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# Priority substances and emerging contaminants in selected Norwegian rivers

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**Project manager for the contractor**

Hans Fredrik Veiteberg Braaten

**Contact person in the Norwegian Environment Agency**

Eivind Farmen

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**Author(s)**

Ian Allan, Marthe Torunn Solhaug Jenssen, Hans Fredrik Veiteberg Braaten

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**Summary - sammendrag**

Riverine inputs and direct discharges to Norwegian coastal waters in 2017 have been estimated in accordance with the OSPAR Commission's principles. This report focuses on EU Water Framework Directive priority substances as well as river basin-specific pollutants (trace metals and organic pollutants) that were monitored with bottle sampling in water and biota sampling (fish). Levels observed were compared with annual average environmental quality standards (AA-EQS) or EQS(biota). A more detailed study of the distribution of emerging contaminants in the river Alna was undertaken.

Elvetilførsler og direkte tilførsler til norske kystområder har blitt estimert for 2017 i henhold til Norges obligasjoner under OSPAR-konvensjonen. Denne rapporten fokuserer på Vannrammedirektivets prioriterte forbindelser i tillegg til nedbørfeltspesifikke stoffer (spormetaller og organiske forbindelser) som ble analysert i vann- og biotaprøver (fisk). Observerte konsentrasjonsnivåer ble sammenlignet med grenseverdier for årlig gjennomsnitt (AA-EQS) og for biota (EQS(biota)). En mer detaljert analyse av nye miljøgifter ble gjennomført i Alna.

**4 emneord**

Water Framework Directive; Priority substances; Emerging contaminants; River monitoring

**4 subject words**

Vannrammedirektivet; proriterte stoffer; nye miljøgifter; elveovervåking

**Front page photo**

Alna river. Photo: Marthe T. S. Jenssen

# Content

Preface ..... 5
Summary ..... 6
Sammendrag ..... 7
1. Introduction ..... 10
1.1 EU WFD priority substances ..... 10
1.2 Emerging contaminants ..... 12
1.3 Project aims ..... 13
2. Materials and methods ..... 14
2.1 Sampling methodologies ..... 14
2.1.1 Sampling for priority substances in five rivers ..... 14
2.1.2 Suspended particulate matter sampling for emerging contaminants ..... 16
2.1.3 Time-proportional water sampling for emerging contaminants ..... 17
2.1.4 Sampling of fish for priority contaminants in five rivers ..... 17
2.1.5 Biota sampling for emerging contaminants in River Alna ..... 20
2.2 Chemical analysis and quality assurance ..... 23
2.2.1 Priority substances in water and fish samples ..... 23
2.2.2 Emerging contaminants in water, SPM and biota from Alna ..... 25
2.2.3 Stable Isotopes ..... 25
2.3 Calculation procedures ..... 26
3. Results and discussion ..... 27
3.1 EU WFD Priority substances and other relevant chemicals in water of five rivers ..... 27
3.1.1 Polycyclic Aromatic Hydrocarbons (PAHs) ..... 27
3.1.2 Organochlorinated compounds (PCBs and pesticides) ..... 29
3.1.3 Polybrominated diphenyl ethers (PBDEs) ..... 29
3.1.4 Hexabromocyclododecane (HBCDD) ..... 30
3.1.5 Short and medium chain chlorinated paraffins (S/MCCPs) ..... 31
3.1.6 Alkylphenols ..... 31
3.1.7 Others ..... 31
3.1.8 Metals ..... 32
3.1.9 Yearly discharge of selected chemicals for the Alna, Drammenselva, Glomma, Numedalslågen and Skienselva for 2017 ..... 34
3.2 EU WFD Priority substances and other relevant chemicals in fish from 5 rivers ..... 34
3.3 Emerging contaminants in River Alna ..... 37
3.3.1 Stable isotopes ..... 37

