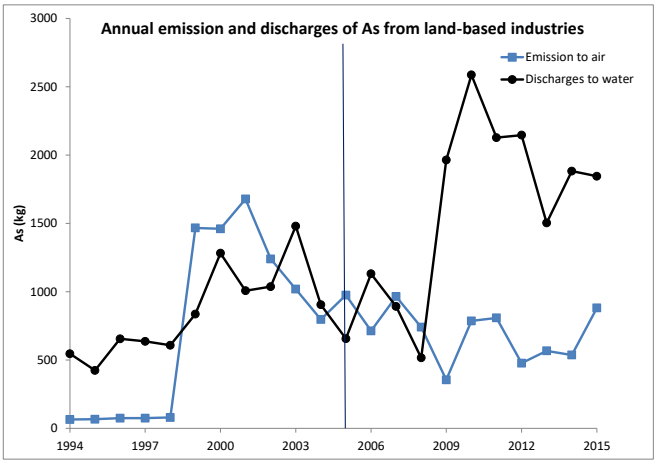


Figure 18. *Annual emissions of As to air and discharges to water from land-based industries in the period 1994-2015 (data from www.norskeutslipp.no, 27 October 2016). The vertical grey line at 2005 marks when the MILKYS-measurements started. Note that emissions and discharges from municipal treatment plants, land runoff, transportation and offshore industry are not accounted for in the figure. New calculation methods for data of emissions and discharges might lead to changes in calculations of present and previous data.*

Total riverine input of As in Norway has been 26 tonnes in 2014 (Skarbøvik *et al.* 2015). Total riverine inputs of As were 14 tonnes to Skagerrak, 6 tonnes to the North sea and 6.7 tonnes to the Norwegian and Barents sea, indicating higher input in the southern part of Norway. There was a decrease for total riverine inputs in the period 1990-2014. Total As load dropped 10 % to 26 tonnes in 2014 compared to the mean for the period 1990-2013 (29 tonnes). In addition to riverine inputs, comes the contribution by direct discharges from sewage and industrial effluents amounting to 2.11 tonnes or about 7 % of the total (29 tonnes). The riverine input to the Inner Oslofjord from Alna river was 0.019 kg As (upper average) in 2014. VEAS sewage treatment plant reported a discharge of 49 kg As in 2015 (VEAS 2016).

3.2.8 Nickel (Ni)

Nickel (Ni) was analysed in cod liver at 13 stations and in blue mussel at 33 stations.

Levels

Note that in the previous report (Green *et al*. 2015) assessment of this contaminant in blue mussel was erroneously based on Class thresholds 25 times higher (see Chapter 3.1).

Only background levels (Class I) of Ni were observed in blue mussels in 2015.

The national environmental classifications system does not include Ni in cod. The highest concentration was found in cod liver from the Inner Oslofjord (st. 30B, 0.16 mg Ni/kg w.w.). At the three stations Bømlo (st. 23B), Munkholmen (st. 80B) and Varangerfjord (st. 10B), data on cod liver was inadequate to perform trend analysis due to concerns about the limit of quantifications.

Upward trends

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

A significant upward long-term trend was found for mussel in Brashavn (st. 11X) in the Varangerfjord.

Class decreased since 2014

Blue mussel at Odderøy (st. I133) was at background (Class I) level in 2015, but was moderately (Class II) polluted in 2014.

Downward trends

Both significant downward long-term and short-term trends were found in blue mussel at Risøy (st. 76A) in the southern part of Norway and in cod from Kristiansand harbour (st. 13B).

Other studies

All blue mussel stations in the Inner and Outer Oslofjord showed acceptable (background) levels of Ni. Blue mussel at Frognerkilen, the mouth of Alna and Bekkelaget were moderately polluted (Class II) for Ni in 2014 (Ruus *et al*. 2015) and at background levels (Class I) in 2013 (Ruus *et al*. 2014). Other investigations found that Ni was at background levels (Class I) in mussel at five stations at Langøya in the Holmestrandfjord in 2015 (Gitmark *et al*. 2016). Blue mussel was up to moderately polluted by Ni in the Kristiansandsfjord in 2015 (Schøyen *et al*. 2016).

Cod liver from the Inner Oslofjord revealed concentration of 0.16 mg/kg Ni (w.w.). Cod liver from a comparable study in Inner Oslofjord in 2015 showed lower concentrations (0.063 mg/kg Ni w.w.) (Ruus *et al*. 2016b).

General, large scale

Discharges of Ni to water from land-based industries had decreased gradually from 2001 (22 590 kg Ni/year) to 2015 (6 342 kg Ni/year) (***Figure 19***).

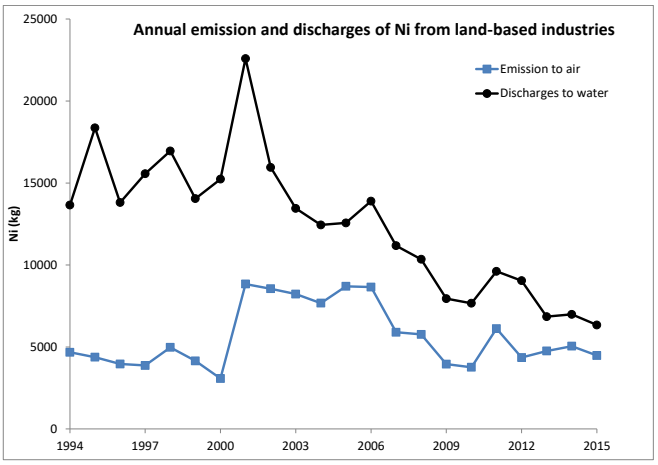


Figure 19. *Annual emissions of Ni to air and discharges to water from land-based industries in the period 1994-2015 (data from www.norskeutslipp.no, 27 October 2016). Note that emissions and discharges from municipal treatment plants, land runoff, transportation and offshore industry are not accounted for in the figure. New calculation methods for data of emissions and discharges might lead to changes in calculations of present and previous data.*

Total riverine input of Ni in Norway was 120 tonnes in 2014 (Skarbøvik *et al*. 2015). Total riverine inputs of Ni were 50 tonnes to Skagerrak, 17 tonnes to the North sea and 53.7 tonnes to the Norwegian and Barents sea. There was a decrease for total riverine inputs in the period 1990-2014. Total Ni load dropped 17 % to 120 tonnes in 2014 compared to the mean for the period 1990-2013 (144 tonnes). In addition to riverine inputs, comes the contribution by direct discharges from sewage and industrial effluents amounting to 8.93 tonnes or about 7 % of the total (129 tonnes). The riverine input to the Inner Oslofjord from Alna river was 0.059 kg Ni (upper average) in 2014. VEAS sewage treatment plant reported a discharge of 306 kg Ni in 2015 (VEAS 2016).

3.2.9 Chromium (Cr)

Chromium (Cr) was analysed in cod liver at 16 stations and in blue mussel at 33 stations.

Levels

Note that in the previous report (Green *et al*. 2015) assessment of this contaminant in blue mussel was erroneously based on Class thresholds 25 times higher (see Chapter 3.1).

Blue mussel at Singlekalven (st. I023) in the Hvaler area and Odderøy (st. I133) in the Kristiansandsfjord were moderately (Class II) polluted with Cr. All other mussels were insignificantly polluted (Class I) with Cr.

Relevant values for background levels of Cr are not available for cod. The highest concentration in cod liver was found in cod liver from Bømlo (st. 23B, 0.15 mg Cr/kg w.w.).

Class increased since 2014

Blue mussel at Singlekalven and Odderøy were moderately polluted in 2015, but were at background levels in 2014.

Upward trends

There were both significant upward long-term and short-term trends in blue mussel at Gressholmen (st. 30A) in the Inner Oslofjord and in Brashavn (st. 11X) in the Varangerfjord.

Class decreased since 2014

Mussels at Solbergstrand (st. 31A) in the Mid Oslofjord, in the Outer Trondheimsfjord (st. 91A2) and at Moholmen (st. I965 in the Ranfjord were moderately (Class II) polluted with Cr in 2014, but were at background levels (Class I) in 2015.

Downward trends

Both significant downward long-term and short-term trends were found in Lastad (st. I131A) in mussel. Significant downward long-term trend was found in mussels from Moholmen (st. I965) in the Ranfjord. Both significant downward long-term and short-term trends were found in cod liver in the Kristiansandsfjord (st. 13B).

Other studies

Blue mussel at Frognerkilen, the mouth of Alna and Bekkelaget were markedly to severely polluted (Class III-IV) for Cr in 2014 (Ruus *et al*. 2015) and at background levels (Class I) in 2013 (Ruus *et al*. 2014). Blue mussel from the Inner Oslofjord was insignificantly polluted with Cr in 2006 to 2013 (Berge 2014). Mussel was insignificantly polluted with Cr at five stations at Langøya in the Holmestrandfjord in 2015 (Gitmark *et al*. 2016). Mussels in the Kristiansandsfjord were at background levels of Cr in 2015 (Schøyen *et al*. 2016).

Cod liver from the Inner Oslofjord revealed a concentration of 0.06 mg/kg Cr (w.w.). Cod liver from a comparable study in Inner Oslofjord in 2015 had lower concentrations (0.019 mg/kg Cr w.w.) (Ruus et *al*. 2016b).

General, large scale trends

Emissions of Cr to air and discharges to water from land-based industries are shown in ***Figure 20***.

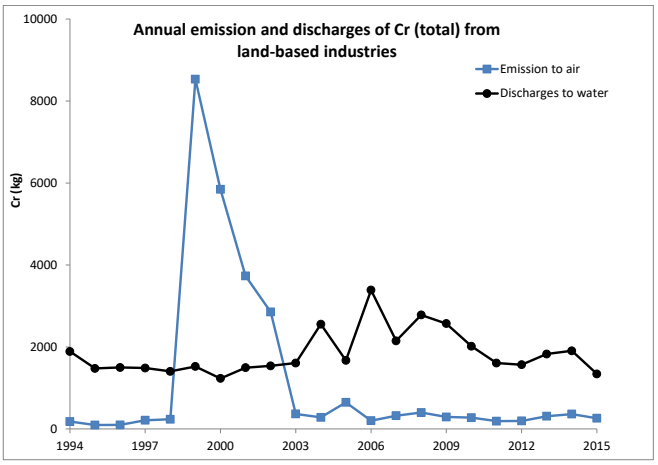


Figure 20. *Annual emissions of Cr to air and discharges to water from land-based industries in the period 1994-2015 (data from www.norskeutslipp.no, 27 October 2016). Note that emissions and discharges from municipal treatment plants, land runoff, transportation and offshore industry are not accounted for in the figure. New calculation methods for data of emissions and discharges might lead to changes in calculations of present and previous data.*

Total riverine input of Cr in Norway has been 70 tonnes in 2014 (Skarbøvik *et al.* 2015). The ranges of total riverine inputs of Cr were 26 tonnes to Skagerrak, 11 tonnes to the North sea and 33.4 tonnes to the Norwegian and Barents sea. There was a decrease for total riverine inputs in the period 1990-2014. Total Cr load dropped 36 % to 70 tonnes in 2015 compared to the mean for the period 1990-2013 (110 tonnes). In addition to riverine inputs, comes the contribution by direct discharges from industrial effluents amounting to 2.48 tonnes or about 3 % of the total (72 tonnes). The riverine input to the Inner Oslofjord from Alna river was 0.063 kg Cr (upper average) in 2015. VEAS sewage treatment plant reported a discharge of 78 kg Cr in 2015 (VEAS 2016).

3.2.10 Cobalt (Co)

Cobalt (Co) was analysed in cod liver at 16 stations and in blue mussel at 33 stations.

Levels

There is no national classification for Co in blue mussel or cod. The highest concentration in mussel was found at Gressholmen (st. 30A, 0.14 mg Co/kg w.w.) and the highest concentration in cod liver was found in the Inner Oslofjord (st. 30B, 0.092 mg Co/kg w.w.).

Upward trends

Both significant upward long-term and short-term trends were observed in blue mussel at Bjørnebærviken (st. I969) in the Ranfjord.

Downward trends

Both significant downward long-term and short-term trends were observed in blue mussel at Risøy (st. 76A). A significant downward long-term trend was also observed at Ranaskjær (st. 63A) in the Hardangerfjord.

General, large scale trends

Discharges of Co to water from land-based industries showed decreasing values from 2011 (754 kg Co/year) to 2015 (501 kg Co/year) (***Figure 21***).

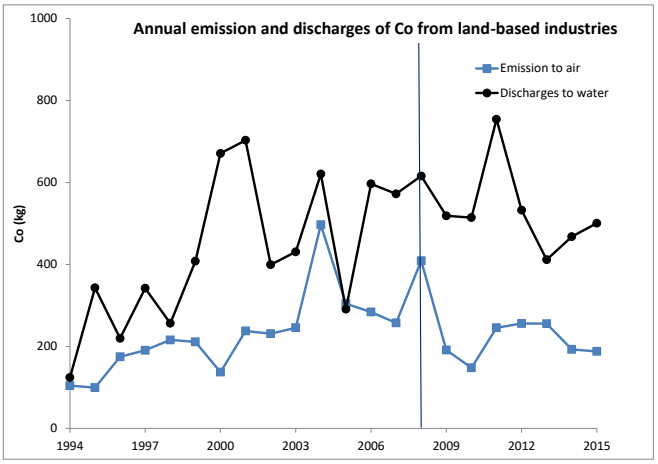


Figure 21. *Annual emissions of Co to air and discharges to water from land-based industries in the period 1994-2015 (data from www.norskeutslipp.no, 27 October 2016). The vertical grey line at 2005 marks when the MILKYS-measurements started. Note that emissions and discharges from municipal treatment plants, land runoff, transportation and offshore industry are not accounted for in the figure. New calculation methods for data of emissions and discharges might lead to changes in calculations of present and previous data.*

3.2.11 Tributyltin (TBT)

Tributyltin (TBT) was analysed in blue mussel and dog whelk (*Nucella lapillus*) at eight stations and in common periwinkle (*Littorina littorea*) at one station. Imposex (VDSI) was investigated in *Nucella lapillus* at all eight stations.

Levels and trends of TBT in blue mussel

Blue mussel at Akershuskaia (st. I301) and Gressholmen (st. 30A) in the Inner Oslofjord were moderately (Class II) polluted by TBT in 2015, but were at background levels (Class I) in 2014. There were no changes in TBT-trends in mussels from 2014 to 2015, except for no significant short-term trend at Færder (st. 36A) in 2015 while a significant downward short-term trend was found in 2014.

There were both significant downward long-term and short-term trends of TBT in mussel from Akershuskaia (st. I301) and Gressholmen (st. 30A) in the Inner Oslofjord, at Odderøy (st. I133) in the Kristiansandsfjord, and at Espevær (st. 22A) on the west coast.

A significant downward long-term trend was observed at Færder (st. 36A). At Gåsøya (st. I304), Solbergstrand (st. 31A) and Tjøme (st. 36A1), there were insufficient data to do temporal trend analysis.

Concentrations and trends of TBT in dog whelk

There is no national classification for TBT-concentrations in dog whelk. The highest organotin level was found at Melandsholmen close to Haugesund (6.28 µg/kg w.w.) on the west coast of Norway. There were no changes in TBT-trends in gastropods from 2014 to 2015.

There were both significant downward long-term and short-term trends at Færder (st. 36G), Melandsholmen (st. 227G1) and Espevær (st. 22G). At Risøy (st. 76G), Gåsøy (st. 15G), Lastad (st. 131G), Svolvær (st. 98G) and Brashavn (st. 11G), TBT-data was inadequate for trend analysis due to concerns about the limit of quantifications.

Concentrations and trends of TBT in common periwinkle

There were no significant trends of TBT at Fugløyskjær in the Grenland area in 2015, as in 2014. The TBT-concentration was <1.2 µg/kg (w.w.).

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

The effects of TBT were low (VDSI<0.828) at all stations investigated in 2015. There were no changes from 2014 to 2015. There were significant downward long-term trends at all stations, except for at Brashavn where no trends were observed. It can be noted that VDSI-values at this location have been low during the whole monitoring period since 2002. No effects (VDSI=0) were found at Færder, Lastad, Gåsøy and Brashavn in 2015. These results, including Risøy (VDSI=0.061), Espevær (VDSI=0.036) and Lofoten (VDSI=0.077) were below the OSPARs Background Assessment Criteria (BAC=0.3, OSPAR 2009). The VDSI at Melandsholmen had increased from 0.448 in 2014 to 0.828 in 2015. These results were over BAC but below the OSPARs Ecotoxicological Assessment Criteria (EAC=2, OSPAR 2013).

Other studies

Mussel was insignificantly polluted with TBT at four stations at Langøya in the Holmestrandfjord in 2015 (Gitmark *et al*. 2016).

General, large scale trends

The results show that the Norwegian legislation banning application of organotin on ships shorter than 25 meters in 1990 and longer than 25 meters in 2003/2008, has been effective in reducing imposex in dog whelk populations. Some of the previously effected snail populations have also re-established. The international convention that was initiated by the International Maritime Organization (IMO) did not only ban application of organotin on ships after 2003 but also stated that organotin 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 22*** and ***Figure 23***). The exceptions being for VDSI for snails from Varangerfjord where 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 24***.

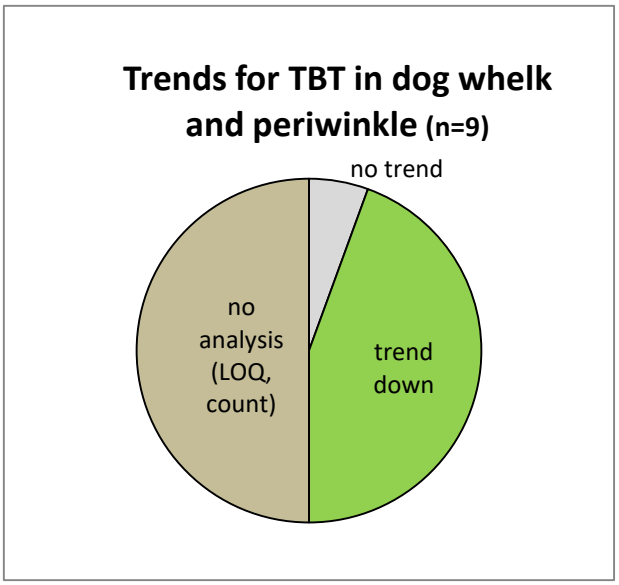


Figure 22. *Frequency of trends for TBT in dog whelk (n=8) and periwinkle (n=1) (1991-2015). No upward trends were detected. Concerns about LOQ prevented some trend analyses.*

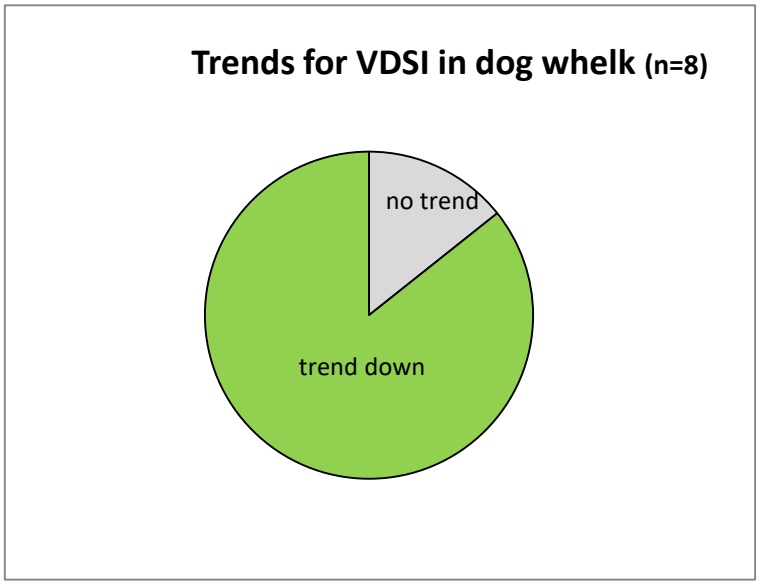


Figure 23. *Frequency of trends for VDSI in dog whelk (n=8) (1991-2015). No upward trends were detected.*

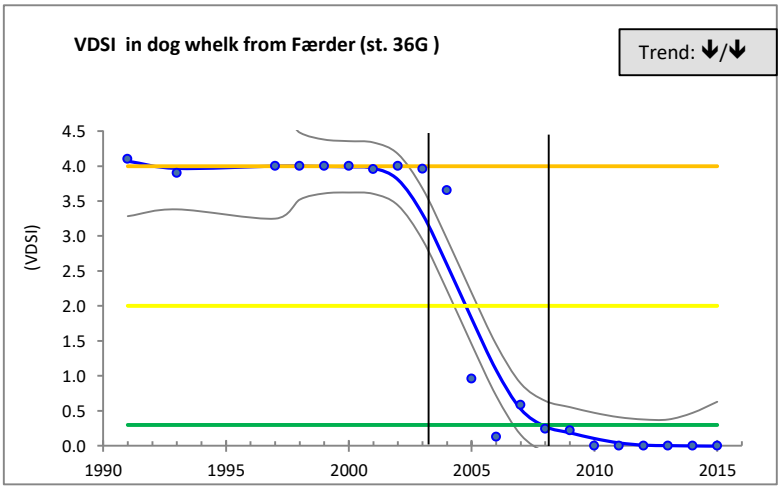


Figure 24. *Changes in VDSI for dog whelk from Færder (st. 36G) (1991-2015). The vertical black lines indicate the initial ban of TBT in 2003 and total ban in 2008. The horizontal lines indicate OSPAR classes (see* ***Table 30*** *in* **Appendix C***). The green line indicates OSPAR Background Assessment Criteria (BAC = 0.3), the yellow line indicates the OSPAR Ecotoxicological Assessment Criteria (EAC = 2) and the orange line indicates that the population of snails is impacted because of reduced reproductivity.*

Discharges of tributyltin and trifenyltin to water from land-based industries from 1997 to 2015 is shown in ***Figure 25***, but do not adequately reflect loads to the marine environment in that this does not include discharges from maritime activities for this period. The values were high in 2003 (487 g tributyltin and trifenyltin/year) and 2009 (504 g tributyltin and trifenyltin/year).

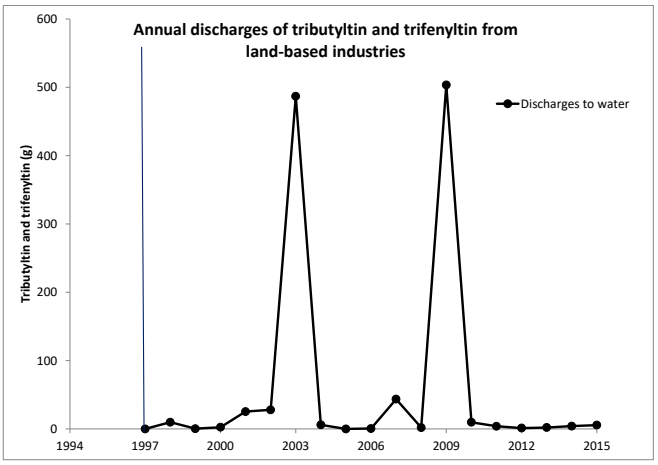


Figure 25. *Annual discharges of tributyltin and trifenyltin to water from land-based industries in the period 1997-2014 (data from www.norskeutslipp.no, 27 October 2016). The vertical grey line at 1997 marks when the MILKYS-measurements started. Note that emissions and discharges from municipal treatment plants, land runoff, transportation and offshore industry are not accounted for in the figure. New calculation methods for data of discharges might lead to changes in calculations of present and previous data.*

National quality standard for EU-priority substances

Norway has provided a quality standard for TBT of 150 μg/kg w.w. in shellfish/fish (Arp *et. al*. 2014). There were no exceedances of this quality standard when applied on the concentrations observed in blue mussel in 2015.

If the national quality standard was applied to all the blue mussel data, including historical data, from stations presumed to be less impacted by contamination, 4.1 % of the medians would have exceeded the limit (cf. Arp *et al*. 2014) compared to 5.1 % that would have exceeded Class II (see Chapter 3.7, ***Figure 52***).

3.2.12 Polychlorinated biphenyls (PCB-7)

Polychlorinated biphenyls (defined here as PCB-7, see ***Table 4***) are a group of chlorinated organic compounds that previously had a broad industrial and commercial application. PCB-7 was analysed in cod liver at 15 stations and in blue mussel at 33 stations. Note that in the previous report (Green *et al.* 2015) assessment of this contaminant in blue mussel was erroneously based on an upper limit for Class I as 4 µg/kg w.w. instead of 3 µg/kg w.w. as suggested in Appendix C (see also Chapter 3.1).

Important levels exceeding Class I

Mussels from Akershuskaia (st. I301) and Gressholmen (st. 30A) in the Inner Oslofjord, Odderøy (st. I133) in the Kristiansandsfjord and Nordnes (st. I241) in Bergen were moderately polluted (Class II) in 2015.

Cod liver from the Inner Oslofjord (st. 30B) (***Figure 26***) was markedly polluted (Class III) with PCB-7, as in most years during the observation period. Cod liver from Kristiansand harbour (st. 13B), Bergen harbour (st. 24B) and Ålesund (st. 28B) were moderately polluted (Class II).

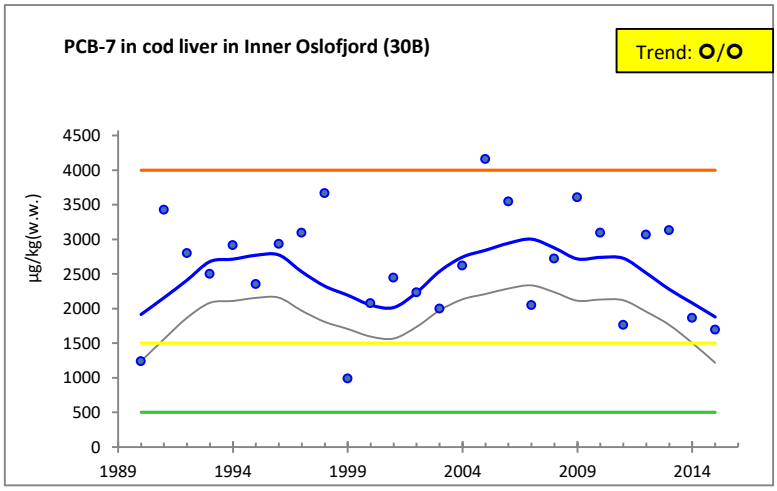


Figure 26. *Median concentrations (mg/kg w.w.) of PCB-7 in cod liver from 1990 to 2015 in the Inner Oslofjord (st. 30B).*

Class increased since 2014

PCB-concentrations in blue mussel at Odderøy (st. I133) was at background levels (Class I) in 2014, but was moderately polluted (Class II) in 2015.

Upward trends

There were significant upward short-term trends for PCB-7 in blue mussel at Odderøy (st. I133A) in the Kristiansandsfjord and Ranaskjær (st. 63A) in the Hardangerfjord.

No upward trends for PCB-7 were found in cod liver.

Class decreased since 2014

Blue mussel in the Outer Trondheimsfjord (st. 91A2) was moderately polluted (Class II) in 2015 but was insignificantly polluted (Class I) in 2014.

Downward trends/low levels
For blue mussel, there were significant downward long-term trends at 19 of the 33 stations (***Table 11***). In addition, a significant downward short-term trend was observed in mussel at Gåsøya (st. I304) in the Inner Oslofjord.

There were both significant downward long-term and short-term trends for PCB-7 in cod liver from the Inner Trondheimsfjord (st. 80B). Significant downward long-term trends were observed in cod at Farsund (st. 15B), Bømlo (st. 23B) and in the Varangerfjord (st. 10B).

Inner Oslofjord
Cod liver caught at 100 m depth in the Inner Oslofjord (st. 30B) was markedly polluted while blue mussel from Akershuskaia (st. I301) and Gressholmen (st. 30A) were moderately polluted with ΣPCB-7. Mussel at other stations in the Oslofjord like Gåsøya, Ramtonholmen, Håøya, Solbergstrand, Mølen and Tjøme were insignificantly polluted with ΣPCB-7.

Other studies
Cod liver from the Inner Oslofjord revealed a concentration of 1693 μg ΣPCB-7/kg (w.w.). Cod liver from a comparable study in Inner Oslofjord in 2015 had higher concentrations (3321.9 mg ΣPCB-7/kg w.w.) (Ruus *et al*. 2016b). The high concentrations of ΣPCB-7 in cod liver from the Inner Oslofjord during the last years have been confirmed in another study which showed that cod liver from Bekkelaget and Frognerkilen was markedly to severely polluted (Class III-IV) with 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 when results were normalised to lipid content.

Monitoring of blue mussel in the Inner Oslofjord showed that mussels were up to markedly polluted with 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). Blue mussel at all seven stations in the Kristiansandsfjord was insignificantly polluted with PCB-7 in the period 2010 to 2013 (Schøyen *et al*. 2014).

Historical data on entry of PCBs to the Inner Oslofjord is not available. Present entry of PCBs to the fjord has however been calculated to be around 3.3 kg/year (Berge *et al*. 2013b). 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 PCBs observed in cod liver are probably related to these activities both in past and present, as well as reduced water exchange with the Outer fjord.

PCB-concentrations in trout from Mjøsa have varied unsystematically from 2005 to 2014, and no significant trend was detected (Løvik *et al*. 2016).

General, large scale trends
On a national level, the results show that the concentrations of PCBs in general have decreased in both cod and blue mussel over the whole monitoring period and no significant upward trends for PCBs in mussels and cod were observed except for upward short-term trends for PCB-7 in blue mussel at Odderøy and Ranaskjær.

In Norway the use of 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 27***. High emission was reported in 2008 (140 g PCB/year), and the emission was 42 g PCB/year in 2015. The discharges to water had decreased from 14.99 g PCB in 2013 to 3.61 g PCB in 2015 Investigations by Schuster *et al.* (2010) indicate that emissions in the northern Europe have declined during the period 1994-2008 by about 50 %.

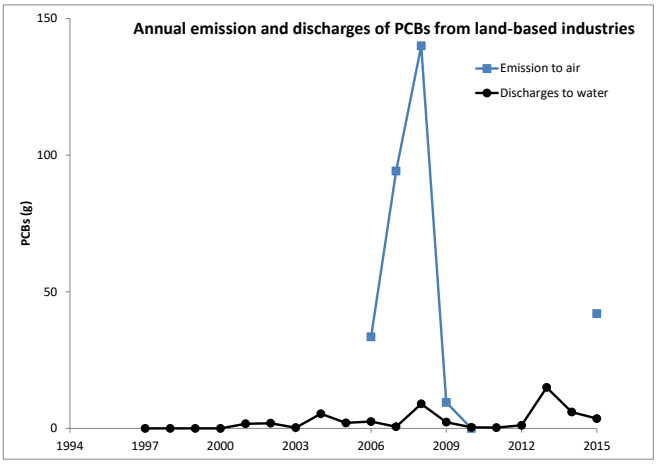


Figure 27. *Annual emissions of PCBs to air and discharges to water from land-based industries in the period 1997-2015 (data from www.norskeutslipp.no, 27 October 2016). No data for emissions to air are reported for 1994-2005 and 2011-2014. No data for discharges to water are reported for 1994-1996. Note that emissions and discharges from municipal treatment plants, land runoff, transportation and offshore industry are not accounted for in the figure. New calculation methods for data of emissions and discharges might lead to changes in calculations of present and previous data.*

If the national quality standard was applied to all the mussel, cod liver and cod fillet data, including historical data, from stations presumed to be less impacted by contamination, over 53 % (100 % for cod liver) of the medians would have exceeded the limit compared to <1 % that would have exceeded Class II (see Chapter 3.7, ***Figure 53***).

3.2.13 Dichlorodiphenyldichloroethylene (ppDDE)

Dichlorodiphenyldichloroethylene (ppDDE) was analysed in cod liver at seven stations and in blue mussel at 21 stations.

Important levels exceeding Class I

Blue mussel at Kvalnes (st. 56A) in the Mid Sørfjord was severely polluted (Class IV), but the concentration had decreased from 30 µg/kg w.w. in 2014 to 17 µg/kg w.w. in 2015 (***Figure 28***) and dropped from Class V to IV. Mussels at Krossanes (st. 57A) and Utne (st. 64A) in the Outer Sørfjord were markedly (Class III) polluted while mussel at Byrkjenes (st. 51A) and Eitrheimsneset (st. 52A) in the Inner Sørfjord and at Vikingneset (st. 65A) in the Hardangerfjord were moderately (Class II) polluted.

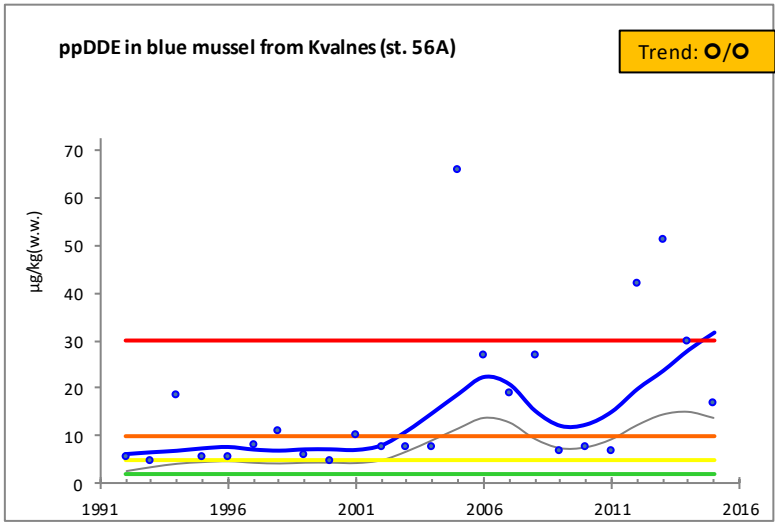


Figure 28. *Median concentrations (mg/kg w.w.) of ppDDE in blue mussel from 1992 to 2015 in the Mid Sørfjord at Kvalnes (st. 56A).*

Cod liver from the Inner Sørfjord (st. 53B) was moderately polluted (Class II) with ppDDE.

Class increased since 2014

Blue mussel at Krossanes and Utne had increased from being moderately polluted in 2014, to being markedly polluted in 2015. Mussel at Byrkjenes, Eitrheimsneset and Vikingneset were at background levels in 2014, while they were moderately polluted in 2015.

Class decreased since 2014

Mussels at Kvalnes was extremely polluted (Class V) with ppDDE in 2014 while they were severely polluted (Class IV) in 2015.

Downward trends/low levels

There was a significant downward long-term trend in blue mussel at Risøy (st. 76A). At Skallneset (st. 10A2) and Brashavn (st. 11X) in the Varangerfjord, data was inadequate for long-term trend analysis due to concerns about the limit of quantifications.

Both significant downward long-term and short-term trends for ppDDE were found in cod liver from Farsund (st. 15B), Bømlo (st. 23B) and in the Varangerfjord (st. 10B). Significant downward long-term trends were observed in cod liver from the Inner Oslofjord (st. 30B) and Færder (st. 36B).

Other studies, Inner Oslofjord
Monitoring in the Inner Oslofjord showed that blue mussel was up to moderately polluted (Class II) with ΣDDE+DDD in 2013 (Berge 2014).

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).

Other studies, Sørfjord
In the Outer Sørfjord, blue mussel from Krossanes (st. 57A) had concentration of 5.8 μg/kg ppDDE (w.w.) and mussels from Utne (st. 64A), on the opposite side of the fjord, had concentration of 7.8 μg/kg ppDDE (w.w.). Mussels from a comparable study in the Sørfjord in 2015 had higher concentrations at Krossanes (11.0 μg DDT/kg w.w.) and at Grimo (26.7 μg DDT/kg w.w.), on the opposite side (Ruus *et al*. 2016a).

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 in the Sørfjord was uncertain. Analyses of supplementary stations between Kvalnes and Krossanes in 1999 indicated that there could be local 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, one north of Kvalnes and the second 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.

General, large scale trends

DDT is banned in all countries in Europe, USA and Canada. In Norway, the use of DDT was restricted in 1969 and the last approved use of DDT was discontinued in 1988. However, DDT from landfills and orchards can still be a problem.

If the EQS was applied to all the blue mussel, cod liver and cod fillet data, including historical data, from both stations impacted and stations presumed to be less impacted by contamination, <1 % of the medians would have exceeded the limit and only 4.9 % would have exceeded Class II (see Chapter 3.7, ***Figure 53***).

3.2.14 Polycyclic aromatic hydrocarbons (PAHs)

Polycyclic aromatic hydrocarbons (PAHs)[11] was analysed in blue mussel at 11 stations. The main sources of PAH in coastal waters include discharges from smelting industry and waste incinerators.

Important levels exceeding Class I

Mussels from Akershuskaia (st. I301) in the Inner Oslofjord, and Moholmen (st. I965) and Bjørnebærviken (st. I969) in the Ranfjord were moderately polluted (Class II). All other stations had concentrations of PAHs at background levels.

Class increased since 2014

Mussels at Akershuskaia (st. I301) and Bjørnebærviken (st. I969) were moderately (Class II) polluted in 2015, but were insignificantly (Class I) polluted in 2014.

Downward trends

A significant downward long-term trend was observed at Gressholmen (st. 30A) in the Inner Oslofjord. A significant downward short-term trend was found at Moholmen (st. I965) in the Ranfjord.

Other studies

Monitoring of blue mussel in another study in the Inner Oslofjord showed that mussels were up to markedly polluted with PAH-16 at Rådhuskaia/Pipervika in 2013 (Berge 2014). Mussels at all other stations in the Inner Oslofjord were up to moderately polluted in the period from 2006 to 2013 (Berge 2014).

An investigation at Langøya in the Holmestrandfjord in 2015 documented that mussels were insignificantly polluted with PAHs at four stations (Gitmark *et al*. 2016). Mussels at two stations in the Kristiansandsfjord were moderately polluted with 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.

General, large scale trends

Emissions of PAHs to air and discharges to water from land-based industries from 2012 to 2015 can be seen in ***Figure 29***. In 2015, the emission to air was 76 002 kg PAHs while it was 958 kg in 2014. Most emission of PAHs to air came from Vest-Agder (58 768 kg in 2015), while no data was reported from 1994 to 2014. The discharges to water were 4 853 kg PAHs in 2015 and 14 kg in 2014. In 2015, 2 421 kg PAHs was discharged from Møre and Romsdal and 1 395 kg PAHs from Vest-Agder.

[11] For this report the total is 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 (see **Appendix B**).

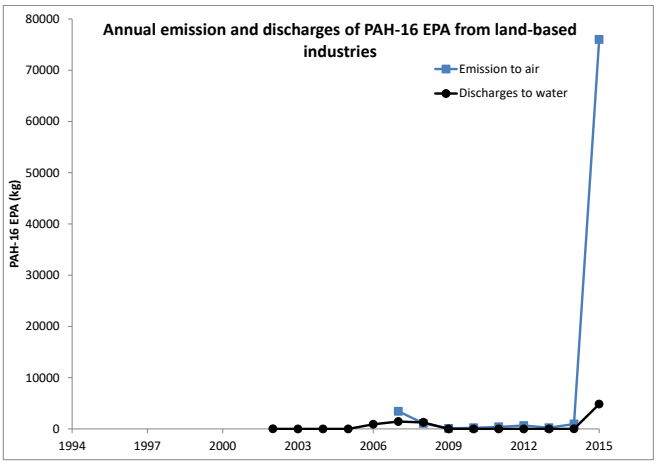


Figure 29. *Annual emissions of PAHs (PAH-16 EPA) to air and discharges to water from land-based industries in the period 2002-2015 (data from www.norskeutslipp.no, 27 October 2016). No data for emissions to air are reported for 1994-2006. No data for discharges to water are reported for 1994-2001. Note that emissions and discharges from municipal treatment plants, land runoff, transportation and offshore industry are not accounted for in the figure. New calculation methods for data of emissions and discharges might lead to changes in calculations of present and previous data.*

Environmental Quality Standards (EQS) for EU-priority substances

The EQS (2013/39/EC) for fluoranthene (30 µg/kg w.w.) in biota for "molluscs" was not exceeded in any of the mussel samples (see **Table 12**).

Another recent survey showed that blue mussel exceeded EQS for fluoranthene at Toraneskaia, but not at Bjørnebærviken or Moholmen in the Ranfjord 2015 (Øxnevad *et al.* 2016). Blue mussel was below EQS for fluoranthene at Svensholmen in the Kristiansandsfjord (Håvardstun and Næs 2016).

3.2.15 Sum carcinogenic polycyclic aromatic hydrocarbons (KPAHs)

Sum carcinogenic polycyclic aromatic hydrocarbons (KPAHs) was analysed in blue mussel at 11 stations.

Important levels exceeding Class I

The concentrations level of the potentially most carcinogenic PAHs (KPAHs, cf. **Appendix B**) in blue mussel was classified as moderately polluted (Class II) at Moholmen (st. I965) in the Ranfjord.

Downward trends

Both significant long-term and short-term trends were found in blue mussel at Moholmen (st. I965) in the Ranfjord. Significant downward short-term trends were observed in mussel from Akershuskaia (st. I301) in the Inner Oslofjord and at Bjørnebærviken (st. I969) in the Ranfjord.

Other studies

Blue mussel from the Inner Oslofjord was found to be severely polluted with 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 were insignificantly polluted with KPAH in 2015 (Gitmark *et al*. 2016). Blue mussel at Odderøy and Svensholmen in the Kristiansandsfjord were markedly polluted with KPAH in 2012 and 2013 (Schøyen *et al*. 2014).

3.2.16 Benzo[a]pyrene (B[a]P)

Benzo[a]pyrene (B[a]P) was analysed in blue mussel at 11 stations.

Important levels exceeding Class I

The highest concentration (0.66 µg/kg w.w.) was found at Moholmen (st. I965) in the Ranfjord where the mussels were moderately polluted (Class II) with B[a]P. All other mussel samples were at background levels (Class I).

Class decreased since 2014

Blue mussel at Gåsøya (st. I304) in the Inner Oslofjord and at Singlekalven (st. I023) in the Hvaler area were at background levels (Class I) in 2015, while they were moderately polluted (Class II) in 2014.

Downward trends

Both significant long-term and short-term trends were found in blue mussel at Moholmen (st. I965) in the Ranfjord. Significant downward short-term trends were observed in mussel from Bjørnebærviken (st. I969). At three stations, data was inadequate for trend analysis.

Other studies

A previous study of blue mussel in the Inner Oslofjord showed that mussels were severely polluted with B[a]P at Rådhuskaia/Pipervika in 2013 (Berge 2014). Mussels from Langøya in the Holmestrandfjord in 2015 were insignificantly polluted with B[a]P (Gitmark *et al*. 2016).

Environmental Quality Standards (EQS) for EU-priority substances

The EQS (2013/39/EC) for B[a]P is 5 µg/kg w.w. in biota (biota EQS relate to fish). Applying this EQS for blue mussel, all concentrations of B[a]P were below the EQS applied for biota/fish (see **Table 12**).

Another recent survey due to operational monitoring in compliance with the EU Water Framework Directive showed that blue mussel exceeded EQS for B[a]P at Toraneskaia, but not at Bjørnebærviken or Moholmen in the Ranfjord 2015 (Øxnevad *et al*. 2016). Blue mussel was below EQS at Svensholmen in the Kristiansandsfjord (Håvardstun and Næs 2016).

If the EQS was applied to all the blue mussel data, including historical data, from stations presumed to be less impacted by contamination, 4.5 % of the medians would have exceeded the limit, whereas 30.5 % would have exceeded Class II (see Chapter 3.7, ***Figure 55***).

3.2.17 Polybrominated diphenyl ethers (PBDEs)

Polybrominated diphenyl ethers (PBDEs) are a group of brominated flame retardants used in a variety of products. PBDEs were in 2015 analysed in cod liver at 10 stations and in blue mussel at 11 stations.

Levels of cod liver

The tetrabromodiphenyl ether BDE47 was the dominant congener in cod liver and the concentration was highest in the Inner Oslofjord (st. 30B, 14.5 µg/kg w.w.) (***Figure 30***). The lowest BDE47-concentration in liver was found in cod from Bømlo (st. 23B, 0.93 µg/kg w.w.).

All data for BDE126 and -196 were below the limit of quantifications in 2015.

Upward trends

Of all PBDEs, significant short-term upward trends were found at Bømlo (st. 23B) for BDE154.

Downward trends

Both significant downward long-term and short-term trends were found in cod liver from the Inner Oslofjord (st. 30B) for BDE28, -47, -99 and -100. This was also the result at Kristiansand harbour (st. 13B) for BDE28 and at Bømlo (st. 23B) for BDE47. This was also the case at Tromsø harbour (st. 43B2) for BDE47 and -99.

Significant downward long-term trends were found at Færder (st. 23B) for BDE-47, and at Bømlo (st. 23B) for BDE28 and-100.

Statistical considerations

The standard deviation varied considerably among stations, also for other PBDEs. The highest deviation was found in Bergen harbour (st. 24B) for BDE47 (***Table 13***). In 2014, the highest deviations were found at in the Inner Trondheimsfjord (st. 80B) for BDE47 and -100. It seems like the deviations were highest in affected areas.

In the urban areas like Oslo and Trondheim harbour, some of the BDE-congeners in cod liver had significantly higher levels than in remote areas like Færder and Bømlo (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 PBDEs in 1993, 1996 and 2001 (***Figure 31***). Samples for similar analyses were also collected from the Færder area (st. 36B) in 1993 and 1996, and from Bømlo (st. 23B) on the west coast in 1996 and 2001. In 2015, PBDEs were analysed in cod from 10 stations (***Table 13***). Of the PBDEs, only congeners BDE28, -47, -99, -100 and -154 were over the quantification limit in at least half of the samples from each station.

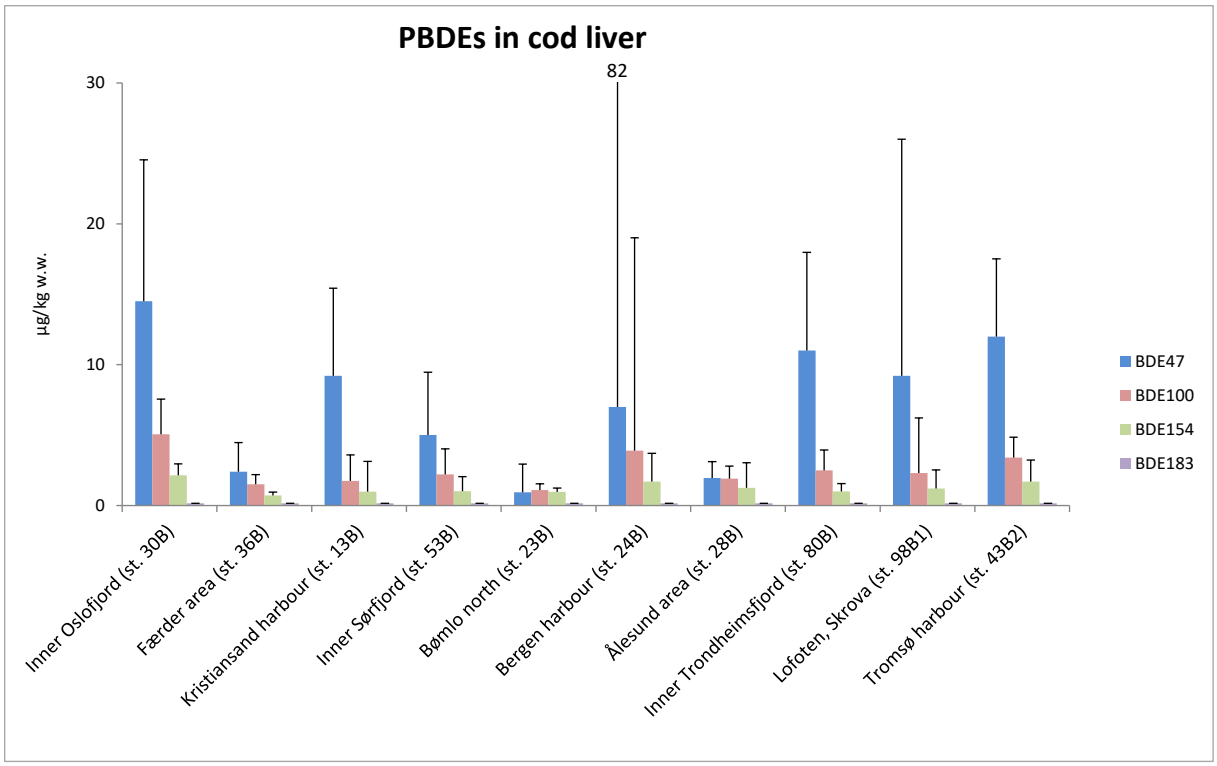


***Figure 30**. Median concentrations (µg/kg w.w.) of PBDEs in cod liver in 2015. Only the results are shown where concentrations were above the quantification limit for half or more of the samples. The error bar indicates one standard deviation above the median.*

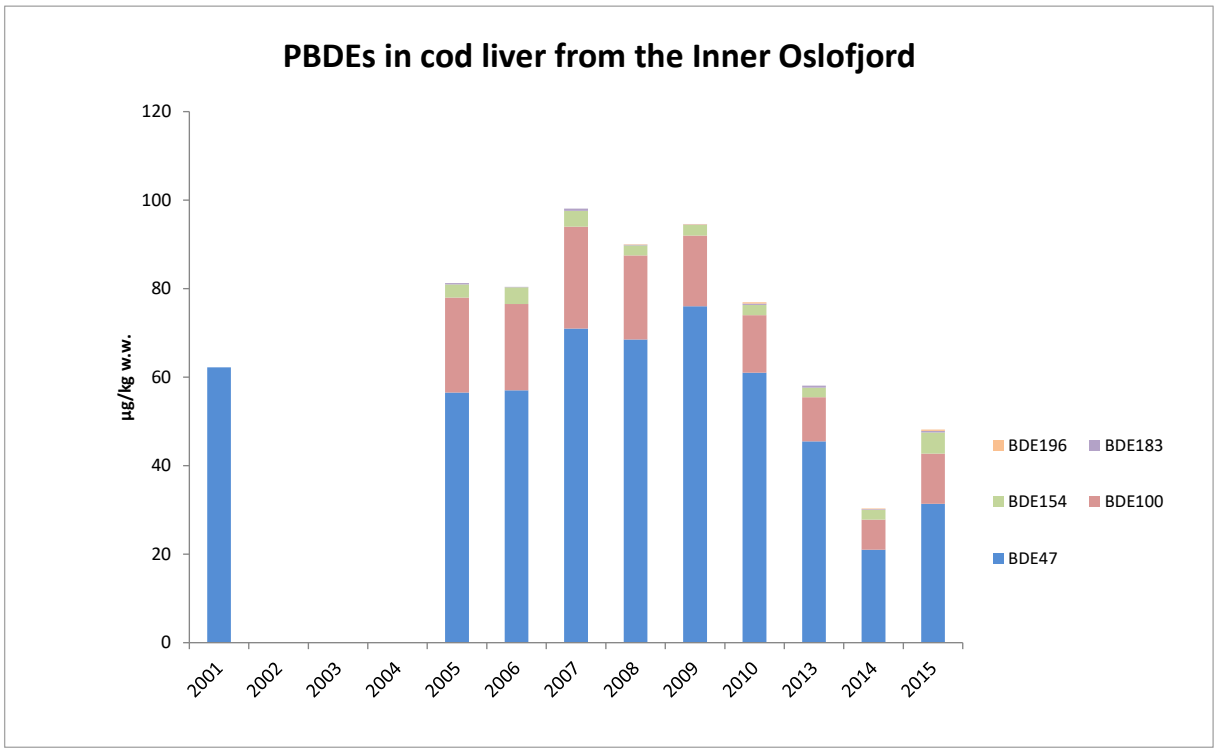


***Figure 31**. Median concentrations (µg/kg w.w.) of PBDEs in cod liver from 2001 to 2015 in the Inner Oslofjord (st. 30B).*

***Table 13**. Median concentrations (µg/kg w.w.) and standard deviations for PBDE congeners in blue mussel and cod liver in 2015. 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 the maximum number of individuals used in one of the pooled samples. Shaded cells indicate that the median was the limit of quantification (LOQ) and value shown in these cells is one half of this limit. The standard deviation (S.d.) is based on all values and where values below the LOQ are taken as half. Detectable data information (D.d.i.) indicates the number of data above the LOQ (if any) and the numbers within the square brackets indicate the minimum and maximum values in this category. BDE6S is the sum of BDE -28, -47, -99, -100, -153 and -154 as used in the EQS (see **Table 7**, see also Chapter 2.8 for more details and Appendix B for description of chemical codes.)*

Component	Count	BDE28			BDE47			BDE99			BDE100			BDE126			BDE153		
Species and sampling locality	2015	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																			
Tjøme (st. 36A1)	3(3-50)	0.004	0.000		0.036	0.001	3[0.034 - 0.037]	0.009	0.002	1[0.019]	0.009	0.001		0.009	0.001		0.013	0.001	
Færder (st. 36A)	1(1-100)	0.004	0.000		0.050	0.000	1[0.05]	0.027	0.000	1[0.027]	0.009	0.000		0.009	0.000		0.014	0.000	
Singlekalven (st. I023)	3(3-120)	0.002	0.003	2[0.002 - 0.006]	0.041	0.004	3[0.034 - 0.042]	0.025	0.004	3[0.02 - 0.026]	0.011	0.000	3[0.011 - 0.012]	0.002	0.000		0.002	0.000	
Bjørkøya (st. 71A)	3(3-70)	0.001	0.000	3[0.001 - 0.002]	0.035	0.002	3[0.034 - 0.038]	0.019	0.001	3[0.018 - 0.021]	0.011	0.001	3[0.01 - 0.011]	0.001	0.000		0.002	0.000	
Croftholmen (st. I712)	3(3-80)	0.002	0.000	3[0.002 - 0.003]	0.052	0.004	3[0.046 - 0.054]	0.031	0.002	3[0.027 - 0.031]	0.017	0.001	3[0.015 - 0.017]	0.001	0.000		0.001	0.000	1[0.003]
Brevik church (st. I714)	3(3-20)	0.001	0.000	1[0.001]	0.043	0.001	3[0.042 - 0.044]	0.019	0.003	3[0.016 - 0.021]	0.015	0.000	3[0.014 - 0.015]	0.001	0.000		0.001	0.000	
Nordnes (st. I241)	3(3-30)	0.006	0.000	3[0.006 - 0.007]	0.216	0.007	3[0.207 - 0.22]	0.146	0.010	3[0.129 - 0.147]	0.056	0.002	3[0.054 - 0.059]	0.001	0.000		0.018	0.002	3[0.016 - 0.019]
Måløy (st. 26A2)	3(3-58)	0.002	0.000	3[0.001 - 0.002]	0.031	0.000	3[0.031 - 0.032]	0.013	0.001	3[0.012 - 0.014]	0.009	0.000	3[0.009 - 0.01]	0.001	0.000		0.001	0.000	
Outer Trondheimsfjord (st. 91A2)	3(3-74)	0.002	0.000	3[0.002 - 0.002]	0.032	0.001	3[0.03 - 0.033]	0.010	0.000	3[0.009 - 0.01]	0.009	0.000	3[0.009 - 0.009]	0.001	0.000		0.002	0.000	
Bodø harbour (st. 97A2)	3(3-120)	0.001	0.000	2[0.001 - 0.001]	0.046	0.005	3[0.039 - 0.048]	0.024	0.002	3[0.021 - 0.024]	0.018	0.002	3[0.016 - 0.018]	0.001	0.000		0.002	0.000	
Lofoten, Svolvær (st. 98A2)	3(3-120)	0.000	0.000	1[0.001]	0.015	0.001	3[0.014 - 0.017]	0.003	0.000	3[0.003 - 0.003]	0.005	0.000	3[0.004 - 0.005]	0.001	0.000		0.001	0.000	
Cod, liver																			
Inner Oslofjord (st. 30B)	12(11-3)	0.230	0.101	11[0.11 - 0.42]	14.500	10.040	12[4.8 - 44]	0.105	0.338	6[0.11 - 1]	5.050	2.504	12[1.9 - 10]	0.050	0.000		0.050	0.000	
Færder area (st. 36B)	15(9-2)	0.050	0.209	7[0.1 - 0.91]	2.400	2.065	14[0.84 - 6.8]	0.050	0.036	2[0.18 - 0.22]	1.500	0.691	15[0.34 - 2.6]	0.050	0.000		0.050	0.000	
Kristiansand harbour (st. 13B)	14(10-3)	0.210	0.242	13[0.11 - 0.91]	9.200	6.226	14[0.25 - 25]	0.315	0.168	11[0.14 - 0.7]	1.750	1.842	14[0.74 - 6.8]	0.050	0.000		0.050	0.000	
Inner Sørfjord (st. 53B)	14(4-5)	0.215	0.216	9[0.16 - 0.74]	5.000	4.461	14[0.31 - 15]	0.050	0.321	2[0.31 - 1.3]	2.200	1.821	14[0.17 - 6.3]	0.050	0.000		0.050	0.000	
Bømlo north (st. 23B)	15	0.390	0.192	14[0.12 - 0.7]	0.930	2.005	15[0.41 - 8]	0.050	0.039	1[0.25]	1.100	0.432	15[0.79 - 2.5]	0.050	0.000		0.050	0.000	
Bergen harbour (st. 24B)	15(2-2)	1.300	2.831	15[0.51 - 12]	7.000	40.179	15[3.9 - 160]	0.260	0.286	12[0.14 - 1.1]	3.900	15.111	15[1.7 - 60]	0.050	0.000		0.050	0.000	
Ålesund area (st. 28B)	6	0.570	0.428	5[0.2 - 1.3]	1.950	1.168	6[0.14 - 3.4]	0.205	0.114	4[0.16 - 0.38]	1.900	0.901	6[0.15 - 2.4]	0.050	0.000		0.050	0.000	
Inner Trondheimsfjord (st. 80B)	15	0.430	0.236	14[0.2 - 0.91]	11.000	6.978	14[3.3 - 29]	0.050	0.124	4[0.17 - 0.54]	2.500	1.435	14[1.7 - 6.3]	0.050	0.000		0.050	0.000	
Lofoten, Skrova (st. 98B1)	15	0.340	0.366	13[0.18 - 1.5]	9.200	16.812	15[2.7 - 72]	2.200	2.028	14[0.15 - 7.9]	2.300	3.922	15[1.1 - 17]	0.050	0.000		0.050	0.000	
Tromsø harbour (st. 43B2)	13(2-2)	0.360	0.159	12[0.11 - 0.63]	12.000	5.513	13[5.7 - 24]	0.130	0.355	8[0.13 - 1.3]	3.400	1.444	13[1.3 - 5.9]	0.050	0.036	1[0.23]	0.050	0.017	1[0.16]

Table 13. *(cont.)*

Component	Count	BDE154			BDE183			BDE196			BDE209			BDE6S			BDESS		
Species and sampling locality	2015	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																			
Tjøme (st. 36A1)	3(3-50)	0.013	0.001		0.021	0.002		0.042	0.003		0.415	0.026		0.037	0.011	3[0.034 - 0.055]	0.037	0.011	3[0.034 - 0.055]
Færder (st. 36A)	1(1-100)	0.014	0.000		0.023	0.000		0.045	0.000		0.445	0.000		0.078	0.000	1[0.078 - 0.078]	0.078	0.000	1[0.078 - 0.078]
Singlekalven (st. I023)	3(3-120)	0.002	0.000		0.004	0.001		0.008	0.002		0.369	0.516	3[0.239 - 1.19]	0.082	0.010	3[0.065 - 0.084]	0.451	0.523	3[0.304 - 1.274]
Bjørkøya (st. 71A)	3(3-70)	0.002	0.000		0.003	0.000		0.005	0.001		0.050	0.008		0.067	0.004	3[0.063 - 0.072]	0.067	0.004	3[0.063 - 0.072]
Croftholmen (st. I712)	3(3-80)	0.003	0.000	3[0.003 - 0.003]	0.002	0.000		0.005	0.000		0.246	0.062	3[0.147 - 0.26]	0.108	0.009	3[0.094 - 0.109]	0.354	0.057	3[0.255 - 0.355]
Brevik church (st. I714)	3(3-20)	0.001	0.000		0.002	0.001		0.005	0.001		0.049	0.009		0.076	0.004	3[0.072 - 0.08]	0.076	0.004	3[0.072 - 0.08]
Nordnes (st. I241)	3(3-30)	0.016	0.002	3[0.014 - 0.017]	0.016	0.003	3[0.014 - 0.02]	0.007	0.001		0.252	0.069	3[0.251 - 0.371]	0.460	0.022	3[0.426 - 0.467]	0.727	0.083	3[0.696 - 0.853]
Måløy (st. 26A2)	3(3-58)	0.001	0.000		0.002	0.000		0.004	0.001		0.043	0.006		0.055	0.001	3[0.054 - 0.056]	0.055	0.001	3[0.054 - 0.056]
Outer Trondheimsfjord (st. 91A2)	3(3-74)	0.002	0.000		0.003	0.000		0.007	0.001		0.070	0.010		0.052	0.002	3[0.05 - 0.053]	0.052	0.002	3[0.05 - 0.053]
Bodø harbour (st. 97A2)	3(3-120)	0.002	0.000		0.003	0.000		0.005	0.000		0.050	0.000		0.090	0.008	3[0.076 - 0.09]	0.090	0.008	3[0.076 - 0.09]
Lofoten, Svolvær (st. 98A2)	3(3-120)	0.001	0.000		0.002	0.000		0.004	0.000		0.042	0.001		0.022	0.003	3[0.022 - 0.026]	0.022	0.003	3[0.022 - 0.026]
Cod, liver																			
Inner Oslofjord (st. 30B)	12(11-3)	2.150	0.802	12[0.79 - 3.9]	0.150	0.000		0.150	0.000		0.250	0.000		23.635	12.203	12[7.49 - 56.2]	23.635	12.203	12[7.49 - 56.2]
Færder area (st. 36B)	15(9-2)	0.710	0.241	15[0.3 - 1.1]	0.150	0.000		0.150	0.000		0.250	0.000		4.610	2.923	15[0.68 - 10.65]	4.610	2.923	15[0.68 - 10.65]
Kristiansand harbour (st. 13B)	14(10-3)	0.980	2.142	14[0.16 - 8.7]	0.150	0.000		0.150	0.000		0.250	0.000		12.375	10.201	14[1.15 - 41.56]	12.375	10.201	14[1.15 - 41.56]
Inner Sørfjord (st. 53B)	14(4-5)	1.020	1.024	14[0.16 - 3.2]	0.150	0.000		0.150	0.000		0.250	0.213		8.860	7.027	14[0.64 - 23.89]	8.860	7.027	14[0.64 - 23.89]
Bømlo north (st. 23B)	15	0.970	0.258	15[0.7 - 1.5]	0.150	0.000		0.150	0.000		0.250	0.000		3.430	2.550	15[2.49 - 12.86]	3.430	2.550	15[2.49 - 12.86]
Bergen harbour (st. 24B)	15(2-2)	1.700	1.995	15[0.61 - 7.6]	0.150	0.000		0.150	0.000		0.250	0.000		17.180	59.318	15[6.96 - 239.9]	17.180	59.318	15[6.96 - 239.9]
Ålesund area (st. 28B)	6	1.250	1.784	6[0.32 - 5.2]	0.150	0.000		0.150	0.000		0.250	0.000		6.045	4.112	6[0.61 - 12.48]	6.045	4.112	6[0.61 - 12.48]
Inner Trondheimsfjord (st. 80B)	15	1.000	0.552	14[0.72 - 2.4]	0.150	0.000		0.150	0.000		0.250	0.000		14.720	9.025	15[0 - 37.96]	14.720	9.025	15[0 - 37.96]
Lofoten, Skrova (st. 98B1)	15	1.200	1.330	15[0.54 - 6.1]	0.150	0.000		0.150	0.000		0.250	0.000		13.590	24.090	15[5.36 - 104.5]	13.590	24.090	15[5.36 - 104.5]
Tromsø harbour (st. 43B2)	13(2-2)	1.700	1.521	13[0.47 - 5.7]	0.150	0.000		0.150	0.000		0.250	0.000		17.770	7.165	13[9.39 - 32.56]	17.770	7.165	13[9.39 - 32.56]

Levels in blue mussel

Only congeners BDE28, -47, -99 and -100 showed concentrations above the quantification limit for half or more of the samples at all stations (***Table 13***, ***Figure 32***, ***Table 11***).

The most dominant congener in 2015 was BDE47, as was also the case in the previous year. BDE47, - was detected at all stations in 2015, as in 2014. The highest median concentrations were found in mussels from Nordnes (st. I241) in Bergen harbour (0.216 µg BDE47/kg w.w., 0.146 µg BDE99/kg w.w. and 0.056 µg BDE100/kg w.w.).

The highest concentrations of BDE153 (0.018 µg/kg w.w.) and BDE154 (0.016 µg/kg w.w.) were also found at Nordnes close to the centre of Bergen.

Downward trends

Both significant downward long-term and short-term trends were found in cod liver from Lofoten (st. 98A2) for BDE47, -99 and -100, and from Bjørkøya (st. 71A) for BDE47 in mussels.

Statistical considerations

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).

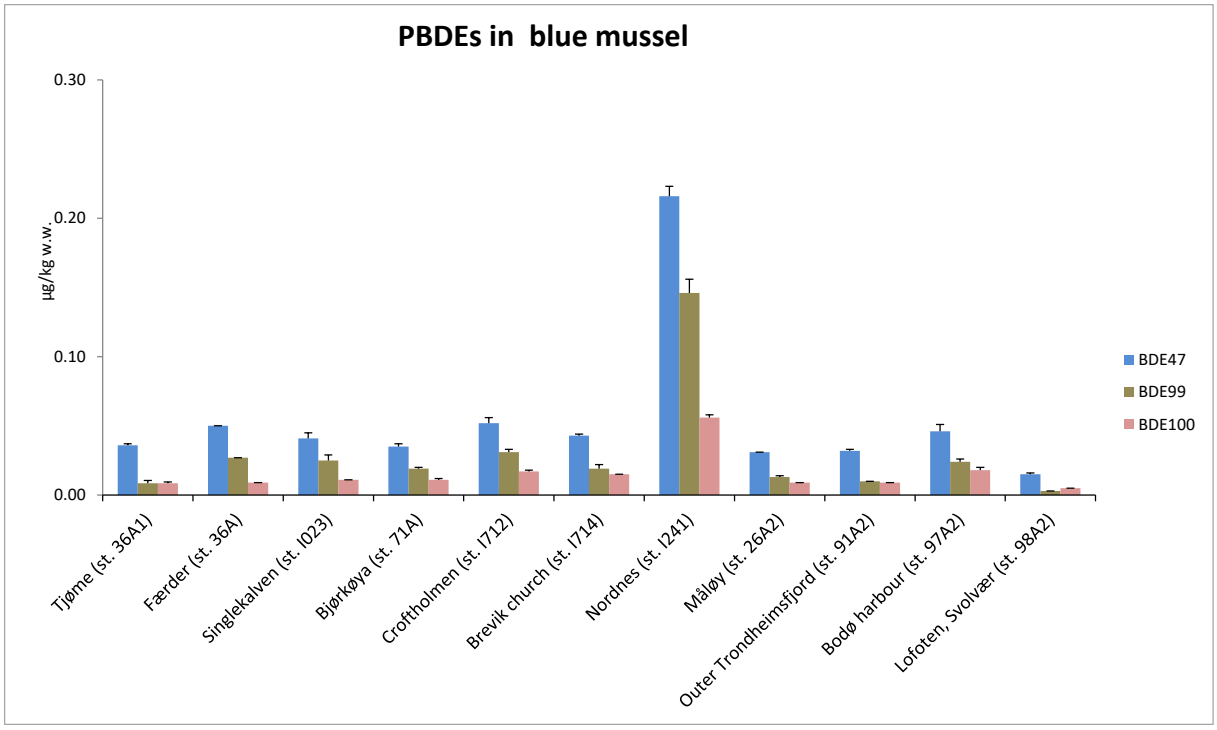


Figure 32*. Median concentrations (µg/kg w.w.) of PBDEs in blue mussel in 2015. Only the results where concentrations were above the quantification limit for half or more of the samples are shown. The error bar indicates one standard deviation above the median.*

Environmental Quality Standards (EQS)

The EQS (2013/39/EC) for polybrominated diphenylethers (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 BDE47 alone in cod liver would have exceeded this EQS value at all stations (see **Table 12**). These results indicate that the EQS might not be a useful criterion to judge the condition of the environment with respect to this contaminant in biota. EQS in blue mussel, cod liver and cod fillet, including historical data, are further discussed in Chapter 3.7.

Inner Oslofjord

Parts of the Inner Oslofjord are densely populated with much urban activities and accompanying PBDEs in certain products. The high concentrations of PBDEs observed in cod are probably related to these activities, as well as reduced water exchange with the Outer fjord.

In the Inner Oslofjord, cod liver showed a concentration of 14.5 µg BDE47/kg (w.w.), while the concentration in a comparable study in 2015 (Ruus *et al.* 2016b) was 20.4 µg BDE47/kg (w.w.). The concentration of BDE100 was 5.05 µg /kg (w.w.) in this study, while it was 8.8 µg/kg (w.w.) in the other study. The concentration of BDE154 was 2.15 µg/kg (w.w.) in this study, while it was 2.5 µg/kg (w.w.) in the comparable study.

A study of flounder liver from the Inner Oslofjord in 2013 (Ruus *et al.* 2014) showed generally substantially lower (e.g. a factor of~35 for BDE47) concentrations than the median concentration measured in cod in 2012 (Ruus *et al.* 2014). 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).

Other studies

Median concentrations for the sum of PBDEs 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 30***) 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.* 2011a) and three cod stations in the Norwegian Sea (5.89, 12.9 and 19 µg/kg w.w.) (Green *et al.* 2012b). It cannot be disregarded that this high background concentration might be too high. The median found in the Inner Oslofjord for sum PBDE/BDEs (31.72 µg/kg w.w.) was for the first time below the interval for sum PBDEs of 37-112 µg/kg w.w. found in other contaminated areas (Fjeld *et al.* 2005, Berge *et al.* 2006). Bakke *et al.* (2007) found mean concentrations of sum of PBDEs 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 in 2015, as in 2013. The low concentrations of BDE99 could be due to the debromination to BDE47, because BDE99 is more suseptable to biotransformation than other common PBDE such as BDE47 (Streets *et al.* 2006). Furthermore, BDE47 is also reported to be a more stable congener than BDE99, (Benedict *et al.* 2007). 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). In recent years, there has been a clear reduction of PBDE-concentrations in freshwater fish from Mjøsa (Løvik *et al.* 2016).

General, large scale trends

There were 10 significant short-term downward trends. In cod liver, this applied for BDE47, -99, and -100 in the Inner Oslofjord (st. 30B), for BDE47 at Bomlo (st. 23B) and for BDE47 and -99 in Tromsø harbour (st. 43B2). In blue mussel, this applied for BDE47 at Bjørkøya (st. 71A) and for BDE47, -99, and -100 in Svolvær in Lofoten.

One significant upward short-term trend for BDE154 was found in cod liver at Bømlo (st. 23B).

There were 13 significant downward long-term trends. In cod liver, this applied for BDE49, -99, -100 and -154 in the Inner Oslofjord (st. 30B), for BDE47 at Færder (st. 36B), for BDE47 and -100 at Bømlo (st. 23B), and for BDE47 and -99 at Tromsø harbour (st. 43B2). In blue mussel, this applied for BDE47 at Bjørkøya (st. 71A), and for BDE47, -99 and-100 at Svolvær in Lofoten (st. 98A2).

These results are more in line with 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). Furthermore, both the penta- and octa PBDE mixtures has been globally regulated through the Stockholm convention since 2009.

3.2.18 Perfluorinated alkylated substances (PFAS)

Perfluorinated alkylated substances (PFAS) are organofluorine compounds used as oil-, stain- and water-repellent surfactants and a number of other products. PFAS were analysed in cod liver at nine stations (***Table 11*** and ***Figure 33***). PFAS have been analysed annually in cod liver since 2005. Samples collected in the Inner Oslofjord (st. 30B) and Bømlo (st. 23B) in 1993 have also been analysed for PFAS.

Levels and trends

PFOS and PFOSA at all stations revealed assumed background concentrations. Significant downward trends for PFOS were dominating in 2015, as in 2014.

PFOS

The median concentration of perfluoroctonoic sulphonate (PFOS) in cod liver was highest in the Inner Oslofjord (st. 30B, 6.5 µg/kg w.w.) and lowest in Bergen harbour (st. 24B, 0.66 µg/kg w.w.) (***Table 14***). The concentration found in the Inner Oslofjord had increased from 5.5 µg/kg (w.w.) in 2014 to 6.5 µg/kg (w.w.) in 2015. At Færder (st. 36B) the concentrations had decreased from 3.2 µg/kg (w.w.) in 2014 to 2.4 µg/kg (w.w.) in 2015. Significant downward trends were identified at six of the nine stations. There were both significant downward long-term and short-term trends for PFOS at Færder (st. 36B), Kristiansand harbour (st. 13B), the Inner Sørfjord (st. 53B) and Tromsø harbour (st. 43B2). Significant downward short-term trends were observed in the Inner Oslofjord (st. 30B) and at Bømlo (st. 23B).

PFOSA

Perfluorooctane sulphonamide (PFOSA) had a maximum median concentration of 9.9 µg/kg (w.w.) in the Inner Oslofjord, and a minimum level at Tromsø harbour (0.4 µg/kg w.w.). The concentration of PFOSA was higher than PFOS in the Inner Oslofjord and Færder (***Figure 33***, ***Figure 34)***. The median concentrations of the remaining PFAS were mostly below the quantification limits (***Table 11***, ***Table 14***).

Cod from the Inner Oslofjord and Outer Oslofjord had significant higher levels of PFOS and PFOSA in liver than all other stations (Tukey-Kramer HSD test, see also ***Figure 33***).

Environmental Quality Standards (EQS) for EU-priority substances

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 liver to whole fish because this conversion is uncertain. If it is assumed, for this exercise, that the same concentration is found in cod liver as in the whole fish, then the results of PFOS would not be exceeded at any station (maximum concentration 6.5 µg/kg w.w. in the Inner Oslofjord).

The EQS for PFOS and the national quality standard for PFOA in blue mussel and cod, including historical data, are further discussed in Chapter 3.7.

Inner Oslofjord

Parts of the Inner Oslofjord are densely populated with much urban activities including presence of PFOSA in certain products. PFOSA is a precursor compounds in the production of fluorinated polymers but may also add to the exposure due to their degradation into PFOS. 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, 2013, 2014 and 2015, PFOSA was the dominating substance (18, 19, 10, 7, 9 and 10 µg/kg w.w., respectively) compared to PFOS (16, 5, 7, 3, 6 and 7 µg/kg w.w., respectively). Schøyen & Kringstad (2011) analysed PFAS in cod blood samples from the same individuals which were analysed in the MILKYS 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).

Other studies

Cod liver from the Inner Oslofjord had concentrations of 6.5 µg PFOS/kg (w.w.) and 9.9 µg PFOSA/kg (w.w.) in 2015. Cod liver from a comparable study in the Inner Oslofjord in 2015 had lower concentrations of both PFOS (3.3 µg/kg w.w.) and PFOSA (4.6 µg/kg w.w.) (Ruus *et al.* 2016b).

Median concentrations of PFOS in cod liver 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.* 2007). All concentrations observed in this study were lower. The average concentration of PFOS in cod liver from two stations in the North Sea was 1.55 and 0.95 µg/kg w.w. (Green *et al.* 2011a) and from three stations in the Norwegian Sea was 0.75, 0.82 and 11 µg/kg w.w. (Green *et al.* 2012b).

PFAS in freshwater fish was investigated in 2015 (Fjeld *et al.* 2016). The concentrations of long-chained compounds, like PFOS and PFOSA, increased with trophic levels with the highest levels in brown trout (*Salmo trutta*) liver. The mean PFOS-concentrations in fish liver from the three main lakes (Mjøsa, Randsfjorden and Femunden) were in the range of 2–12 µg/kg w.w. The PFOS-levels were considerably elevated in perch (*Perca fluviatilis*) liver from Tyrifjorden and Vansjø with mean concentrations of 183 and 346 µg/kg w.w., respectively. Concentrations of PFOS in liver varied considerably but were on the average about 25 times higher than in fillet. The differences between fillet and liver concentrations seemed to increase with decreasing carbon chain length.

PFOA has been strictly regulated nationally in consumer products from June 2014[12]. PFOA-data at all stations was inadequate for trend analysis due to concerns about the limit of quantifications.

General, large scale trends

Six of the nine stations showed significant downward short-term trends in PFOS for the period 2006-2015. Significant downward trends for PFOS were also dominating in 2013 and 2014, unlike the previous year (2012) when no trends were observed. The observed downward trends could reflect the overall reduction in production and use of PFAS for the past 30 years (Nost *et al.* 2014, Axmon *et al.* 2014). It is however unclear why downward trends were not seen in 2012. A decrease in concentrations of PFAS in Sweden has been reported for food items (Johansson *et al.* 2014) and

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

herring (Ullah *et al*. 2014). A sharp decline in concentrations of PFAS (as well as PBDEs) after 2002 was found in dried blood spots from newborns in New York state (Ma *et al*. 2013).

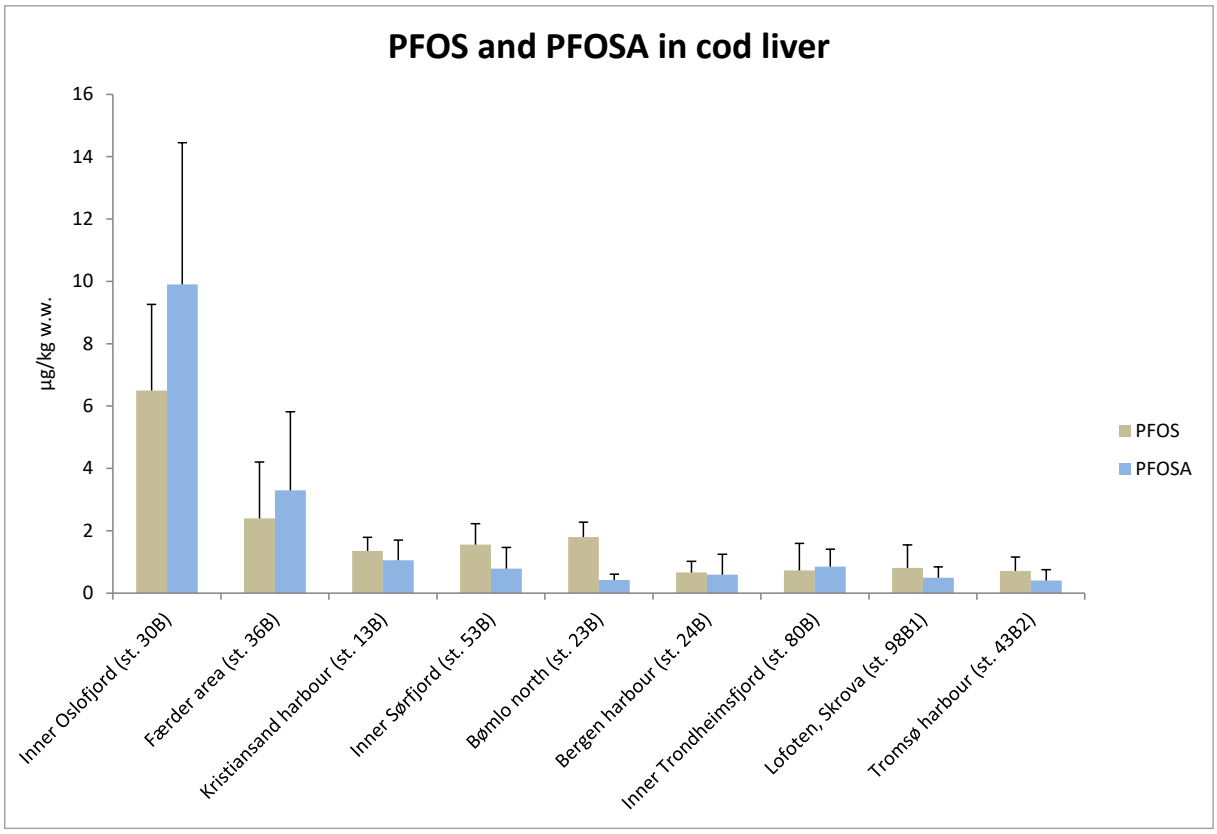


***Figure 33**. Median concentrations (µg/kg w.w.) of two PFAS compounds in cod liver in 2015. The error bar indicates one standard deviation above the median. (See also **Table 14**).*

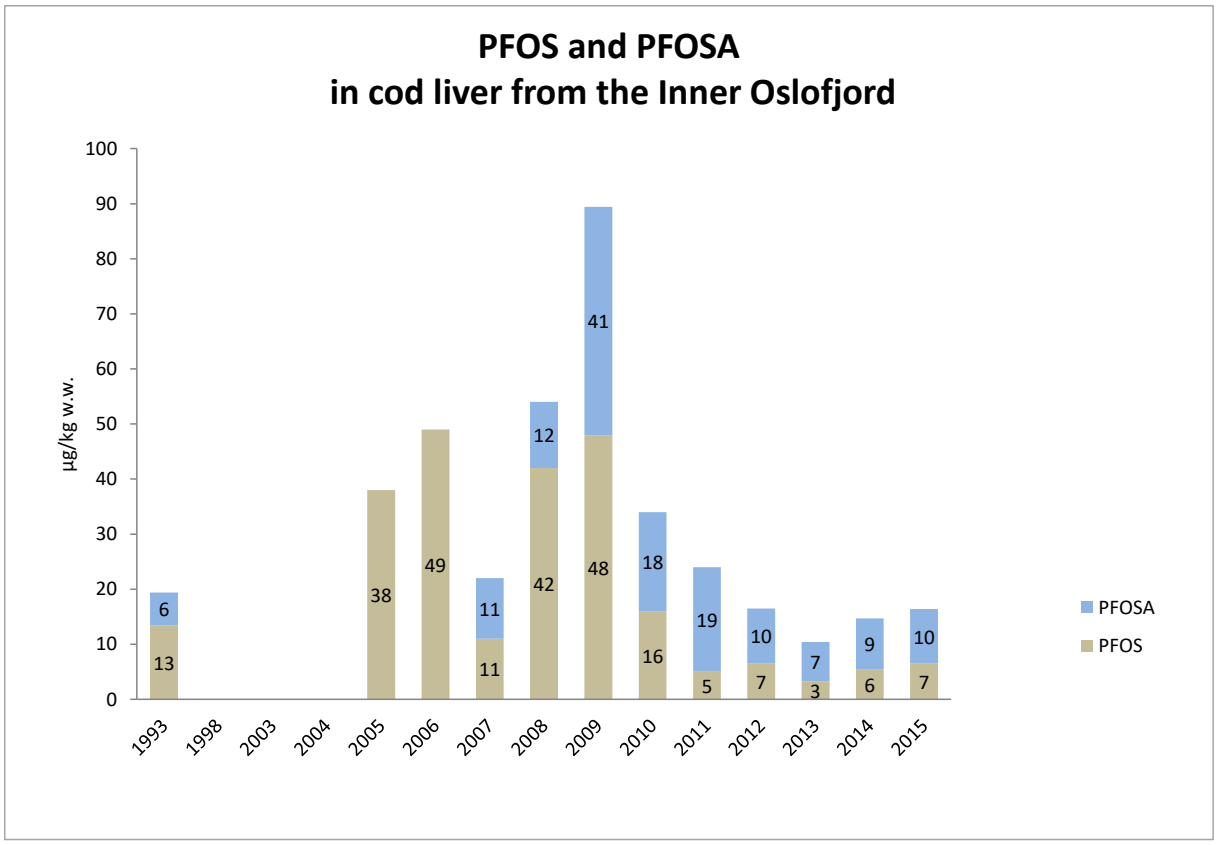


***Figure 34**. Median concentrations (µg/kg w.w.) of PFOS and PFOSA in cod liver from 1993 to 2015 in the Inner Oslofjord (st. 30B).*

***Table 14**. Median concentrations (µg/kg w.w.) and standard deviations of the PFAS-compounds analysed in cod liver in 2015. 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 the maximum number of individuals used in one of the pooled samples. Shaded cells indicate that the median was the limit of quantification (LOQ) and value shown in these cells is one half of this limit. The standard deviation (S.d.) is based on all values and where values below the LOQ are taken as half. Detectable data information (D.d.i.) indicates the number of data above the LOQ (if any) and the numbers within the square brackets indicate the minimum and maximum values in this category. (See Chapter 2.8 for more details and Appendix B for description of chemical codes.)*

Component	Count	PFBS			PFHPA			PFHXA			PFHXS		
Species and sampling locality	2015	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)	12(11-3)	0.1	0		0.25	0		0.25	0		0.05	0.004	2[0.11 - 0.11]
Færder area (st. 36B)	15(9-2)	0.1	0		0.25	0		0.25	0		0.05	0.018	1[0.17]
Kristiansand harbour (st. 13B)	14(10-3)	0.1	0		0.25	0		0.25	0		0.05	0	
Inner Sørfjord (st. 53B)	14(4-5)	0.1	0		0.25	0		0.25	0		0.05	0	
Bømlo north (st. 23B)	15	0.1	0		0.25	0		0.25	0		0.05	0	
Bergen harbour (st. 24B)	15(2-2)	0.1	0		0.25	0		0.25	0.021	1[0.58]	0.05	0	
Inner Trondheimsfjord (st. 80B)	15	0.1	0		0.25	0		0.25	0		0.05	0	
Lofoten, Skrova (st. 98B1)	15	0.1	0		0.25	0		0.25	0		0.05	0	
Tromsø harbour (st. 43B2)	13(2-2)	0.1	0		0.25	0		0.25	0		0.05	0	

***Table 14**.* (cont.)

Component	Count	PFNA			PFOA			PFOS			PFOSA		
Species and sampling locality	2015	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)	12(11-3)	0.25	0		0.25	0.009	1[0.53]	6.5	2.762	12[2.8 - 12]	9.9	4.552	12[4.6 - 19]
Færder area (st. 36B)	15(9-2)	0.25	0		0.25	0		2.4	1.802	15[1.2 - 7.9]	3.3	2.518	15[0.67 - 10]
Kristiansand harbour (st. 13B)	14(10-3)	0.25	0		0.25	0		1.35	0.435	14[0.76 - 2.4]	1.05	0.65	14[0.51 - 2.6]
Inner Sørfjord (st. 53B)	14(4-5)	0.25	0.079	4[0.54 - 0.78]	0.25	0.12	1[0.95]	1.55	0.673	14[0.16 - 2.6]	0.78	0.683	13[0.12 - 2.7]
Bømlo north (st. 23B)	15	0.25	0		0.25	0		1.8	0.478	15[1.3 - 2.7]	0.42	0.181	15[0.15 - 0.91]
Bergen harbour (st. 24B)	15(2-2)	0.25	0		0.25	0		0.66	0.359	15[0.26 - 1.3]	0.59	0.656	14[0.31 - 2.9]
Inner Trondheimsfjord (st. 80B)	15	0.25	0.111	2[0.54 - 0.93]	0.25	0		0.73	0.86	15[0.34 - 3.4]	0.85	0.556	15[0.3 - 2]
Lofoten, Skrova (st. 98B1)	15	0.25	0		0.25	0		0.81	0.733	15[0.31 - 3]	0.49	0.353	15[0.17 - 1.5]
Tromsø harbour (st. 43B2)	13(2-2)	0.25	0		0.25	0		0.71	0.448	13[0.24 - 1.4]	0.4	0.35	9[0.28 - 1.1]

3.2.19 Hexabromocyclododecanes (HBCD)

Hexabromocyclododecanes (HBCD) was analysed in cod liver at 12 stations and in blue mussel at 10 stations.

HBCD is a persistent pollutant which bioaccumulates and undergo long-range transports. HBCD is one of the substances identified as priority hazardous substances (2013/39/EU) and was globally regulated under the Stockholm convention in 2013 . The EQS (167 µg/kg w.w.) refers to fish and this threshold was not exceeded by any median concentration. Cod from the Inner Oslofjord had the highest concentration of HBCD in the liver (***Figure 35***). HBCD is here the sum of the α–, β–, and γ–diastereomers. The median concentration of HBCD in cod liver from the Inner Oslofjord (st. 30B) was 6.8 µg/kg w.w., and there was high variation (***Table 15***). The median concentration of HBCD in cod liver from the Inner Oslofjord was lower than in 2014, but no significant trend was detected. Cod from Bergen harbor, Ålesund area and Lofoten had slightly lower liver concentrations of HBCD than detected in the Inner Oslofjord cod. Cod from Hvaler had lowest concentrations of HBCD in the liver.

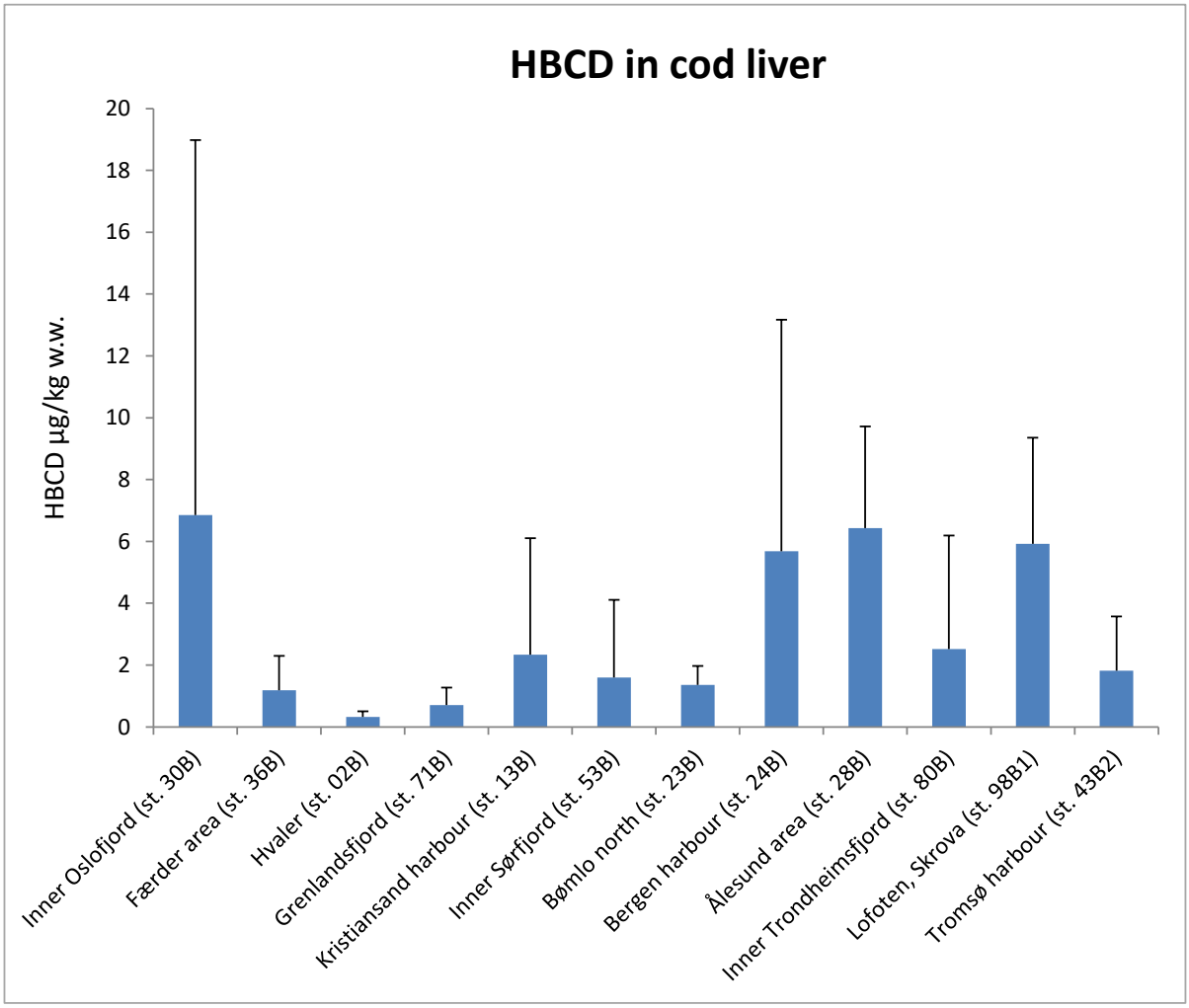


***Figure 35**. Median concentration (µg/kg w.w.) of HBCD (sum of the α–, β–, and γ–diastereomers) in cod liver in 2015. The error bar indicates one standard deviation above the median.*

***Table 15**. 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 in 2015.* 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 the maximum number of individuals used in one of the pooled samples. Shaded cells indicate that the median was the limit of quantification (LOQ) and value shown in these cells is one half of this limit. The standard deviation (S.d.) is based on all values and where values below the LOQ are taken as half. Detectable data information (D.d.i.) indicates the number of data above the LOQ (if any) and the numbers within the square brackets indicate the minimum and maximum values in this category. *(See Chapter 2.8 for more details and Appendix B for description of chemical codes.)*

Component	Count	α–HBCD			γ–HBCD			β–HBCD			HBCD		
Species and sampling locality	2015	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													
Tjøme (st. 36A1)	3(3-50)	0.027	0.024		0.025	0.017		0.015	0.005		0.000	0.000	3[0 - 0]
Singlekalven (st. I023)	3(3-120)	0.092	0.013	3[0.069 - 0.092]	0.018	0.012	2[0.018 - 0.029]	0.003	0.001		0.111	0.028	3[0.069 - 0.121]
Bjørkøya (st. 71A)	3(3-70)	0.056	0.004	3[0.05 - 0.057]	0.007	0.001	3[0.006 - 0.008]	0.002	0.001	1[0.005]	0.062	0.007	3[0.057 - 0.07]
Croftholmen (st. I712)	3(3-80)	0.062	0.004	3[0.059 - 0.067]	0.007	0.003	3[0.007 - 0.013]	0.001	0.000	1[0.003]	0.069	0.009	3[0.066 - 0.083]
Brevik church (st. I714)	3(3-20)	0.053	0.005	3[0.045 - 0.054]	0.007	0.001	3[0.006 - 0.008]	0.002	0.001	2[0.002 - 0.004]	0.062	0.006	3[0.053 - 0.065]
Nordnes (st. I241)	3(3-30)	0.265	0.004	3[0.262 - 0.27]	0.052	0.002	3[0.051 - 0.055]	0.024	0.011	3[0.012 - 0.034]	0.340	0.014	3[0.33 - 0.356]
Måløy (st. 26A2)	3(3-58)	0.064	0.002	3[0.061 - 0.066]	0.006	0.000	3[0.005 - 0.006]	0.002	0.001	1[0.004]	0.070	0.005	3[0.067 - 0.076]
Outer Trondheimsfjord (st. 91A2)	3(3-74)	0.087	0.021	3[0.066 - 0.109]	0.023	0.006	2[0.023 - 0.03]	0.011	0.005	2[0.011 - 0.011]	0.122	0.043	3[0.066 - 0.15]
Bodø harbour (st. 97A2)	3(3-120)	0.016	0.002	3[0.014 - 0.017]	0.001	0.003	1[0.007]	0.001	0		0.017	0.002	3[0.016 - 0.02]
Lofoten, Svolvær (st. 98A2)	3(3-120)	0.06	0.008	3[0.049 - 0.064]	0.006	0.001		0.006	0.001		0.06	0.008	3[0.049 - 0.064]
Cod, liver													
Inner Oslofjord (st. 30B)	12(11-3)	6.835	11.889	12[1.17 - 45.4]	0.040	0.185	7[0.037 - 0.676]	0.031	0.053	6[0.032 - 0.215]	6.854	12.131	12[1.17 - 46.291]
Færder area (st. 36B)	15(9-2)	1.190	1.077	15[0.087 - 3.42]	0.029	0.109	7[0.064 - 0.482]	0.028	0.011	2[0.068 - 0.096]	1.190	1.104	15[0.238 - 3.484]
Hvaler (st. 02B)	5(4-3)	0.291	0.187	5[0.183 - 0.669]	0.015	0.063	2[0.032 - 0.172]	0.015	0.001		0.326	0.177	5[0.215 - 0.669]
Grenlandsfjord (st. 71B)	15(11-2)	0.649	0.572	15[0.293 - 2.58]	0.015	0.007	2[0.036 - 0.056]	0.015	0.002		0.704	0.573	15[0.293 - 2.58]
Kristiansand harbour (st. 13B)	14(10-3)	2.230	3.789	14[0.504 - 15.6]	0.066	0.135	14[0.03 - 0.547]	0.015	0.032	5[0.029 - 0.145]	2.336	3.772	14[1.008 - 15.722]
Inner Sørfjord (st. 53B)	14(4-5)	1.220	2.463	14[0.438 - 8.28]	0.043	0.228	3[0.433 - 0.827]	0.016	0.026	2[0.074 - 0.122]	1.602	2.505	14[0.438 - 8.28]
Bømlo north (st. 23B)	15	1.360	0.632	15[0.219 - 2.49]	0.015	0.106	6[0.033 - 0.44]	0.015	0.002	1[0.036]	1.360	0.610	15[0.256 - 2.523]
Bergen harbour (st. 24B)	15(2-2)	5.680	7.397	15[1.11 - 23.7]	0.106	0.104	11[0.038 - 0.365]	0.015	0.015	2[0.061 - 0.081]	5.680	7.491	15[1.157 - 23.814]
Ålesund area (st. 28B)	6	6.125	3.160	6[3.34 - 11.8]	0.326	0.137	6[0.202 - 0.555]	0.032	0.045	2[0.035 - 0.163]	6.426	3.292	6[3.577 - 12.252]
Inner Trondheimsfjord (st. 80B)	15	2.460	3.374	14[0.782 - 12.1]	0.067	0.324	6[0.063 - 1.06]	0.030	0.104	5[0.079 - 0.349]	2.523	3.665	15[0 - 13.112]
Lofoten, Skrova (st. 98B1)	15	5.000	3.384	15[0.34 - 10.3]	0.015	0.299	7[0.049 - 1.2]	0.016	0.064	7[0.031 - 0.211]	5.925	3.432	15[0.34 - 10.468]
Tromsø harbour (st. 43B2)	13(2-2)	1.720	1.755	13[0.458 - 6.24]	0.035	0.031	10[0.025 - 0.136]	0.011	0.003	1[0.031]	1.815	1.757	13[0.458 - 6.279]

Cod liver showed about-100 times higher concentrations than in blue mussel on a wet weight basis (compare ***Figure 36*** and ***Figure 37***). The difference was smaller on a lipid basis. There are some indications of biomagnification for specific diastereomers of HBCD (Haukås 2009).