3.3.2 UV filters in River Alna ..... 38
3.3.3 Organophosphorus compounds in the River Alna ..... 40
3.3.4 Bisphenols in River Alna ..... 43
3.3.5 PFAS in River Alna ..... 46
4. Conclusions ..... 52
5. References ..... 55

**Attachments:**

1. *Details of the fish samples collected from the Rivers Alna, Stryneelva, Stjørdalselva, Eidselva, Reisa and Snarumselva in 2017*
2. *Yearly discharges of chemicals from the Rivers Alna, Drammenselva, Glomma, Numedalslågen and Skienselva for 2017*

# Preface

The Norwegian Environment Agency (NEA) has commissioned the Norwegian Institute for Water Research (NIVA), in collaboration with consortium partners, to carry out the monitoring activities within the Norwegian River Monitoring Programme. Results from the 2017 monitoring activities are presented in three thematic reports, of which this report presents the "contaminants" results, consisting of data on the Water Framework Directive (WFD) priority substances and emerging contaminants from a selection of rivers.

Besides NIVA, the "contaminants" part of the River Monitoring Programme has involved the following collaborating partners: The Norwegian Water Resources and Energy Directorate (NVE), the Norwegian Institute for Air Research (NILU), the Norwegian Institute for Nature Research (NINA), and the Institute for Energy Technology (IFE). Contact persons at NEA has been Eivind Farmen and Malene Vågen Dimmen.

At NIVA, Øyvind Kaste and Hans Fredrik Veiteberg Braaten co-ordinated the river monitoring programme in 2017. Other co-workers at NIVA include Ian Allan (main author of this report, interpretation of data), Marthe Torunn Solhaug Jenssen (coordination and participation to field work, coordination of sample analysis), Kine Bæk (responsible for organic analyses, and main contact with NILU for the analyses undertaken there), and Marit Villø (contact person at NIVA's laboratory for inorganic samples).

NVE has been responsible for the hydrological modelling, Eurofins has carried out the mercury analyses, NILU has analysed selected priority substances and emerging contaminants, and IFE has determined stable isotopes in biota. NINA has been responsible for collection of fish, while all other sampling has been conducted by Marthe Torunn Solhaug Jenssen.

Quality assurance of the report has been carried out by Sondre Meland, NIVA.

Oslo, Nov. 11th 2018
Hans Fredrik Veiteberg Braaten

# Summary

The monitoring of rivers as part of the Norwegian River Monitoring Programme (RMP) is conducted on a yearly basis and is partly focused on the estimation of contaminant loads to the sea in response to Norway's obligations in the Oslo-Paris Convention. For the period 2013-2016, the focus was on the measurement of contaminant levels and loads in three rivers, namely the Alna, Drammenselva and Glomma. For 2017, the programme was modified to increase the number of rivers that are monitored from three to ten (Alna, Drammenselva, Glomma, Numedalslågen, Skienselva, Stryneelva, Stjørdalselva, Eidselva, Reisa and Snarumselva) and to increase the relevance of the programme's results to fulfil monitoring objectives of the EU Water Framework Directive (WFD) through an increase in the range of contaminants that are analysed for (increased focus on WFD priority substances), and change in the matrices selected for analysis.

For five rivers, the monitoring of priority substances and river basin specific substances was performed by bottle sampling with a sampling frequency of 4 times per year. One sampling location per river (usually the RMP monitoring sites) was used and results were compared with EU WFD annual average environmental quality standards (AA-EQS). For priority organic substances the water EQS given in EU directives are expressed as total concentrations in the "whole water" sample to separate from the dissolved concentrations of the metals Pb, Ni, Hg and Cd that refer to filtered water samples. A further five rivers were monitored by analysing WFD priority substances and other substances (lipophilic ones) in composite fish samples obtained from three sampling locations per river.

A second component of this RMP was a more detailed investigation of the distribution of relatively more emerging substances in the River Alna. This work focused on selected UV filters, organophosphorus compounds (OPs), bisphenols and Perfluoro chemicals (PFAS). Since these compounds vary widely in their physico-chemical properties, a range of sampling methodologies were employed for this task and included composite water sampling, suspended particulate matter sampling, sampling of lower trophic level organisms (benthic macroinvertebrates and periphyton) and brown trout (*Salmo trutta*). Sampling was undertaken on two occasions, in May and September 2017.

The levels of priority substances in water were below EQS for most riverine sampling locations. Bottle sampling resulted in much data below limits of quantification, i.e. left-censored data. In most cases LOQs fulfilled WFD method performance criteria. Bottle sampling in the rivers Alna, Drammenselva, Glomma, Numedalslågen and Skienselva showed that concentrations of PAHs were the highest (closest to or above WFD AA-EQS) for the sampling site of the River Alna. Whole water concentrations of benzo[a]pyrene was close to AA-EQS at selected monitoring locations for all rivers. The $\Sigma_7$PCBs was below LOQ for all rivers, however this sum of LOQs is significantly higher than the proposed AA-EQS of 0.0024 ng $L^{-1}$. PBDEs were only detected in water samples from the Alna, but remained a factor of five below AA-EQS. The sum of isomers of HBCDD was above AA-EQS for water samples from the Alna. Mean concentrations of MCCPs and 4-tert-octylphenol were at or above AA-EQS level for the monitoring site on the river Alna. For the remaining rivers, all data for S/MCCPs, alkylphenols, chlorfenvinphos, cybutryne and DEHP from other rivers were below LOQ. Filtered metal concentrations were below AA-EQS for all rivers except for the River Alna, where estimated concentrations of As, Cu, Cr and Zn were close to or above EQS, and substantially higher and more variable than for the samples from the other rivers. Estimated fluxes of $\Sigma_{16}$PAHs are in reasonable agreement with previous data

from passive sampling and SPM sampling. Because of the high proportion data of <LOQ, considerable uncertainty is associated with yearly discharge estimates of most contaminants from these rivers.

Fish monitoring of Stryneelva, Stjørdalselva, Eidselva, Reisa and Snarumselva in 2017 showed that $\Sigma_7$PCBs and PBDEs are close to or above $EQS_{biota}$ in all samples. This agrees with the results from the reference river monitoring programme that showed concentrations of these substances above EQS in fish samples[1]. Levels of other priority substances in fish samples from these five rivers were well below respective $EQS_{biota}$. The assessment of the level of 4-tert-octylphenol in fish was not possible as a result of LOQs that were higher than the $EQS_{biota}$.

UV filters were most consistently found in suspended particulate matter samples. Biota monitoring showed variable results for UV filters. UV-327 and UV-328 were most consistently found across all matrices. As for the UV filter, SPM appeared generally more promising for sampling of organophosphorus compounds in the River Alna than composite water sampling. Organophosphorus compounds consistently detected in water and SPM were TEP, TiBP, TnBP, and TBEP. TCEP, TCPP, sum TCP and TEHP were consistently detected in SPM. Data from the analysis of lower trophic level organisms (benthic macroinvertebrates and periphyton) showed a similar pattern of contamination with consistent detection of TCPP, TiBP, DBPhP, TnBP, TDCPP, and TBEP. TCPP, TnBP, sumTCP, and EHDP were consistently detected in all fish samples analysed. TEP was only detected in muscle samples. Notably, while TPP was not detected in other samples, it was consistently found in fish samples. In general, many of the bisphenols were detected in SPM (4,4', BPA, 4,4'-BPS, 2,2'-BPF, 2,4'-BPF, and 4,4'-BPF). BPA (4,4'-BPA) was found in all lower trophic level samples. Other bisphenols such as 4,4'-BPS, 2,4'BPF, and 4,4'-BPF were also found in higher amounts than other bisphenols in these lower trophic level samples. With regards the fish sample analyses, bisphenols could only be found in muscle samples and at concentrations similar on a wet weight basis to those measured in lower trophic level organisms. PFOS, PFOA, 6:2 FTS, PFBS, PFPS, PFHxS, PFPA, PFHxA, PFHpA, PFNA and PFDA were found in composite water samples from the Alna while only PFOS was measured above LOQ in SPM. The detection of PFAS compounds in periphyton and benthic macroinvertebrates was relatively erratic. Only PFDoA and PFOS were consistently found in these samples. A higher number of PFAS compounds were found in liver samples than in whole fish. On a wet weight basis, PFAS concentrations were consistently higher in liver samples. PFDA, PFDoA, PFTrDA, PFTeDA, PFOS, PFDS and PFOSA were measured above LOQ in all fish samples. PFOS showed the highest concentrations of all PFAS compound monitored. In general, composite sampling with the automated/autonomous sampler as undertaken here is not ideal for the monitoring of emerging contaminants because of blank and contamination issues.