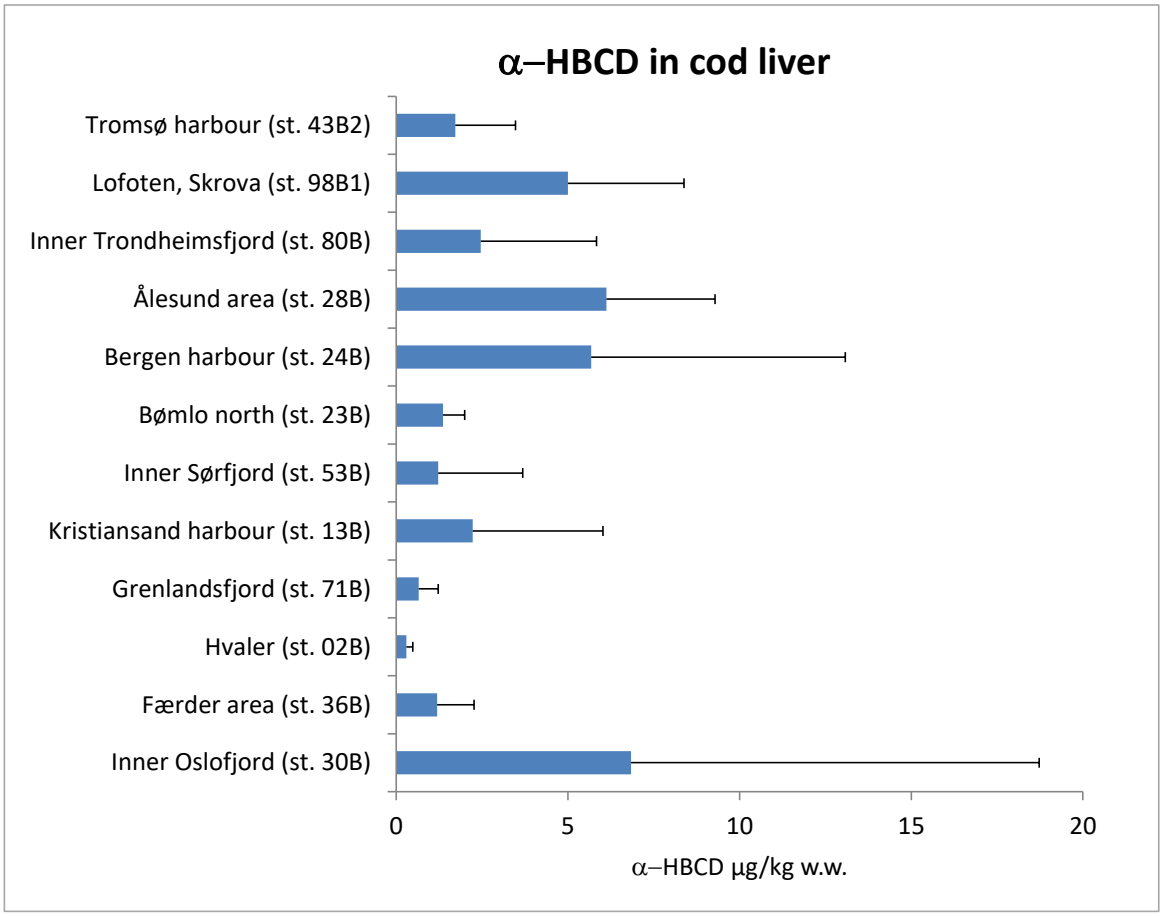


Figure 36*. Mean concentration (µg/kg w.w.) of α–HBCD in cod liver in 2015. The error bar indicates one standard deviation above the mean.*

Blue mussel from Bergen harbour (Nordnes, st. I241) had concentrations of α–HBCD that were significantly higher than for all the other stations (Tukey-Kramer HSD test, see also **Figure 37**).

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 38***).

Riverine loads for HBCDD isomers for 2014 has been estimated to to be in the rane 0.026-4.2 g/year for river Alna (Inner Oslofjord), 35-280 g/year for river Drammenselva (Mid Oslofjord) and 210-1079 g/year for river Glomma (Outer Oslofjord) (Skarbøvik et al. 2015).

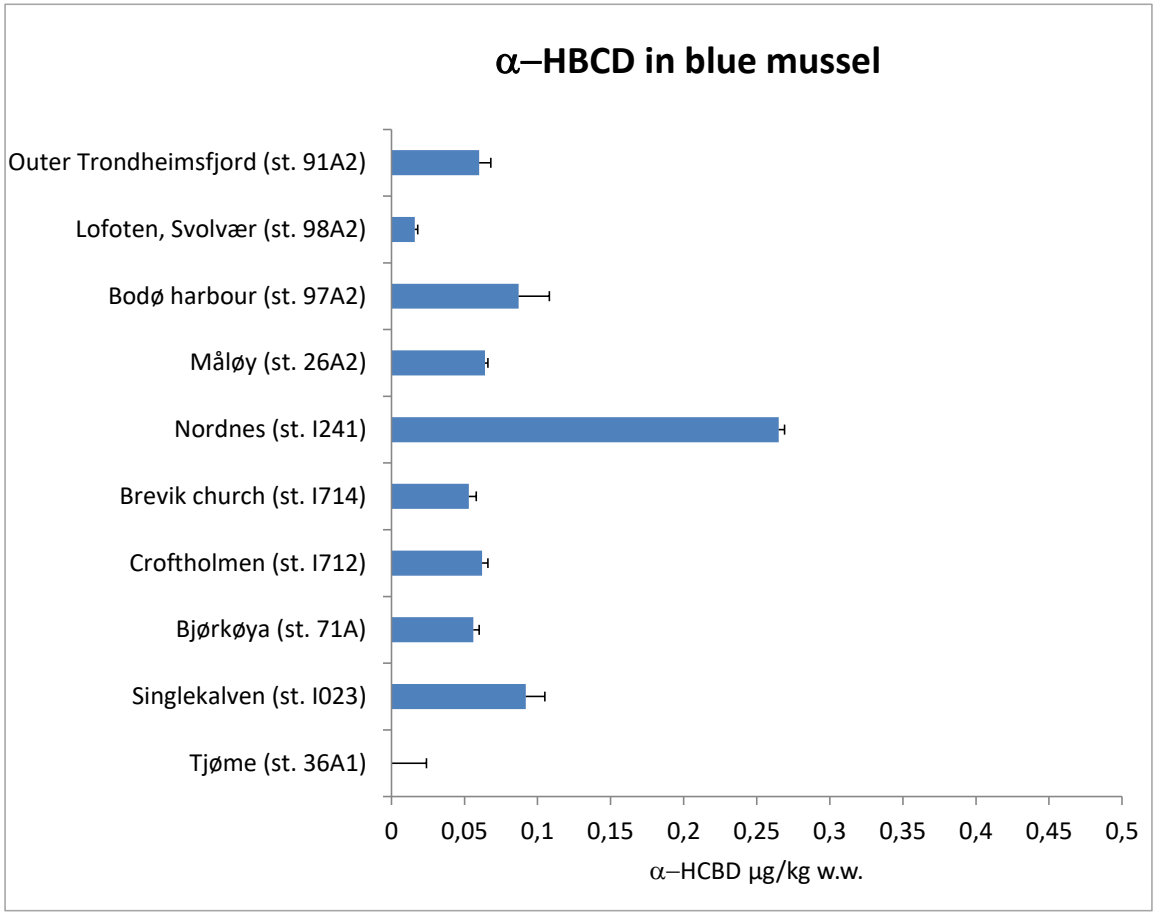


***Figure 37**. Mean concentration (µg/kg w.w.) of α–HBCD in blue mussel in 2015. The error bar indicates one standard deviation above the mean.*

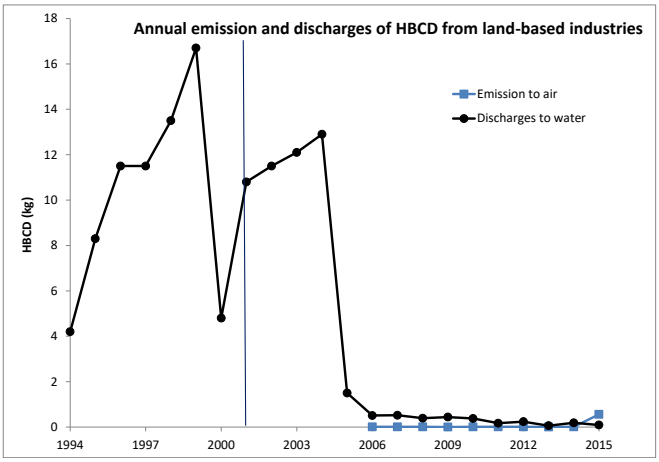


***Figure 38**. Annual emissions of HBCD to air and discharges to water from land-based industries in the period 1994-2015 (data from www.norskeutslipp.no, 27 October 2016). HBCD has been monitored in this project since 2001 (indicated with a vertical line). No data for emissions to air are reported for 2002-2005. Note that emissions and discharges from municipal treatment plants, land runoff, transportation and offshore industry are not accounted for in the figure. New calculation methods for data of emissions and discharges might lead to changes in calculations of present and previous data.*

3.2.20 Chlorinated paraffins (SCCP and MCCP)

Chlorinated paraffins are complex mixtures of polychlorinated organic coumpounds. They are mainly used in metal working fluids, sealants, as flame-retardants in rubbers and textiles, in leather processing and in paints and coatings. Their persistence, bioaccumulation, potential for long-ranged environmental transport and toxicity mean that they may have harmful environmental effects at a global level. Chlorinated paraffins were analysed in cod liver at 10 stations and in blue mussel at 10 stations.

Chlorinated paraffins are subdivided according to their carbon chain length into short chain chlorinated paraffins (SCCPs, $C_{10\text{-}13}$) and medium chain chlorinated paraffins (MCCPs, $C_{14\text{-}17}$). There is EQS for SCCP in biota of 6000 µg/kg w.w., and EQS for MCCP of 170 µg/kg w.w. (M-608, 2016). 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 as a lubricant in machinery for manufacturing metal products. 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 that the discharges from the use of imported products have been reduced by 39 % from 1995 to 2010[1].

Riverine loads for SCCPs for 2014 has been estimated to 0.82 kg/year for river Alna (Inner Oslofjord), 6.9 kg/year for river Drammenselva (Mid Oslofjord) and 15.8-19.4 kg/year for river Glomma (Outer Oslofjord) (Skarbøvik 2015). Riverine loads for MCCPs for 2014 has been estimated to 0.31 kg/year for river Alna, 4.2 kg/year for river Drammenselva and 11.8 kg/year for river Glomma.

The concentration of SCCP in cod liver ranged from 27 to 506 µg/kg w.w., with highest concentrations in cod from Bergen harbour (st. 24B, ***Figure 39***, ***Table 16***) with a ranged of 264 to 1930 µg/kg w.w. Cod from the Inner Oslofjord had concentrations of SCCP in liver in the range 34.7 to 81.1 µg/kg w.w . Ruus *et al.* (2016b) found similar levels of SCCP in cod from the Inner Oslofjord (3.5 to 107 µg/kg w.w.). Concentrations observed in samples from urban areas are frequently higher than from other more sparsely populated areas.

The concentration of SCCP in blue mussel ranged from 0.63 to 10.5 µg/kg w.w. in this study and the highest concentration was found in the samples from Tjøme (st. 36A1, ***Figure 40***).

Cod from Ålesund area (st. 23B) had highest concentration of MCCPs with median concentration of 1202 µg/kg w.w. and a range of 292 to 7750 µg/kg w.w. *There was high individual* variation (***Figure 41***, ***Table 16***). Cod from Bergen harbour had also high concentrations of MCCPs in liver, with median concentration of 743 µg/kg.

The concentrations of MCCPs in blue mussel were lower than in cod, and ranged from 11.1 to 115 µg/kg w.w. Blue mussel from Færder (st. 36A) and Tjøme (st.36A1) in the Outer Oslofjord had the highest concentration of MCCPs (***Figure 42***).

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

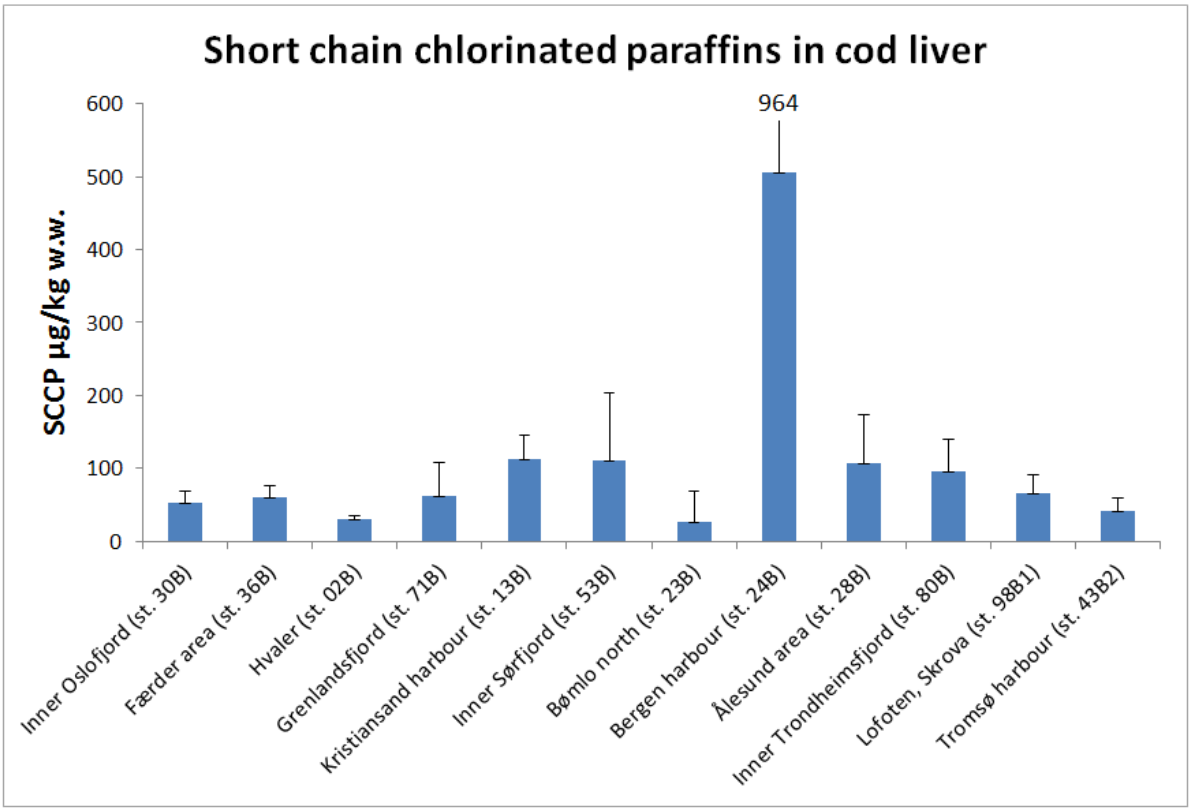


***Figure 39**. Median concentration (µg/kg w.w.) of short chain chlorinated paraffins (SCCP) in cod liver in 2015. The error bar indicates one standard deviation above the median.*

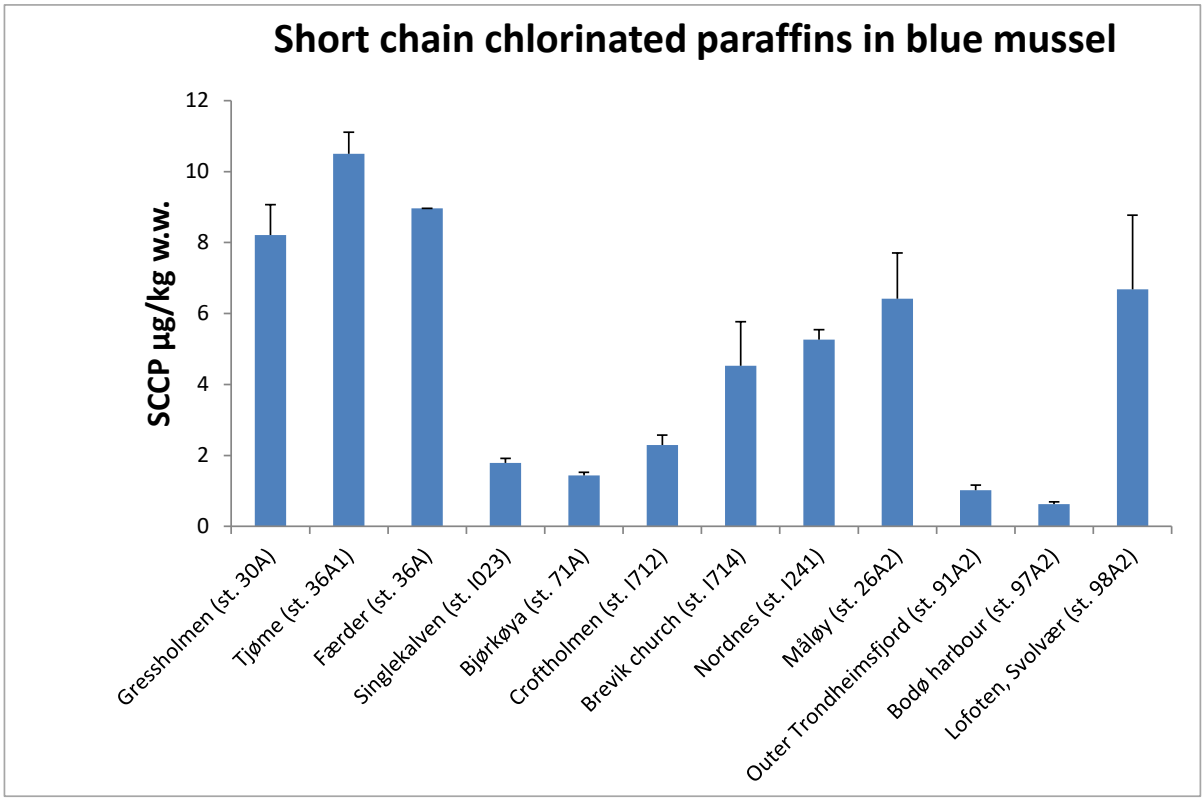


***Figure 40**. Median concentration (µg/kg w.w.) of short chain chlorinated paraffins (SCCP) in blue mussel in 2015. The error bar indicates one standard deviation above the median.*

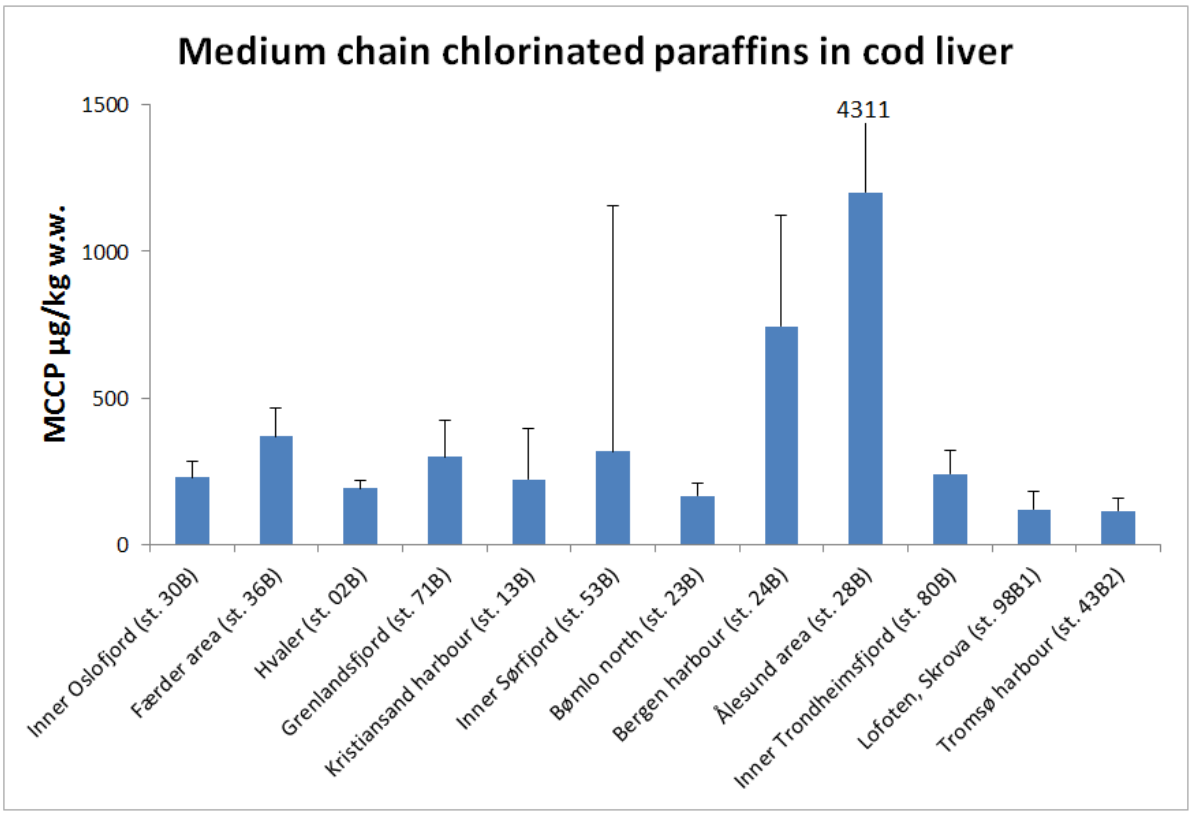


***Figure 41**. Median concentration (µg/kg w.w.) of medium chain chlorinated paraffins (MCCPs) in cod liver in 2015. The error bar indicates one standard deviation above the median.*

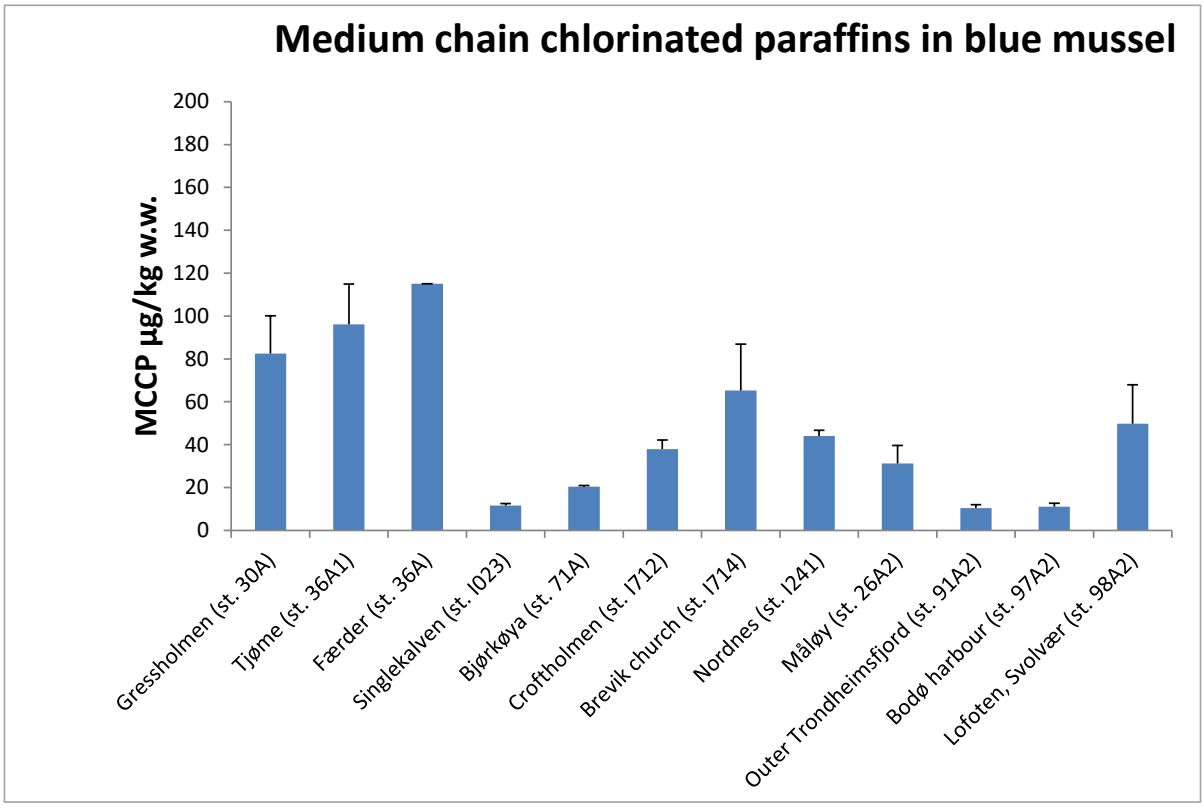


***Figure 42**. Median concentration (µg/kg w.w.) of medium chain chlorinated paraffins (MCCPs) in blue mussel in 2015. The error bar indicates one standard deviation above the median.*

Table 16. *Median concentrations (µg/kg w.w.) with standard deviation of short chain chlorinated paraffins (SCCPs) and medium chain chlorinated paraffins (MCCPs) in blue mussel and cod in 2015. 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 the maximum number of individuals used in one of the pooled samples. Shaded cells indicate that the median was the limit of quantification (LOQ) and value shown in these cells is one half of this limit. The standard deviation (S.d.) is based on all values and where values below the LOQ are taken as half. Detectable data information (D.d.i.) indicates the number of data above the LOQ (if any) and the numbers within the square brackets indicate the minimum and maximum values in this category. (See Chapter 2.8 for more details.*)

Component	Count	SCCP			MCCP		
Species and sampling locality	2015	Med.	S.d.	D.d.i	Med.	S.d.	D.d.i
Blue mussel							
Gressholmen (st. 30A)	3(3-156)	8.21	0.860	3[7.69 - 9.37]	82.50	17.616	3[63.6 - 98.8]
Tjøme (st. 36A1)	3(3-50)	10.5	0.608	3[9.5 - 10.6]	96.1	18.86	3[85.3 - 122]
Færder (st. 36A)	1(1-100)	8.96	0	1[8.96]	115	0	1[115]
Singlekalven (st. I023)	3(3-120)	1.79	0.123	3[1.6 - 1.83]	11.6	0.917	3[11 - 12.8]
Bjørkøya (st. 71A)	3(3-70)	1.44	0.085	3[1.35 - 1.52]	20.4	0.513	3[20.1 - 21.1]
Croftholmen (st. I712)	3(3-80)	2.29	0.284	3[1.83 - 2.35]	37.9	4.244	3[36.9 - 44.7]
Brevik church (st. I714)	3(3-20)	4.53	1.241	3[3.36 - 5.84]	65.3	21.65	3[41.1 - 84.3]
Nordnes (st. I241)	3(3-30)	5.26	0.285	3[4.99 - 5.56]	44.1	2.57	3[39.7 - 44.2]
Måløy (st. 26A2)	3(3-58)	6.42	1.285	3[4.24 - 6.51]	31.2	8.472	3[18 - 33.8]
Outer Trondheimsfjord (st. 91A2)	3(3-74)	1.02	0.146	3[0.869 - 1.16]	10.4	1.652	3[10.1 - 13.1]
Bodø harbour (st. 97A2)	3(3-120)	0.63	0.06	3[0.6 - 0.715]	11.1	1.503	3[8.99 - 11.9]
Lofoten, Svolvær (st. 98A2)	3(3-120)	6.68	2.092	3[5.74 - 9.74]	49.8	18.15	3[23.2 - 57.9]
Cod, liver							
Inner Oslofjord (st. 30B)	11(10-3)	52.9	14.75	11[34.7 - 81.1]	228	55.74	11[125 - 307]
Færder area (st. 36B)	15(9-2)	60	16.03	15[22.9 - 74.4]	368	98.78	15[169 - 594]
Hvaler (st. 02B)	5(4-3)	29.5	5.449	5[26.3 - 40.5]	190	28.36	5[151 - 217]
Grenlandsfjord (st. 71B)	15(11-2)	62.6	44.47	15[35.5 - 158]	298	125.9	15[166 - 595]
Kristiansand harbour (st. 13B)	14(10-3)	112	32.54	14[52.2 - 156]	220.5	175	14[87.4 - 645]
Inner Sørfjord (st. 53B)	14(4-5)	110.5	92.87	14[51.8 - 329]	316	839.3	14[174 - 3450]
Bømlo north (st. 23B)	15	27	41.41	15[17.9 - 180]	166	42.54	15[125 - 257]
Bergen harbour (st. 24B)	15(2-2)	506	458.1	15[264 - 1930]	743	381.9	15[300 - 1580]
Ålesund area (st. 28B)	6	107	67.19	6[70.8 - 251]	1202	3108	6[292 - 7750]
Inner Trondheimsfjord (st. 80B)	15	95.1	43.78	15[23.9 - 182]	239	79.96	15[143 - 416]
Lofoten, Skrova (st. 98B1)	15	65.8	25.62	15[22.3 - 120]	118	63.86	15[34.3 - 297]
Tromsø harbour (st. 43B2)	13(2-2)	40.9	17.84	13[25.8 - 91]	114	41.77	13[70.7 - 240]

3.2.21 Organophosphorus flame retardants (PFRs)

Organophosphorus flame retardants (PFRs) were analysed in cod liver at 10 stations and in blue mussel at 10 stations.

Many of the PFRs are persistent and bioaccumulate. 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). TDCP and TCEP are suspected to cause cancer, and neurological and reproductive harm. Some of the PFRs are suspected to be carcinogenic (TBP, TCEP and TDCP). TCEP is on the priority list of Norwegian Environment Agency[1]. 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).

The concentrations of PFRs were low; all median concentrations were below the quantification limits (***Table 17***). It should be noted that PFRs are generally difficult to separate from the lipid portion of a sample before chemical analysis 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 quantification limit. This problem can vary from sample to sample. Hence more variable and higher quantification limits can be found when compared to other contaminant groups such as PCBs, PBDEs (***Table 13***) or PFAS (***Table 14***).

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

***Table 17**. Median concentrations (µg/kg w.w.) with standard deviation of organophosphorus flame retardants (PFRs) in blue mussel and cod liver in 2015. 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 the maximum number of individuals used in one of the pooled samples. Shaded cells indicate that the median was the limit of quantification (LOQ) and value shown in these cells is one half of this limit. The standard deviation (S.d.) is based on all values and where values below the LOQ are taken as half. Detectable data information (D.d.i.) indicates the number of data above the LOQ (if any) and the numbers within the square brackets indicate the minimum and maximum values in this category. (See Chapter 2.8 for more details and Appendix B for description of chemical codes.)*

Component	Count	TBEP			TBP			TCEP			TCPP			TCRP		
Species and sampling locality	2014	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(3-156)	0.3	0.5		0.3	0.1		0.1	0.0		0.3	0.1		0.5	0.1	
Tjøme (st. 36A1)	3(3-50)	2.8	1.4		2.8	1.4		1.4	0.7		2.8	1.4		5.6	2.9	
Færder (st. 36A)	2(2-100)	6.7	0.1		6.7	0.1		3.3	0.0		6.7	0.1		13.4	0.1	
Singlekalven (st. I023)	3(3-120)	1.7	0.1		1.7	0.1		0.9	0.1		1.7	0.1		3.4	0.3	
Bjørkøya (st. 71A)	3(3-70)	0.3	2.2		0.3	2.2		0.1	1.1		0.3	2.2		0.6	4.5	
Croftholmen (st. I712)	3(3-80)	0.2	3.2		0.2	2.4		0.1	1.2		0.2	2.4		0.5	4.8	
Brevik church (st. I714)	3(3-20)	8.5	1.1		8.5	1.1		4.3	0.6		8.5	1.1		17.0	2.2	
Nordnes (st. I241)	3(3-30)	0.3	0.0		0.3	0.0		0.2	0.0		0.3	0.0		0.7	0.1	
Måløy (st. 26A2)	3(3-58)	0.4	0.0		0.4	0.0		0.2	0.0		0.4	0.0		0.8	0.0	
Outer Trondheimsfjord (st. 91A2)	3(3-74)	1.7	0.2		1.7	0.2		0.8	0.1		1.7	0.2		3.3	0.3	
Bodø harbour (st. 97A2)	3(3-120)	1.8	0.2		1.8	0.2		0.9	0.1		1.8	0.2		3.6	0.4	
Lofoten, Svolvær (st. 98A2)	3(3-120)	0.3	0.1		0.3	0.1		0.1	0.0		0.3	0.1		0.5	0.1	
Cod, liver																
Inner Oslofjord (st. 30B)	12(11-3)	9.0	1.1		9.0	1.1		4.5	0.5		9.0	1.1		18.0	2.1	
Færder area (st. 36B)	15(9-2)	6.4	2.1		6.4	2.1		3.2	1.0		7.0	2.3	3[13.1 - 17.5]	12.7	4.1	
Hvaler (st. 02B)	5(4-3)	8.9	0.9		8.9	0.9		4.5	0.4		8.9	0.9		17.8	1.7	
Grenlandsfjord (st. 71B)	15(11-2)	9.6	1.5		9.6	1.5		4.8	0.7		9.6	1.5		19.2	2.9	
Kristiansand harbour (st. 13B)	14(10-3)	6.4	2.1		6.4	2.1		3.2	1.0		7.0	2.3	3[13.1 - 17.5]	12.7	4.1	
Inner Sørfjord (st. 53B)	14(4-5)	8.9	0.9		8.9	0.9		4.5	0.4		8.9	0.9		17.8	1.7	
Bømlo north (st. 23B)	15	9.6	1.5		9.6	1.5		4.8	0.7		9.6	1.5		19.2	2.9	
Bergen harbour (st. 24B)	7	9.3	1.9		9.3	1.9		4.6	0.9		9.3	1.9		18.6	3.8	
Ålesund area (st. 28B)	6	9.3	1.9		9.3	1.9		4.6	0.9		9.3	1.9		18.6	3.8	
Inner Trondheimsfjord (st. 80B)	15	8.0	2.1		8.0	2.1		4.0	1.1		8.0	2.1		16.0	4.3	
Lofoten, Skrova (st. 98B1)	15	10.1	4.1		10.1	4.1		5.1	2.0		10.1	4.1		20.1	8.2	
Tromsø harbour (st. 43B2)	13(2-2)	5.6	0.9		5.6	0.9		2.8	0.4		5.6	0.9		11.1	1.7	

Table 17. *(cont.)*

Component	Count	TDCP			TEHP			TIBP			TOCRP			TPHP			EHDPP		
Species and sampling locality	2014	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(3-156)	0.1	0.2		0.2	0.2	1[0.366]	0.5	0.1		0.1	0.0		0.1	0.2		0.3	0.4	
Tjøme (st. 36A1)	3(3-50)	0.6	0.3		1.4	0.7		5.6	2.9		1.4	0.7		1.4	0.7		2.8	1.4	
Færder (st. 36A)	2(2-100)	1.3	0.0		3.3	0.0		13.4	0.1		3.3	0.0		3.3	0.0		6.7	0.1	
Singlekalven (st. I023)	3(3-120)	0.3	0.0		0.9	0.0		3.4	0.3		0.9	0.1		0.9	0.1		1.7	0.1	
Bjørkøya (st. 71A)	3(3-70)	0.1	0.4		0.1	1.1		0.6	4.5		0.1	1.1		0.1	1.1		0.3	2.2	
Croftholmen (st. I712)	3(3-80)	0.0	0.5		0.2	1.2		0.5	4.8		0.1	1.2		0.1	1.2		0.2	0.0	
Brevik church (st. I714)	3(3-20)	1.7	0.2		4.3	0.6		17.0	2.2		4.3	0.6		4.3	0.6		8.5	1.1	
Nordnes (st. I241)	3(3-30)	0.1	0.0		0.4	0.2		0.7	0.1		0.2	0.0		0.5	0.0	3[0.501 - 0.522]	0.3	0.0	
Måløy (st. 26A2)	3(3-58)	0.1	0.3		0.2	0.0		0.8	0.0		0.2	0.0		0.3	0.4	1[1.25]	0.5	3.1	1[6.36]
Outer Trondheimsfjord (st. 91A2)	3(3-74)	0.3	0.0		0.8	0.1		3.3	0.3		0.8	0.1		0.8	0.1		1.7	0.2	
Bodø harbour (st. 97A2)	3(3-120)	0.4	0.1		0.9	0.1		3.6	0.4		0.9	0.1		0.9	0.1		7.4	3.1	2[7.37 - 9.81]
Lofoten, Svolvær (st. 98A2)	3(3-120)	0.1	0.1	1[0.328]	0.1	0.0		0.5	0.1		0.1	0.0		0.1	0.0		0.3	0.7	1[1.77]
Cod, liver																			
Inner Oslofjord (st. 30B)	12(11-3)	1.8	0.3		4.5	0.5		18.0	2.1		4.5	0.5		4.5	0.5		9.0	1.1	
Færder area (st. 36B)	15(9-2)	1.6	2.2	3[7.4 - 7.5]	3.4	1.0		12.7	4.1		3.2	1.0		3.2	1.0		7.8	12.0	4[37.3 - 42.9]
Hvaler (st. 02B)	5(4-3)	1.9	0.2		4.5	0.4		17.8	1.7		4.5	0.4		4.5	0.4		8.9	0.9	
Grenlandsfjord (st. 71B)	15(11-2)	2.0	0.3		4.8	0.7		19.2	2.9		4.8	0.7		4.8	0.7		9.6	1.5	
Kristiansand harbour (st. 13B)	14(10-3)	1.6	2.2	3[7.4 - 7.5]	3.4	1.0		12.7	4.1		3.2	1.0		3.2	1.0		7.8	12.0	4[37.3 - 42.9]
Inner Sørfjord (st. 53B)	14(4-5)	1.9	0.2		4.5	0.4		17.8	1.7		4.5	0.4		4.5	0.4		8.9	0.9	
Bømlo north (st. 23B)	15	2.0	0.3		4.8	0.7		19.2	2.9		4.8	0.7		4.8	0.7		9.6	1.5	
Bergen harbour (st. 24B)	7	2.1	3.7	2[7.76 - 17.5]	4.6	0.9		18.6	3.8		4.6	0.9		4.6	0.9		10.7	13.5	2[38.3 - 68.5]
Ålesund area (st. 28B)	6	2.1	3.7	2[7.76 - 17.5]	4.6	0.9		18.6	3.8		4.6	0.9		4.6	0.9		10.7	13.5	2[38.3 - 68.5]
Inner Trondheimsfjord (st. 80B)	15	1.6	0.8	1[5.74]	4.0	1.1		16.0	4.3		4.0	1.1		4.0	1.1		8.0	3.1	1[23.9]
Lofoten, Skrova (st. 98B1)	15	2.1	1.2	1[7.67]	5.1	2.0		20.1	8.2		5.1	2.0		5.1	2.0		10.7	6.4	
Tromsø harbour (st. 43B2)	13(2-2)	1.1	0.2		2.8	0.4		11.1	1.7		2.8	0.4		2.8	0.4		5.6	0.9	

3.2.22 Bisphenol A (BPA)

Bisphenol A (BPA) was analysed in cod liver from 10 locations and in blue mussel from 11 stations.

BPA is derived from epoxy resins and polycarbonate plastics (Belfroid *et al*. 2002). BPA 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. BPA is on the priority list of Norwegian Environment Agency[1].

Most of the median concentrations of BPA found in blue mussel were below the quantification limit, and only two samples had concentrations above the quantification limit (***Table 18***). This was blue mussel from Gressholmen (st. 30A), in the inner Oslofjord.

The concentrations of BPA in cod liver were low, and only one sample was above the quantification limit (***Table 18***). Hence, no conclusion can be drawn regarding possible differences between stations. BPA was detected in samples of cod liver in another monitoring project from the inner Oslofjord in 2015 (Ruus et al. 2016). The concentrations ranged between 12 and 195 µg/kg wet weight. The chemical analysis were done by another laboratory.

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

***Table 18**. Median concentrations (µg/kg w.w.) with standard deviation of bisphenol A (BPA) in blue mussel and cod liver in 2015. 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 the maximum number of individuals used in one of the pooled samples. Shaded cells indicate that the median was the limit of quantification (LOQ) and value shown in these cells is one half of this limit. The standard deviation (S.d.) is based on all values and where values below the LOQ are taken as half. Detectable data information (D.d.i.) indicates the number of data above the LOQ (if any) and the numbers within the square brackets indicate the minimum and maximum values in this category. (See Chapter 2.8 for more details.)*

Component	Count	BPA		
Species and sampling locality	2015	Med.	S.d.	D.d.i.
Blue mussel				
Gressholmen (st. 30A)	3(3-156)	1.1	6.9	2[1.1 - 13]
Tjøme (st. 36A1)	3(3-50)	0.5	0.0	
Færder (st. 36A)	2(2-100)	0.5	0.0	
Singlekalven (st. I023)	3(3-120)	0.5	0.0	
Bjørkøya (st. 71A)	3(3-70)	0.5	0.0	
Croftholmen (st. I712)	3(3-80)	0.5	0.0	
Brevik church (st. I714)	3(3-20)	0.5	0.0	
Nordnes (st. I241)	3(3-30)	0.5	0.0	
Måløy (st. 26A2)	3(3-58)	0.5	0.0	
Outer Trondheimsfjord (st. 91A2)	3(3-74)	0.5	0.0	
Outer Trondheimsfjord (st. 91A2)	3(3-74)	0.5	0.0	
Bodø harbour (st. 97A2)	3(3-120)	0.5	0.0	
Cod, liver				
Inner Oslofjord (st. 30B)	12(11-3)	0.5	0.0	
Færder area (st. 36B)	15(9-2)	0.5	0.0	
Hvaler (st. 02B)	5(4-3)	0.5	0.0	
Grenlandsfjord (st. 71B)	15(11-2)	0.5	0.7	1[3.6]
Kristiansand harbour (st. 13B)	14(10-3)	0.5	0.0	
Inner Sørfjord (st. 53B)	14(4-5)	0.5	0.0	
Bømlo north (st. 23B)	15	0.5	0.0	
Ålesund area (st. 28B)	6	0.5	0.0	
Inner Trondheimsfjord (st. 80B)	15	0.5	0.0	
Tromsø harbour (st. 43B2)	13(2-2)	0.5	0.0	

3.2.23 Tetrabrombisphenol A (TBBPA)

Tetrabrombisphenol A (TBBPA) was analysed in cod liver at 10 stations and in blue mussel at 11 stations.

TBBPA is a polybrominated flame retardant and is an endocrine disruptor and immunotoxicant.

Concentrations of TBBPA found in cod liver and blue mussel were below the limit of quantification for all samples except for one (***Table 19***). The exception was for liver in one cod from the Ålesund area (st. 28B) that had a concentration of 0.372 µg/kg w.w.

Table 19*. Median concentrations (µg/kg w.w.) with standard deviation of TBBPA in blue mussel and cod liver in 2015. 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 the maximum number of individuals used in one of the pooled samples. Shaded cells indicate that the median was the limit of quantification (LOQ) and value shown in these cells is one half of this limit. The standard deviation (S.d.) is based on all values and where values below the LOQ are taken as half. Detectable data information (D.d.i.) indicates the number of data above the LOQ (if any) and the numbers within the square brackets indicate the minimum and maximum values in this category. (See Chapter 2.8 for more details.)*

Component	Count	TBBPA		
Species and sampling locality	2015	Med.	S.d.	D.d.i.
Blue mussel				
Tjøme (st. 36A1)	3(3-50)	0.2	0.0	
Færder (st. 36A)	1(1-100)	0.3	0.0	
Singlekalven (st. I023)	3(3-120)	0.0	0.0	
Bjørkøya (st. 71A)	3(3-70)	0.0	0.0	
Croftholmen (st. I712)	3(3-80)	0.0	0.0	
Brevik church (st. I714)	3(3-20)	0.0	0.0	
Nordnes (st. I241)	3(3-30)	0.0	0.0	
Måløy (st. 26A2)	3(3-58)	0.1	0.1	
Outer Trondheimsfjord (st. 91A2)	3(3-74)	0.0	0.0	
Bodø harbour (st. 97A2)	3(3-120)	0.0	0.0	
Lofoten, Svolvær (st. 98A2)	3(3-120)	0.0	0.0	
Cod, liver				
Inner Oslofjord (st. 30B)	12(11-3)	0.2	0.0	
Færder area (st. 36B)	15(9-2)	0.3	0.0	
Hvaler (st. 02B)	5(4-3)	0.3	0.1	
Grenlandsfjord (st. 71B)	15(11-2)	0.3	0.1	
Kristiansand harbour (st. 13B)	14(10-3)	0.3	0.0	
Inner Sørfjord (st. 53B)	14(4-5)	0.2	0.1	
Bømlo north (st. 23B)	15	0.3	0.1	
Ålesund area (st. 28B)	6	0.2	0.1	1[0.372]
Inner Trondheimsfjord (st. 80B)	15	0.2	0.0	
Tromsø harbour (st. 43B2)	13(2-2)	0.2	0.0	

3.2.24 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 alklyphenols and are on the EQSD list of priority hazardous substances. EQS for nonylphenol is 3000 µg/kg w.w., and EQS for octylphenol is 0.004 µg/kg w.w. In the MILKYS programme, they were analysed for the first time in samples from 2012. In Norway it has since 2005 been prohibited to produce, import, export, sell or use nonylphenols, octylphenols and their ethoxylates with the exception of paints, varnish, lubricants and finished products.