# Sammendrag

Overvåking av norske elver gjennomføres årlig som en del av *Elveovervåkingsprogrammet* og fokuserer blant annet på estimering av tilførsler av miljøgifter til norske havområder som en del av Norges obligasjoner under Oslo-Paris konvensjonen. For perioden 2013-2016 ble konsentrasjoner og tilførsler av miljøgifter målt og beregnet i tre elver, Alna, Drammenselva

[1] http://www.miljodirektoratet.no/Documents/publikasjoner/M1002/M1002.pdf

og Glomma. I 2017 ble omfanget endret fra tre til ti elver, i tillegg til et økt fokus på at resultater skal innfri målsetningene for overvåking i EUs Vannrammedirektiv. Dette inkluderer blant annet at det analyseres et økt antall miljøgifter (økt fokus på Vannrammedirektivets prioriterte stoffer).

For overvåking av prioriterte stoffer og andre utvalgte forbindelser ble vannprøver samlet inn fra fem av elvene (Alna, Drammenselva, Glomma, Numedalslågen og Skienselva) fire ganger per år ved hver prøvestasjon (vanligvis stasjonen som benyttet i Elveovervåkingsprogrammets «grunnprogram»). Prøvene ble sammenlignet med vannforskriftens grenseverdi for årlig gjennomsnitt (AA-EQS). Ytterligere fem elver ble overvåket ved å analysere prioriterte stoffer og andre forbindelser (lipofile forbindelser) i blandprøver av fisk fra tre ulike stasjoner i hver elv (Stryneelva, Eidselva, Reisa og Snarumselva).

En tilleggskomponent ved denne delen av Elveovervåkingsprogrammet var en mer detaljert analyse av utvalgte nye miljøgifter i Alna. Arbeidet i Alna fokuserte på bestemmelse av UV-stoffer, organofosfater, bisfenoler og perfluorerte forbindelser (PFAS). Ettersom disse forbindelsene varierer i sine respektive fysisk-kjemiske egenskaper, ble en rekke forskjellige prøvetakingsmetoder benyttet. Innsamlede prøver inkluderte blandprøver av vann, suspendert partikulært materiale (SPM), biologisk materiale som representerer lavere trofiske nivåer (bunndyr, elvemose og begroingsalger) og fisk (ørret, *Salmo trutta*). Prøveinnsamling ble gjennomført ved to anledninger, i mai og september 2017.