Alkylphenols were analysed in cod liver from 10 locations and in blue mussel from 12 stations. The concentrations in both cod liver and blue mussel were low. Most of the concentrations were below the quantification limits (***Table 20***). Nine of the blue mussel stations had median concentrations of 4-t-nonylphenol that were above the quantification limits. In cod, one station had higher conentrations of alkylphenols in cod liver than the other stations. Cod liver from Tromsø harbour (st. 43B2) had median concentrations of four alkylpehnols (4-n-NP, 4-n-OP, 4-t-NP and 4-t-OP) that were above the quantification limits. All the concentrations of nonylpehonl were below the EQS. The quantification limits for octylphenols were higher than the EQS, so all detected concentrations of octylphenols were above the EQS.

General, large scale

The discharges of phenols from land-based industries to water increased in the period from 2002 to 2008 (4730 kg) and then gradually decresed to 1434 kg in 2015 (***Figure 43***).

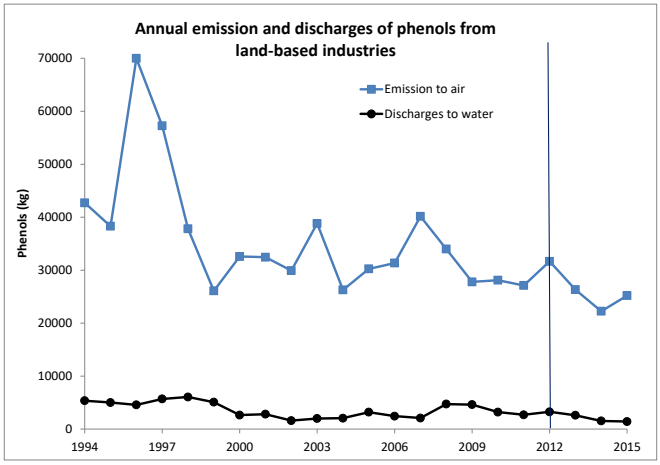


Figure 43. *Annual emissions of phenols to air and discharges to water from land-based industries in the period 1994-2015 (data from www.norskeutslipp.no, 27 October 2016). Phenols have been monitored in this project since 2001 (indicated with a vertical line). Note that emissions and discharges from municipal treatment plants, land runoff, transportation and offshore industry are not accounted for in the figure. New calculation methods for data of emissions and discharges might lead to changes in calculations of present and previous data.*

Table 20. *Median concentrations (µg/kg w.w.) with standard deviation of alkylphenols in blue mussel and cod liver in 2015. 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 the maximum number of individuals used in one of the pooled samples. Shaded cells indicate that the median was the limit of quantification (LOQ) and value shown in these cells is one half of this limit. The standard deviation (S.d.) is based on all values and where values below the LOQ are taken as half. Detectable data information (D.d.i.) indicates the number of data above the LOQ (if any) and the numbers within the square brackets indicate the minimum and maximum values in this category. (See Chapter 2.8 for more details and Appendix B for description of chemical codes.)*

Component	Count	4-n-NP			4-n-OP			4-t-NP			4-t-OP		
Species and sampling locality	2015	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(3-156)	1.0	0.00		1.0	0.00		2.5	0.00		1.0	0.00	
Tjøme (st. 36A1)	3(3-50)	10.0	0.00		25.0	0.00		250.0	0.00		10.0	0.00	
Færder (st. 36A)	2(2-100)	25.0	0.00		25.0	0.00		50.0	0.00		25.0	0.00	
Singlekalven (st. I023)	3(3-120)	2.5	0.00		2.5	0.88	1[6.52]	171.0	23.64	3[152 - 199]	2.5	0.00	
Bjørkøya (st. 71A)	3(3-70)	2.5	0.00		2.5	0.00		188.0	18.52	3[181 - 216]	2.5	0.00	
Croftholmen (st. I712)	3(3-80)	2.5	0.00		2.5	0.75	1[6.29]	159.0	103.78	3[81.5 - 287]	2.5	0.00	
Brevik church (st. I714)	3(3-20)	5.0	0.00		5.0	4.04	1[17]	248.0	140.82	3[66.7 - 344]	5.0	0.00	
Nordnes (st. I241)	3(3-30)	2.5	0.00		2.5	0.00		361.0	117.60	3[252 - 487]	2.5	0.00	
Måløy (st. 26A2)	3(3-58)	5.0	0.00		5.0	0.00		81.9	14.98	3[56.8 - 83.5]	5.0	0.00	
Outer Trondheimsfjord (st. 91A2)	3(3-74)	2.5	0.00		2.5	0.13	1[5.23]	393.0	200.33	3[363 - 724]	2.5	0.00	
Bodø harbour (st. 97A2)	3(3-120)	2.5	0.00		2.5	0.00		243.0	87.09	3[163 - 337]	2.5	0.00	
Lofoten, Svolvær (st. 98A2)	3(3-120)	1.4	0.32	2[1.42 - 1.63]	1.9	0.31	3[1.85 - 2.42]	14.4	2.22	3[12.7 - 17.1]	2.0	0.31	
Cod, liver													
Inner Oslofjord (st. 30B)	12(11-3)	25.0	0.00		25.0	0.00		50.0	0.00		25.0	0.00	
Færder area (st. 36B)	15(9-2)	25.0	0.00		25.0	0.00		50.0	0.00		25.0	0.00	
Hvaler (st. 02B)	5(4-3)	10.0	0.00		5.0	0.00		50.0	0.00		5.0	0.00	
Grenlandsfjord (st. 71B)	15(11-2)	25.0	0.00		5.0	0.00		50.0	0.00		5.0	0.62	
Kristiansand harbour (st. 13B)	14(10-3)	25.0	0.00		25.0	0.00		50.0	0.00		25.0	0.00	
Inner Sørfjord (st. 53B)	14(4-5)	5.0	2.67		5.0	8.12	3[16.8 - 28.2]	50.0	13.36		5.0	3.63	
Bømlo north (st. 23B)	15	25.0	10.56		25.0	14.08		50.0	0.00		25.0	14.08	
Ålesund area (st. 28B)	6	5.0	16.33		5.0	2.49	1[16.1]	50.0	0.00		10.0	24.01	
Inner Trondheimsfjord (st. 80B)	15	10.0	0.00		10.0	0.00		50.0	0.00		10.0	0.00	
Tromsø harbour (st. 43B2)	13(2-2)	131.0	66.29	13[18.1 - 190]	29.8	20.53	13[5.83 - 70.9]	71.0	162.42	13[21.4 - 531]	13.7	5.72	13[5.62 - 27.8]

3.3 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. OSPAR 2013).

3.3.1 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. Quantification methods for OH-pyrene have been improved two times since the initiation of these analyses in the CEMP/MILKYS 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 quantification. 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 are 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 2015 the median concentration of OH-pyrene metabolites in bile from cod in the Inner Oslofjord (st. 30B) was about twice as high as in 2014. In other words, there was an apparent increase after observing that the median 2014-concentration was 10 % lower than the 2013-concentration and 30 % lower than the 2012-concentration. A significant upward temporal trend could be observed in Sørfjorden (st. 53B) over the last 10 years (Appendix F). Median OH-pyrene bile concentration in 2015 was above the ICES/OSPAR assessment criterion (background assessment criteria, BAC) in this area as well as in fish from the Inner Sørfjord (st. 53B) and Lista area (st. 15B). Median OH-pyrene bile concentration in 2015 was below the ICES/OSPAR assessment criterion at Bømlo 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.

3.3.2 ALA-D in blood cells

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

In 2015, ALA-D activities in the blood of cod from the Inner Oslofjord (st. 30B), Sørfjorden (st. 53B) and the Bømlo area (st. 23B) had apparently decreased slightly, or were at the approximate same level as the two previous years. Trend analyses suggest a significant downward temporal trend over the last 10 years at the reference station (Bømlo area; 23B; Appendix F). No significant temporal trend in lead concentrations, could be observed over the last 10 years (Appendix F).

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 in the Bømlo-Sotra area (st. 23B), and Varangerfjord (st. 10B; only data to 2001, not shown) (Green *et al*. 2015). The ALA-D activity at Bømlo in 2015 was apparently 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 2013-2015) 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, though with a relatively large individual variation.

3.3.3 EROD-activity 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 2015, median EROD-activity in liver of cod from the Inner Oslofjord (30B) was similar to that observed in 2013 (i.e. approximately twice as high as in 2012 and 2014). Since 2000, the median EROD-activity has generally been higher in the Inner Oslofjord compared to the reference station on the west coast (Bømlo, st. 23B). This was also the case in 2015. The median EROD activity in cod from Sørfjorden (st. 53B) was also higher than at the reference station (Bømlo, 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.

3.4 Monitoring of contaminants with passive samplers

3.4.1 General comments on methods

Freely dissolved concentrations are calculated from the masses of the chemical absorbed during exposure and the sampling rate estimated from the PRC data. Sampling rates, R_s for the samplers deployed for a year from July 2015 until July-August 2016 were low, particularly considering the high surface area of the samplers (the sampling rate is proportional to the surface area of the sampler). Sampling rates for such sampler configuration can easily be an order of magnitude higher than those obtained here. However the present sampling rates were similar to those obtained in the three previous deployments in Hvaler, Inner Oslofjord and Ålesund harbour from 2012-2015 (***Table 21***). The standard errors on the estimation of sampling rates for the period 2015-2016 were ~ 20 %. 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 BDE-209). 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).

***Table 21**. Estimated sampling rates, R_s for AlteSil silicone rubber samplers (1000 cm^2, 30 g) deployed at three sites for > 300 days.*

	Site					
	Hvaler		Inner 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
R_s* for 2015	0.42	0.62	0.63	0.62	1.30	1.43
+/-	0.03	0.18	0.05	0.06	0.08	0.08
R_s* for 2016	0.7	0.7	2.0	1.2	1.4	1.5
+/-	0.14	0.16	0.28	0.26	0.36	0.20

* R_s (L d^{-1}) at $\log K_{sw}$ = 5

3.4.2 Results and discussion

As shown in ***Table 22***, most compounds were below limits of quantification. Non-negligible amounts of para-t-octylphenol and para-t-nonylphenol (4-t-OP, 4-t-NP), were measured in field control samplers (and/or in solvent blanks). This affected limits of quantification for these compounds. Overall limits of quantification depend on the quality of sampler preparation, contamination during sampler extraction and analysis, and instrumental limits of quantification. The limit of quantification (expressed as concentration in water) for these two compounds was estimated based on 3 x mean of masses of the compounds found in control samplers.

Freely dissolved concentrations of alkylphenols were below limits of quantification. These limits of quantification are calculated based on the residual amounts of these chemicals in preparation and control samplers. Masses for chemicals accumulated in exposed samplers were not significantly higher than amounts measured in control samplers. Para-n-octylphenol (4-n-OP) and para-n-nonylphenol (4-n-NP) were at concentrations below 60 pg L^{-1}, levels well below the WFD EQS level (Appendix G) of 0.01 and 0.3 μg L^{-1}, respectively. Para-t-octylphenol and para-t-nonylphenol were also below limits of quantification with those ranging from 0.2 to 5 ng L^{-1}.

***Table 22**. Freely dissolved concentrations measured with silicone rubber samplers exposed at three sites.*

Substances		**Freely dissolved contaminant concentrations**		
Sites	**Unit**	**Hvaler**	**Inner Oslofjord**	**Ålesund harbour**
Alkylphenols				
4-t-OP	ng L^{-1}	< 5[a]	< 5[a]	< 5[a]
4-t-NP	ng L^{-1}	< 1.2	< 0.9[a]	< 0.2
4-n-OP	ng L^{-1}	< 0.06	< 0.02	< 0.03
4-n-NP	ng L^{-1}	< 0.03	< 0.006	< 0.02
HBCD				
α-HBCD	pg L^{-1}	< 5	9.8 (*40*)	< 3
β-HBCD	pg L^{-1}	< 5	2.6 (*32*)	< 3
γ-HBCD	pg L^{-1}	< 5	< 3	< 3
PBDEs				
BDE47	pg L^{-1}	< 12	3.8 (*2*)	3.2 (*4*)
BDE99	pg L^{-1}	< 35	< 11	< 6
BDE100	pg L^{-1}	< 35	< 11	< 6
BDE126	pg L^{-1}			
BDE153	pg L^{-1}	< 15	< 3	< 2
BDE154	pg L^{-1}	< 15	< 3	< 2
BDE183	pg L^{-1}	< 15	< 3	< 2
BDE196	pg L^{-1}	< 20	< 3	< 2
BDE209	pg L^{-1}	< 100	< 20	< 25

[a]) Limit of quantification 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.

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. Freely dissolved concentrations of the α and β-isomers of HBCD of 9.8 and 2.6 pg L^{-1} respectively were estimated for the Inner Oslofjord. For α-HBCD, this value is very similar to those found for the Oslofjord in previous years (Green *et al*. 2014, 2015). Freely dissolved concentrations appear to be well below WFD EQS values for HBCD (2013/39/EU). HBCD isomers were not found above limits of quantification at Hvaler nor in Ålesund harbour (with limits of quantification in the range 3-5 pg L^{-1}). Partitioning, chemical and biological transformation are processes that can be isomer specific. The α-HBCD isomer is also the least hydrophobic and more water soluble of HBCD isomers and this may partly explain why this is the only isomer detected.

Most PBDEs were found below limits of quantification. As for previous years, the exposure of samplers for almost a year (2015-2016) resulted in the accumulation of significant amounts of many different brominated substances rendering the quantification of specific PBDEs challenging. Freely dissolved concentrations of 3.8 and 3.2 pg L^{-1} for BDE-47 were estimated for the Inner Oslofjord and Ålesund harbour. The variability of duplicate measurements is very low (Relative Percent difference < 10 %). These values are lower than previous measurements (2012-2014). These values are in the range of those obtained for silicone rubber samplers exposed at Andøya (4.8 pg L^{-1}) and Bjørnøya (6-7 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). These are generally of the same order of magnitude as the freely dissolved concentrations for the Inner Oslofjord. Freely

dissolved concentrations of α–HBCD and BDE47 for the Oslofjord for the period 2012-2016 are shown in ***Figure 44***.

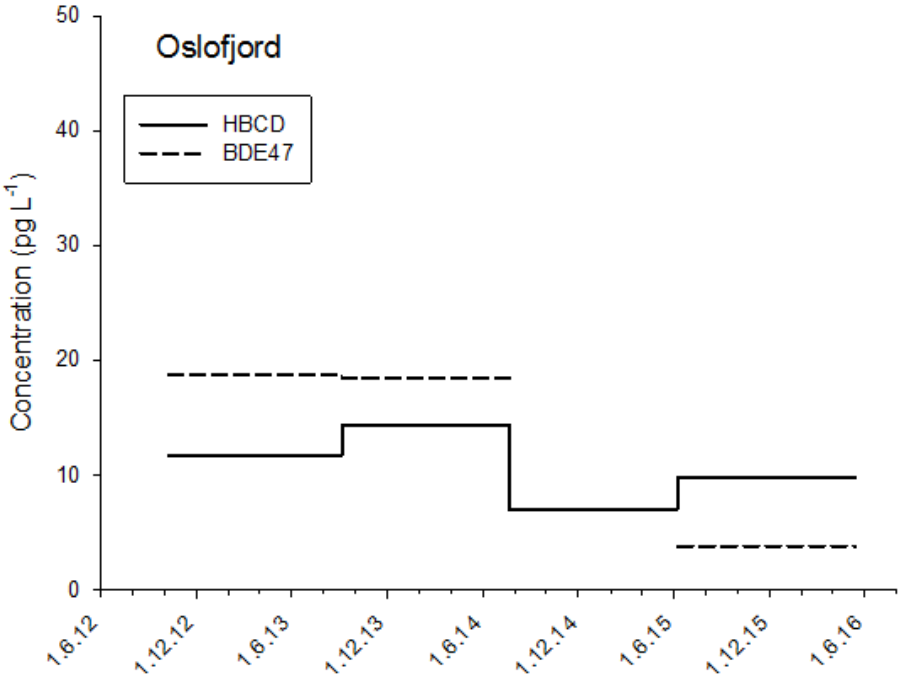


Figure 44. *Freely dissolved concentrations of BDE47 and α–HBCD in the Inner Oslofjord for the period 2012-2016.*

3.5 Analysis of stable isotopes

3.5.1 General description of method

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 = $a + b * (\text{Trophic Level})$

Then:

$TMF = 10^b$

TMFs 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 23***). 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 selected contaminants (BDE-47, -99, -100 and -209, SCCP and MCCP, PFOS and PFOSA), relationships between concentrations and $\delta^{15}N$ have been investigated 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 PCB153 (another compound with known biomagnifying properties), is plotted against δ15N in cod. The data material for Hg is larger (more individuals analysed per station), than for the other contaminants. Noteworthy observations from these regressions are referred to, below.

3.5.2 Results and discussion

There were no great differences in $\delta^{13}C$ between mussels or fish from the different areas, with some exceptions. 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 one full trophic level, while the differences observed were generally lower, except between stations situated at each end of the scale (***Figure 44***). The geographical differences in cod isotopic signatures are also largely reflected in the blue mussel isotopic signatures (***Figure 44***), indicating geographical differences in the baseline isotopic signatures (see discussion below). 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 it has previously been shown that differences in e.g. mercury content in tusk from Sørfjord area could be partly attributed to small differences in trophic position (or $\delta^{15}N$) (less than one full trophic level) (Ruus *et al*. 2013b), indicating that differences in $\delta^{15}N$, corresponding to less than one full trophic level aslo are of interest in terms of explaining differfences in bioaccumulation.

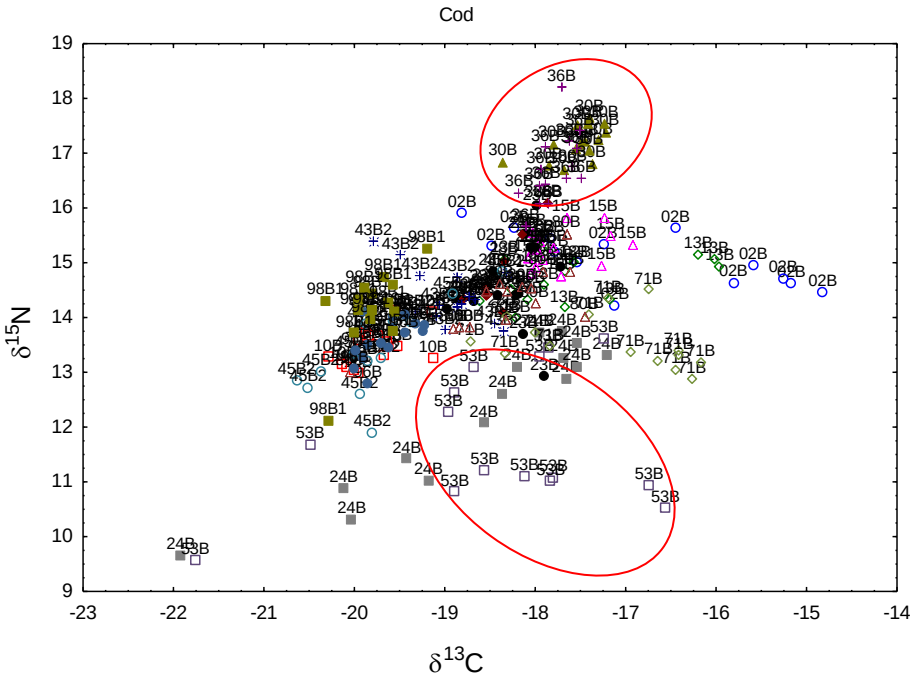
***Table 23**. Summary of analyses of stable isotopes: $\delta^{13}C$ and $\delta^{15}N$ in blue mussel and cod, 2015. Statistics shown are count (n), mean and standard deviation.*

	Blue mussel						Atlantic Cod					
	$\delta^{13}C_{VPDB}$			$\delta^{15}N_{AIR}$			$\delta^{13}C_{VPDB}$			$\delta^{15}N_{AIR}$		
Station ID	n	mean	st.dev.	n	mean	st.dev.	n	mean	st.dev.	n	mean	st.dev.
presumed less impacted, summary >>	**3**	**-20.77**	**0.13**	**3**	**6.08**	**0.13**	**15**	**-18.56**	**0.46**	**15**	**14.70**	**0.52**
Færder area (st. 36B)							15	-17.79	0.22	15	16.70	0.63
Hvaler (st. 02B)							14	-16.87	1.34	14	15.08	0.50
Farsund area (st. 15B)							15	-17.73	0.38	15	15.26	0.33
Bømlo north (st. 23B)							15	-18.28	0.36	15	14.61	0.76
Helgeland (st. 96B)							15	-19.65	0.27	15	13.62	0.38
Lofoten, Skrova (st. 98B1)							15	-19.80	0.29	15	14.16	0.69
Varangerfjord (st. 10B)							15	-19.77	0.33	15	13.47	0.36
Mølen (st. 35A)	3	-19.65	0.08	3	6.64	0.05						
Tjøme (st. 36A1)	3	-19.55	0.15	3	7.56	0.05						
Færder (st. 36A)	2	-19.52	0.04	2	7.40	0.08						
Singlekalven (st. I023)	3	-19.80	0.11	3	7.26	0.34						
Bjørkøya (st. 71A)	3	-19.73	0.04	3	6.13	0.13						
Gåsøy (st. 15A)	3	-20.78	0.17	3	8.18	0.10						
Krossanes (st. 57A)	3	-20.36	0.24	3	3.00	0.14						
Ranaskjær (st. 63A)	3	-20.18	0.19	3	3.54	0.14						
Lille Terøy (st. 69A)	3	-21.41	0.08	3	3.65	0.12						
Espevær (st. 22A)	3	-21.23	0.14	3	7.50	0.11						
Måløy (st. 26A2)	3	-21.63	0.12	3	5.02	0.08						
Outer Trondheimsfjord (st. 91A2)	3	-22.97	0.06	3	6.01	0.17						
Lofoten, Svolvær (st. 98A2)	3	-22.89	0.13	3	6.80	0.23						
Brashavn (st. 11X)	3	-21.12	0.27	3	6.46	0.10						
presumed more impacted, summary >>	**3**	**-20.21**	**0.14**	**3**	**6.05**	**0.25**	**14**	**-18.31**	**0.73**	**14**	**14.06**	**0.70**
Inner Oslofjord (st. 30B)							15	-17.54	0.29	15	17.19	0.30
Grenlandsfjord (st. 71B)							15	-17.19	0.86	15	13.57	0.48
Kristiansand harbour (st. 13B)							15	-17.57	0.86	15	14.74	0.45
Inner Sørfjord (st. 53B)							15	-18.42	1.34	15	11.76	1.23
Bergen harbour (st. 24B)							15	-18.61	1.30	15	12.31	1.33
Ålesund area (st. 28B)							8	-18.40	0.28	8	14.82	0.69
Inner Trondheimsfjord (st. 80B)							15	-18.33	0.65	15	14.32	0.59
Tromsø harbour (st. 43B2)							15	-18.94	0.42	15	14.39	0.49
Hammerfest harbour (st. 45B2)							15	-19.75	0.58	15	13.48	0.79
Gressholmen (st. 30A)	3	-20.46	0.26	3	7.30	0.19						
Gåsøya (st. I304)	3	-19.85	0.01	3	7.73	0.15						
Håøya (st. I306)	3	-19.13	0.15	3	7.75	0.11						
Ramtonholmen (st. I307)	3	-19.13	0.07	3	7.51	0.08						
Kirkøy (st. I024)	3	-20.02	0.20	3	8.20	0.54						
Croftholmen (st. I712)	3	-20.04	0.07	3	5.35	0.11						
Brevik church (st. I714)	3	-20.47	0.06	3	7.12	0.17						
Odderøy (st. I133)	3	-22.41	0.04	3	5.50	0.21						
Byrkjenes (st. 51A)	3	-19.77	0.29	3	3.38	0.58						
Eitrheimsneset (st. 52A)	3	-19.86	0.30	3	2.96	0.54						
Kvalnes (st. 56A)	3	-20.31	0.06	3	2.59	0.21						
Bodø harbour (st. 97A2)	3	-21.01	0.22	3	7.25	0.10						
Average between the two groups	**3**	**-20.49**	**0.14**	**3**	**6.07**	**0.19**	**15**	**-18.43**	**0.59**	**15**	**14.38**	**0.61**

Although there were generally no major differences in $\delta^{15}N$ between cod from different locations, individual cod from the Sørfjord (station 53B) and Bergen harbour (station 24B; both in Hordaland County) stand out with particularly low $\delta^{15}N$ signature (***Figure 44***). The same is shown for mussels from the Sørfjord (stations 51A, 52A, 56A and 57 A, as well as 63A in the Hardangerfjord area), 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 45***) indicating a high baseline (and not a higher trophic position of the Oslofjord cod). Furthermore, this was also shown in 2012, 2013 and 2014. In fact the stations show very similar patterns from 2012, through

2013 and 2014, to 2015 in terms of isotopic signatures, suggesting that this is a spatial trend more than a temporal trend. Bergen harbour (station 24B) was introduced in 2015.

a



b

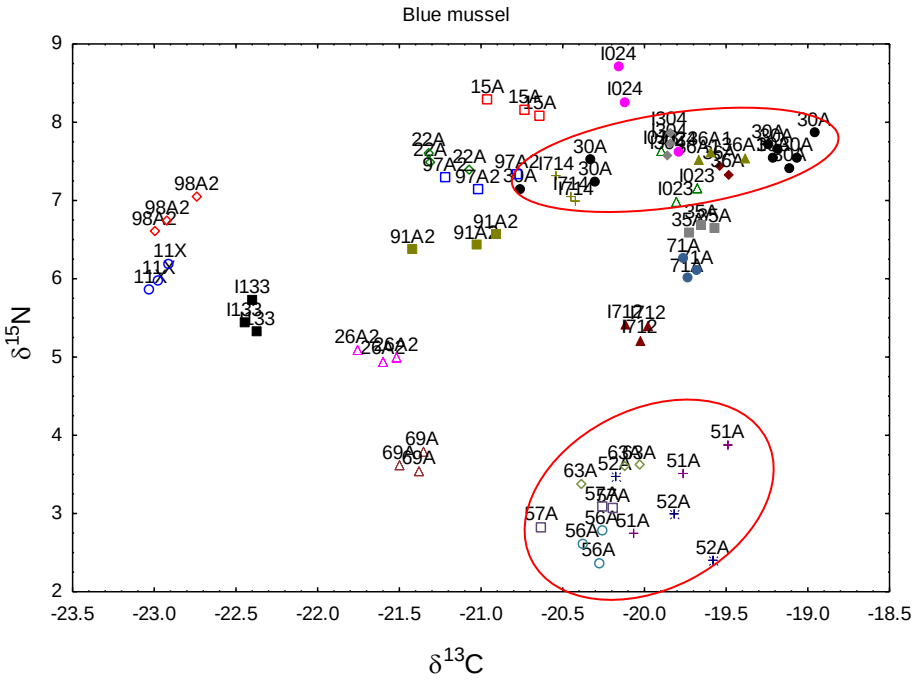


Figure 45. *$\delta^{13}C$ plotted against $\delta^{15}N$ in for cod (a) and blue mussel (b). Station codes are superimposed. Red ellipses indicate cod and blue mussel from the Inner Oslofjord and the Sørfjord, respectively.*

Plotting $\delta^{15}N$ against the concentration of Hg in cod could suggest higher concentrations in individuals with higher $\delta^{15}N$ (significant linear regression between $\delta^{15}N$ and Log[Hg] ;P<0.00001, with very poor goodness-of-fit; R^2=0.1327; ***Figure 46***), However, this is likely partly a result of different exposure, as well as difference in isotopic signature (baseline) among stations. But a linear regression excluding stations 53B and 30B also produced significant result (R^2=0.2347; P<0.0001). However, from ***Figure 46***, there are some indications of increasing Hg-concentrations with increasing $\delta^{15}N$ within stations. Linear regressions isolated for each station produced significant positive linear relationships between $\delta^{15}N$ and Log[Hg] for stations 02B, 13B 15B, 23B, 24B, 28B, 36B, 43B2 and 45B2.

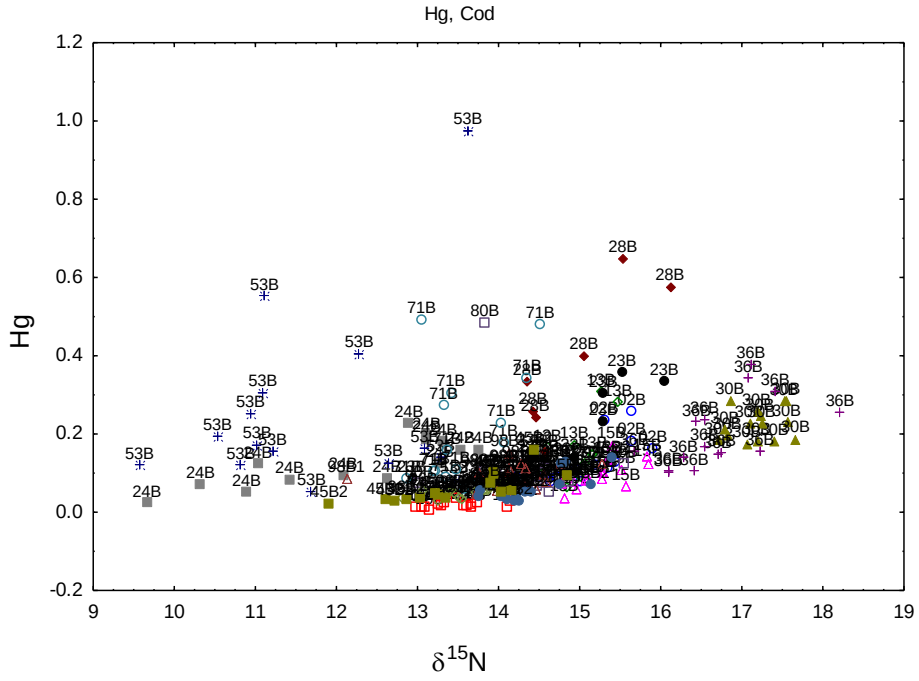


Figure 46. *$\delta^{15}N$ plotted against the concentration of Hg in cod. Station codes are superimposed.*

As Hg, PCB153 is a compound with known biomagnifying properties (Ruus *et al*. 2016b). Plotting $\delta^{15}N$ against the concentration of PCB153 in cod did not suggest higher concentrations in individuals with higher $\delta^{15}N$ (***Figure 47***). However, this could also partly be a result of different exposure, as well as difference in isotopic signature (baseline) among stations (high PCB153-exposure as well as low $\delta^{15}N$ in cod from Bergen harbour, 24B, and some individuals from Sørfjorden, 53B). A linear regression excluding stations 24B and 53B produced a significant positive relationship between log[PCB-153] and $\delta^{15}N$ (R^2=0.1670; P<0.00001). Linear regressions isolated for each station produced significant positive linear relationships between $\delta^{15}N$ and Log[CB153] for stations 24B, 28B and 45B2.

Plotting $\delta^{15}N$ against the concentration of PFOS in cod could suggest higher concentrations in individuals with higher $\delta^{15}N$ (significant linear regression between $\delta^{15}N$ and Log[PFOS], with poor goodness-of-fit; R^2=0.1307; P=<0.0006; ***Figure 48***), However, this could partly be a result of different exposure, as well as difference in isotopic signature (baseline) among stations (high PFOS-exposure as well as high $\delta^{15}N$ in cod from 36B). But a linear regression excluding station 36B also produced significant result (R^2=0.0545; P=<0.0326). Linear regressions isolated for each station produced a significant positive linear relationship between $\delta^{15}N$ and Log[PFOS] for station 24B (Bergen harbour).

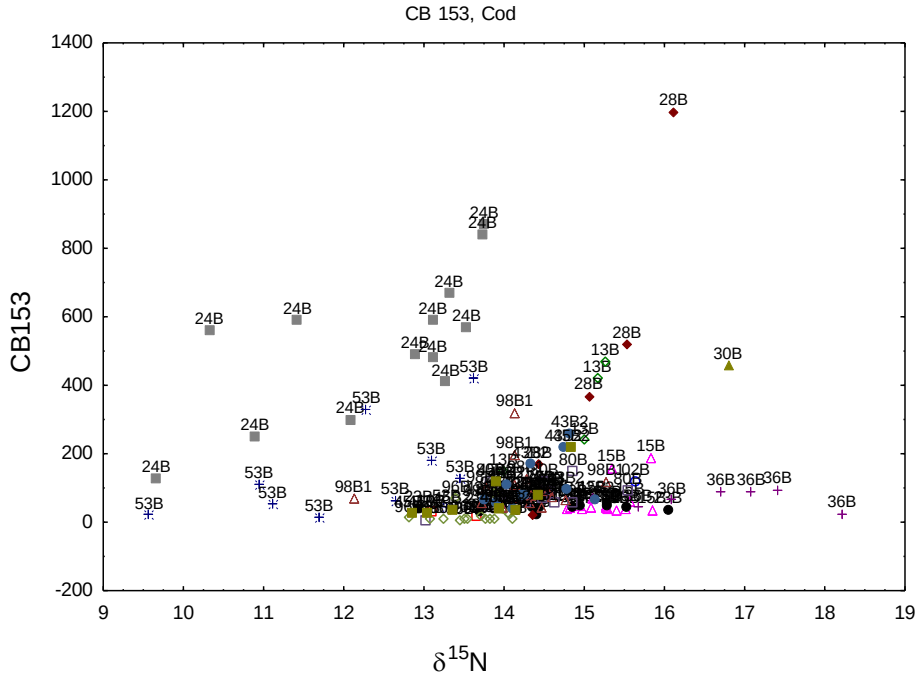


Figure 47. *δ^{15}N plotted against the concentration of PCB153 in cod. Station codes are superimposed.*

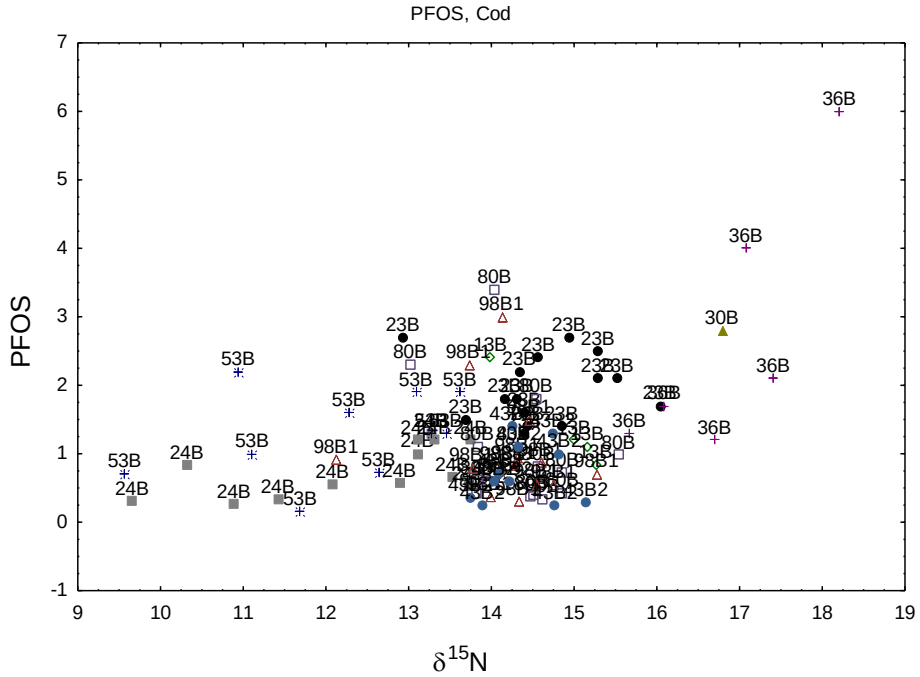


Figure 48. δ^{15}N plotted against the concentration of PFOS in cod. Station codes are superimposed.

3.6 Time trends for contaminants in cod when taking length into account

In last year's report (Green *et al.* 2015) we made an analysis of time trends of Hg in cod in Inner Oslo fjord, taking into account the correlation between cod length and concentration of Hg in muscle. We found that in this case, length had a significant effect on the perception of time trends; in particular, most of the apparent increase in Hg concentrations in cod in recent years can be explained by an increase in the mean size of the sampled cod. The correlation between length and Hg concentration is probably caused by accumulation of Hg as cod grows older; i.e., length acts as a proxy for age. In this chapter, we extend this analysis to all contaminants that have been in the JAMP/MILKYS program for some years, and all stations presently included in the program. Thus, for each time series (one contaminant at one station), we analyze time trends based on 'length-adjusted' concentrations and compare this to time trends based on the standard 'median' method (i.e. using median concentration for each year).

For technical reasons, the analysis of time trends in this chapter is slightly different from the main analysis of this report which are summarized in ***Table 11***. Most importantly, the results in ***Table 11*** is based on calculating non-linear time trends, while in this chapter we calculated linear time trends (for practical reasons; see details below). Therefore, the time trends of median values in some cases differ between ***Table 11*** and ***Table 25***. The main point of this chapter is to assess the effects with and without length-adjustment (i.e., the comparison internally is shown in ***Table 25***).

3.6.1 Methods

In summary, the procedure consisted of three phases: First, the data was prepared, which includes treatment of data below the quantification limit. In the second phase, we found the relationship between length and contaminant concentration for each contaminant, station, and year. From this, the expected concentration for fish of 'standard length' was calculated. We used three 'standard lengths': 40, 50 and 60 cm. In the third phase, we used these expected concentrations. Here, we tested whether there is a time trend (significant increase or decrease) in the concentrations of e.g. 40 cm cod. This was done for each contaminant and station. The three phases are described in more detail below.

Phase 1) Preparation of the data. We used all available contaminant concentrations in cod, back to 1981, for the chemical compounds that are used in the present report. As in the main analysis (***Table 11***), we used cod fillet samples for Hg and cod liver samples for all other compounds. A portion of the measurements (ca. 12%; 8126 of the 61826 measurements) are below the limit of quantification (LOQ). A statistically appropriate way to handle such data is to use the 'tobit' model for censored data (Tobin 1958). However, estimation of the model parameters (using the *vlgm* function in the R package *VGAM*, i.e., Vector Generalized Linear Models) is very slow and doesn't always succeed easily. As a pragmatic alternative, we instead replaced them with a random number (using a uniform distribution) between *LOQ*/2 and *LOQ*, where *LOQ* is the limit of quantification. This is not a perfect method, but at least avoids the artefacts that are created by choosing a single value (e.g. *LOQ*/2) as the replacement value. As this obviously may be affected by the exact random values that are picked, we picked these random values 20 times, creating 20 new data sets, each with different random values for the less-than's. The analyses below (phases 2 and 3) were then performed for each of these 20 data sets. In the end of the analyses, the results from these 20 analyses are summarized using median values (see "Phase 3" below).

Phase 2) Calculating expected concentration for fish of 'standard length'. For each contaminant, station, and year, we analysed the relationship between log(contaminant concentration) as

response variable and length (using log-concentration as response variable and length as explanatory variable). In ordinary linear regression, this relationship may easily be affected by one or a few outliers. However, due to the large number of regressions (3563 combinations of contaminant, station, and year), assessing outliers by manual checking of graphs was impractical and prone to human error. We therefore used robust regression methods (Ripley 2004) as implemented in the *rml* command of the *MASS* library in R (Venables and Ripley 2002). These methods decrease the influence of outliers (and possible errors in the database) substantially. As the first choice, we used the MM-estimator proposed by Yohai, Stahel & Zamar (1991), which combines high robustness (i.e. low sensitivity to outliers) with high efficiency (i.e. low standard error of the slope). When this method did not converge to a solution, we used Huber's M-estimator with tuning parameter c = 1.345 (the default in the *rml* command) as our second choice. Whether the MM- or M-estimator was used, we get a linear regression model, which then was used to predict log-concentration for 40, 50 and 60 cm cod. These predicted log-concentrations were then used as input for phase 3.

Phase 3) Calculating trends of 'standard length' concentrations over time. For each of the three standard lengths and for each contaminant and station, we performed linear regression for expected concentration as a function of year. This resulted in two numbers: the estimate of slope (change in log-concentration per year) and an associated t-value (the test statistic of linear regression). However, since we actually used 20 data sets with different random values, we got 20 slope estimates and 20 t-values for each contaminant and station. These were summarized by using the median value of each. Finally, we calculated the p-value based on the median t-value (whether the time trend is statistically significant or not).

For comparison, we also calculated time trends based on linear regression of median concentrations (per contaminant, station and year). For the latter analyses, length was not taken into account, but otherwise the time trend analysis (Phase 3) was identical (including using the same 20 data sets with different random values). Note that these time trends are not identical to the main time trend analysis of this report (***Table 11***). The similarity is that both analyses are based median values. However, in this chapter we use linear regression for detecting significant time trends, while the main analyses summarized in ***Table 11*** uses non-linear regression to "smooth" the time series, followed by comparing the last smoothed value of the time series with the first one. Another difference is the treatment of measurements below the limit of quantification (see *Phase 1*).

We used the following criteria for including a time series in the analyses: the time series should include at least 5 years, and at least 3 of those years must contain at least 5 fish in the sample.

The estimate of the time trend (the slope; *b*) is originally given as change in log-concentration per year, but for presentation, we have transformed it to percent change per year, using the formula

$$percent\ change = 100*(\exp(b) - 1)$$

In the figures, only results for 40 cm and 60 cm cod are presented.

3.6.2 Results

The analysis resulted in 224 time series (combinations of contaminants and stations) for cod. About 80% of the time series showed the same result whether we used the standard median method or length-adjusted concentrations (**Table 24**): In about half of the series (51.8 %; 116 time series) there were no significant time trends, and in about 30% of the time series there was a downward trend over time using median values or length-adjusted time series for all lengths from 40 to 60 cm. For the remaining 18.3 % of the time series, there was a tendency for discrepancies. For 12.5%

of the time series, the median values indicated a downward trend but the trend disappeared for some lengths (7.1%) or for all lengths (5.4%). In 4.5% of the series, the situation was opposite: median values did not indicate any (significant) trend, but there was a downward trend for at least one length when concentrations were adjusted for length. Finally, in three time series, median values did not indicate any (significant) trend, but there was an *upward* trend for at least one length. However, in one of the latter cases (Ag at station 30B), the time series has an outlier (it was sampled in 1993 and then in 2007-2014) which makes the time trend less trustworthy.

The results for each contaminant and station are shown in ***Table 25***. The table shows that for some of the metals at some stations, downwards trends indicated using median values disappear if length is taken into account. One example is shown in ***Figure 49*** and***Figure 49 Figure 50***. The graph indicates a frequently positive relationship between copper concentrations and fish size in most years. At the same time, the median size of cod sampled in the 1990s was typically around 50 cm, while the cod sampled the last years have been substantially smaller (between 30 and 40 cm in 2014). Together, this creates a downward time trend in median values, while it appears that at least some of that trend can be attributed to catching cod of smaller size. In addition, very small size of cod caught in a single year (2004) causes very low length-adjusted values for large cod and thereby increased uncertainty in the time trend (***Figure 50***). In this case it doesn't affect the slope of the time trend much.

It should be noted that a whole lot of regressions have been run, both for the concentration-length relationship and then for the time trends of concentration. It is therefore expected that some results (5% of the time series) are due to chance. Also, since we report trends that are below the $P < 0.05$ limit, the changes in time trends between methods may be very small, but just push the P-value just past the $P = 0.05$ limit (from $P < 0.05$ to $P > 0.05$ or vice versa).

3.6.3 Conclusion

Of the 224 time series (combinations of contaminants and stations) analyzed, the analyses indicate that for the large majority, taking length into account doesn't change time trend results: the time trend is either not significant, or significantly downward, using either method. However, in some cases including length appears to change the results. In most of those cases, including length reveals no time trend for some or all lengths (small or large fish), when median concentration values showed a downward trend. Due to large variation in cod size among years, length-adjustment tends to create outliers (e.g. ***Figure 50***). If length-adjustment were to be used routinely, one would need to deal with such methodological issues in a good way.