Konsentrasjonene av de prioriterte stoffer var lavere en vanndirektivets miljøkvalitetsstandarder (EQSer) for de fleste av prøvelokalitetene. Mange av de aktuelle forbindelsene ble bestemt i stikkprøver av vann, og på grunn av lave nivåer har store deler av datamaterialet konsentrasjoner under gjeldende analytiske kvantifiseringsgrenser (LOQ). I de fleste tilfeller innfridde LOQ vannforskriftens ytelseskriterier. I vannprøver fra Alna, Drammenselva, Glomma, Numedalslågen og Skienselva ble det målt konsentrasjoner av polysykliske aromatiske hydrokarboner (PAH) i nærheten av eller over Vannrammedirektivets AA-EQS bare i Alna. Konsentrasjoner av benzo[a]pyren var i nærheten av AA-EQS i alle de fem elvene. Summen av syv polyklorerte bifenyler ($\Sigma_7$PCB) var under LOQ for alle elvene, men det bemerkes at LOQ er signifikant høyere enn den foreslåtte AA-EQS (0.0024 ng $L^{-1}$). Polybrominerte difenyletere (PBDE) ble bare detektert i vannprøver fra Alna, men var også der en faktor fem lavere enn AA-EQS. Summen av isomerer av heksabromocyklododekan (HBCDD) var over AA-EQS for Alna. Gjennomsnittlig konsentrasjoner av mellomkjedete klorerte parafiner (MCCP) og 4-tert-oktylfenol var på nivå med AA-EQS eller over for målestasjonen i Alna. For de fire andre elvene var alle konsentrasjoner av kort- (SCCP) og MCCP, alkylfenoler, klorfenvinfos, cybutryne og ftalater (DEHP) under LOQ. Konsentrasjonen av filtrerte metaller var lavere enn AA-EQS for alle elvene bortsett fra i Alna. I Alna var de estimerte konsentrasjonene av As, Cu. Cr og Zn nære eller over EQS og betydelig mye høyere og mer variable enn i de andre elvene. Nivåer av estimerte tilførsler av $\Sigma_{16}$PAH kan sammenlignes med tidligere data innsamlet ved bruk av passive prøvetakere og SPM. På grunn av den store mengden data med konsentrasjoner under LOQ er det store usikkerheter knyttet til estimerte beregninger av årlige tilførsler av de fleste miljøgiftene fra disse fem elvene.

I fiskeprøver fra Stryneelva, Stjørdalselva, Eidselva, Reisa og Snarumselva var konsentrasjonene av $\Sigma_7$PCB og PBDE i nærheten av eller over $EQS_{biota}$ for alle elvene. Dette samsvarer med resultater fra overvåkningen av referanseelver som viste konsentrasjoner over $EQS_{biota}$ av disse stoffene i fiskeprøver. Konsentrasjoner av andre prioriterte stoffer i fiskeprøvene fra disse elvene var godt under gjeldende $EQS_{biota}$. Vurdering av nivåene av *4-tert-oktylfenol i fisk var ikke mulig da LOQ var høyere enn* $EQS_{biota}$.

UV-stoffene ble oftest kvantifisert i prøver av SPM, mens overvåking av disse stoffene i biota viste mer varierende resultater. UV-327 og UV-328 ble oftest kvantifisert uavhengig av prøvematriks. Som for UV-stoffene var også organofosfatene lettere å detektere i prøver av SPM enn i blandprøver av vann fra Alna. Organofosfater som ble kvantifisert i prøver av vann og SPM inkluderer TEP, TiBP, TnBP og TBEP. TCEP, TCPP, summen av TCP og TEHP ble gjennomgående detektert i SPM. Et tilsvarende kontamineringsmønster ble dokumentert for prøvene av biologisk materiale på lavere trofiske nivåer (bentiske organismer, elvemose og begroingsalger). TCPP, TnBP, summen av TCP og EHDP ble gjennomgående detektert i alle fiskeprøvene som ble analysert. TEP ble kun detektert i prøver av muskel. Interessant nok ble TPP ikke kvantifisert i andre prøvematrikser enn fisk.