Table 24. *Number and percentage of time series which had significant ($P < 0.05$) trends using either of the methods.*

Trends	Number	Percent
No significant time trends using either method	116	51.8
No time trend for medians; decrease for at least one length	10	4.5
No time trend for medians; increase for at least one length	3	1.3
Decrease for medians; no trend for any length	12	5.4
Decrease for medians; decrease for some but not all lengths	16	7.1
Decrease for medians; decrease for all lengths	67	29.9
Sum	**224**	**100.0**

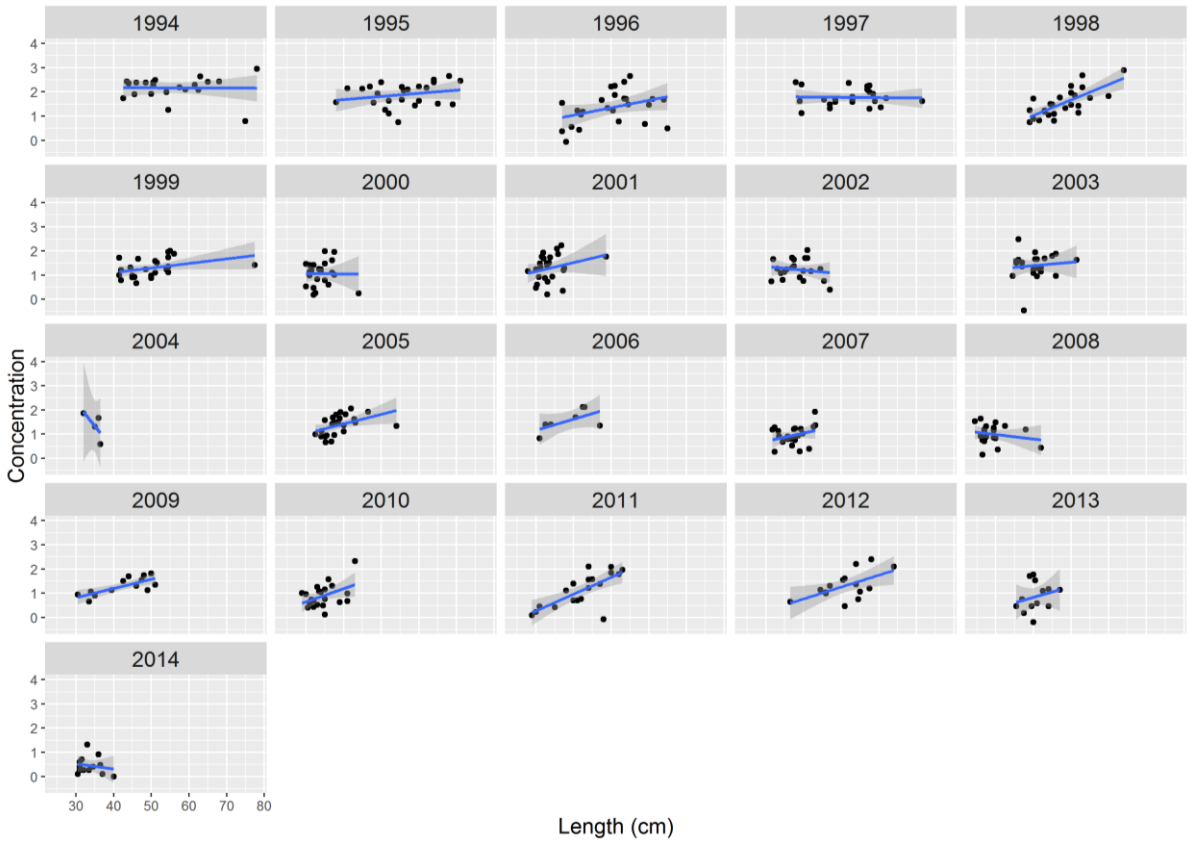


***Figure 49**. Concentration vs. length for copper (Cu) at station 10B (Varangerfjord).*

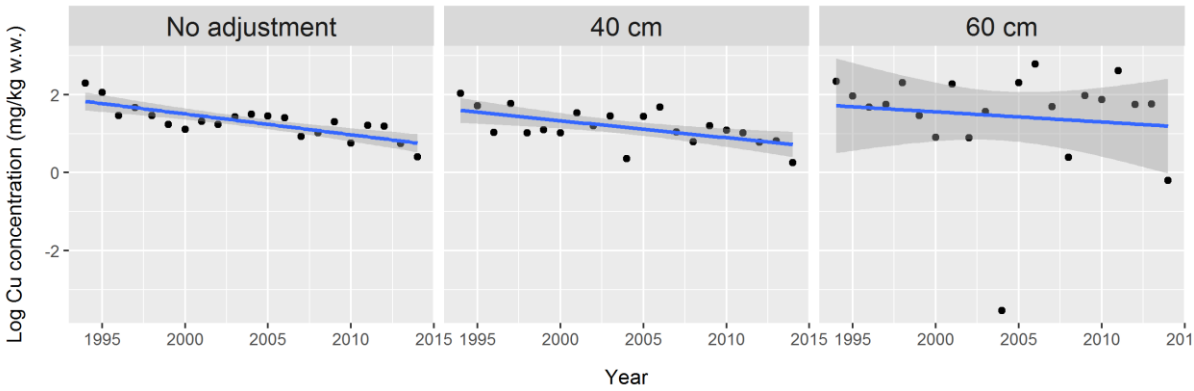


***Figure 50**. Concentration over time for copper (Cu) at station 10B (Varangerfjord), using median log concentration without length concentration each year (left) as well as length-adjusted concentrations (middle and right). The outlier value for 60 cm cod in 2004 is caused by exceptionally small-sized cod used in 2004.*

***Table 25**. Significant time trends using median concentration values (no adjustment for length) or length-adjusted concentrations. While the format of the table is similar to **Table 11**, the symbols of this table cannot be directly compared to the results of **Table 11**, as the time trend is not calculated in identical ways (see main text); the main purpose of this table is the comparison between the first and second symbol internally in this table. For each substance and station, the first symbol indicates the result using median concentration values, the second symbol the result using length-adjusted concentrations. Arrows indicate downward (↓) or upward (↑) trends, or no significant trend (○). For the length-adjusted concentrations (the second symbol), we used ↓ to indicate that all lengths (40, 50 and 60 cm) had a downward trend, "?" to indicate that only one or two of the lengths had a downward trend, **and** ↑ to indicate that at least one of the lengths (40, 50 and 60 cm) had an upward trend. The coloured cells are the time series where the two methods yielded different results (see explanation below table).*

St.	Ag	As	Co	Cd	Cr	Cu	Hg	Ni	Pb	Zn	PCB28	PCB52	PCB101	PCB118	PCB138	PCB153	PCB180	ppDDE	SCCP	MCCP	BDE47	BDE100	BDE209	PFOS	PFOSA	PFBS
30B	o↑	↓↓	oo	oo	oo	o↓	oo	oo	oo	oo	oo	oo	oo	oo	oo	oo	oo	oo			oo	oo	↓↓	oo	oo	↓↓
36B	oo	oo	oo	↓↓	oo	↓↓	↓ o	oo	↓↓	↓↓	oo	oo	oo	oo	oo	oo	oo	oo			↓↓	oo	↓ ?	↓ ?	oo	↓↓
13B	o↓	↓ ?	oo	oo	↓o	oo	oo	↓ o	oo	oo	oo	oo	oo	o↑	o↑	oo	oo				oo	oo	oo	↓↓	oo	↓↓
15B	oo	oo	oo	oo	↓ ?	oo	oo	oo	↓↓	oo	↓↓	↓ ?	↓↓	↓↓	↓↓	↓ ?	↓↓	↓↓								
53B				oo		oo	oo		oo	oo	oo	oo	oo	oo	oo	oo	oo	oo	↓↓	o↓	oo	oo	oo	↓↓	oo	↓↓
23B	oo	↓↓	oo	oo	oo	oo	oo	oo	↓↓	oo	↓↓	↓ ?	↓ ?	↓↓	↓↓	↓ ?	↓ ?	↓↓	oo	oo	↓↓	↓↓	↓ o	oo	o↓	↓↓
80B	↓ o	oo	oo	oo	↓↓	oo	oo	oo	oo	oo	↓ o	↓ o	↓ o	↓↓	↓↓	↓↓	↓↓				oo	o↓	oo	↓ o	↓ o	↓↓
98B1	oo	oo	oo	oo	↓ o	oo	oo	oo	↓ ?	oo	↓↓	↓↓	↓↓	↓↓	↓↓	↓↓	↓↓	↓↓			↓↓	o↓	oo	oo	↓ ?	↓↓
43B2	oo	↓↓	oo	↓ ?	oo	oo	oo	oo	oo	↓↓	o↓	o↓	↓↓	↓↓	↓↓	↓↓	↓↓				↓↓	↓↓	oo	↓↓	↓↓	↓↓
10B	oo	oo	o↓	↓ ?	↓ o	↓?	oo	↓↓	o↓	↓ ?	↓↓	↓↓	↓↓	↓↓	↓↓	↓↓	↓↓	↓↓								

Explanation of cell colour:

Median values: no significant time trend. Length-adjusted values: downward time trend (for at least one length).

Median values: Significant downward time trend. Length-adjusted values: no time trend for one or two lengths.

Median values: Significant downward time trend. Length-adjusted values: no time trend for all lengths.

Median values: no significant time trend. Length-adjusted values: upward time trend (for at least one length).

3.7 Note on application of quality standards

3.7.1 Background

For the past twenty years contaminant concentrations have been assessed using the Norwegian environmental classification system for biota (Molvær *et al*. 1997). The system has five classes derived from presumed background concentrations and addresses water, sediment and biota. In this chapter only the system for biota is used for the comparisons with quality standards. The system is specfic with respect to species and tissue. The upper limit of the first and best class is the presumed high background concentration based on published studies or data from Norwegian monitoring programmes. Classes II to V were subjectively determined, but it should be noted that there have been only minor revisions in the twenty years the system for biota has been in use (see Appendix C).

With the implimentation of the Water Framework Directive (WFD) in 2000 (2000/60/EC) and the consequent adoption in Norwegian legislation in 2006, the level of contamination could be assessed using a risk-based approach (2008/105/EC, later replaced by 2013/39/EU). This was largely based on individual toxicological studies on a small group of species, not always marine. Uncertianty of relevance to the marine ecosystem was compensated by risk factors; the more the uncertainty the lower the concentration of the quality standard. It should be noted that these quality standards are not species or tissue specific. In this regard, the EU has developed technical guidance documents (EC 2011, 2014) so that each member state could opt for deriving their own quality standards as long as these provided the same level of environmental protection (2013/39/EU §17).

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, the system of the Norwegian Environment Agency provides the primary assessment criteria. 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.

Norway has supplmented EU's list of EQS with quality standards of their own for biota for other hazardous substances (Arp *et al*. 2014, Miljødirektoratet 2016). With these quality standards the use of the classification system has been given less priority. For example in the recent series of operational monitoring in accordance with the WFD the classification system on contaminants in biota was applied, with few exceptions, only where quality standards were not available (Berge 2016a, 2016b, Gitmark *et al*. 2016, Håvardstund & Næs 2016, Øxnevad *et al*. 2016, Ruus *et al*. 2016a, Schøyen *et al*. 2016).

3.7.2 Materials and methods

OSPAR (2016) has done an initial study on converting the EQS for mercury in biota (20 µg/kg wet weight) to an appropriate limit for each of the indicator species-tissues that the OSPAR monitoring programme uses. This was done by using the aforementioned EU technical guidance documents. This work-intensive study demonstrated that the conversion could be done but hightlighted the uncertainties that were involved. To apply such an effort for each of the contaminants where there are quality standards in biota was considered unfeasible within the scope of this report. Therefore, in this comparison exercise quality standards were applied directly to the main species-tissue monitored under MILKYS: blue mussel, cod liver and cod fillet.

The focus of this exercise is to assess how these two systems have rated areas considered remote from point sources, and if the quality standards are particularly high, and how they would rate areas considered to to be more impacted by point sources.

Blue mussel and cod have been monitored under the MILKYS programme since the 1980s. The stations monitored are both impacted areas and less impacted areas. There are a total of 52 stations (36 mussel stations and 16 cod stations). Using the ICES classification the stations that were considered less impacted by contamination were grouped; 27 total, 20 mussel stations and 7 cod stations (ICES classification B and RH in ***Table 26***). This comparison exercise is based on the annual median values for the period 1981-2015. The number of years each station was monitored varied from one to 35. All stations were sampled in 2015. The limit of quantification was used for those results below this limit.

For this comparison, median concentrations were termed “acceptable” if they were below the quality standard or in Class I or II in the classification system.

***Table 26**. Blue mussel and cod stations used for the comparison between Norwegian Environmental Agency classification system and quality standards. The ICES subjective classification was used to group the stations with respect to contamination: background or reference (B), representative of general conditions of contamination (RH) and impacted directly by discharges of contamination (IH). The number indicates the number of years where monitoring of one or more contaminants occurred during the period 1981-2015.*

Station-name	Species	B	RH	IH
Outer Trondheimsfjord (st. 91A2)	blue mussel	4		
Lofoten, Svolvær (st. 98A2)	blue mussel	18		
Skallneset (st. 10A2)	blue mussel	20		
Helgeland (st. 96B)	cod	3		
Lofoten, Skrova (st. 98B1)	cod	22		
Varangerfjord (st. 10B)	cod	22		
Solbergstrand (st. 31A)	blue mussel		34	
Mølen (st. 35A)	blue mussel		35	
Tjøme (st. 36A1)	blue mussel		3	
Færder (st. 36A)	blue mussel		29	
Singlekalven (st. I023)	blue mussel		21	
Bjørkøya (st. 71A)	blue mussel		35	
Risøy (st. 76A)	blue mussel		24	
Gåsøy (st. 15A)	blue mussel		25	
Krossanes (st. 57A)	blue mussel		30	
Ranaskjær (st. 63A)	blue mussel		28	
Utne (st. 64A)	blue mussel		4	
Vikingneset (st. 65A)	blue mussel		29	
Lille Terøy (st. 69A)	blue mussel		23	
Espevær (st. 22A)	blue mussel		26	
Måløy (st. 26A2)	blue mussel		4	
Bjørnebærviken (st. I969)	blue mussel		21	
Brashavn (st. 11X)	blue mussel		19	
Færder area (st. 36B)	cod		35	
Kirkøy, Hvaler (st. 02B)	cod		4	
Farsund area (st. 15B)	cod		26	
Bømlo north (st. 23B)	cod		26	
Akershuskaia (st. I301)	blue mussel			22
Gressholmen (st. 30A)	blue mussel			32
Gåsøya (st. I304)	blue mussel			21
Håøya (st. I306)	blue mussel			20
Ramtonholmen (st. I307)	blue mussel			20
Kirkøy (st. I024)	blue mussel			19
Croftholmen (st. I712)	blue mussel			21
Brevik church (st. I714)	blue mussel			1
Lastad (st. I131A)	blue mussel			21
Odderøy (st. I133)	blue mussel			21
Byrkjenes (st. 51A)	blue mussel			30
Eitrheimsneset (st. 52A)	blue mussel			27
Kvalnes (st. 56A)	blue mussel			29
Nordnes (st. I241)	blue mussel			20
Moholmen (st. I965)	blue mussel			15
Bodø harbour (st. 97A2)	blue mussel			4
Inner Oslofjord (st. 30B)	cod			32
Grenlandsfjord (st. 71B)	cod			4
Kristiansand harbour (st. 13B)	cod			7
Inner Sørfjord (st. 53B)	cod			29
Bergen harbour (st. 24B)	cod			1
Ålesund area (st. 28B)	cod			3
Inner Trondheimsfjord (st. 80B)	cod			7
Tromsø harbour (st. 43B2)	cod			7
Hammerfest harbour (st. 45B2)	cod			3

3.7.3 Results

There are 23 contaminants or groups of contaminants that have quality standards for biota. Of these 11 can be assessed by EU's EQS (2013/39/EU) and the remaining can be assessed by national quality standards (Arp *et al.* 2014, *Miljødirektoratet* 2016) (***Table 7***). Nine of the 23 can also be classified by the Norwegian Environmental Agency classification system for biota. Only two of these 23 have not been monitored under this programme (Dicofol and heptachlor, including heptachlorexpoxide). The 21 remaining contaminants were monitored during some part of the period 1981-2015, and at least in 2015 except for dioxins, hexachlorobutadiene and lindane (γ-HCH). A total of 10049 medians were used in this comparison, 40 % from less impacted stations (***Table 27***).

Median concentrations of PBDE (n=169, sum of BDE-28, -47, 99, 100, 153 and -154) and octylphenol (n=80, 4-T-NP used as an indicator) for all the stations always exceeded the quality standard of 0.0085 and 0.004 µg/kg w.w., respectively. PBDE was 0.012 µg/kg w.w. for blue mussel and 0.93 µg/kg w.w. for cod liver. BDE47 alone was always higher than the standard.

The median concentrations of nine contaminants never exceeded (with one exception[1]) the quality standards even when considering all the stations, *viz*:

- Short chained chloralkanes (SCCP, n=98) had a maximum of 1160 µg/kg w.w. (cod liver) compared to the quality standard of 6000 µg/kg w.w.
- Hexabromocyclododecane (α-HBCD as an indicator, n=91) had a maximum of 24.5 µg/kg w.w. (cod liver) compared to the quality standard of 167 µg/kg w.w.,
- Hexachlorcyclohexane (α-HCH as an indicator, n=1193) had a maximum of 37.5 µg/kg w.w. (cod liver) compared to the quality standard of 61 µg/kg w.w.,
- Hexachlorobutadiene (n=4) had a maximum of 0.2 µg/kg w.w. (blue mussel) compared to the quality standard of 55 µg/kg w.w.,
- Nonylphenol (4-T-NP as an indicator,n=79), had a maximum of 682 µg/kg w.w. (cod liver) compared to the quality standard of 3000 µg/kg w.w.,
- Pentachlorobenzene (n=1189), had a maximum of 19.5 µg/kg w.w. (cod liver) compared to the quality standard of 50 µg/kg w.w.
- PFOA (n=86), had a maximum of 20 µg/kg w.w. (a LOQ cod liver) compared to the quality standard of 91 µg/kg w.w.
- Anthracene (n=356), had a maximum of 18 µg/kg w.w. (blue mussel) compared to the quality standard of 2400 µg/kg w.w.
- Benzo[a]anthracene (n=347), had a maximum of 63 µg/kg w.w. (blue mussel) compared to the quality standard of 304 µg/kg w.w.

The comparison for the remaining 10 contaminants are discussed below.

[1] A single case of 78 µg γ–HCH/kg w.w. in blue mussel in 2002.

Table 27. *Comparison between Norwegian Environmental Agency classification system (Cl, Molvær et al. 1997) and quality standards (Qs) from the Water Framework Directive (WFD) (cf. Environmental Quality Standard Directive-2013/39/EU) or national quality standards (concerns substancers in blue bold type, Norwegian Environment Agency (NEA, Miljødirektoratet 2016)) for hazardous substances in "biota". White boxes indicate no classification system, green boxes indicate no exceedences of Class II or Qs, red boxes indicate only exceedences of Qs, purple boxes indicate that one or more classes applied or both exceedences and non-exceedences were registered. The numbers indicate the number of annual median concentrations from this monitoring for blue mussel (M) and cod (G) liver (Gl) and fillet (Gf). n.d. indicates no data. This overview covers all stations (All) and those considered less impacted by contamination (R), 1981-2015, see* ***Table 26****.*

	All MG		All M		All Gl		All Gf		R MG		R M		R Gl		R Gf	
Hazardous substance	Cl	Qs	Cl	Qs	Cl	Qs	Cl	Qs	Cl	Qs	Cl	Qs	Cl	Qs	Cl	Qs
Brominated diphenylether																
[indicator: ΣPBDEs 28, 47, 99, 100, 153, 154]	169		68		100		1		79		36		43		n.d.	
C10-C13 Chloroalkanes (SCCP)																
	98		41		55		2		46		26		20		n.d.	
C14-C17 Chloroalkanes (MCCP)																
	93		38		53		2		43		24		19		n.d.	
DDT, total																
[indicator: p,p-DDE]	1212		796		219		197		531		313		117		101	
Dioxins																
[indicator: TCDDN - nordic model]	111		99		9		3		43		31		9		3	
Hexabromocyclododecane (HBCD)																
[indicator: α–HBCD]	91		39		50		2		45		24		20		1	
Hexachlorobenzene (HCB)																
	1283		868		218		197		564		346		117		101	
Hexachlorcyclohexane (HCH)																
[indicator: γ–HCH]	1193		790		211		192		513		308		105		100	
Hexachlorobutadiene (HCBD)																
	4		4		n.d.		n.d.		n.d.		n.d.		n.d.		n.d.	
Mercury and its compounds																
[indicator: total mercury]	1298		1020		2		276		563		423		2		138	
Nonylphenol																
[indicator: 4-T-NP]	79		36		38		5		35		22		12		1	
Octylphenol																
[indicator: 4-N-OP]	80		36		39		5		35		22		12		1	
Pentachlorobenzene (QCB)																
	1189		782		213		194		523		306		116		101	
Perflurooctanoic acid (PFOA)																
	86		n.d.		86		n.d.		36		n.d.		36		n.d.	
Perfluorooctane sulfonic acid (PFOS)																
	86		n.d.		86		n.d.		36		n.d.		36		n.d.	
Polyaromatic hydrocarbons (PAH) [1)]																
Anthracene																
	351		346		4		1		44		44		n.d.		n.d.	
Benzo(a)anthracene																
	347		345		1		1		44		44		n.d.		n.d.	
Benzo(a)pyrene																
	348		346		1		1		44		44		n.d.		n.d.	
Fluoranthene																
	352		344		4		4		44		44		n.d.		n.d.	
Polychlorinated biphenyls (PCB)																
[indicator: ΣCBs 28, 52, 101, 118, 138, 153, 180]	1346		894		254		198		599		370		129		100	
Tributyltinn compounds (TBT)																
	233		220		13		n.d.		108		98		10		n.d.	

1) Crustaceans and molluscs. (Monitoring of these PAHs not appropriate for fish)

Mercury

Application of the quality standard of 20 µg/kg w.w. (EUs EQS) on median concentrations of blue mussel from less impacted stations revealed 64.8 % were acceptable (below the EQS) (***Figure 51***). Using the classification system revealed over 95% of medians were in Class I or II. The preferred matrix for investigating mercury in fish is the muscle tissue. For cod fillet from less impacted stations only 11.6 % were acceptable according to the EQS whereas 98.6 % could be considered acceptable using the classification system.

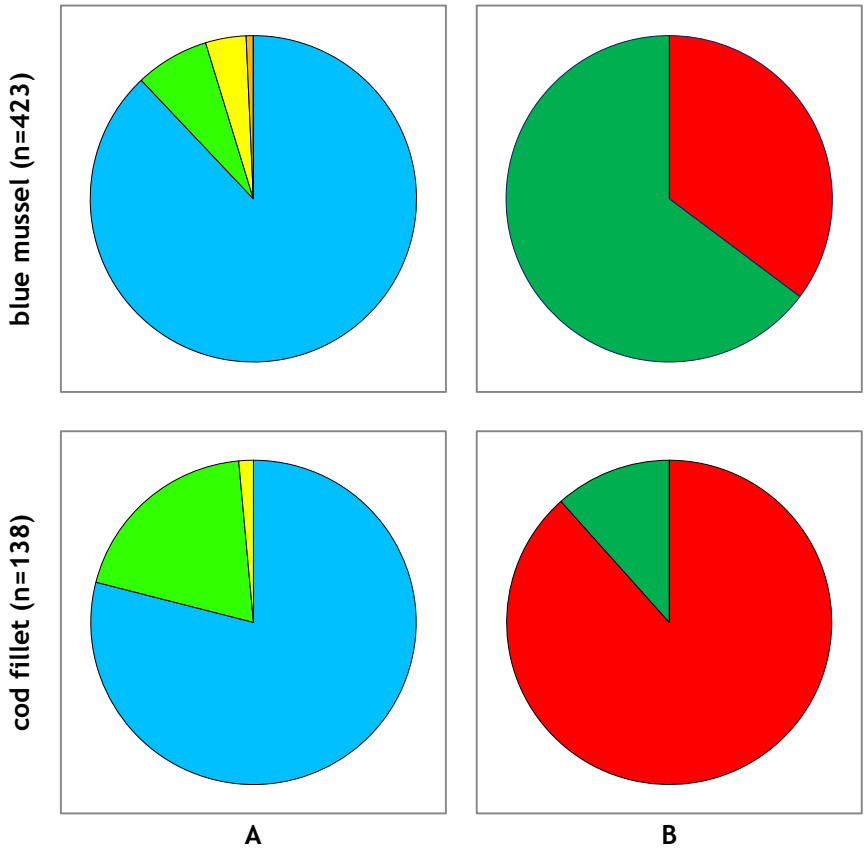


Figure 51. *Assessment of mercury in blue mussel and cod fillet from less impacted stations using the five-class classification system (**A**) and the quality standard (**B**) based on annual median concentrations. Colour coding in Figure A refers to classification colours (cf.* ***Table 29***). The green and red *colour coding in Figure B refers to the count below and and above the standard, respectively (cf.* ***Table 7***).

TBT

Application of the national quality standard of 150 µg/kg w.w. (EUs EQS) on median concentrations of blue mussel from less impacted stations showed that 95.9 % were acceptable (***Figure 52***B). This corresponded closely to the results when using the classification system that showed that 94.9% of medians were acceptable (Class I or II) (***Figure 52***A). There was insufficient data to do a comparison in cod liver or cod fillet.

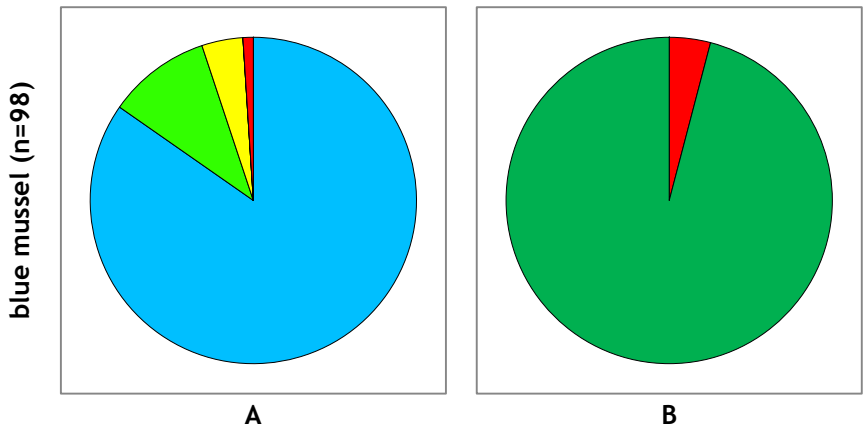


Figure 52*. Assessment of TBT in blue mussel from less impacted stations using the five-class classification system (**A**) and the quality standard (**B**) based on annual median concentrations. Colour coding in Figure A refers to classification colours (cf. **Table 29**).* The green and red *colour coding in Figure B refers to the count below and and above the standard, respectively (cf. **Table 7**).*

PCB

PCB has been monitored sufficiently in all three tissues (cod fillet, cod liver, and mussel soft tissue). Application of the national quality standard of 1 µg/kg w.w. on median concentrations of blue mussel from less impacted stations indicated 58.1 % were acceptable, whereas the medians were acceptable in all but one case in the classification system (***Figure 53***). For cod liver and fillet from less impacted stations only 0 % and 63 % were acceptable, respectivley whereas in the classification system there was only one case (liver) that was unacceptable.

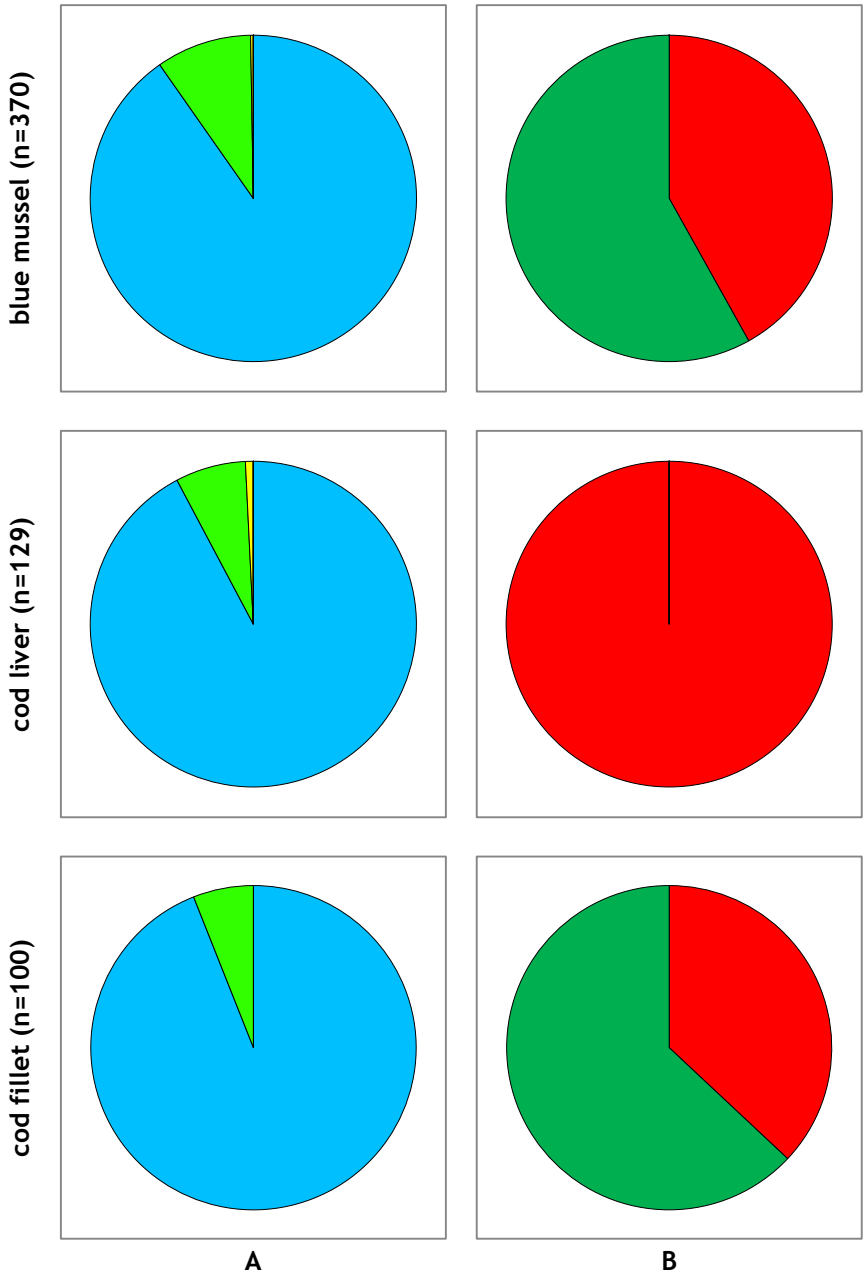


Figure 53. *Assessment of PCB-7 in blue mussel, cod liver and cod fillet from less impacted stations using the five-class classification system (**A**) and the quality standard (**B**) based on annual median concentrations. Colour coding in Figure A refers to classification colours (cf.* ***Table 29***). The green and red *colour coding in Figure B refers to the count below and and above the standard, respectively (cf.* ***Table 7***).

DDT

For DDT ppDDE was used as an indicator. Application of the national quality standard of 650 µg/kg w.w. on all of the median concentrations of blue mussel, cod liver and cod fillet from less impacted stations indicated that all 531 cases were acceptable. The classification system detected only 11 cases above Class II (all blue mussel). When applying these systems to just impacted stations, only six cases (of 681, all cod liver) were unacceptable with respect the quality standard (***Figure 54***). The classification system revealed 31 cases for blue mussel, nine cases for cod liver and eight cases for cod fillet were unacceptable.

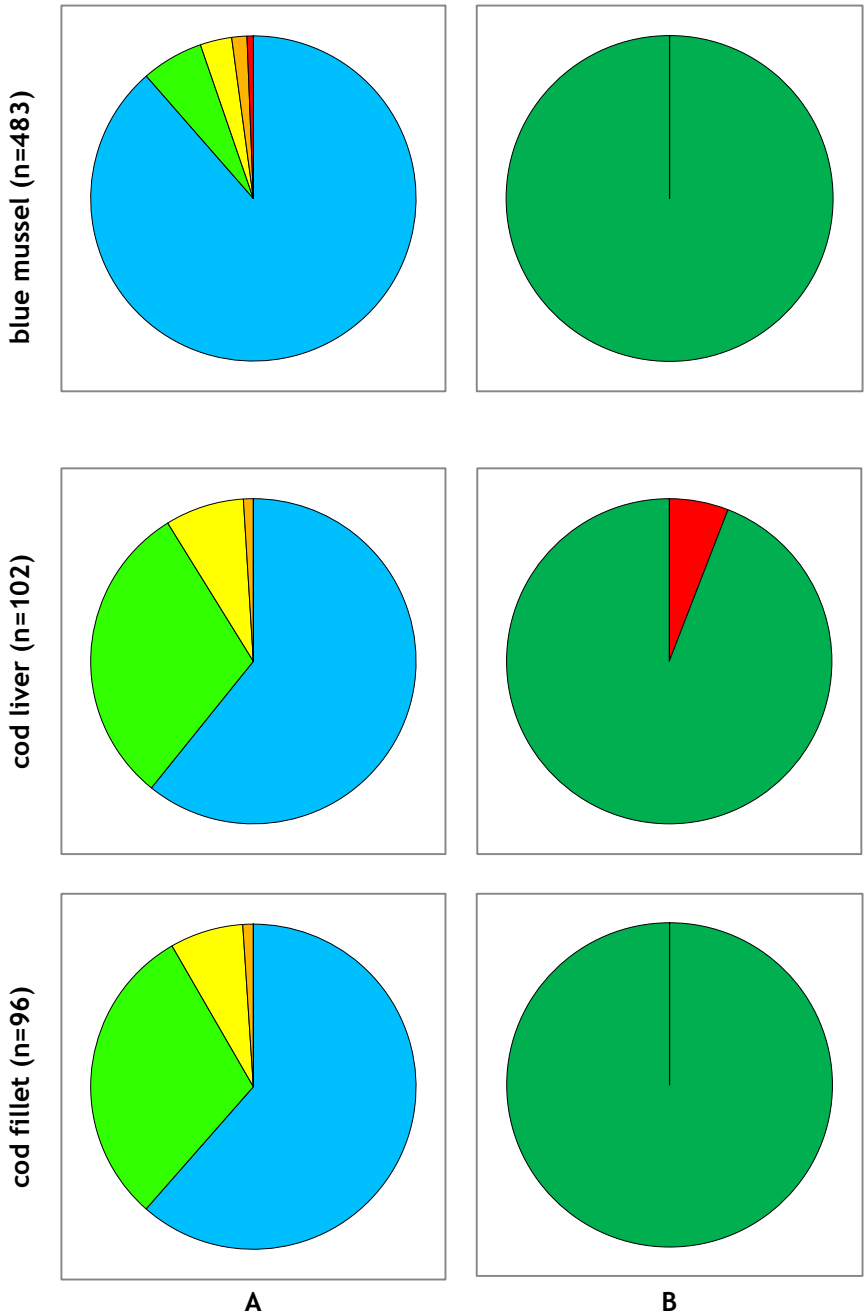


Figure 54*. Assessment of ppDDE in blue mussel, cod liver and cod fillet from impacted stations using the five-class classification system (**A**) and the quality standard (**B**) based on annual median concentrations. Colour coding in Figure A refers to classification colours (cf.* ***Table 29***). The green and red *colour coding in Figure B refers to the count below and and above the standard, respectively (cf.* ***Table 7****).*

Benzo[a]pyrene and fluoranthene

PAHs are only monitored in blue mussel. Application of the EU's EQS of 5 µg/kg w.w. on the median concentrations of benzo[a]pyrene (BaP) indicated that two (of 44) were unacceptable, whereas, whereas nine were unacceptable with respect to the classification system (***Figure 55***). For fluoranthene 12 medians were unacceptable with respect to the EQS of 30 µg/kg w.w. Fluorathene is not included in the classification system.

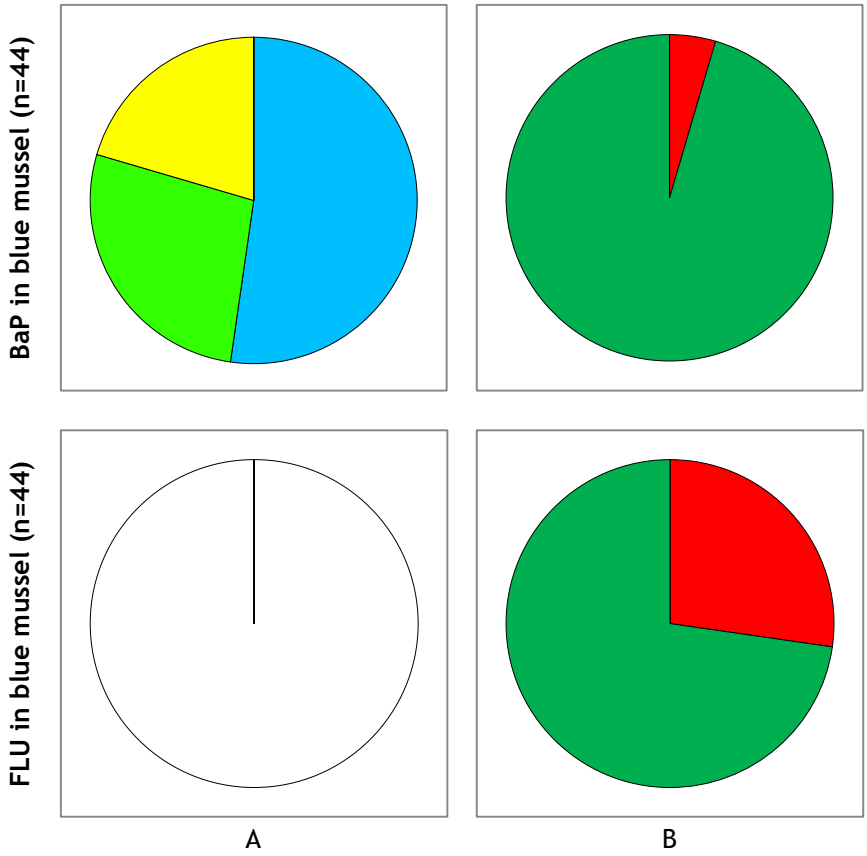


Figure 55*. Assessment of benzo[a]pyrene (BaP) and fluoranthene (FLU) in blue mussel from less impacted stations using the backgroundfive-class classification system (**A**) and the quality standard (**B**) based on annual median concentrations. Colour coding in Figure A refers to classification colours (cf.* ***Table 29***). FLU is not classified The green and red *colour coding in Figure B refers to the count below and and above the standard, respectively (cf.* ***Table 7****).*

PFOS

Application of the national quality standard of 9.1 µg/kg w.w. (EUs EQS) on median concentrations of cod liver from less impacted stations showed that 75 % were acceptable (***Figure 57***). PFOS is not included in classification system, but using assumed a presumed high background concentration of 0.5 µg/kg w.w. (***Table 31***) 94.4% of medians were below this limit. PFOS in blue mussel and cod fillet has not been investigated.

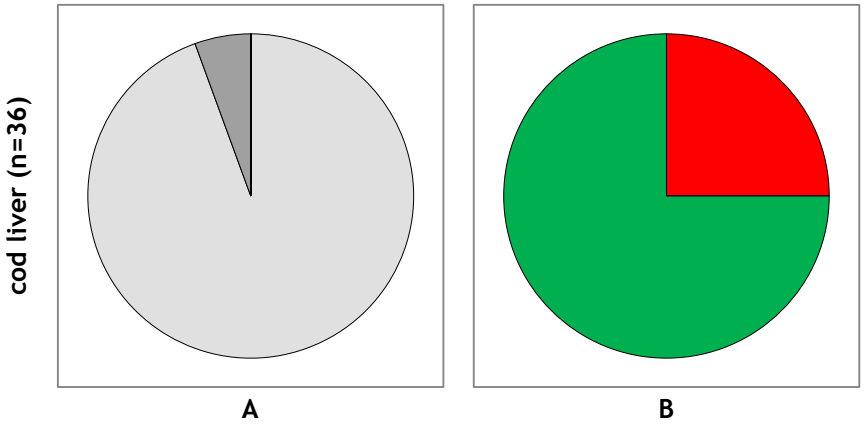


Figure 56. *Assessment of PFOS in cod liver from less impacted stations using the suggested limit for high background (**A**) and the quality standard (**B**) based on annual median concentrations. Light and dark grey colour in Figure A indicates below and above background, respectively.* The green and red *colour coding in Figure B refers to the count below and and above the standard, respectively (cf. **Table 7**).*

MCCP

Application of the national quality standard of 170 µg/kg w.w. on median concentrations of cod liver from less impacted stations showed that 84.2 % were acceptable, 67.9 % when all stations were considered (***Figure 57***). MCCP is not included in classification system below this limit. There was insufficient data to do a comparison in cod liver or cod fillet.

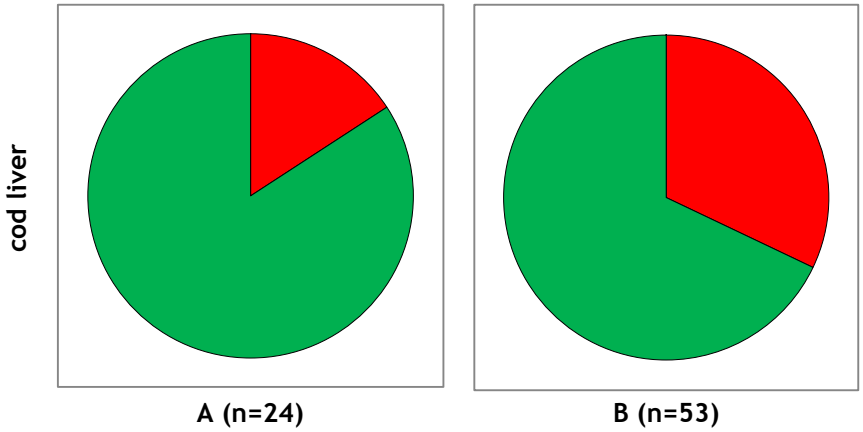


Figure 57. *Assessment of MCCP in cod liver from less impacted stations (**A**) and all stations (**B**) using based on annual median concentrations.* The green and red *colour coding refers to the count below and and above the standard, respectively (cf. **Table 7**).*

HCB

Application of the EU's EQS of 10 µg/kg w.w. on all of the median concentrations of cod liver from impacted stations indicated that 75.2 % were acceptable, whereas all of them were acceptable with respect to the classification system (***Figure 58***). In blue mussel there was only one unacceptable case (of 522), whereas the classification system detected 68 that were unacceptable. None of the cod fillet medians were unacceptable using the quality standard, however eight were unacceptable using the classificaiton systems.

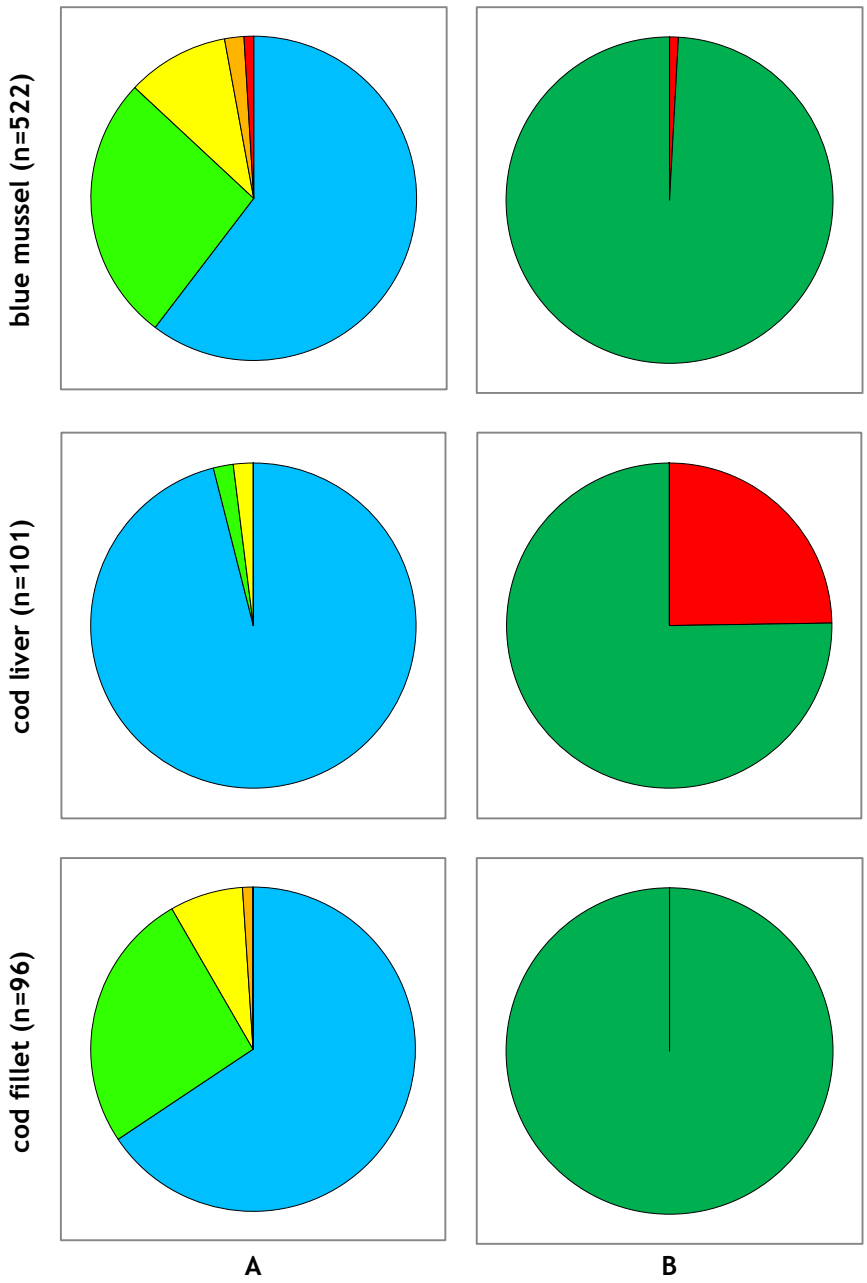


Figure 58. *Assessment of HCB in blue mussel, cod liver and cod fillet from impacted stations using the five-class classification system (**A**) and the quality standard (**B**) based on annual median concentrations. Colour coding in Figure A refers to classification colours (cf.* ***Table 29***). The green and red *colour coding in Figure B refers to the count below and and above the standard, respectively (cf.* ***Table 7***).

Dioxins

Application of the EU's EQS of 0.0065 µg/kg w.w. on the median concentrations of blue mussel, from less impacted stations indicated 95.2 % acceptable data, whereas under the classification system 57.1 % were acceptable (***Figure 59***). The few data available for cod liver and cod fillet (a total of 12) were only from less-impacted stations and were acceptable in all but three cases (codliver). In the classification system, these 12 cases were acceptable. Note that this assessment was based on TCDDN as indicator for dioxin and TCDDN does not take into account dioxin-like PCBs.

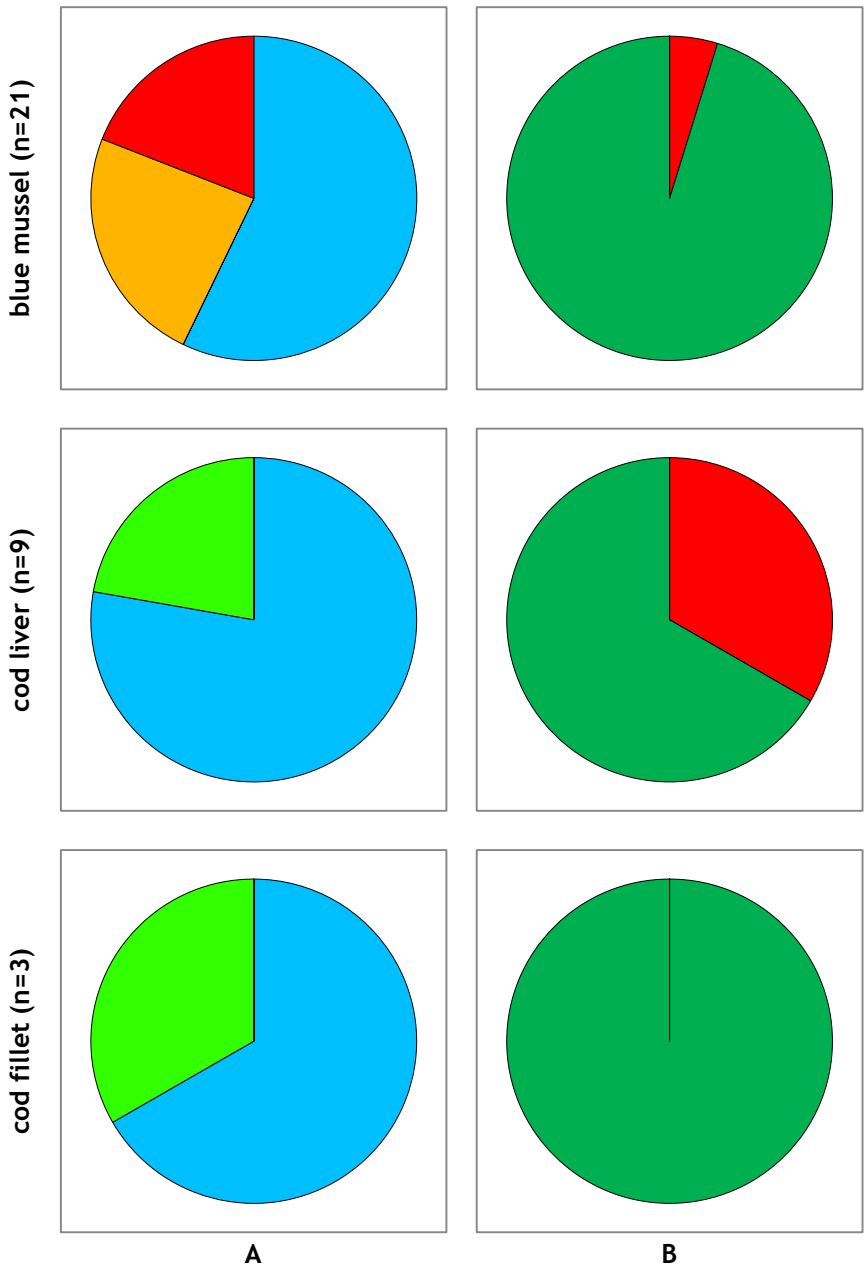


Figure 59. *Assessment of dioxins (TCDDN) in blue mussel, cod liver and cod fillet from less impacted stations using the five-class classification system (**A**) and the quality standard (**B**) based on annual median concentrations. Colour coding in Figure A refers to classification colours (cf.* ***Table 29***). The green and red *colour coding in Figure B refers to the count below and and above the standard, respectively (cf.* ***Table 7***).

3.7.4 Main challenges

There are two main challenges with these quality standards for contaminants in biota that prevent them from being easily applied. The first is that they are generally not species or tissue specific but refer to whole organisms. To address this, the monitoring programme must either analyse the whole organism, currently done for blue mussel but not for fish where liver and fillet are monitored, or convert the concentrations found to apply to the whole organisms. The latter was tested for mercury on the indicator species-tissues that OSPAR applies (OSPAR 2016). The study revealed that with conversion applying EU's techncial guidance documents (EC 2011, 2014), 99 % of the OSPAR data exceeded the EQS and would not be compliant. Furthermore, they concluded that a goal to reduce this portion significantly would not be feasible. The authors note that the EQS approach is not readily extendable to the marine environment and that bioaccumulation factors and trophic magnification factors, which are key variables for the conversion, should not be generic, but rather species/region specific. EQS in general apply to fish, and to apply an EQS for a contaminant which demonstrates trophic magnifications to a species at a lower trophic level, e.g. blue mussel, the EQS will be lower. OSPAR (2016) showed that direct application of the EQS to shellfish resulted in a significant number of exceedences. Hence, applying a lower EQS to species at a lower trophic level would only show a worse environmental status.

The second main challenge is that it is in conflict with an earlier national classification system. For example for mercury the EQS is 20 µg/kg w.w. whereas the upper limit for Class II (often considered the division between acceptable and not acceptable status) is 100 µg/kg w.w. for blue mussel and 300 µg/kg w.w. for cod fillet, and for hexachlorobenzen (HCB) the EQS is 10 µg/kg w.w., whereas the upper limit for Class II is 0.3 µg/kg w.w. for blue mussel and 0.5 µg/kg w.w. for cod fillet (cf. ***Table 7*** and Appendix C). In other words, the quality standards appear to be more stingent (too low) for mercury compared to the classification system but too lax for HCB. In this report, when considering less impacted stations and where the classification system identified over 80 % of the annual medians as acceptable, less than 20% were considered acceptable when using quality standards for mercury in cod fillet and PCBs in cod liver in all three indicator tissues. When considering the presumably less stringent quality standard for HCB, in examining the impacted stations, the classification identified 74 cases that were unacceptable whereas the quality standard system detected 26. The quality standard for DDE might also be considered less stringent. The classification identified 48 cases that were unacceptable whereas the quality standard system detected only six.

If there are important concerns about the development and application of quality standards with respect to these two challenges, then there is reason to be careful using quality standards on other contaminants especially if remedial action is to take place. The results from this exercise revealed that all annual median concentrations of PBDE and octylphenol exceeded the quality standard indicating that the standards for these two contaminants and quite possibly also mercury and PCBs are too low to be useful to determine whether or not remedial action should take place. There should also be some concern about standards that are so high that exceedences are rare, as for SCCP, HBCH, HCH HCBD, nonylphenol, pentachlorbenzene, PFOA, anthracene, benzo[a]anthracene and possibly also DDE, HCB and dioxins.

The implementation of any system to assess anthropogenic impact should be a tool to guide management towards achieving a better environment. The system should be fact-based and provide enough nuance to be operational. A risk-based system and a classification that has been based on presumed background levels have each their merits and can be useful tools. However, the usefulness of current risk based quality standards should be improved to be more operational. In this regard it is suggested that both systems should be applied to assess the results from monitoring of hazardous substances.

4. Conclusions

This programme examines long-term changes for legacy contaminants in biota along the coast of Norway in both polluted areas and areas remote from point sources. In addition, the programme includes supplementary investigations funded by the Ministry of Climate and Environment. 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 and PFOS.
- The decrease in TBT can be related to legislation banning the use of this substance.
- Significant long-term increase in mercury was found in cod from the Inner Oslofjord. The concentrations were however lower in 2015 than in 2014. The reasons for the upward trend are at least in part related to the length of fish caught. Both significant upward long-term and short term trends were found at Bømlo for mercury, while significant upward short-term trends were found at Færder and Farsund.
- Highest concentrations of PBDEs, predominantly BDE47, were found in the Inner Oslofjord and Tromsø harbour for cod liver, and in Bergen harbour (Nordnes) for blue mussel.
- Blue mussel from one station in the Sørfjord was severely polluted with DDE, presumably related to the earlier use of DDT as pesticide in this orchard district.
- Cod liver from the Inner Oslofjord and the Outer Oslofjord had significantly higher levels of PFOS and PFOSA than the seven other stations investigated.
- Significant downward short-term trends at six of the nine stations were identified for PFOS in cod liver.
- The dominant hexabromocyclododecane in cod liver was α–HBCD. The concentration of α–HBCD in cod liver was highest in the Inner Oslofjord and in blue mussel it was highest in Bergen harbour, probably related to urban activities.
- Short chain chlorinated paraffins (SCCP) and medium chain chlorinated paraffins (MCCP) were highest in blue mussel from the Outer Oslofjord. SCCP in cod liver was highest in cod from Bergen harbour, and MCCP in cod liver was highest in the Ålesund area.
- The median concentrations of organophosphorus flame retardants (PFRs) were low or for the most part below the quantification limit.
- The median concentrations of bisphenol A were below the quantification limit or low (as in cod from Bømlo).
- The median concentrations of TBBPA were generally below the quantification limit.
- Alkylphenol results have indicated that 4-t-nonylphenol and 4-n-octylphenol were the most dominant. High concentrations were not consistant with proximity to urban areas.
- The ICES/OSPAR Background Assessment Criteria (BAC) for OH-pyrene in cod bile was exceeded at all stations investigated, except for the reference station (Bømlo area; st. 23B).
- Inhibited ALA-D activity in cod liver from the Inner Oslofjord and Inner Sørfjord indicated exposure to lead.
- EROD activities in cod liver from the Inner Oslofjord indicated exposure to contaminants.
- The Inner Oslofjord, and to a lesser degree the harbour areas of Bergen, Kristiansand, Trondheim, seems all together to be an area where contaminants tend to appear in high concentrations. This is probably caused by a high population in watershed area, a multitude of urban activities, and former and present use of products containing contaminants. A reduced water exchange in the Inner Oslofjord with the outer fjord will also contribute to higher contaminant levels in water and biota.

- High levels of PCBs and Hg in cod are reasons for concern, particularly in the Inner Oslofjord. There is some evidence that elevated concentrations may result from increased fish length due to poor recruitment of cod in recent years in this area.
- Freely dissolved contaminant concentrations measured with passive sampling are mostly close to or below limits of quantification in the low pg/L range.
- Results from stabile isotopes indicate that the stations show very similar patterns from 2012 to 2015 in terms of isotopic signatures, suggesting that this is a spatial trend more than a temporal trend.
- In the large majority of cases, the statistical conclusions regarding time trends of contaminants would not change if length of the sampled cod was taken into account
- Current risk-based quality standards should be improved to be more operational. It is suggested that both the risk-based and background-based systems be applied to assess the results from monitoring of hazardous substances.

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Appendix A
Quality assurance programme

Information on Quality Assurance

The laboratories (NIVA and subcontractor Eurofins) have participated in the QUASIMEME international intercalibration exercises and other proficiency testing programmes relevant to chemical and imposex analyses.

The quality assurance programme is corresponding to the 2014 programme (cf. Green *et al*. 2015). The results for QUASIMEME round 2015-1 and 2015-2, FAPAS 1270 and FAPAS 1264 apply to the 2015 samples. The results are acceptable.

NIVA participated in the last round of QUASIMEME Laboratory Performance Studies "imposex and intersex in Marine Snails BE1" performed 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/IEC 17025:2005, except for the PFCs.

Summary of quality control results
Standard Reference Materials (SRM) as well as in-house reference materials were analysed regularly (***Table 28***). Fish protein (DORM-4) was used as SRM for the control of the determination of metals. The reference material for determination of BDEs and HBCDDs in blue mussel was an internal reference (fish oil). For determination of PCBs, DDTs and PAHs in blue mussel, as well as HBCDDs, PCBs, DDTs and BDEs in liver, Quasimeme biota samples with known true value was applied (for 4'4-DDT in liver the SRM BCR598 was used). For bisphenol-A, canned peach reference material was used. For TBBPA, spiked fish oil was used for quality assurance, and for chlorinated paraffines and octyl/nonylphenols, spiked fish meal was used. For organophosphorous flame retardants, spiked internal reference material was used.

***Table 28**. Summary of the quality control of results for the 2015 biota samples analysed in 2015-2016. The Standard Reference Materials (SRM) DORM-4* (fish protein) for blue mussel, fish liver and fish fillet.* Folkehelsa RM Halibut 2012** *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), PCBs (µg/kg), DDTs (µg/kg), HBCDDs (pg/g), PAH (µg/kg), TBBPA (ng/sample), BPA (µg/kg), SCCP/MCCP (ng/sample) octyl-/nonylphenol (ng/sample), organophosphorus 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**	SB/LI	DORM-4	m	53	35	0.020	0.003
As	**Arsenic**	SB/LI	DORM-4	6.80 ± 0.64	53	35	6.45	0.36
Cd	**Cadmium**	SB/LI	DORM-4	0.306 ± 0.015	53	35	0.307	0.018
Cr	**Chromium**	SB/LI	DORM-4	1.87 ± 0.16	53	35	1.8	0.1
Co	**Cobalt**	SB/LI	DORM-4	m	53	35	0.23	0.02
Cu	**Copper**	SB/LI	DORM-4	15.9 ± 0.9	53	35	14.31	0.9
Hg	**Mercury**	SB/MU	DORM-4	0.410 ± 0.055	52	35	0.38	0.04
Ni	**Nickel**	SB/LI	DORM-4	1.36 ± 0.22	53	35	1.23	0.12
Pb	**Lead**	SB/LI	DORM-4	0.416 ± 0.053	53	35	0.404	0.033
Zn	**Zinc**	SB/LI	DORM-4	52.2 ± 3.2	53	35	46.5	2.3
Sn	**Tin**	SB/LI	DORM-4	0.056 ± 0.010	39	35	0.115	0.035
BDE28	**2,2,4' Tribromodiphenylether**	LI	QBC032BT	0.39	26	7	0.382	0.036
BDE100	**2,2',4,4',6-Pentabromodiphenylether**	LI	QBC032BT	6.91	26	7	6.209	1.517
BDE153	**2,2',4,4'5,5'-Hexabromodiphenylether**	LI	QBC032BT	0.86[1)]	26	7	0.709	0.098
BDE154	**2,2',4,4',5,6'-Hexabromodiphenylether**	LI	QBC032BT	1.68	26	7	2.123	0.254
BDE47	**2,2',4,4',-Tetrabromodiphenylether**	LI	QBC032BT	23.2[1)]	26	7	17.721	4.990
BDE99	**2,2',4,4',5-Pentabromodiphenylether**	LI	QBC032BT	0.01[1)]	26	7	0.008	0.002
BDE28	**2,2,4' Tribromodiphenylether**	SB	Internal RM (fish oil)	m	26	7	85.6	5
BDE100	**2,2',4,4',6-Pentabromodiphenylether**	SB	Internal RM (fish oil)	m	26	7	333	14
BDE153	**2,2',4,4'5,5'-Hexabromodiphenylether**	SB	Internal RM (fish oil)	m	26	7	62.2	2
BDE154	**2,2',4,4',5,6'-Hexabromodiphenylether**	SB	Internal RM (fish oil)	m	26	7	189	17
BDE47	**2,2',4,4',-Tetrabromodiphenylether**	SB	Internal RM (fish oil)	m	26	7	1617	27
BDE99	**2,2',4,4',5-Pentabromodiphenylether**	SB	Internal RM (fish oil)	m	26	7	253	5
CB101	**PCB congener PCB-101**	SB	QOR110BT	3.25	42	11	2.99	0.25
CB118	**PCB congener PCB-118**	SB	QOR110BT	2.20	42	11	2.14	0.17
CB138	**PCB congener PCB-138**	SB	QOR110BT	7.93	42	11	5.64	0.37
CB153	**PCB congener PCB-153**	SB	QOR110BT	4.46	42	11	7.39	0.59
CB180	**PCB congener PCB-180**	SB	QOR110BT	0.48	42	11	0.52	0.06
CB28	**PCB congener PCB-28**	SB	QOR110BT	0.37	42	11	0.45	0.06
CB52	**PCB congener PCB-52**	SB	QOR110BT	1.11	42	11	1.28	0.10
DDEPP	**4.4'-DDE**	SB	QOR110BT	1.4	42	11	1.65	0.20
TDEPP	**4.4'-DDD**	SB	QOR110BT	0.59	42	11	0.36	0.07
DDTPP	**4.4'-DDT**	SB	QOR110BT	0.14	42	11	0.30	0.33
DDEPP	**4.4'-DDE**	LI	QOR108BT	83.1	29	7	74,4	7,6
TDEPP	**4.4'-DDD**	LI	QOR108BT	26.7	26	7	20.5	7.5
DDTPP	**4.4'-DDT**	LI	BCR598	179	24	7	170.9	23.3
α-HBCDD	**α-Hexabromocyclododecane**	SB/LI	Internal RM (fish oil)	m	m	m	1.21	0.08
ß-HBCDD	**ß- Hexabromocyclododecane**	SB/LI	Internal RM (fish oil)	m	m	m	0.08	0.02

Code	Contaminant	Tissue type	SRM type	SRM value confidence interval	N	W	Mean value	Standard deviation
γ-HBCDD	γ- Hexabromocyclododecane	SB/LI	Internal RM (fish oil)	m	m	m	0.32	0.03
CB101	PCB congener PCB-101	LI	QOR108BT	63.7	29	8	61.6	6.7
CB118	PCB congener PCB-118	LI	QOR108BT	69.9	29	8	65.8	6.1
CB138	PCB congener PCB-138	LI	QOR108BT	219	29	8	175.9	21.4
CB153	PCB congener PCB-153	LI	QOR108BT	204.77	29	8	199.2	17.76
CB180	PCB congener PCB-180	LI	QOR108BT	45.5	29	8	45.4	5.4
CB28	PCB congener PCB-28	LI	QOR108BT	10.5	29	8	10.5	1.1
CB52	PCB congener PCB-52	LI	QOR108BT	23.7	29	8	25.7	2.9
ACNE	Acenaphthene	SB	QPH065BT	0.77	57	7	0.78	0.22
ACNLE	Acenaphthylene	SB	QPH065BT	0.45	55	7	0.62	0.38
ANT	Anthracene	SB	QPH065BT	0.75	57	7	1.56	0.72
BAP	benzo[a]pyrene	SB	QPH065BT	1.50	57	7	1.45	0.24
BBJF	Benzo[b+j]fluoranthene	SB	QPH065BT	4.99	57	7	4.25	0.75
BKF	Benzo[k]fluoranthene	SB	QPH065BT	2.00	57	7	3.08	0.44
BAA	Benzo[a]anthracene	SB	QPH065BT	5.26	57	7	4.91	0.62
CHR	Chrysene	SB	QPH065BT	7.19	57	7	6.28	0.64
DBA3A	Dibenzo[ac,ah]anthracene	SB	QPH065BT	0.43	57	7	0.35	0.10
FLE	Fluorene	SB	QPH065BT	1.59	57	7	1.02	0.27
FLU	Fluoranthene	SB	QPH065BT	13.80	57	7	14.65	3.30
ICDP	Indeno[1,2,3-cd]pyrene	SB	QPH065BT	1.52	57	7	1.03	0.27
NAP	Naphthalene	SB	QPH065BT	5.05	55	7	3.28	1.12
PA	Phenanthrene	SB	QPH065BT	8.18	57	7	7.84	0.84
BGHIP	Benzo(g,h,i)perylene	SB	QPH065BT	2.39	57	7	11.77	0.40
PYR	Pyrene	SB	QPH065BT	11.10	57	7	12.87	2.84
TBBPA	Tetrabromobisphenol-A	SB/LI	Internal RM (spiked fish oil)	m	m	m	1.48	0.10
BPA	Bisphenol-A	SB/LI	peach, canned	4.15 ± 0.52	42	20	4.23	0,56
SCCP	C10-C13 Chlorinated paraffines	SB/LI	Internal RM (spiked fish meal)	m	m	m	1833	572
MCCP	C13-C17 Chlorinated paraffines	SB/LI	Internal RM (spiked fish meal)	m	m	m	4263	1368
	4-n-nonylphenol	LI/SB	Internal RM (spiked fish meal)	50	m	m	40.7	0.84
	4-n-octylphenol	LI/SB	Internal RM (spiked fish meal)	50	m	m	38.5	1.13
	4-Nonylphenol	LI/SB	Internal RM (spiked fish meal)	m	m	m	m	m
	4-tert-octylphenol	LI/SB	Internal RM (spiked fish meal)	50	m	m	41.9	6.37
TIBP	Triisobutylphosphate	LI/SB	Internal RM (spiked)	5565	11	6	4669	390
TBP	Tributylphosphate	LI/SB	Internal RM (spiked)	5217	11	6	5014	161
TCEP	Tris(2-chloroethyl)phosphate	LI/SB	Internal RM (spiked)	5217	11	6	5180	325
TCPP	Tris(2-chloro-isopropyl)phosphate	LI/SB	Internal RM (spiked)	5565	11	6	4923	568
TDCP	Tris(1,3-chloro-isopropyl)phosphate	LI/SB	Internal RM (spiked)	5217	11	6	5203	338
TBEP	Tris(2-butoxyethyl)phosphate	LI/SB	Internal RM (spiked)	5217	11	6	5158	507
TPP	Triphenylphosphate	LI/SB	Internal RM (spiked)	5217	11	6	5108	270
EHDPP	2-Ethylhexyl-diphenylphosphate	LI/SB	Internal RM (spiked)	5217	11	6	4728	925
TEHP	Tris(2-ethylhexyl) phosphate	LI/SB	Internal RM (spiked)	5217	11	6	5627	665
ToCrP	o-Tricresylphosphate	LI/SB	Internal RM (spiked)	5217	11	6	5430	392
TCrP	Tricresylphosphate	LI/SB	Internal RM (spiked)	5165	11	6	5172	266
PFBS	Perfluorobutane sulphonate	LI		100 %[2)]	7	m	93	7,9
PFHxA	Perfluorohexane acid	LI		100 %[2)]	7	m	99	7,5

Code	Contaminant	Tissue type	SRM type	SRM value confidence interval	N	W	Mean value	Standard deviation
PFHpA	**Perfluoroheptane acid**	LI		100 %[2)]	7	m	102	4,5
PFOA	**Perfluorooctane acid**	LI		100 %[2)]	7	m	102	5,3
PFNA	**Perfluorononane acid**	LI		100 %[2)]	7	m	99	3,7
PFOS	**Perfluorooctane sulphonate**	LI		100 %[2)]	7	m	105	11,6
PFOSA	**Perfluorooctane sulphone amide**	LI		100 %[2)]	7	m	97	3,6
PFHxS	**Perfluorohexane sulphonate**	LI		100 %[2)]	7	m	97	4,8
PFDA	**Perfluorodecanoic acid**	LI		100 %[2)]	7	m	99	4,8
PFUDA	**Perfluoroundecanoic acid**	LI		100 %[2)]	7	m	105	11,2
PFDS	**Perfluorodecanesulphonate**	LI		100 %[2)]	7	m	76	10,1

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

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

1) Not certified value.

2) 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

Abbreviation[1]	English	*Norwegian*	Param. group
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
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, 6]	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	*Samme betegnelse 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

Abbreviation[1]	English	*Norwegian*	Param. group
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, fotnote 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 (foreldet metode)*	
BAP_P	% BAP of PAHΣΣ	*% BAP av PAHΣΣ*	
BAPPP	% BAP of P-Σn	*% BAP av P-Σn*	
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 PCBs, includes PCB-Σ7	*sum PCBer, inkluderer PCB-Σ7*	

Abbreviation[1]	English	*Norwegian*	Param. group
TECBW	sum of PCB-toxicity equivalents after WHO model, see **TEQ**	*sum PCB- toksisitets ekvivalenter etter WHO modell, se **TEQ***	
TECBS	sum of PCB-toxicity equivalents after SAFE model, see **TEQ**	*sum PCB-toksisitets 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*	
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

Abbreviation[1]	English	*Norwegian*	Param. group
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- toksisitets ekvivalenter etter Nordisk modell, se **TEQ***	
TCDDI	sum of TCDD-toxicity equivalents after international model, see **TEQ**	*sum TCDD-toksisitets ekvivalenter etter internasjonale modell, se **TEQ***	
BIOICIDES			
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
Triclosan	5-chloro-2-2,4-dichlorophenoxy)phenol	*5-kloro-2-2,4-diklorofenoxy)fenol*	OC-CL
Diuron	3-(3,4-dichlorophenyl)-1,1-dimethylurea	*3-(3,4-diklorofenyl)-1,1-dimetylurea*	OC-CL
Irgarol	a triazine (nitrogen containing heterocycle)	*en triazin (nitrogen holdig heterosykle)*	
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

Abbreviation[1]	English	*Norwegian*	Param. group
DDEPP	p,p'-DDE	*p,p'-DDE*	OC-DD
DDTOP	o,p'-DDT	*o,p'-DDT*	OC-DD
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, foreldet 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
BDE126	3,3',4,4',5'-pentabromodiphenyl ether	3,3',4,4',5'-*pentabromdifenyleter*	OC-BR
BDE138	2,2',3,4,4',5'-hexabromodiphenyl ether	*2,2',3,4,4',5'-heksabromdifenyleter*	OC-BR

Abbreviation[1]	English	*Norwegian*	Param. group
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
BDE4S	sum of BDE -85, -99, -100, -119	*sum av BDE -85, -99, -100, -119*	OC-BR
BDE6S	sum of BDE -28, -47, -99, -100, -153, -154	*sum av BDE -28, -47, -99, -100, -153, -154*	OC-BR
BDESS	sum of all BDEs	*sum av alle BDEer*	OC-BR
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
HCBD	hexachlorobutadiene	*hexaklorobutadien*	OC-CL
PFAS	**perfluorinated alkylated substances**	***Perfluoralkylerte stoffer***	
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}*	
Alkylphenols	**phenols/chlorophenols**	***fenoler/klorfenoler***	

Abbreviation[1]	English	*Norwegian*	Param. group
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*	
PFRs	**Phosphorus Flame Retardants**	***Fosforflammehemmere***	
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***	
BBP	benzylbutylphthalate	*benzylbutylftalat*	
DBP[6]	dibutylphthalate	*dibutylftalat*	
DBPA	dibutyladipat	*dibutyladipat*	
DEHA	diethylhexcyladipate	*dietylheksyladipat*	
DEHP	di(2-ethylhexyl)-phthalate	*di(2-etylhexyl)-ftalat*	
DEP	dietylphthale	*dietylftalat*	
DEPA	diethyladipat	*dietyladipat*	
DIBP	diisobutylphthalate	*diisobutylftalat*	
DIDP	diisodectylyphthalate	*diisodekylftalat*	
DIHP	diisoheptylphthalate	*diisoheptylftalat*	
DINCH	1,2-Cyclohexane dicarboxylic acid diisononyl ester	*1,2-sykloheksan dikarboksyl syre diisononyl ester*	
DIPA	diisobutyl adipate	*diisobutyladipat*	
DMP	dimethylphthalate	*dimetylftalat*	
DNOP	di-n-octylphthalte	*di-n-oktylftalt*	
DPF	diphenylphthalate	*difenylftalat*	

Abbreviation[1]	English	*Norwegian*	Param. group
SDD	dinonylphthalte+diisononylphthalate	*dinonylftalat+diisononylftalat*	
TBP	tributylphosphate	*tributylfosfat*	
TOA	tributyl-o-acetylcitrate	*tributyl-o-acetylcitrate*	
Triclosan	triclosan	*triklosan*	
[not defined]	dodecylfenol	*dodecylfenol*	
Diuron	Duiron	*Durion*	
Irgarol	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
VDSI	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 for luftforskning*	
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 (often called PAH-16) minus naphthalene (dicyclic), so that the Norwegian Environmental Agency 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 Norwegian Environmental Agency 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'

6) DBP is ambiguous; a code for both a PAH and an phthalate. DBP as a PAH was only measured in 1992 whereas DBP as an phthalate has been measure in 2012 and 2013. A correction in the data base is needed in this regard.

*) 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: • 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] • non-ortho and mono-ortho substituted chlorobiphenyls after WHO model (Ahlborg *et al.* 1994) [3] or Safe (1994, cf. NILU pers. comm.)	*"Toxisitetsekvivalentfaktorer" for de giftigste forbindelsene innen følgende grupper.* • *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-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 29**. 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]	<2	6	20	40	>40
	mg/kg	d.w.	<10	30	100	200	>200
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]	<0.6	2	6	12	>12
	mg/kg	d.w.	<3	10	30	60	>60
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	w.w. [2]	<0.06	0.2	0.4	1	>1
	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	w.w. [2]	<0.02	0.01	0.4	1	>1
	mg/kg	d.w.	<0.1	0.5	2	5	>5
∑PCB-7	µg/kg	w.w.	<4 [5]	15	40	100	>100
		d.w. [2]	<20 [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 [4]	w.w.	< 0.1	0.3	1	2	> 2
Cod, liver							
∑PCB-7	µg/kg	w.w.	<500	1500	4000	10000	>10000

Contaminant			Classification (upper limit for Classes I-IV) *Degree of pollution*				
			I *Insignificant*	II *Moderate*	III *Marked*	IV *Severe*	V *Extreme*
∑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)]	ng/kg [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 [4)]	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]) ng/kg = 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 30**. OSPAR classification of vas deferens sequence index (VDSI) in dog whelk (OSPAR 2013). For this report, the short name for each class ("Insignificant", "Moderate", etc) has been adopted from the Norwegian Environment Agency classification system. OSPAR has a sixth class, not shown here and not applied in this report, that indicates that* dog whelks were absent or expired.

		Classification (upper limit for Classes A-E) *Degree of pollution*				
		A *Insignificant* [1)]	B *Moderate* [2)]	C *Marked* [3)]	D *Severe* [4)]	E *Extreme* [5)]
VDSI		0.3	2	4	5	>5

[1]) The level of imposex in the more sensitive gastropod species is close to zero (0-30 % of females have imposex) indicating exposure to TBT concentrations close to zero, which is the objective in the OSPAR Hazardous Substances Strategy. [Author's note: this level marks OSPAR's Background Assessment Criteria (BAC)]

[2]) The level of imposex in the more sensitive gastropod species (30-~100 % of females have imposex) indicates exposure to TBT concentrations below the exotoxicological assessment cirteria (EAC) derived by OSPAR for TBT. For example, adverse effects in the more sensitive taxa of the ecosystem caused by long-term expsosure to TBT are predicted to be unlikely to occur.

[3]) The level of imposex in the more sensitive gastropod species indicates exposure to TBT concentrations higher than EAC derived for TBT. For example, there is a risk of adverse effects such as reduced growth and recruitment, in the more sensitive taxa of the ecosystem caused by long-term expsosure to TBT.

[4]) The reproductive capacity in the populations of the more sensitive gastropod species, such as *Nucella lapillus*, is afffected as a result of the presence of sterile females, but some repoductively capable females remain. For example, there is evidence of adverse effets that can be dreictly associated with the exposure to TBT.

[5]) Polulations of the more sensitive gastropod species, such as *Nucella lapillus, are unable to reproduce. The majority of, if not all, females within the population have been sterilized*

***Table 31**. 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 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	10.0 [2)]	2.0 [3)]	20.0	
Mercury	0.2 [2)]	0.04 [3)]		0.1 [2)]
Zinc	200.0 [2)]	40.0 [3)]	30.0	
∑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)] 0.0000002 [2)]		0.00001 [9)]	
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
Maps of stations

Nominel station positions 1981-2015
(cf. Appendix E)

Appendix D (cont.) Map of stations

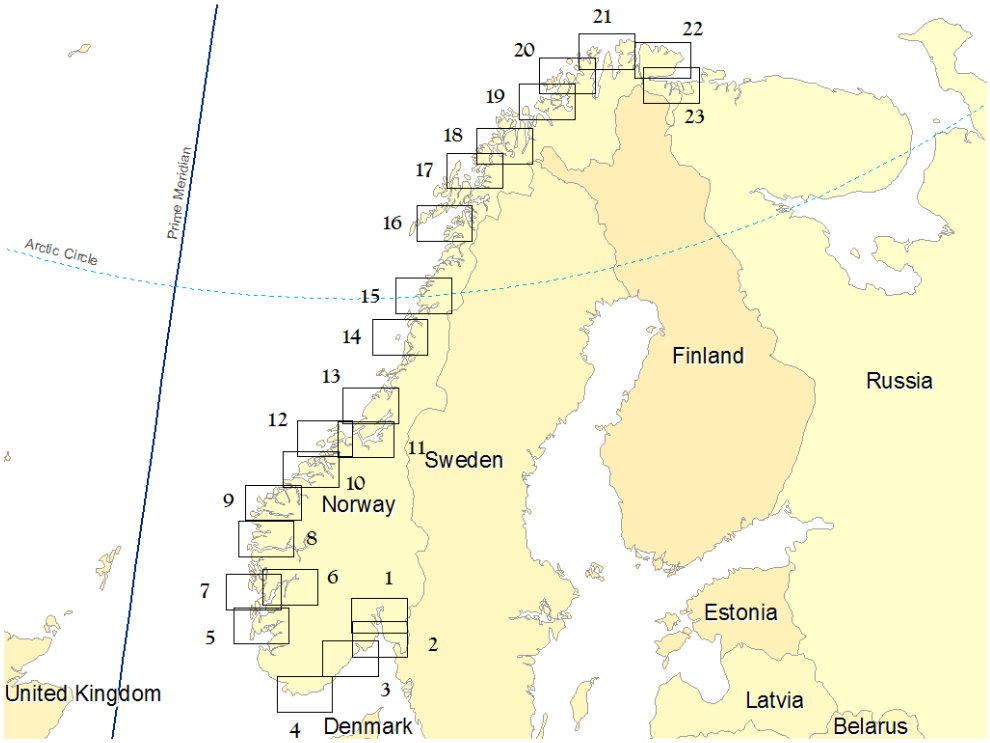
NOTES

The station's nominal position is plotted, and not the specific positions that may have differed from one year to another. The locations of passive sampling stations are indicated in **Figure 4** and are not shown in this Appendix. The maps are generated using ArcGIS version 9.1.

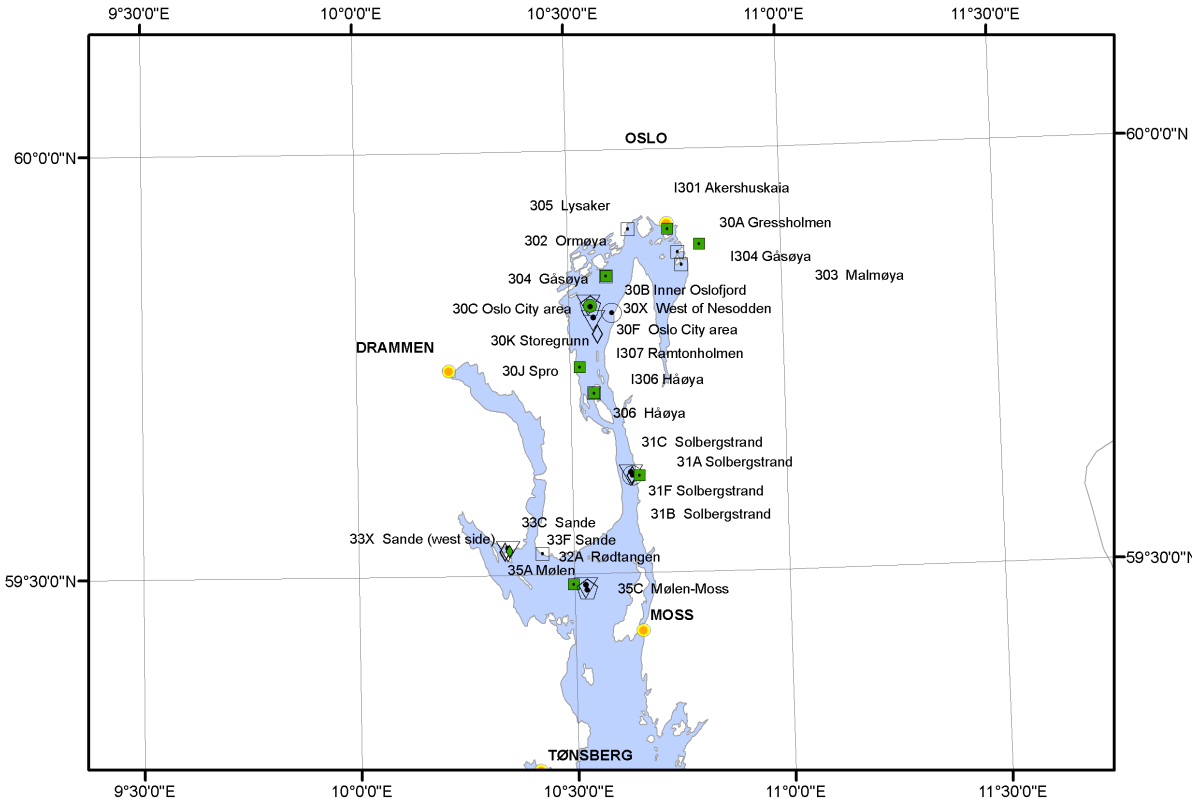
The following symbols and codes apply:

All years	2015	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	

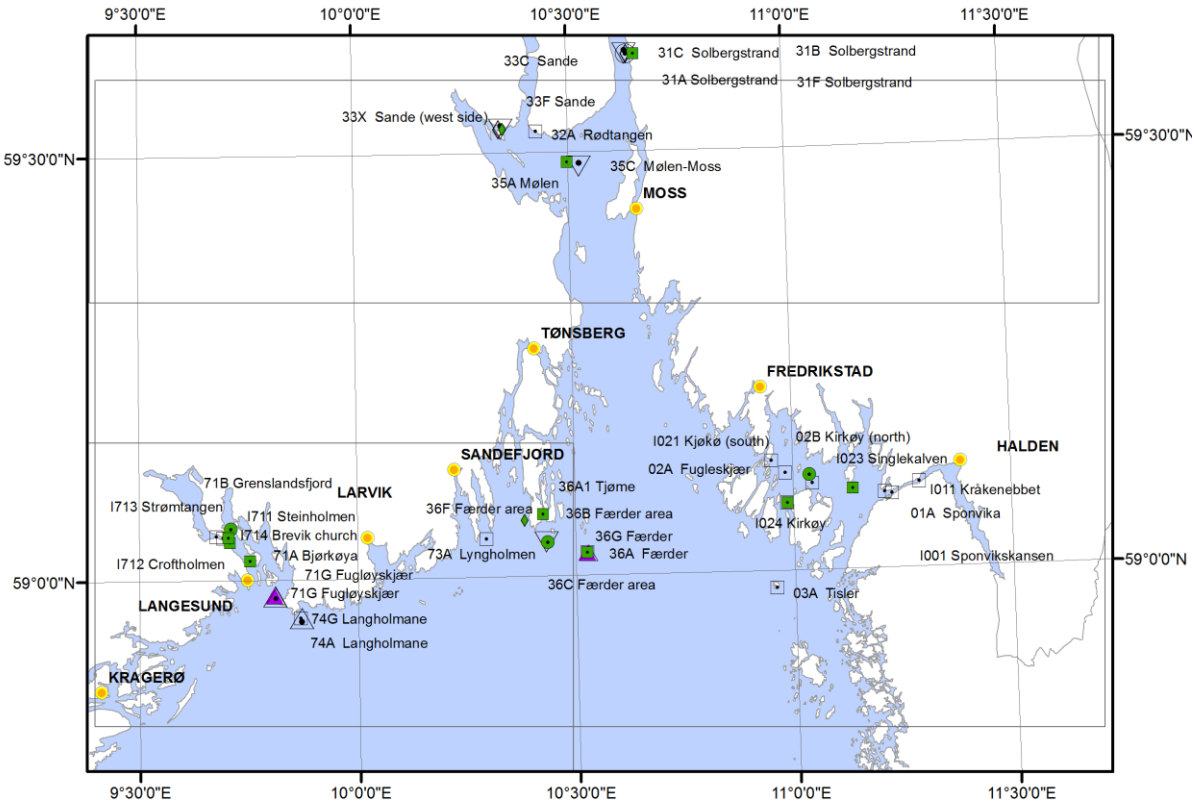
1) Supplementary station used in the blue mussel pollution (I) or reference (R) index of the Norwegian Environment Agency (cf. Green *et al.* 2011b).



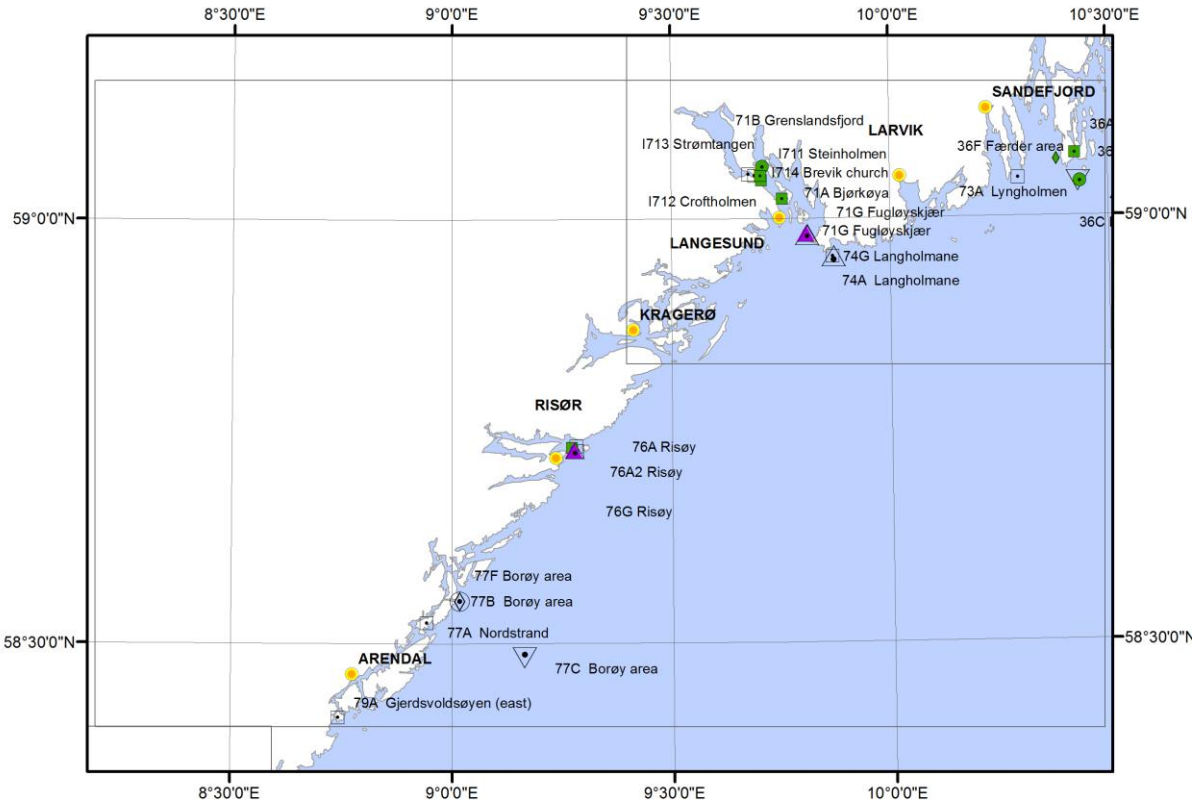
MILKYS stations Norway. Numbers indicate map references that follow.
Note: distance between two lines of latitude is 15 nautical miles (= 27.8 km).


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
OSLO
I301 Akershuskaia
305 Lysaker
30A Gressholmen
302 Ormøya
I304 Gåsøya
303 Malmøya
304 Gåsøya
30B Inner Oslofjord
30C Oslo City area
30X West of Nesodden
30F Oslo City area
DRAMMEN
30K Storegrunn
I307 Ramtonholmen
30J Spro
I306 Håøya
306 Håøya
31C Solbergstrand
31A Solbergstrand
31F Solbergstrand
31B Solbergstrand
33C Sande
33X Sande (west side)
33F Sande
32A Rødtangen
35A Mølen
35C Mølen-Moss
MOSS
TØNSBERG

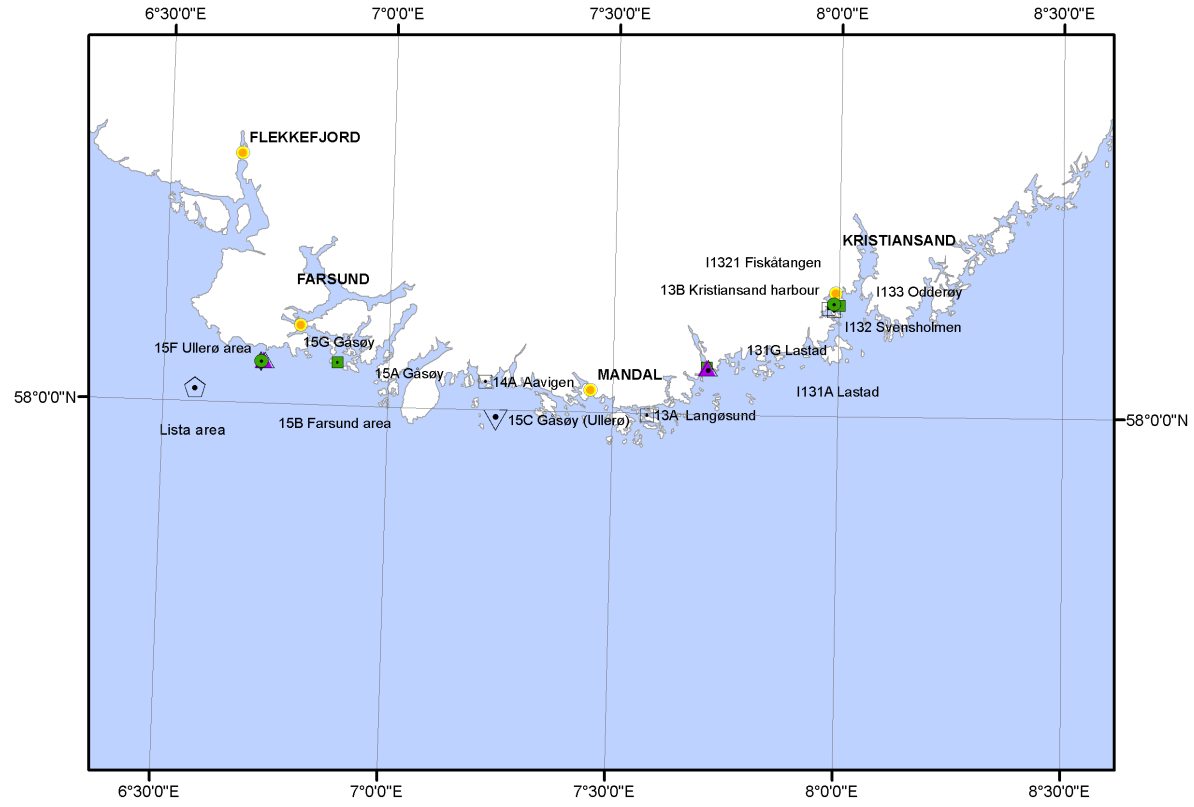
MAP 1


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
33C Sande
31C Solbergstrand
31B Solbergstrand
31A Solbergstrand
31F Solbergstrand
33F Sande
33X Sande (west side)
32A Rødtangen
35C Mølen-Moss
35A Mølen
MOSS
TØNSBERG
FREDRIKSTAD
I021 Kjøkø (south)
02B Kirkøy (north)
HALDEN
I023 Singlekalven
SANDEFJORD
02A Fugleskjær
I011 Kråkenebbet
71B Grenslandsfjord
LARVIK
36A1 Tjøme
I713 Strømtangen
36F Færder area
36B Færder area
01A Sponvika
I711 Steinholmen
I024 Kirkøy
I714 Brevik church
36G Færder
71A Bjørkøya
73A Lyngholmen
36A Færder
I001 Sponvikskansen
I712 Croftholmen
71G Fugløyskjær
36C Færder area
03A Tisler
71G Fugløyskjær
LANGESUND
74G Langholmane
74A Langholmane
KRAGERØ

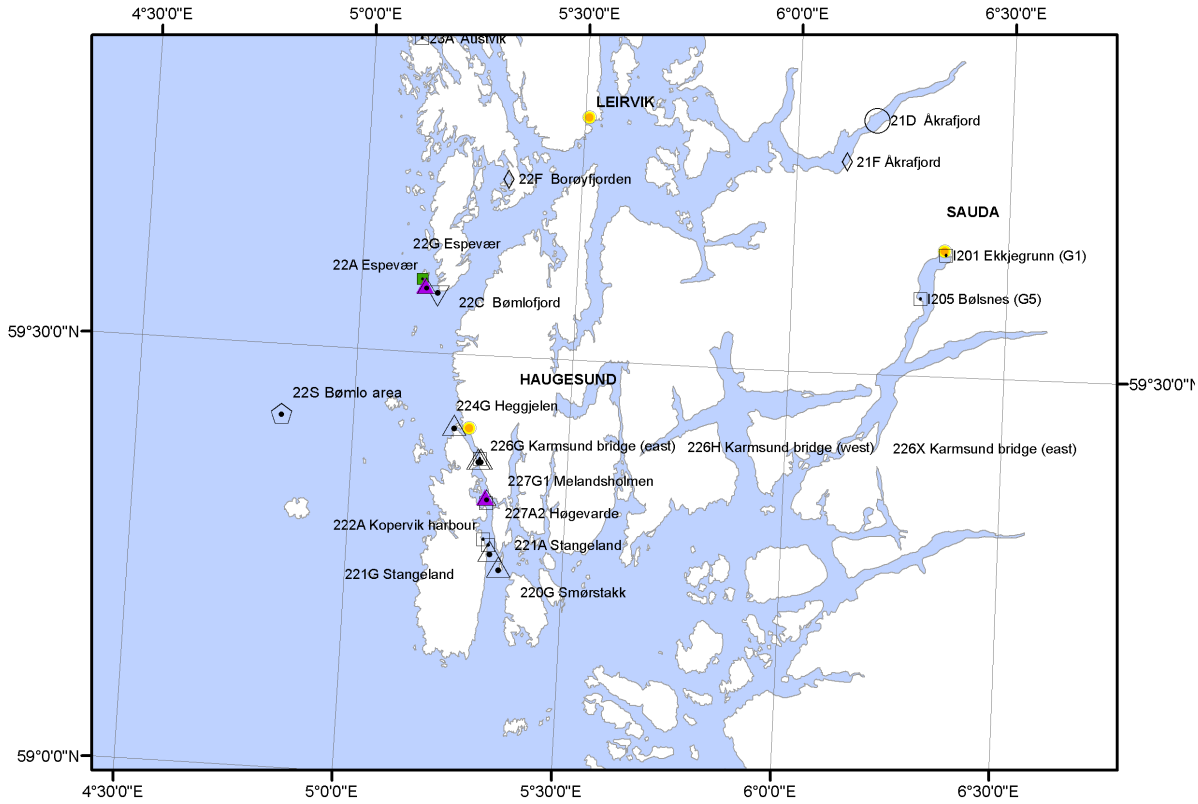
MAP 2


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
71B Grenslandsfjord
I713 Strømtangen
I711 Steinholmen
I714 Brevik church
36F Færder area
71A Bjørkøya
73A Lyngholmen
I712 Croftholmen
71G Fugløyskjær
71G Fugløyskjær
LANGESUND
74G Langholmane
74A Langholmane
KRAGERØ
RISØR
76A Risøy
76A2 Risøy
76G Risøy
77F Borøy area
77B Borøy area
77A Nordstrand
ARENDAL
77C Borøy area
79A Gjerdsvoldsøyen (east)