Mange av bisfenolene ble detektert i SPM, inkludert 4,4', BPA, 4,4'-BPS, 2,2'-BPF, 2,4'-BPF, og 4,4'-BPF. BPA (4,4', BPA) ble kvantifisert i alle prøver av biota på lavere trofiske nivåer. Konsentrasjoner av bisfenolene 4,4'-BPS, 2,4'BPF og 4,4'-BPF, var høyere enn for andre bisfenoler i disse prøvene. For fiskeprøvene ble bisfenolene kun detektert i muskelprøver og ved konsentrasjoner på våtvekt-basis tilsvarende det som ble funnet lavere i næringskjeden. PFOS, PFOA, 6:2 FTS, PFBS, PFPS, PFHxS, PFPA, PFHxA, PFHpA, PFNA og PFDA ble alle kvantifisert i blandprøver av vann fra Alna, mens bare PFOS ble målt over LOQ i prøver av SPM. Konsentrasjoner av PFAS i bentiske invertebrater, elvemose og begroingsalger var svært varierende, og kun PFDoA og PFOS ble gjennomgående detektert i disse prøvene. Et høyere antall PFAS-forbindelser ble detektert i prøver av lever sammenlignet med hel fisk, og på våtvekt-basis var PFAS-konsentrasjoner høyere i lever. PFDA, PFDoA, PFTrDA, PFTeDA, PFOS, PFDS og PFOSA ble målt til nivåer over LOQ i alle fiskeprøver, og de høyeste konsentrasjonene ble funnet av PFOS. Biokonsentrasjonsfaktorer i ørret var mulig å beregne for fire PFAS-forbindelser. Erfaringer fra 2017 viser at innsamling av blandprøver av vann ved bruk av en automatisk vannprøvetaker ikke er ideelt for overvåking av nye miljøgifter på grunn av utfordringer ved høye blanknivåer og mulig prøvekontaminering.

# 1. Introduction

The Norwegian River Monitoring Programme (RMP) monitors the contaminant loads from Norway to the sea as part of Norway's obligations in the Oslo-Paris Commission (OSPAR). OSPAR's main aim is to protect the marine environment of the North East Atlantic[2]. Reporting of the EU Water Framework Directive (WFD) priority substances and emerging contaminants is part of this monitoring.

A total of 20 rivers was monitored in Norway as part of the RMP in 2017 (Table 1), where five of these were prioritised for the determination of WFD priority substances (PS), river basin-specific pollutants and emerging contaminants. Additionally, five rivers were sampled for fish, including Snarumselva, Eidselva, Stryneelva, Stjørdalselva, and Reiselva, where priority substances were analysed.

**Table 1. Parameters investigated in the Norwegian River Monitoring Programme 2017**

**A summary table of groups of parameters investigated in the Norwegian River Monitoring Program (RMP). Rivers Glomma, Alna, Drammenselva, Numedalslågen, and Skienselva where investigated for EU Water Framework Directive (WFD) priority substances and emerging contaminants in 2017.**

| River | Group of parameters estimated (n=yearly sampling events) | | | |
|---|---|---|---|---|
| | General water chemistry* | Metals** | WFD priority substances* | Emerging contaminants |
| **Glomma** | n = 16 | n = 4 | n = 4 | n = 4 |
| **Alna** | n = 12 | n = 4 | n = 4 | n = 4 |
| **Drammenselva** | n = 16 | n = 4 | n = 4 | n = 4 |
| **Numedalslågen** | n = 12 | n = 4 | n = 4 | n = 4 |
| **Skienselva** | n = 12 | n = 4 | n = 4 | n = 4 |

* Includes pH, dissolved, total and particulate organic carbon, fractions of nutrients P and N, silicate. ** Includes arsenic (As), lead (Pb), cadmium (Cd), chromium (Cr), copper (Cu), mercury (Hg), nickel (Ni) and zinc (Zn).

## 1.1 EU WFD priority substances

*Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy* (hereafter the Water Framework Directive, WFD), was integrated in Norwegian legislation by the "Vannforskriften"[3] in 2007, revised in 2010. Miljødirektoratet has since worked on the application of the WFD in Norway through the development of EQS[4,5] at national-level and

[2] https://www.ospar.org/about

[3] https://lovdata.no/dokument/SF/forskrift/2006-12-15-1446

[4] http://www.miljodirektoratet.no/Documents/publikasjoner/M608/M608.pdf

[5] https://www.miljodirektoratet.no/Documents/publikasjoner/M241/M241.pdf

guidelines for monitoring[6]. The framework aims to protect and restore clean waters across Europe and ensure its long-term, sustainable use, including river basins[7]. The WFD is an environmental management tool, used to determine the overall quality of a water body depending on ecological and/or chemical status. The WFD includes a list of substances that are considered "problematic" for European waters, the so-called priority substances[8]. Environmental Quality Standards (EQSs) are used to assess the chemical status of water bodies using maximum acceptable concentration (MAC) and/or annual average concentration (AA) for the priority substances. Depending on whether the MAC and/or AA are met or not, the chemical status of the water body is described as "good" or "not good"[9].