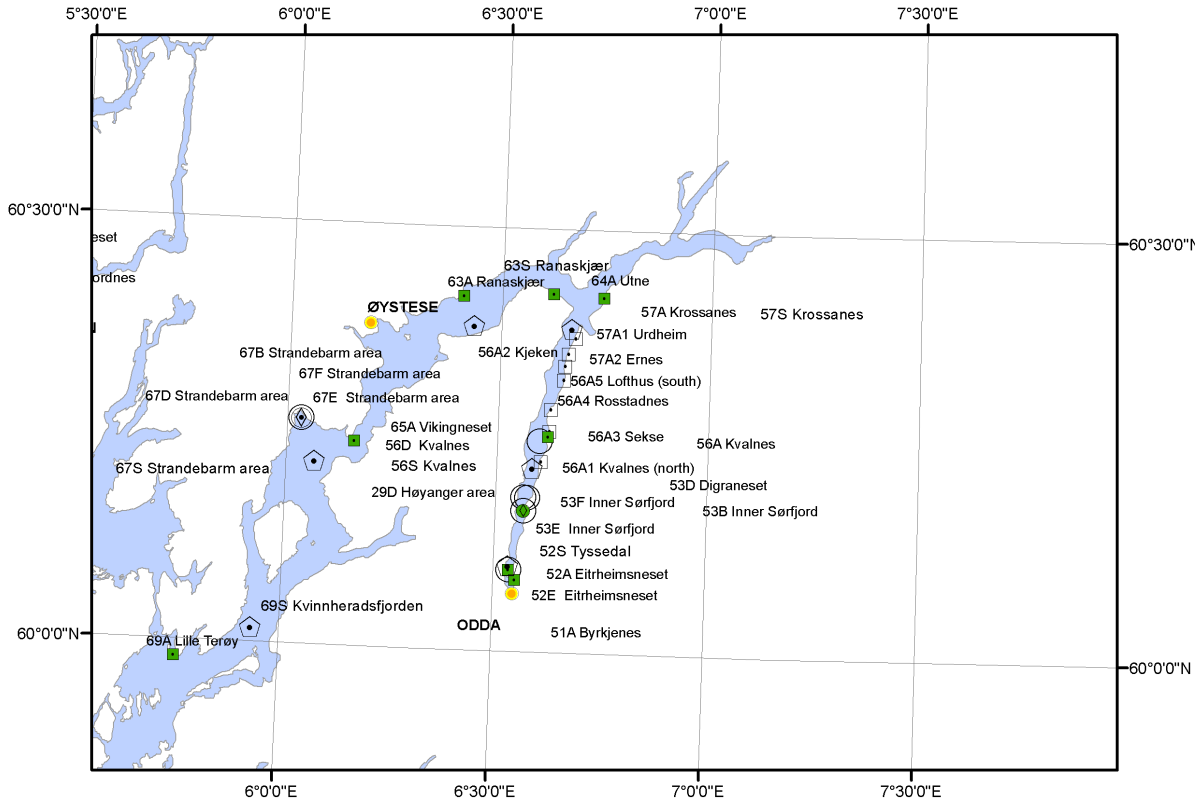
MAP 3


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
FARSUND
KRISTIANSAND
I1321 Fiskåtangen
13B Kristiansand harbour
I133 Odderøy
I132 Syensholmen
15F Ullerø area
15G Gåsøy
15A Gåsøy
14A Aavigen
MANDAL
131G Lastad
I131A Lastad
Lista area
15B Farsund area
15C Gåsøy (Ullerø)
13A Langøsund

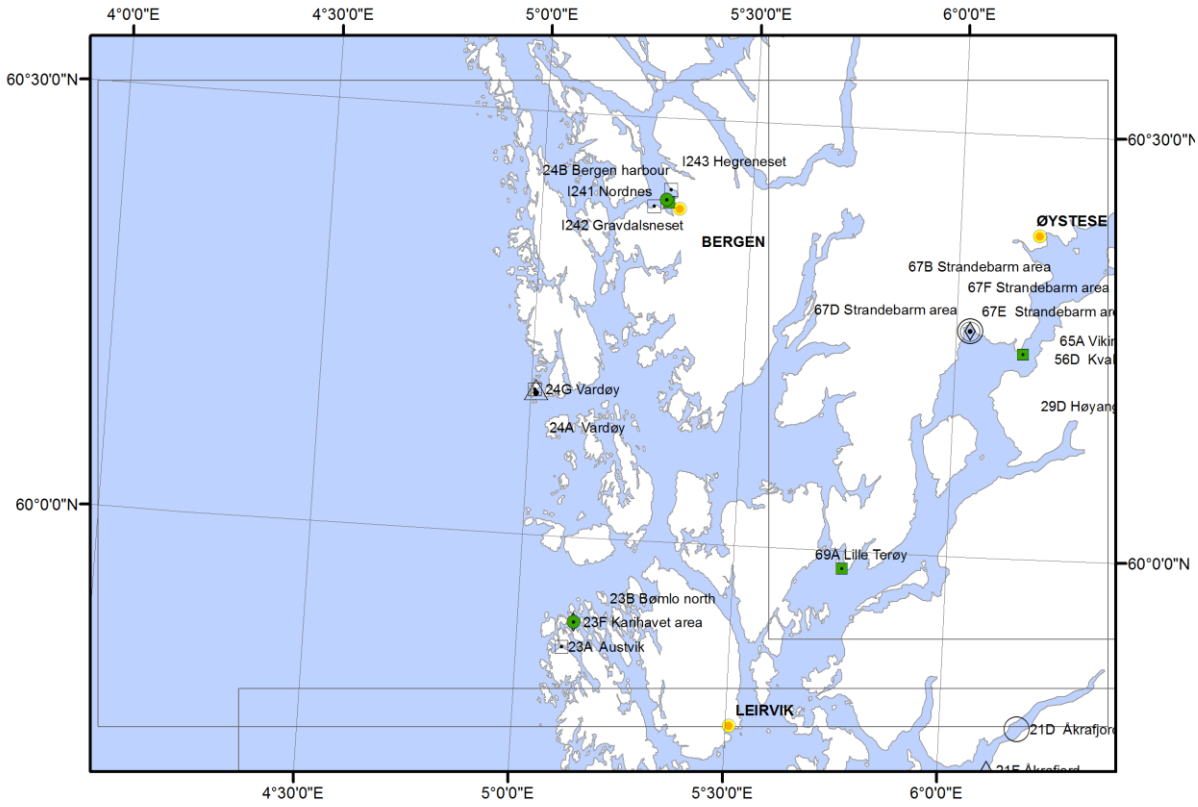
MAP 4


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
23A Austvik
LEIRVIK
21D Åkrafjord
21F Åkrafjord
22F Borøyfjorden
SAUDA
22G Espevær
22A Espevær
201 Ekkjegrunn (G1)
22C Bømlofjord
205 Bølsnes (G5)
HAUGESUND
22S Bømlo area
224G Heggjelen
226G Karmsund bridge (east)
226H Karmsund bridge (west)
226X Karmsund bridge (east)
227G1 Melandsholmen
227A2 Høgevarde
222A Kopervik harbour
221A Stangeland
221G Stangeland
220G Smørstakk

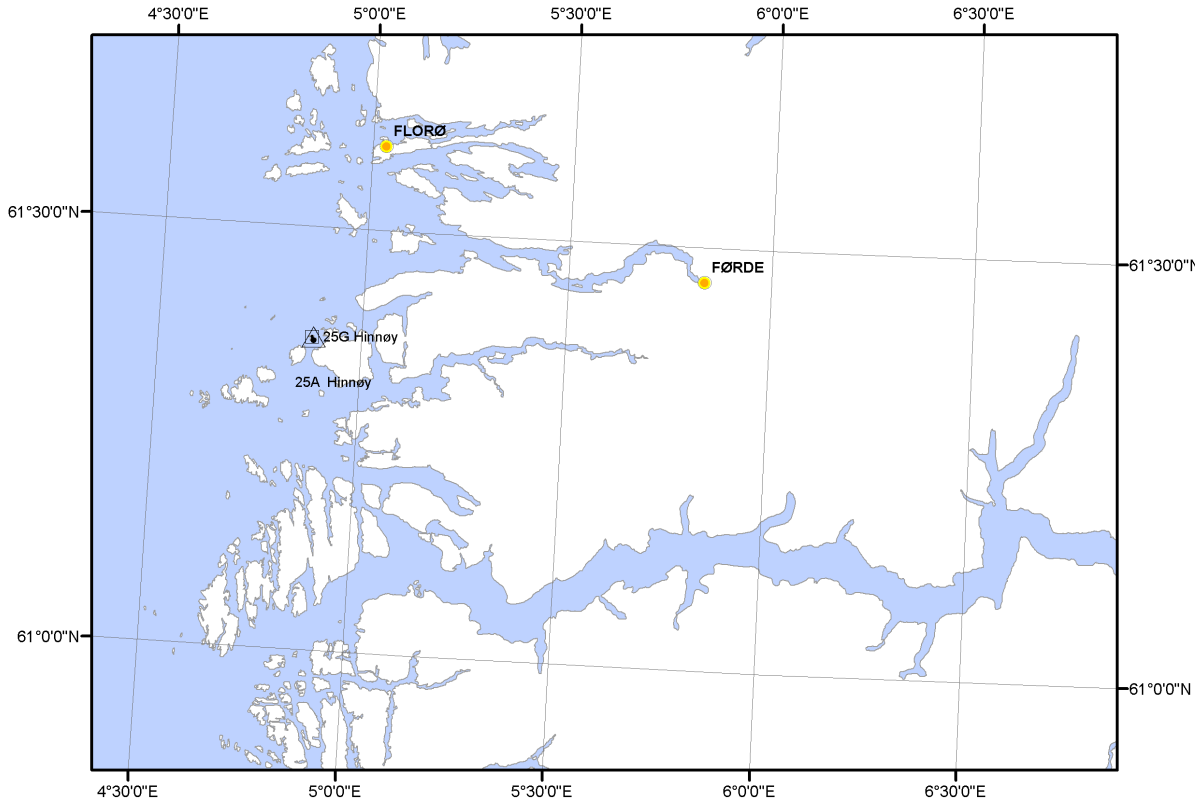
MAP 5


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
63S Ranaskjær
63A Ranaskjær
64A Utne
ØYSTESE
57A Krossanes
57S Krossanes
57A1 Urdheim
67B Strandebarm area
56A2 Kjeken
57A2 Ernes
67F Strandebarm area
56A5 Lofthus (south)
67D Strandebarm area
67E Strandebarm area
56A4 Rosstadnes
65A Vikingneset
56A3 Sekse
56A Kvalnes
56D Kvalnes
67S Strandebarm area
56S Kvalnes
56A1 Kvalnes (north)
53D Digraneset
29D Høyanger area
53F Inner Sørfjord
53B Inner Sørfjord
53E Inner Sørfjord
52S Tyssedal
52A Eitrheimsneset
52E Eitrheimsneset
69S Kvinnheradsfjorden
ODDA
69A Lille Terøy
51A Byrkjenes

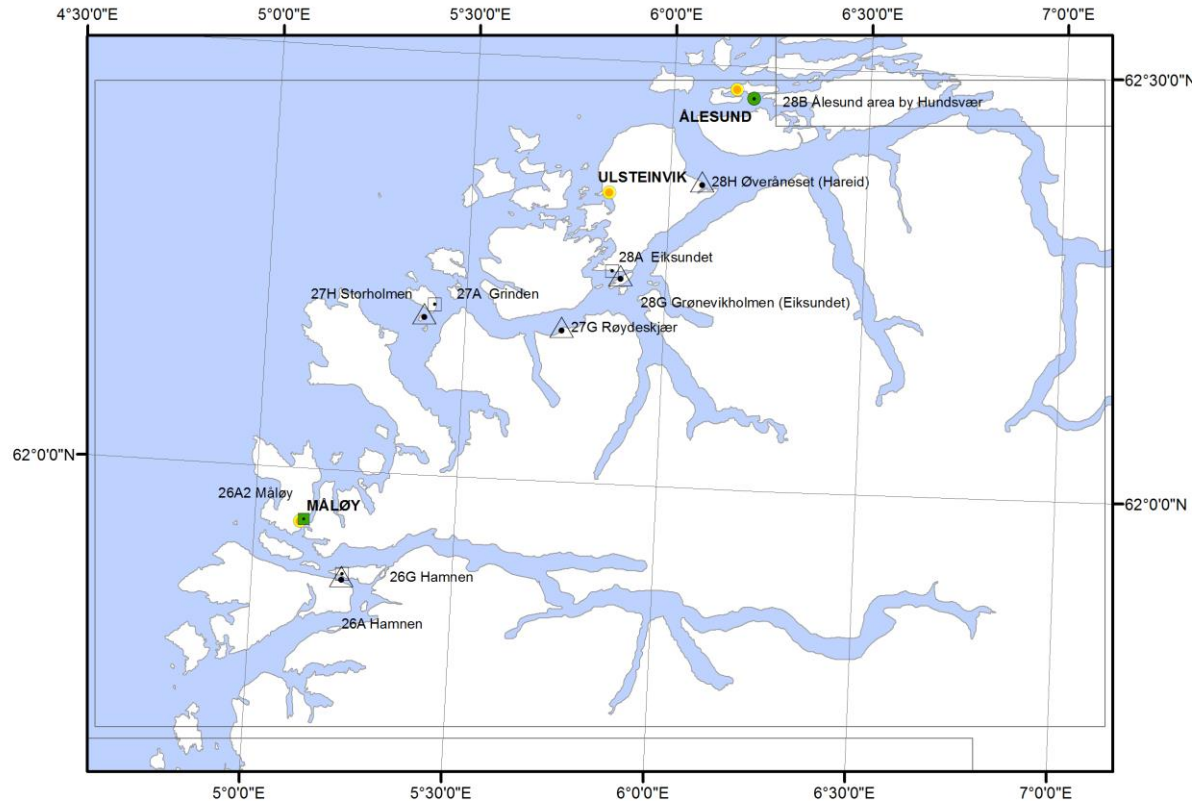
MAP 6


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
24B Bergen harbour
I241 Nordnes
I242 Gravdalsneset
I243 Hegreneset
BERGEN
ØYSTESE
67B Strandebarm area
67F Strandebarm area
67D Strandebarm area
67E Strandebarm ar
65A Vikir
56D Kva
24G Vardøy
24A Vardøy
29D Høyan
69A Lille Terøy
23B Bømlo north
23F Kanhavet area
23A Austvik
LEIRVIK
21D Åkrafjor

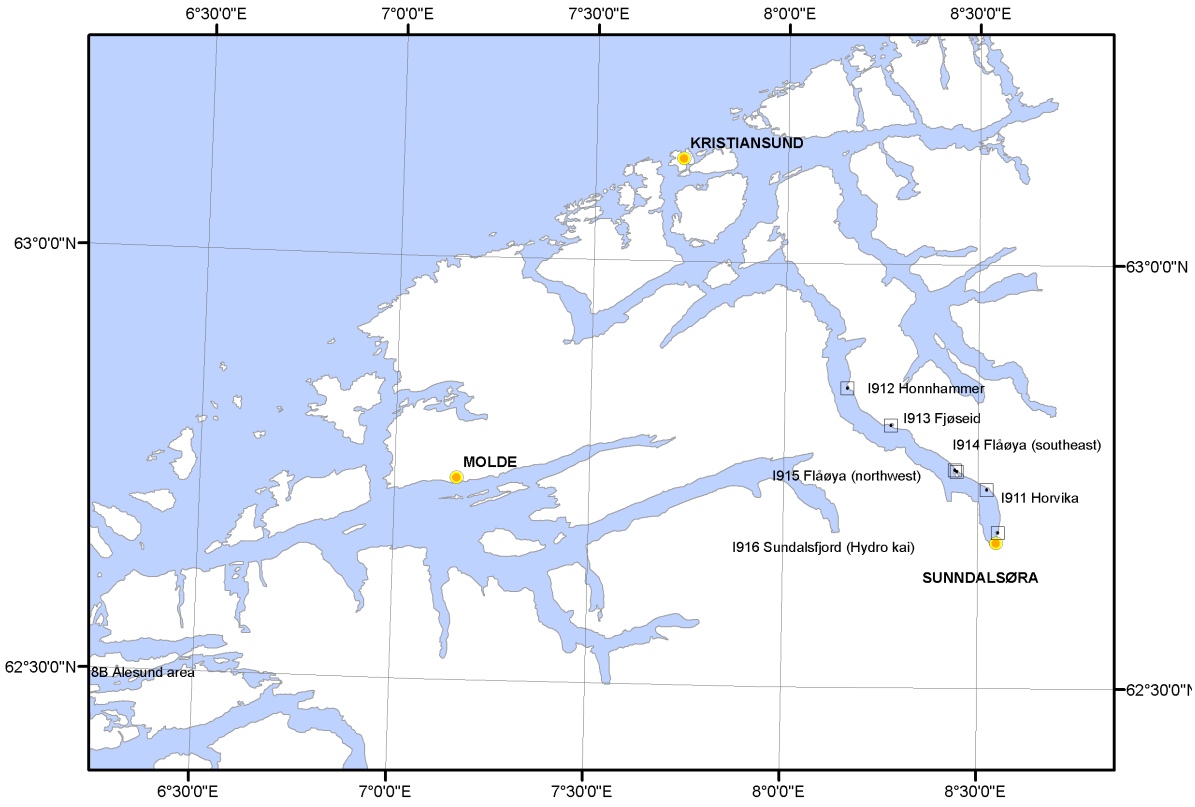
MAP 7


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
FØRDE
25G Hinnøy
25A Hinnøy

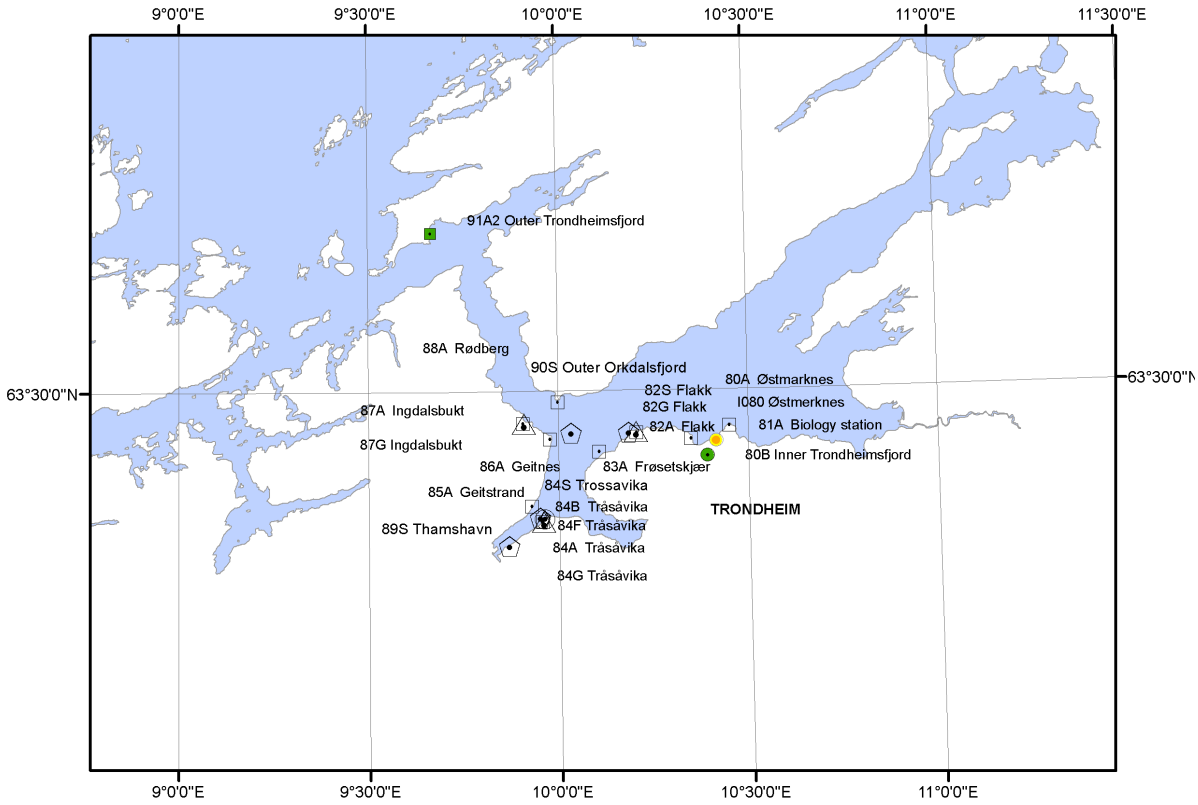
MAP 8


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
28B Ålesund area by Hundsvær
ÅLESUND
ULSTEINVIK
28H Øveråneset (Hareid)
28A Eiksundet
27H Storholmen
27A Grinden
28G Grønevikholmen (Eiksundet)
27G Røydeskjær
26A2 Måløy
MÅLØY
26G Hamnen
26A Hamnen

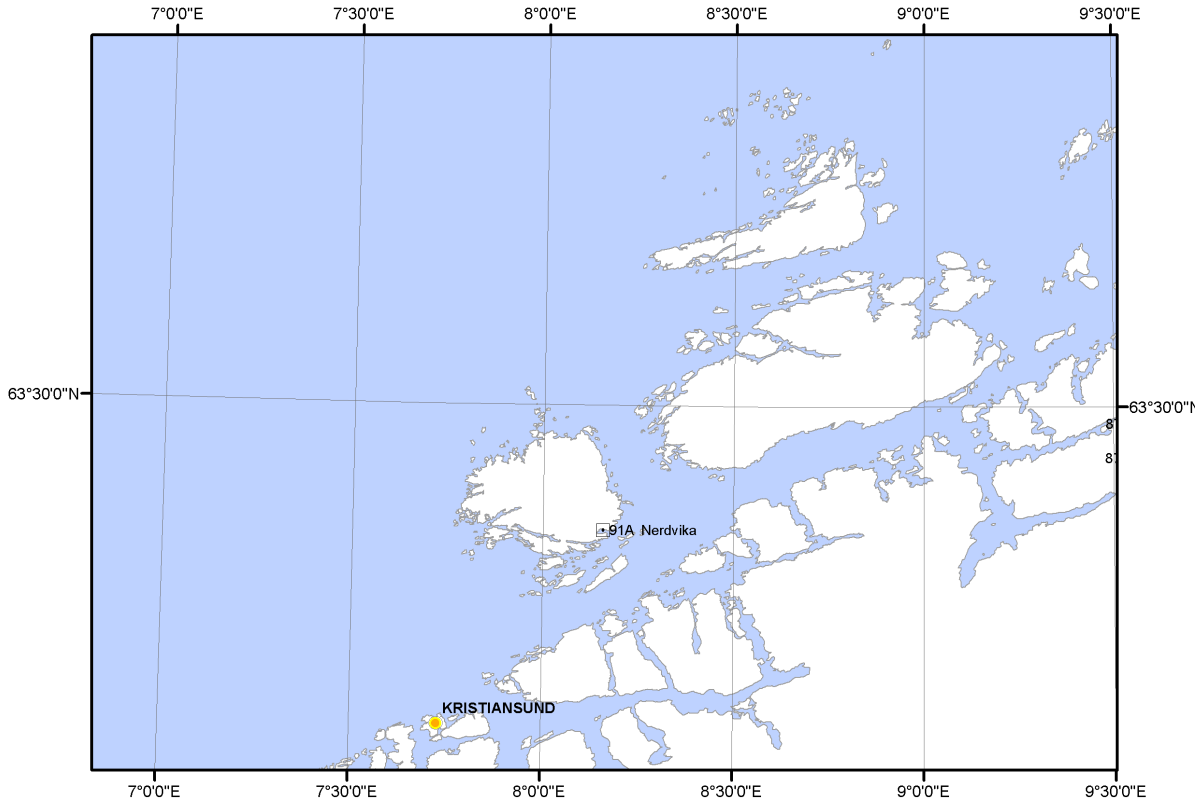
MAP 9


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
MOLDE
I912 Honnhammer
I913 Fjøseid
I914 Fláøya (southeast)
I915 Fláøya (northwest)
I911 Horvika
I916 Sundalsfjord (Hydro kai)
SUNNDALSØRA
8B Ålesund area

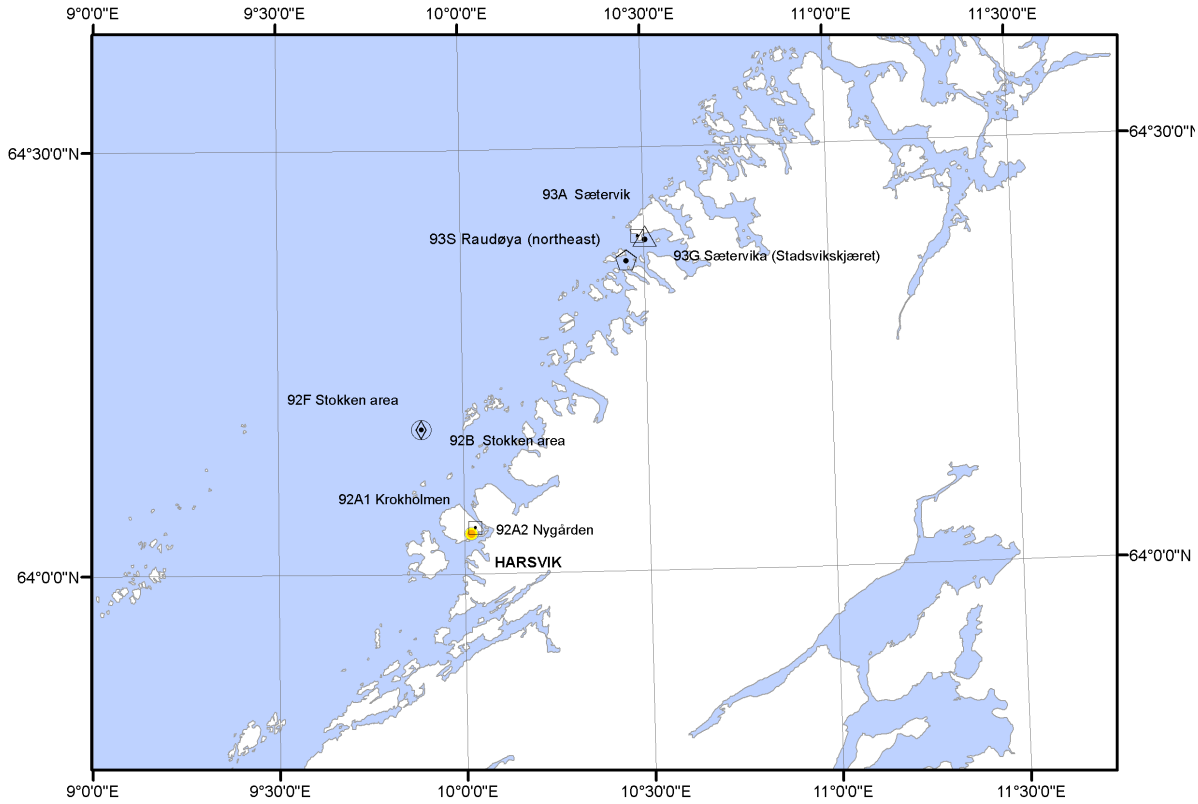
MAP 10


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
88A Rødberg
90S Outer Orkdalsfjord
80A Østmarknes
82S Flakk
82G Flakk
I080 Østmerknes
87A Ingdalsbukt
82A Flakk
81A Biology station
87G Ingdalsbukt
80B Inner Trondheimsfjord
86A Geitnes
83A Frøsetskjær
85A Geitstrand
84S Trossavika
84B Tråsåvika
TRONDHEIM
89S Thamshavn
84F Tråsåvika
84A Tråsåvika
84G Tråsåvika

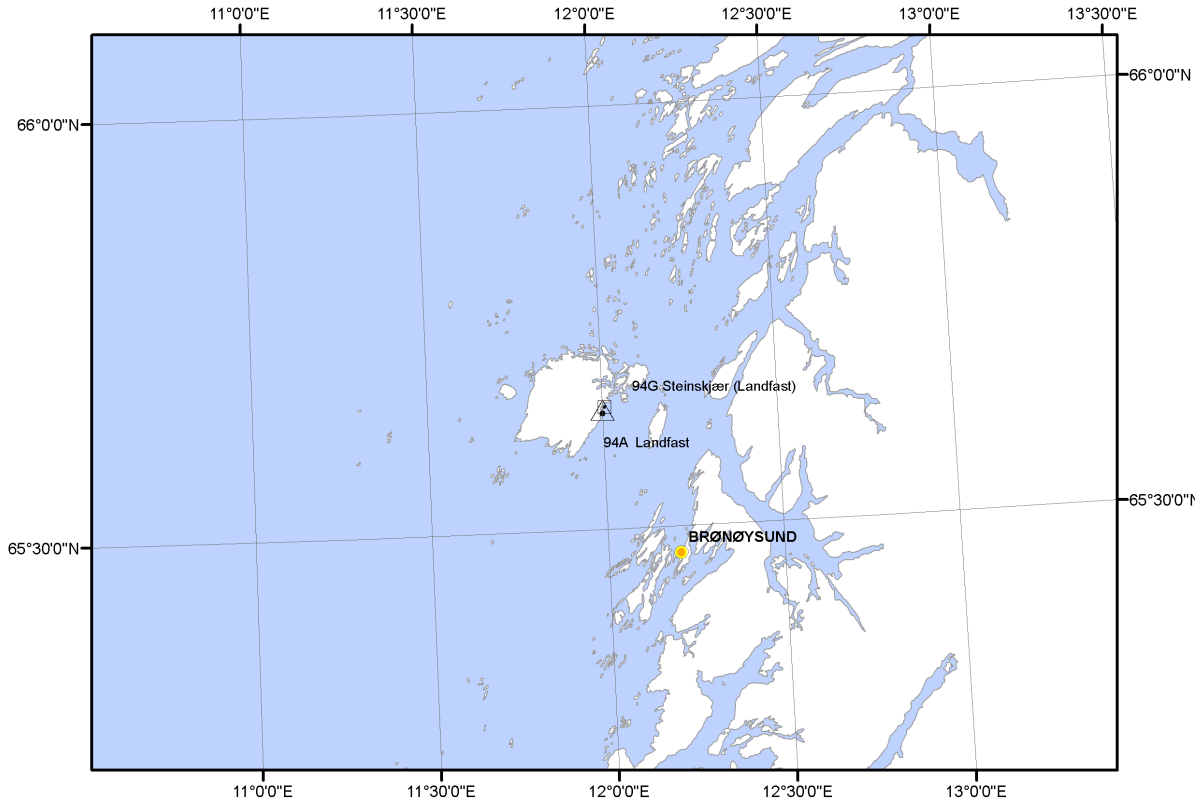
MAP 11


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
91A Nerdvika
KRISTIANSUND

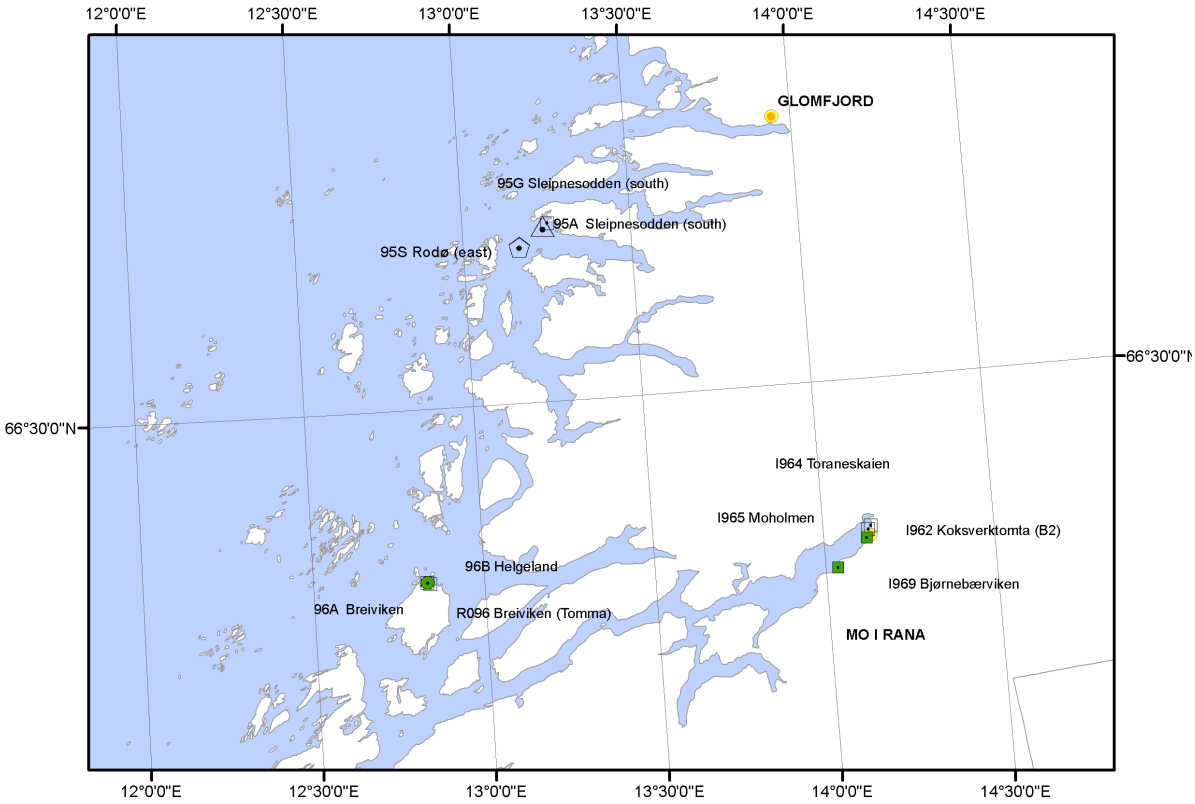
MAP 12


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)
93G Sætervika (Stadsvikskjæret)
92F Stokken area
92B Stokken area
92A1 Krokhölmen
92A2 Nygården
HARSVIK

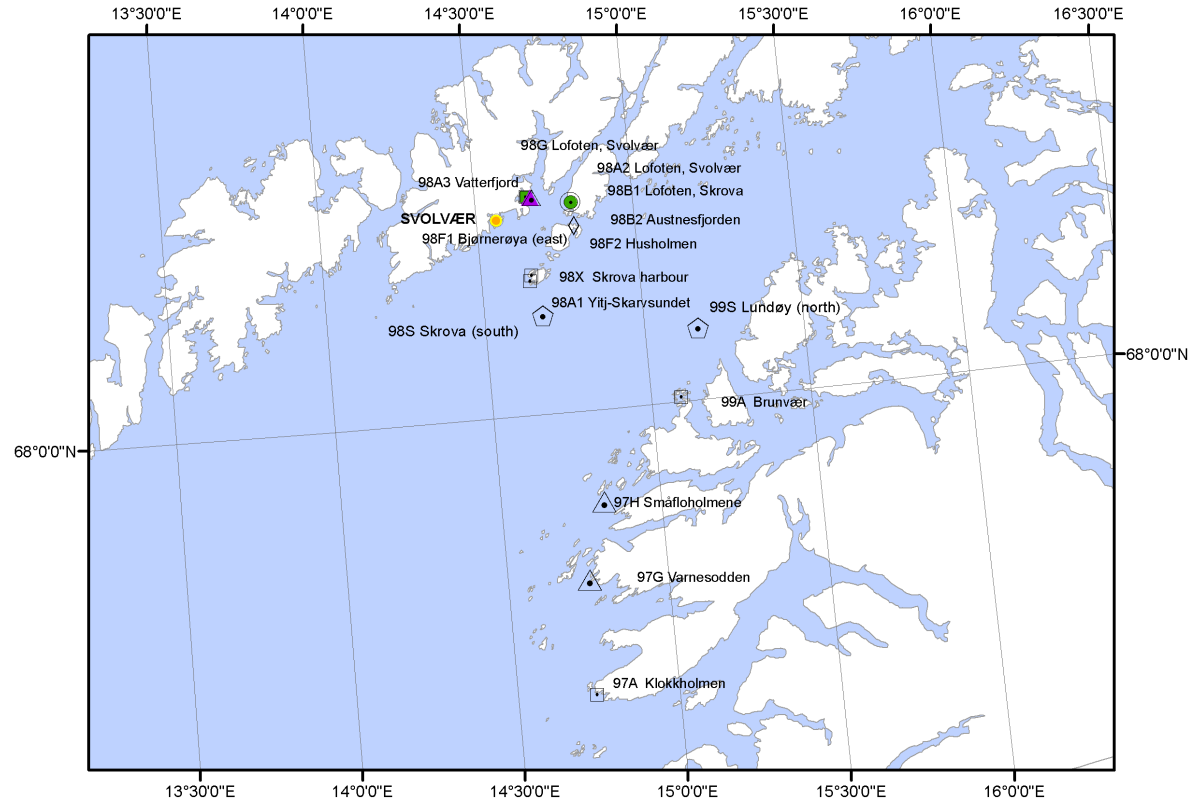
MAP 13


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
94G Steinskjær (Landfast)
94A Landfast
BRØNØYSUND

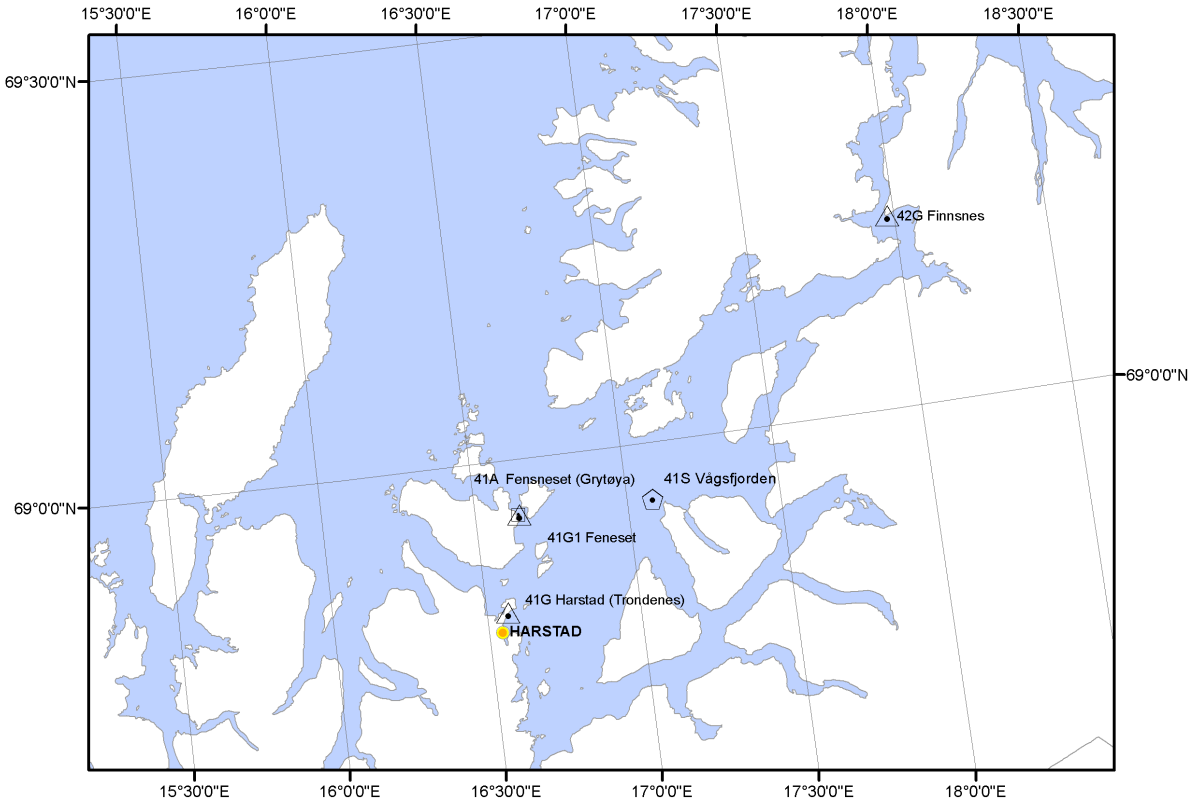
MAP 14


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
95G Sleipnesodden (south)
95A Sleipnesodden (south)
95S Rodø (east)
I964 Toraneskaien
I965 Moholmen
I962 Koksverktomta (B2)
I969 Bjørnebærviken
96B Helgeland
96A Breiviken
R096 Breiviken (Tomma)
MO I RANA

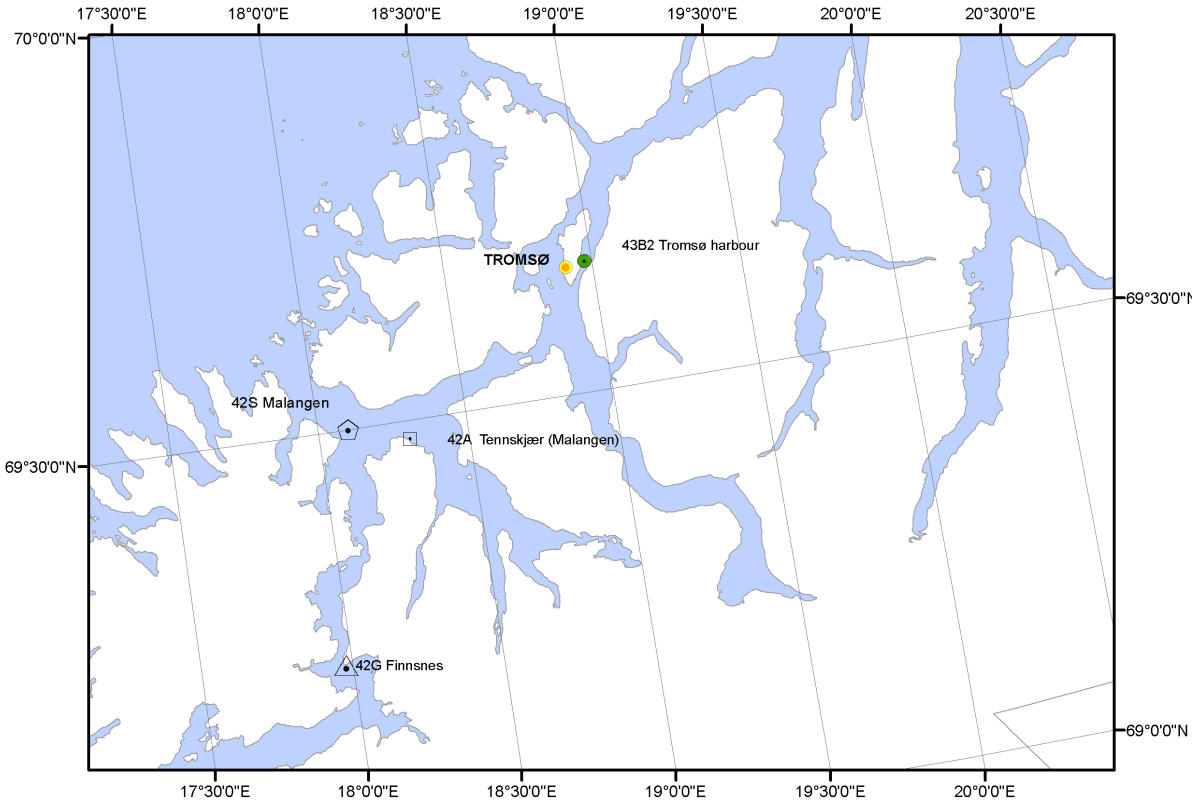
MAP 15


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
98G Lofoten, Svolvær
98A2 Lofoten, Svolvær
98A3 Vatterfjord
98B1 Lofoten, Skrova
SVOLVÆR
98B2 Austnesfjorden
98F1 Bjørnerøya (east)
98F2 Husholmen
98X Skrova harbour
98A1 Yttj-Skarvsundet
99S Lundøy (north)
98S Skrova (south)
99A Brunvær
97H Småfloholmene
97G Varnesodden
97A Klokkholmen

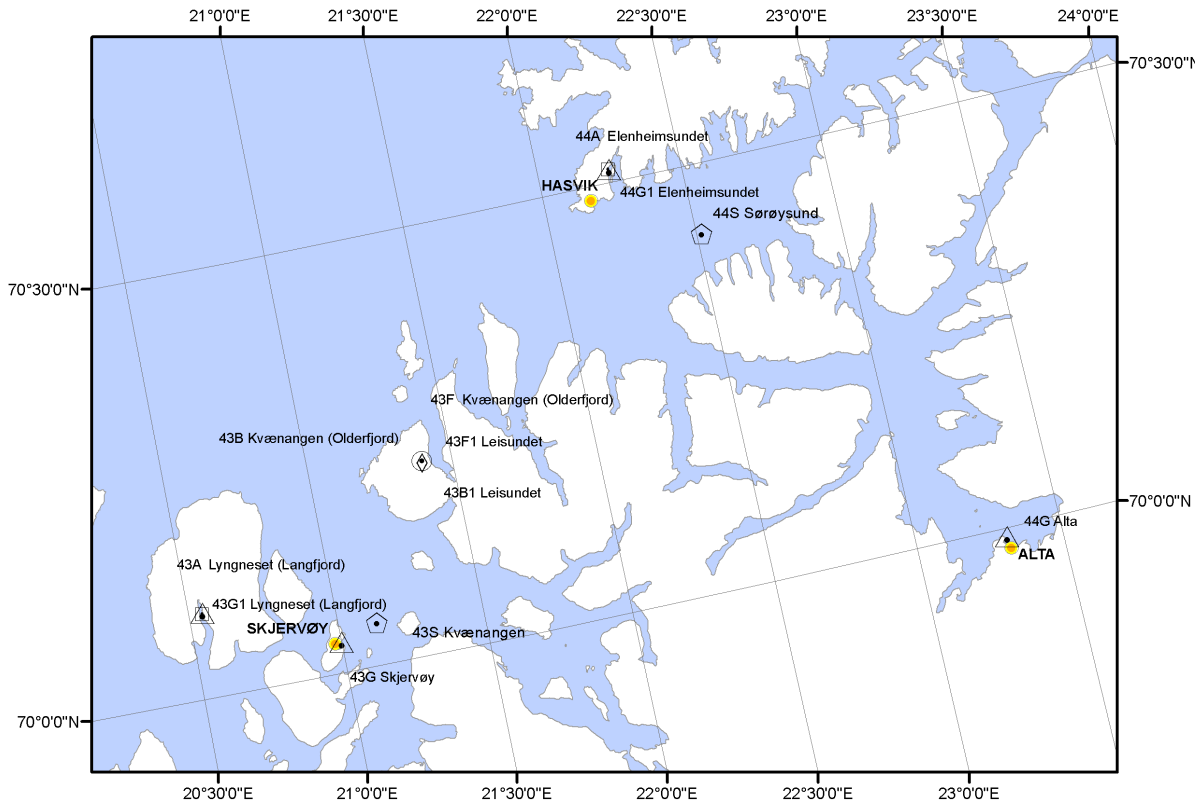
MAP 16


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
41A Fensneset (Grytøya)
41S Vågsfjorden
41G1 Feneset
41G Harstad (Trondenes)
HARSTAD

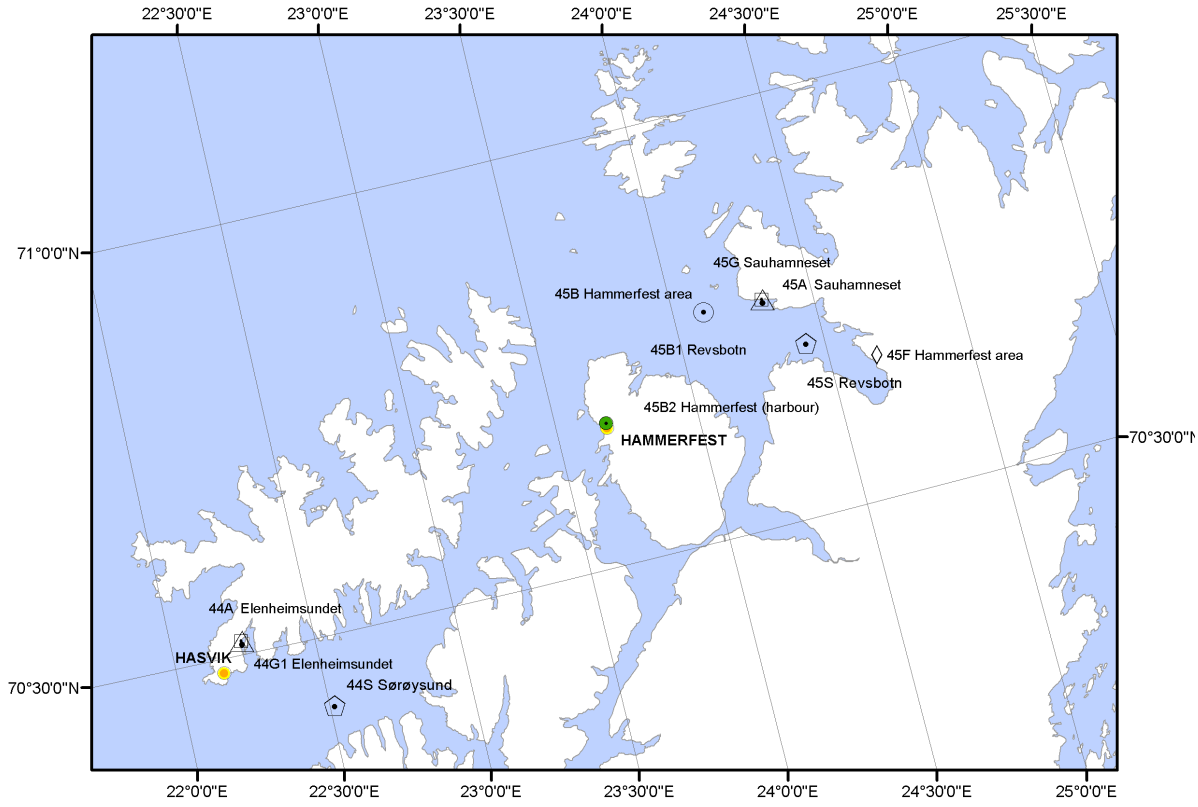
MAP 17


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
69°0'0"N
TROMSØ
43B2 Tromsø harbour
42S Malangen
42A Tennskjær (Malangen)
42G Finnsnes

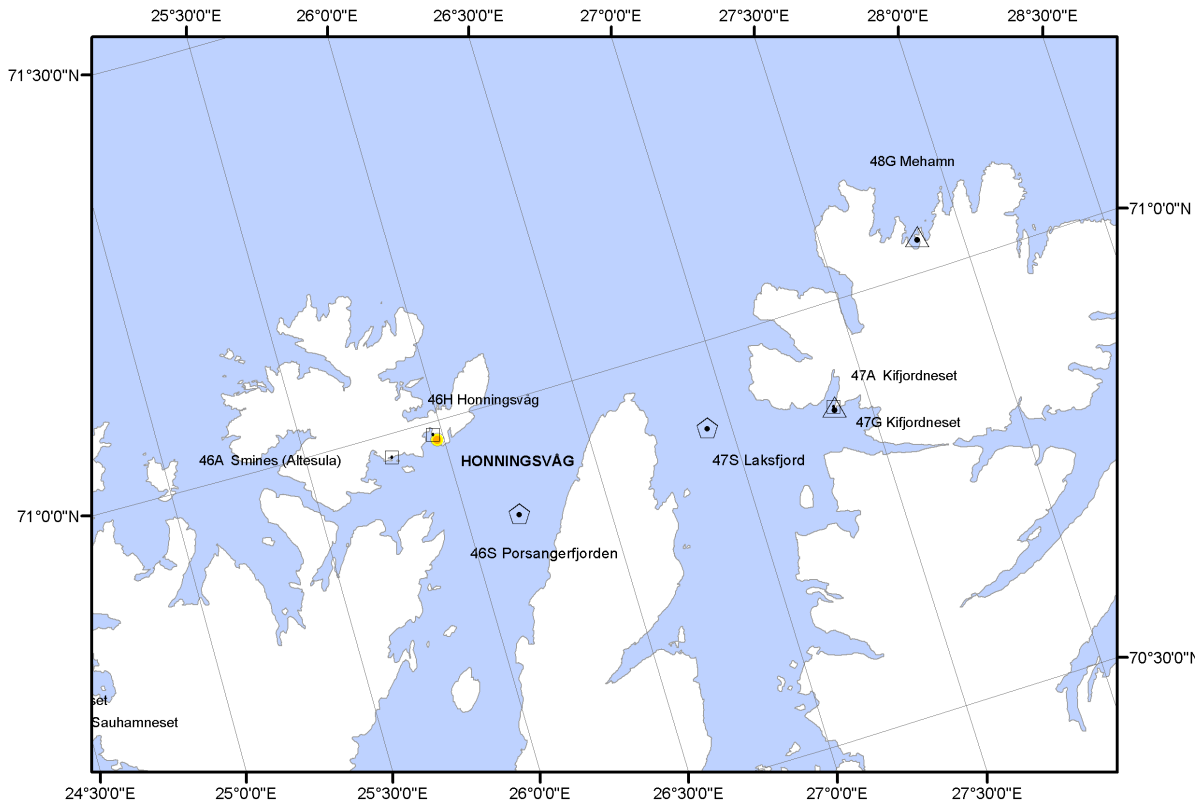
MAP 18


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
44A Elenheimsundet
HASVIK
44G1 Elenheimsundet
44S Sørøysund
43F Kvænangen (Olderfjord)
43B Kvænangen (Olderfjord)
43F1 Leisundet
43B1 Leisundet
44G Alta
ALTA
43A Lyngneset (Langfjord)
43G1 Lyngneset (Langfjord)
SKJERVØY
43S Kvænangen
43G Skjervøy

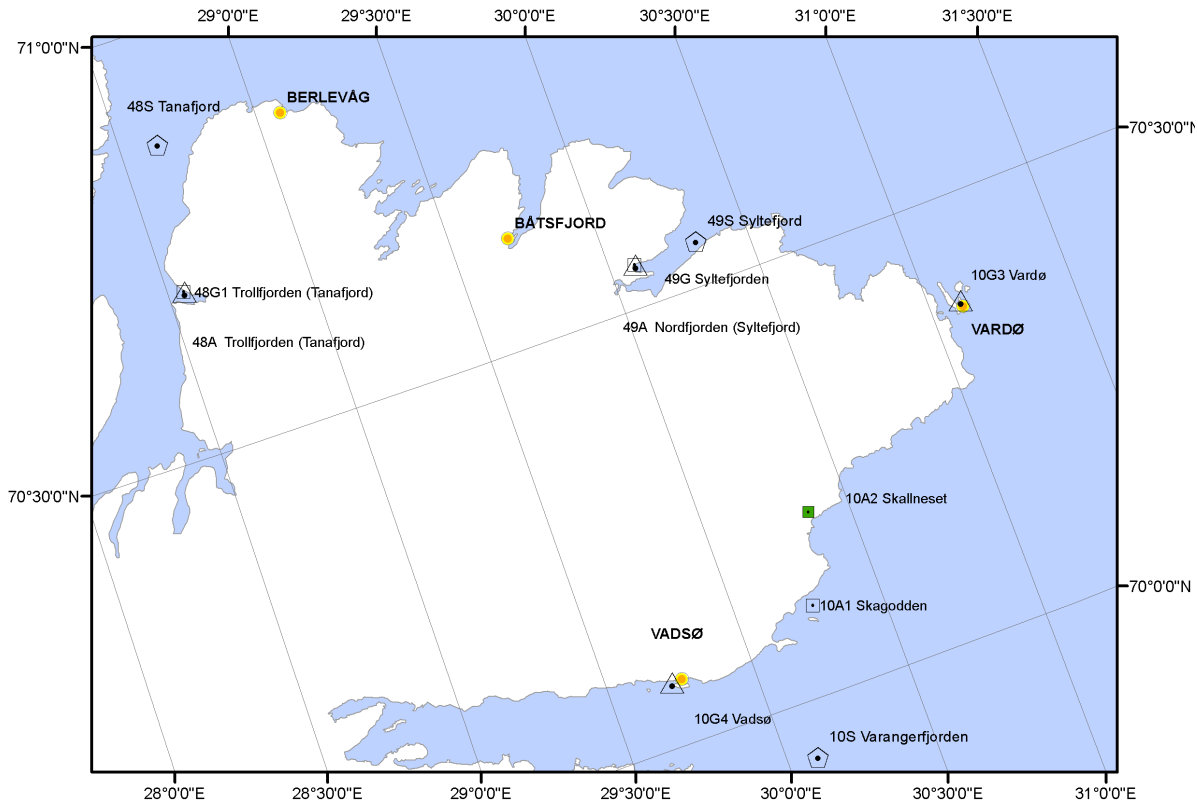
MAP 19


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
45G Sauhamneset
45A Sauhamneset
45B Hammerfest area
45B1 Revsbotn
45F Hammerfest area
45S Revsbotn
45B2 Hammerfest (harbour)
HAMMERFEST
44A Elenheimsundet
HASVIK
44G1 Elenheimsundet
44S Sørøysund

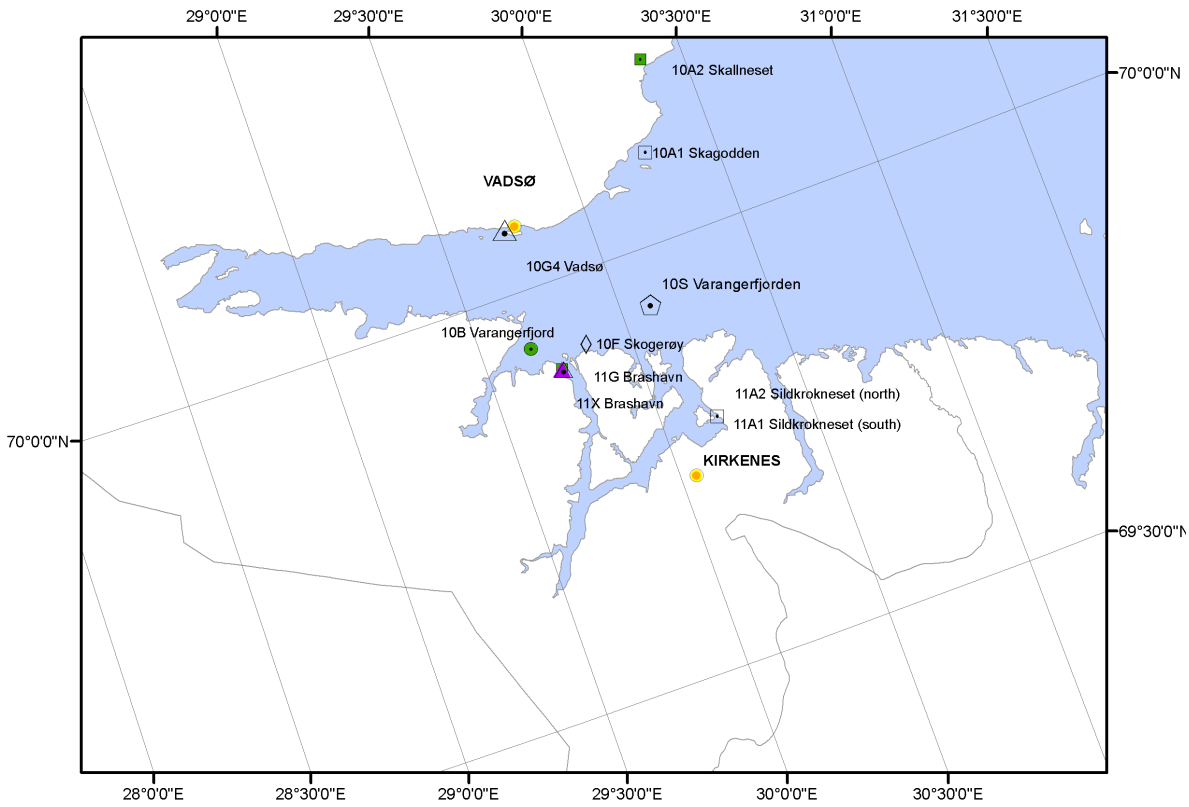
MAP 20


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 Mehamn
47A Kifjordneset
47G Kifjordneset
46H Honningsvåg
46A Smines (Altesula)
HONNINGSVÅG
47S Laksfjord
46S Porsangerfjorden
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
BÅTSFJORD
49S Syltefjord
49G Syltefjorden
10G3 Vardø
VARDØ
48G1 Trollfjorden (Tanafjord)
48A Trollfjorden (Tanafjord)
49A Nordfjorden (Syltefjord)
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
70°0'0"N
69°30'0"N
28°0'0"E
28°30'0"E
29°0'0"E
29°30'0"E
30°0'0"E
30°30'0"E
10A2 Skallneset
10A1 Skagodden
VADSØ
10G4 Vadsø
10S Varangerfjorden
10B Varangerfjord
10F Skogerøy
11G Brashavn
11X Brashavn
11A2 Sildkrokneset (north)
11A1 Sildkrokneset (south)
KIRKENES

MAP 23

Appendix E
Overview of materials and analyses 2014-2015

Nominal station positions are shown on maps in Appendix D

Year:
2014t - samples taken in 2014
2015p – samples planned in 2015
2015t – samples taken in 2015

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) 2015:

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	PBDEs [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
PFRs	PFRs [9)]	x	x			x	x
PHC	PHCs [10)]	x	x			x	x
BE	Biological effects met.[11)]		Imposex	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 (PBDEs), 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: PCB-28,-52,-101,-105,-118,-138,-153,-156,-180, 209, 5-CB, OCS and, when dioxins are analysed, the non-orto-PCBs, i.e. PCB-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 Phthalates, 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)] PFRs – 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 2014-2015 –biota.*

myear	station	STATION NAME	LATITUDE	LONGITUDE	specie	tissue	I-MET	O-MET	O-BR	OC-CB	OC-CL	OC-CP	OC-DD	O-FL	O-PAH	PFR	PHC	O-PHE	BE	ISOTO
2014t	30B	Oslo City area	59.81667	10.55000	GADU MOR	BI													12	
2015p	30B	Oslo City area	59.81667	10.55000	GADU MOR	BI													15	
2015t	30B	Oslo City area	59.81667	10.55000	GADU MOR	BI													13	
2014t	15B	Ullerø area	58.05000	6.71667	GADU MOR	BI													**15**	
2015p	15B	Ullerø area	58.05000	6.71667	GADU MOR	BI													**15**	
2015t	15B	Ullerø area	58.05000	6.71667	GADU MOR	BI													**15**	
2014t	53B	Inner Sørfjord	60.16667	6.56667	GADU MOR	BI													**11**	
2015p	53B	Inner Sørfjord	60.16667	6.56667	GADU MOR	BI													**15**	
2015t	53B	Inner Sørfjord	60.16667	6.56667	GADU MOR	BI													**14**	
2014t	23B	Karihavet area	59.90000	5.13333	GADU MOR	BI													**15**	
2015p	23B	Karihavet area	59.90000	5.13333	GADU MOR	BI													**15**	
2015t	23B	Karihavet area	59.90000	5.13333	GADU MOR	BI													**15**	
2014t	30B	Oslo City area	59.81667	10.55000	GADU MOR	BL													15	
2015p	30B	Oslo City area	59.81667	10.55000	GADU MOR	BL													15	
2015t	30B	Oslo City area	59.81667	10.55000	GADU MOR	BL													15	
2014t	53B	Inner Sørfjord	60.16667	6.56667	GADU MOR	BL													**12**	
2015p	53B	Inner Sørfjord	60.16667	6.56667	GADU MOR	BL													**15**	
2015t	53B	Inner Sørfjord	60.16667	6.56667	GADU MOR	BL													**15**	
2014t	23B	Karihavet area	59.90000	5.13333	GADU MOR	BL													**15**	
2015p	23B	Karihavet area	59.90000	5.13333	GADU MOR	BL													**15**	
2015t	23B	Karihavet area	59.90000	5.13333	GADU MOR	BL													**15**	
2014t	30B	Oslo City area	59.81667	10.55000	GADU MOR	LI	15		15	15	**15**	15	**15**	15		15	15	15	15	
2015p	30B	Oslo City area	59.81667	10.55000	GADU MOR	LI	15		15	15	**15**	15	**15**	15		15	15	15	15	
2015t	30B	Oslo City area	59.81667	10.55000	GADU MOR	LI	12		12	12	**12**	11	**12**	12		12	12	12	15	
2014t	36B	Færder area	59.04050	10.43583	GADU MOR	LI	15		15	15	**15**	15	**15**	15		15	15	15		
2015p	36B	Færder area	59.04050	10.43583	GADU MOR	LI	15		15	15	**15**	15	**15**	15		15	15	15		
2015t	36B	Færder area	59.04050	10.43583	GADU MOR	LI	15		15	15	**15**	15	**15**	15		15	15	15		
2014t	02B	Hvalerbassenget (Kirkøy North)	59.11250	11.03883	GADU MOR	LI	3		3	3		3				3	3	3		
2015p	02B	Hvalerbassenget (Kirkøy North)	59.11250	11.03883	GADU MOR	LI	15		15	15		15				15	15	15		
2015t	02B	Hvalerbassenget (Kirkøy North)	59.11250	11.03883	GADU MOR	LI	5		5	5		5				5	5	5		
2014t	71B	Grenlandsfjord (Brevik area)	59.06117	9.70967	GADU MOR	LI	13		13			13				13	13	13		
2015p	71B	Grenlandsfjord (Brevik area)	59.06117	9.70967	GADU MOR	LI	15		15			15				15	15	15		
2015t	71B	Grenlandsfjord (Brevik area)	59.06117	9.70967	GADU MOR	LI	15		15			15				15	15	15		
2014t	13B	Kristiansand harbour	58.13283	7.98850	GADU MOR	LI	14		14	14		14		14		14	14	14		
2015p	13B	Kristiansand harbour	58.13283	7.98850	GADU MOR	LI	15		15	15		15		15		15	15	15		
2015t	13B	Kristiansand harbour	58.13283	7.98850	GADU MOR	LI	14		14	14		14		14		14	14	14		
2014t	15B	Ullerø area	58.05000	6.71667	GADU MOR	LI	15			15	**15**		**15**							
2015p	15B	Ullerø area	58.05000	6.71667	GADU MOR	LI	15			15	**15**		**15**							

myear	station	STATION NAME	LATITUDE	LONGITUDE	specie	tissue	I-MET	O-MET	O-BR	OC-CB	OC-CL	OC-CP	OC-DD	O-FL	O-PAH	PFR	PHC	O-PHE	BE	ISOTO
2015t	15B	Ullerø area	58.05000	6.71667	GADU MOR	LI	15			15	15		15							
2014t	53B	Inner Sørfjord	60.16667	6.56667	GADU MOR	LI			9	9	9	9	17	9		7	9	7	12	
2015p	53B	Inner Sørfjord	60.16667	6.56667	GADU MOR	LI	15		15	15	15	15	15	15		15	15	15	15	
2015t	53B	Inner Sørfjord	60.16667	6.56667	GADU MOR	LI	14		14	14	14	14	14	14		14	14	14	15	
2014t	23B	Karihavet area	59.90000	5.13333	GADU MOR	LI	14		14	14	14	14	14	14		14	14	14	15	
2015p	23B	Karihavet area	59.90000	5.13333	GADU MOR	LI	15		15	15	15	15	15	15		15	15	15	15	
2015t	23B	Karihavet area	59.90000	5.13333	GADU MOR	LI	15		15	15	15	15	15	15		15	15	15	15	
2014t	24B	Bergen harbour			GADU MOR	LI	0		0	0		0		0		0	0	0		
2015p	24B	Bergen harbour	60.39607	5.27508	GADU MOR	LI	15		15	15		15		15		15	15	15		
2015t	24B	Bergen harbour	60.39607	5.27508	GADU MOR	LI	15		15	15		15		15		15	15	15		
2014t	28B	Ålesund (Hundsvær area)	62.25167	5.86400	GADU MOR	LI	0		0	0		0		0		0	0	0		
2015p	28B	Ålesund (Hundsvær area)	62.25167	5.86400	GADU MOR	LI	15		15	15		15				15	15	15		
2015t	28B	Ålesund (Hundsvær area)	62.25167	5.86400	GADU MOR	LI	6		6	6		6				6	6	6		
2014t	80B	Munkholmen (Inner Trondheimsfjord)	63.45733	10.44950	GADU MOR	LI	15		15	15		15		15		15	15	15		
2015p	80B	Munkholmen (Inner Trondheimsfjord)	63.45733	10.44950	GADU MOR	LI	15		15	15		15		15		15	15	15		
2015t	80B	Munkholmen (Inner Trondheimsfjord)	63.45733	10.44950	GADU MOR	LI	15		15	15		15		15		15	15	15		
2014t	96B	Helgelandskysten (Sandnessjøen area)	66.29617	12.83367	GADU MOR	LI	15			15										
2015p	96B	Helgelandskysten (Sandnessjøen area)	66.29617	12.83367	GADU MOR	LI	15			15										
2015t	96B	Helgelandskysten (Sandnessjøen area)	66.29617	12.83367	GADU MOR	LI	15			15										
2014t	98B1	Bjørnerøya (Lofoten)	68.24667	14.80333	GADU MOR	LI	8		8	8	8	8	8	8		8				
2015p	98B1	Bjørnerøya (Lofoten)	68.24667	14.80333	GADU MOR	LI	15		15	15	15	15	15	15		15				
2015t	98B1	Bjørnerøya (Lofoten)	68.24667	14.80333	GADU MOR	LI	14		15	15	15	15	15	15		15				
2014t	43B2	Tromsø harbour	70.30200	21.42683	GADU MOR	LI	15		15	15		15		15		15	15	15		
2015p	43B2	Tromsø harbour	70.30200	21.42683	GADU MOR	LI	15		15	15		15		15		15	15	15		
2015t	43B2	Tromsø harbour	70.30200	21.42683	GADU MOR	LI	13		13	13		13		13		13	13	13		
2014t	45B2	Hammerfest harbour	70.70000	24.48333	GADU MOR	LI	15			15										
2015p	45B2	Hammerfest harbour	70.70000	24.48333	GADU MOR	LI	15			15										
2015t	45B2	Hammerfest harbour	70.70000	24.48333	GADU MOR	LI	11			11										
2014t	10B	Varangerfjord	69.93333	29.66667	GADU MOR	LI	13			13	15		15							
2015p	10B	Varangerfjord	69.93333	29.66667	GADU MOR	LI	15			15	15		15							
2015t	10B	Varangerfjord	69.93333	29.66667	GADU MOR	LI	11			11	11		11							
2014t	30B	Oslo City area	59.81667	10.55000	GADU MOR	MU	15													15
2015p	30B	Oslo City area	59.81667	10.55000	GADU MOR	MU	15													15
2015t	30B	Oslo City area	59.81667	10.55000	GADU MOR	MU	15													15
2014t	36B	Færder area	59.04050	10.43583	GADU MOR	MU	15													15
2015p	36B	Færder area	59.04050	10.43583	GADU MOR	MU	15													15
2015t	36B	Færder area	59.04050	10.43583	GADU MOR	MU	15													15
2014t	02B	Hvalerbassenget (Kirkøy North)	59.11250	11.03883	GADU MOR	MU	8													8
2015p	02B	Hvalerbassenget (Kirkøy North)	59.11250	11.03883	GADU MOR	MU	15													15
2015t	02B	Hvalerbassenget (Kirkøy North)	59.11250	11.03883	GADU MOR	MU	14													14
2014t	71B	Grenlandsfjord (Brevik area)	59.06117	9.70967	GADU MOR	MU	15													15
2015p	71B	Grenlandsfjord (Brevik area)	59.06117	9.70967	GADU MOR	MU	15													15
2015t	71B	Grenlandsfjord (Brevik area)	59.06117	9.70967	GADU MOR	MU	15													15

myear	station	STATION NAME	LATITUDE	LONGITUDE	specie	tissue	I-MET	O-MET	O-BR	OC-CB	OC-CL	OC-CP	OC-DD	O-FL	O-PAH	PFR	PHC	O-PHE	BE	ISOTO
2014t	13B	Kristiansand harbour	58.13283	7.98850	GADU MOR	MU	15													15
2015p	13B	Kristiansand harbour	58.13283	7.98850	GADU MOR	MU	15													15
2015t	13B	Kristiansand harbour	58.13283	7.98850	GADU MOR	MU	15													15
2014t	15B	Ullerø area	58.05000	6.71667	GADU MOR	MU	15													15
2015p	15B	Ullerø area	58.05000	6.71667	GADU MOR	MU	15													15
2015t	15B	Ullerø area	58.05000	6.71667	GADU MOR	MU	15													15
2014t	53B	Inner Sørfjord	60.16667	6.56667	GADU MOR	MU	15													15
2015p	53B	Inner Sørfjord	60.16667	6.56667	GADU MOR	MU	15													15
2015t	53B	Inner Sørfjord	60.16667	6.56667	GADU MOR	MU	15													15
2014t	23B	Karihavet area	59.90000	5.13333	GADU MOR	MU	15													15
2015p	23B	Karihavet area	59.90000	5.13333	GADU MOR	MU	15													15
2015t	23B	Karihavet area	59.90000	5.13333	GADU MOR	MU	15													15
2014t	24B	Bergen harbour			GADU MOR	LI	0													
2015p	24B	Bergen harbour	60.39607	5.27508	GADU MOR	LI	15													
2015t	24B	Bergen harbour	60.39607	5.27508	GADU MOR	LI	15													
2014t	28B	Ålesund (Hundsvær area)	62.25167	5.86400	GADU MOR	MU	0													0
2015p	28B	Ålesund (Hundsvær area)	62.25167	5.86400	GADU MOR	MU	15													15
2015t	28B	Ålesund (Hundsvær area)	62.25167	5.86400	GADU MOR	MU	8													8
2014t	80B	Munkholmen (Inner Trondheimsfjord)	63.45733	10.44950	GADU MOR	MU	15													15
2015p	80B	Munkholmen (Inner Trondheimsfjord)	63.45733	10.44950	GADU MOR	MU	15													15
2015t	80B	Munkholmen (Inner Trondheimsfjord)	63.45733	10.44950	GADU MOR	MU	15													15
2014t	96B	Helgelandskysten (Sandnessjøen area)	66.29617	12.83367	GADU MOR	MU	15													15
2015p	96B	Helgelandskysten (Sandnessjøen area)	66.29617	12.83367	GADU MOR	MU	15													15
2015t	96B	Helgelandskysten (Sandnessjøen area)	66.29617	12.83367	GADU MOR	MU	15													15
2014t	98B1	Bjørnerøya (Lofoten)	68.24667	14.80333	GADU MOR	MU	15													15
2015p	98B1	Bjørnerøya (Lofoten)	68.24667	14.80333	GADU MOR	MU	15													15
2015t	98B1	Bjørnerøya (Lofoten)	68.24667	14.80333	GADU MOR	MU	15													15
2014t	43B2	Tromsø harbour	70.30200	21.42683	GADU MOR	MU	15													15
2015p	43B2	Tromsø harbour	70.30200	21.42683	GADU MOR	MU	15													15
2015t	43B2	Tromsø harbour	70.30200	21.42683	GADU MOR	MU	15													15
2014t	45B2	Hammerfest harbour	70.70000	24.48333	GADU MOR	MU	15													14
2015p	45B2	Hammerfest harbour	70.70000	24.48333	GADU MOR	MU	15													15
2015t	45B2	Hammerfest harbour	70.70000	24.48333	GADU MOR	MU	15													15
2014t	10B	Varangerfjord	69.93333	29.66667	GADU MOR	MU	15													15
2015p	10B	Varangerfjord	69.93333	29.66667	GADU MOR	MU	15													15
2015t	10B	Varangerfjord	69.93333	29.66667	GADU MOR	MU	15													15
2014t	71G	Fugløyskjær	58.98250	9.80833	LITT LIT	SB		1											1	
2015p	71G	Fugløyskjær	58.98250	9.80833	LITT LIT	SB		1												
2015t	71G	Fugløyskjær	58.98250	9.80833	LITT LIT	SB		1												
2014t	I301	Akershuskaia	59.90533	10.73633	MYTI EDU	SB	3	3		3	3		3		3	3	3			
2015p	I301	Akershuskaia	59.90533	10.73633	MYTI EDU	SB	3	3		3	3		3		3	3	3			
2015t	I301	Akershuskaia	59.90533	10.73633	MYTI EDU	SB	3	3		3	3		3		3	3	3			
2014t	30A	Gressholmen	59.88667	10.80967	MYTI EDU	SB	3	3	3	3	3	3	3		3	3	3	3		3

myear	station	STATION NAME	LATITUDE	LONGITUDE	specie	tissue	I-MET	O-MET	O-BR	OC-CB	OC-CL	OC-CP	OC-DD	O-FL	O-PAH	PFR	PHC	O-PHE	BE	ISOTO
2015p	30A	Gressholmen	59.88667	10.80967	MYTI EDU	SB	3	3		3	3	3	3		3	3	3	3		3
2015t	30A	Gressholmen	59.88667	10.80967	MYTI EDU	SB	3	3		3	3	3	3		3	3	3	3		3
2014t	I304	Gåsøya	59.85133	10.58900	MYTI EDU	SB	3	3		3	3		3		3	3	3			3
2015p	I304	Gåsøya	59.85133	10.58900	MYTI EDU	SB	3	3		3	3		3		3	3	3			3
2015t	I304	Gåsøya	59.85133	10.58900	MYTI EDU	SB	3	3		3	3		3		3	3	3			3
2014t	I306	Håøya	59.71333	10.55517	MYTI EDU	SB	3			3										3
2015p	I306	Håøya	59.71333	10.55517	MYTI EDU	SB	3			3										3
2015t	I306	Håøya	59.71333	10.55517	MYTI EDU	SB	3			3										3
2014t	I307	Ramtonholmen	59.74450	10.52283	MYTI EDU	SB	3			3										3
2015p	I307	Ramtonholmen	59.74450	10.52283	MYTI EDU	SB	3			3										3
2015t	I307	Ramtonholmen	59.74450	10.52283	MYTI EDU	SB	3			3										3
2014t	31A	Solbergstrand	59.61500	10.65667	MYTI EDU	SB	3	3		3	3		3			3	3			
2015p	31A	Solbergstrand	59.61500	10.65667	MYTI EDU	SB	3	3		3	3		3			3	3			
2015t	31A	Solbergstrand	59.61500	10.65667	MYTI EDU	SB	3	3		3	3		3			3	3			
2015p	35A	Mølen	59.48817	10.49800	MYTI EDU	SB	6	1		3				1	1					3
2015t	35A	Mølen	59.48817	10.49800	MYTI EDU	SB	6	1		3				1	1					3
2014t	36A	Færder	59.02717	10.52550	MYTI EDU	SB	0	0	0	0	0	0	0			0	0	0		0
2015p	36A	Færder	59.02717	10.52550	MYTI EDU	SB	2	2	1	2	2	1	2			4	4	2		2
2015t	36A	Færder	59.02717	10.52550	MYTI EDU	SB	2	2	1	2	2	1	2			4	4	2		2
2014t	36A1	Tjøme	59.07357	10.42522	MYTI EDU	SB	3	3	3	3		3				3	3	3		0
2015p	36A1	Tjøme	59.07357	10.42522	MYTI EDU	SB	3	3	3	3	3	3	3			3	3	3		3
2015t	36A1	Tjøme	59.07357	10.42522	MYTI EDU	SB	3	3	3	3	3	3	3			3	3	3		3
2014t	I023	Singlekalven (south)	59.09500	11.13667	MYTI EDU	SB	3		3	3		3			3	3	3	3		3
2015p	I023	Singlekalven (south)	59.09500	11.13667	MYTI EDU	SB	3		3	3		3			3	3	3	3		3
2015t	I023	Singlekalven (south)	59.09500	11.13667	MYTI EDU	SB	3		3	3		3			3	3	3	3		3
2014t	I024	Kirkøy (north west)	59.08000	10.98633	MYTI EDU	SB	3			3										3
2015p	I024	Kirkøy (north west)	59.08000	10.98633	MYTI EDU	SB	3			3										3
2015t	I024	Kirkøy (north west)	59.08000	10.98633	MYTI EDU	SB	3			3										3
2014t	71A	Bjørkøya (Risøyodden)	59.02333	9.75367	MYTI EDU	SB	3		3		3	3	3		3	3	3	3		3
2015p	71A	Bjørkøya (Risøyodden)	59.02333	9.75367	MYTI EDU	SB	3		3	1	3	3	3		3	3	3	3		3
2015t	71A	Bjørkøya (Risøyodden)	59.02333	9.75367	MYTI EDU	SB	3		3	1	3	3	3		3	3	3	3		3
2014t	I712	Croftholmen	59.04533	9.70683	MYTI EDU	SB	1		1		1	1	1		1	1	1	1		1
2015p	I712	Croftholmen	59.04533	9.70683	MYTI EDU	SB	3		3	3	3	3	3		3	3	3	3		3
2015t	I712	Croftholmen	59.04533	9.70683	MYTI EDU	SB	3		3	3	3	3	3		3	3	3	3		3
2014t	I714	Brevik church			MYTI EDU	SB	0		0			0			0	0	0	0		0
2015p	I714	Brevik church	59.05060	9.70440	MYTI EDU	SB	3		3	3	3	3	3		3	3	3	3		3
2015t	I714	Brevik church	59.05060	9.70440	MYTI EDU	SB	3		3	3	3	3	3		3	3	3	3		3
2014t	I131A	Lastad	58.05550	7.70867	MYTI EDU	SB	3								3					
2015p	I131A	Lastad	58.05550	7.70867	MYTI EDU	SB	3								3					
2015t	I131A	Lastad	58.05550	7.70867	MYTI EDU	SB	3								3					
2014t	I133	Odderøy	58.13167	8.00167	MYTI EDU	SB	3	3		3	3		3			3	3			3
2015p	I133	Odderøy	58.13167	8.00167	MYTI EDU	SB	3	3		3	3		3			3	3			3
2015t	I133	Odderøy	58.13167	8.00167	MYTI EDU	SB	3	3		3	3		3			3	3			3

myear	station	STATION NAME	LATITUDE	LONGITUDE	specie	tissue	I-MET	O-MET	O-BR	OC-CB	OC-CL	OC-CP	OC-DD	O-FL	O-PAH	PFR	PHC	O-PHE	BE	ISOTO
2014t	15A	Gåsøy (Ullerø - Kristiansand area)	58.05117	6.88600	MYTI EDU	SB	3			3										3
2015p	15A	Gåsøy (Ullerø - Kristiansand area)	58.05117	6.88600	MYTI EDU	SB	3			3										3
2015t	15A	Gåsøy (Ullerø - Kristiansand area)	58.05117	6.88600	MYTI EDU	SB	3			3										3
2014t	51A	Byrkjenes	60.08500	6.55167	MYTI EDU	SB	3			3	3		3							3
2015p	51A	Byrkjenes	60.08500	6.55167	MYTI EDU	SB	3			3	3		3							3
2015t	51A	Byrkjenes	60.08500	6.55167	MYTI EDU	SB	3			3	3		3							3
2014t	52A	Eitrheimsneset	60.09667	6.53667	MYTI EDU	SB	3			3	3		3							3
2015p	52A	Eitrheimsneset	60.09667	6.53667	MYTI EDU	SB	3			3	3		3							3
2015t	52A	Eitrheimsneset	60.09667	6.53667	MYTI EDU	SB	3			3	3		3							3
2014t	56A	Kvalnes	60.25517	6.62000	MYTI EDU	SB	3			3	3		3							3
2015p	56A	Kvalnes	60.25517	6.62000	MYTI EDU	SB	3			3	3		3							3
2015t	56A	Kvalnes	60.25517	6.62000	MYTI EDU	SB	3			3	3		3							3
2014t	57A	Krossanes	60.42083	6.74217	MYTI EDU	SB	3			3	3		3							3
2015p	57A	Krossanes	60.42083	6.74217	MYTI EDU	SB	3			3	3		3							3
2015t	57A	Krossanes	60.42083	6.74217	MYTI EDU	SB	3			3	3		3							3
2014t	63A	Ranaskjær	60.41833	6.40833	MYTI EDU	SB	3			3	3		3							3
2015p	63A	Ranaskjær	60.41833	6.40833	MYTI EDU	SB	4			3	3		3		1					3
2015t	63A	Ranaskjær	60.41833	6.40833	MYTI EDU	SB	4			3	3		3		1					3
2014t	64A	Utne	60.42367	6.62217	MYTI EDU	SB	3			3			3							
2015p	64A	Utne	60.42367	6.62217	MYTI EDU	SB	3			3			3							
2015t	64A	Utne	60.42367	6.62217	MYTI EDU	SB	3			3			3							
2014t	65A	Vikingneset	60.24167	6.16000	MYTI EDU	SB	3			3	3		3							
2015p	65A	Vikingneset	60.24167	6.16000	MYTI EDU	SB	3			3	3		3							
2015t	65A	Vikingneset	60.24167	6.16000	MYTI EDU	SB	3			3	3		3							
2014t	69A	Lille Terøy	59.97983	5.75583	MYTI EDU	SB	3			3										3
2015p	69A	Lille Terøy	59.97983	5.75583	MYTI EDU	SB	3			3										3
2015t	69A	Lille Terøy	59.97983	5.75583	MYTI EDU	SB	3			3										3
2014t	22A	Espevær (West Coast)	59.58667	5.14167	MYTI EDU	SB	3	3		3	3		3			3	3			3
2015p	22A	Espevær (West Coast)	59.58667	5.14167	MYTI EDU	SB	3	3		3	3		3			3	3			3
2015t	22A	Espevær (West Coast)	59.58667	5.14167	MYTI EDU	SB	3	3		3	3		3			3	3			3
2014t	I241	Nordnes	60.40067	5.30167	MYTI EDU	SB	2		1	2		1				1	1	1		
2015p	I241	Nordnes	60.40067	5.30167	MYTI EDU	SB	3		3	3		3				3	3	3		
2015t	I241	Nordnes	60.40067	5.30167	MYTI EDU	SB	3		3	3		3				3	3	3		
2014t	26A2	Måløy	61.94050	5.12300	MYTI EDU	SB	3		3	3		3				3	3	3		3
2015p	26A2	Måløy	61.94050	5.12300	MYTI EDU	SB	3		3	3		3				3	3	3		3
2015t	26A2	Måløy	61.94050	5.12300	MYTI EDU	SB	3		3	3		3				3	3	3		3
2014t	91A2	Ørland	63.68750	9.66783	MYTI EDU	SB	3		3	3		3				3	3	3		3
2015p	91A2	Ørland	63.68750	9.66783	MYTI EDU	SB	3		3	3		3				3	3	3		3
2015t	91A2	Ørland	63.68750	9.66783	MYTI EDU	SB	3		3	3		3				3	3	3		3
2014t	I965	Moholmen	66.31200	14.12583	MYTI EDU	SB	3								3					3
2015p	I965	Moholmen	66.31200	14.12583	MYTI EDU	SB	3								3					
2015t	I965	Moholmen	66.31200	14.12583	MYTI EDU	SB	3								3					
2014t	I969	Bjørnbærviken	66.27983	14.03550	MYTI EDU	SB	3								3					3

myear	station	STATION NAME	LATITUDE	LONGITUDE	specie	tissue	I-MET	O-MET	O-BR	OC-CB	OC-CL	OC-CP	OC-DD	O-FL	O-PAH	PFR	PHC	O-PHE	BE	ISOTO
2015p	I969	Bjørnbærviken	66.27983	14.03550	MYTI EDU	SB	3								3					
2015t	I969	Bjørnbærviken	66.27983	14.03550	MYTI EDU	SB	3								3					
2014t	97A2	Bodø harbour	67.29500	14.38800	MYTI EDU	SB	3		3	3		3				3	3	3		3
2015p	97A2	Bodø harbour	67.29500	14.38800	MYTI EDU	SB	3		3	3		3				3	3	3		3
2015t	97A2	Bodø harbour	67.29500	14.38800	MYTI EDU	SB	3		3	3		3				3	3	3		3
2014t	98A2	Husvaagen	68.25767	14.66383	MYTI EDU	SB	3		3	3		3			3	3	3	3		
2015p	98A2	Husvaagen	68.25767	14.66383	MYTI EDU	SB	3		3	3		3			3	3	3	3		3
2015t	98A2	Husvaagen	68.25767	14.66383	MYTI EDU	SB	3		3	3		3			3	3	3	3		3
2014t	10A2	Skallneset (Varangerfjord)	70.20833	30.35833	MYTI EDU	SB	3			3	3		3							
2015p	10A2	Skallneset (Varangerfjord)	70.20833	30.35833	MYTI EDU	SB	3			3	3		3							
2015t	10A2	Skallneset (Varangerfjord)	70.20833	30.35833	MYTI EDU	SB	3			3	3		3							
2014t	11X	Brashavn (Varangerfjord)	69.89867	29.74417	MYTI EDU	SB	3			3	3		3							
2015p	11X	Brashavn (Varangerfjord)	69.89867	29.74417	MYTI EDU	SB	3			3	3		3							3
2015t	11X	Brashavn (Varangerfjord)	69.89867	29.74417	MYTI EDU	SB	3			3	3		3							3
2014t	36G	Færder	59.02717	10.52550	NUCE LAP	SB		1											1	
2015p	36G	Færder	59.02717	10.52550	NUCE LAP	SB		1											1	
2015t	36G	Færder	59.02717	10.52550	NUCE LAP	SB		1											1	
2014t	76G	Risøy	58.72800	9.27600	NUCE LAP	SB		1											1	
2015p	76G	Risøy	58.72800	9.27600	NUCE LAP	SB		1											1	
2015t	76G	Risøy	58.72800	9.27600	NUCE LAP	SB		1											1	
2014t	131G	Lastad	58.05550	7.70867	NUCE LAP	SB		1											1	
2015p	131G	Lastad	58.05550	7.70867	NUCE LAP	SB		1											1	
2015t	131G	Lastad	58.05550	7.70867	NUCE LAP	SB		1											1	
2014t	15G	Gåsøy (Ullerø)	58.05167	6.72167	NUCE LAP	SB		1											1	
2015p	15G	Gåsøy (Ullerø)	58.05167	6.72167	NUCE LAP	SB		1											1	
2015t	15G	Gåsøy (Ullerø)	58.05167	6.72167	NUCE LAP	SB		1											1	
2014t	227G1	Melandholmen	59.33350	5.31500	NUCE LAP	SB		1											1	
2015p	227G1	Melandholmen	59.33350	5.31500	NUCE LAP	SB		1											1	
2015t	227G1	Melandholmen	59.33350	5.31500	NUCE LAP	SB		1											1	
2014t	22G	Espevær (West Coast)	59.57917	5.14833	NUCE LAP	SB		1											1	
2015p	22G	Espevær (West Coast)	59.57917	5.14833	NUCE LAP	SB		1											1	
2015t	22G	Espevær (West Coast)	59.57917	5.14833	NUCE LAP	SB		1											1	
2014t	98G	Svolvær area	68.25667	14.67667	NUCE LAP	SB		1								1	1		1	
2015p	98G	Svolvær area	68.25667	14.67667	NUCE LAP	SB		1								1	1		1	
2015t	98G	Svolvær area	68.25667	14.67667	NUCE LAP	SB		1								1	1		1	
2014t	11G	Brashavn	69.89867	29.74417	NUCE LAP	SB		1								1	1		1	
2015p	11G	Brashavn	69.89867	29.74417	NUCE LAP	SB		1								1	1		1	
2015t	11G	Brashavn	69.89867	29.74417	NUCE LAP	SB		1								1	1		1	

Appendix F
Temporal trend analyses of contaminants and biomarkers in biota 1981-2015

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

Only information for those time series that include data for either 2014 or 2015 is shown. The column headings are as follows:

Parameter Code: are described in **Appendix B**
IUPAC: Internation Union of Pure and Applied Chemistry (IUPAC) parameter name (if any).
CAS: Chemical Abstracts Services (CAS) parameter number (if any).
Parameter Name: Common name
Parameter Group: Parameters belong to one of 14 groups
Unit: µg/kg, mg/kg, ng/kg, etc.
Station Code
Station Name
Area: general area (if defined).
County
Water region: Water framework directive (WFD) water region
Water body ID: WFD water body identification
Water body name: WFD water body name

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

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

Basis: wet weight (**W**), dry weight (**D**) or lipid weight (**L**).
[Year columns]: median value for years 1981-2015.
Sample count [year]: 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.
SD [year]: standard deviation.
Class [year]: Norwegian Environment Agency classification (**1**, **2**, **3**, **4** or **5,** corresponding to the agency's Classes I, II, III, IV or V, repsectively) or below (**6**) or above (**7**) presumed "high background" concentration (see Appendix C).
EAC [year]: below (**<EAC**) or above (**>EAC**) OSPARs Environmental Assessment Criteria (EAC).
EQS [year]: below (UQ) or above (OQ) EU's Environmental Quality Standard (EQS). Note: the EU EQRs are based on the whole organism whereas monitoring of fish in MILKYS is on a particular tissue. Hence, comparison is only relevant if it is assumed that the concentration found is the same for all tissues in the fish.

OC: Overconcentration expressed as quotient of median of last year and upper limit to the agency's Class I or presumed "high background" ("m" missing background value).
Trend p(long)[year]: The statistical significance (p)[year] of the trend for the entire time series.
Detectable % change(long)[year]: the percent change that can be detected with 90 % confidence.
First Year(long)[year]: first year in time series.
Last Year(long)[year]: last year in time series.
Number of Years(long)[year]: number of years with data.

Trend p(short)[year]: The statistical significance (p)[year] of the trend for the last 10-year sampling period.
Detectable % change(short)[year]: the percent change that can be detected with 90 % confidence.
First Year(short)[year]: first year in time series for the last 10-year sampling period.
Last Year(short)[year]: last year in time series for the last 10-year sampling period.
Number of Years(short)[year]: number of years with data in time series for the last 10-year sampling period.

Trends [year]: 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 C). For biota, trend analyses were done on time series with five or more years. An upward (🡅) or downward (🡇) arrow indicates statistically significant trends, whereas a zero (O) indicates no trend. A small filled square (▪) indicates that chemical analysis was performed, but either the results were insufficient to do a trend analysis. Results marked with a star (★) indicate that there is insufficient data above the quantification limit to perform a trend analysis. The result from the trend analysis for the entire time series (long-term) is shown before the slash "/", and the result for the last 10 years (short-term) is shown after the slash. 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. Note: the Trend for the previous year are based on time series where the last year has been excluded.

TREND_CHANGE_[year]-[year]: indicates the difference (if any) between the year-before-last results and the last year's results.
CLASS_CHANGE_[year]-[year]: indicates the difference (if any) between the year-before-last results and the last year's results.
EQS_CHANGE_[year]-[year]: indicates the difference (if any) between the year-before-last results and the last year's results.
EAC_CHANGE_[year]-[year]: indicates the difference (if any) between the year-before-last results and the last year's results.

Note on quantification limit in trend analyses: half of the limit is used, however if a substance is included as part of a sum (e.g. PCB-7) then null is used. Note, that the number of such cases and position in a times series may affect whether or not a trend analyses can be applied (see Chapter 2.7).

Appendix G
Passive sampling result-tables

The table below (***Table 32***) 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 32*. 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 is working for a clean and diverse environment. Our primary tasks are to reduce greenhouse gas emissions, manage Norwegian nature, and prevent pollution.

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We implement and give advice on the development of climate and environmental policy. We are professionally independent. This means that we act independently in the individual cases that we decide and when we communicate knowledge and information or give advice.

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