Currently, the list of priority substances consists of 33 compounds for which EQSs have been derived[10] (Table 2).

**Table 2. List of Water Framework priority substances (including CAS numbers and AA-EQS and MAC-EQS)**

| Number | CAS number | Name of priority substance | MAC (µg $L^{-1}$) | AA (µg $L^{-1}$) |
|---|---|---|---|---|
| 1 | 15972-60-8 | Alachlor | 0.7 | 0.3 |
| 2 | 120-12-7 | Anthracene | 0.4 | 0.1 |
| 3 | 1912-24-9 | Atrazine | 2.0 | 0.6 |
| 4 | 71-43-2 | Benzene | 50 | 10 |
| 5 | not applicable | Brominated diphenylether | | |
| | 32534-81-9 | Pentabromodiphenylether (congener numbers 28, 47, 99, 100, 153 and 154) | n.a. | 0.0005 |
| 6 | 7440-43-9 | Cadmium and its compounds | < 0.45 (class 1)<br>0.45 (class 2)<br>0.6 (class 3)<br>0.9 (class 4)<br>1.5 (class 5) | < 0.08 (class 1)<br>0.08 (class 2)<br>0.09 (class 3)<br>0.15 (class 4)<br>0.25 (class 5) |
| 7 | 85535-84-8 | Chloroalkanes, $C_{10}$-$C_{13}$ | 1.4 | 0.4 |
| 8 | 470-90-6 | Chlorfenvinphos | 0.3 | 0.1 |
| 9 | 2921-88-2 | Chlorpyrifos | 0.1 | 0.03 |
| 10 | 107-06-2 | 1,2-Dichloroethane | n.a. | 10 |
| 11 | 75-09-2 | Dichloromethane | n.a. | 20 |
| 12 | 117-81-7 | Di(2-ethylhexyl)phthalate (DEHP) | n.a. | 1.3 |
| 13 | 330-54-1 | Diuron | 1.8 | 0.2 |
| 14 | 115-29-7 | Endosulfan | 0.01 | 0.005 |
| 15 | 206-44-0 | Fluoranthene | 1 | 0.1 |
| 16 | 118-74-1 | Hexachlorobenzene | 0.05 | 0.01 |
| 17 | 87-68-3 | Hexachlorobutadiene | 0.6 | 0.1 |

[6] http://www.miljodirektoratet.no/Documents/publikasjoner/M922/M922.pdf

[7] http://ec.europa.eu/environment/water/participation/pdf/waternotes/water_note1_joining_forces.pdf

[8] http://ec.europa.eu/environment/water/water-dangersub/pri_substances.htm#list

[9] https://circabc.europa.eu/sd/a/0cc3581b-5f65-4b6f-91c6-433a1e947838/TGD-EQS%20CIS-WFD%2027%20EC%202011.pdf

[10] http://ec.europa.eu/environment/water/water-framework/priority_substances.htm

**Table 2. List of Water Framework priority substances (including CAS numbers and AA-EQS and MAC-EQS)**

| Number | CAS number | Name of priority substance | MAC (µg $L^{-1}$) | AA (µg $L^{-1}$) |
|---|---|---|---|---|
| **18** | 608-73-1 | Hexachlorocyclohexane | 0.04 | 0.2 |
| **19** | 34123-59-6 | Isoproturon | 1.0 | 0.3 |
| **20** | 7439-92-1 | Lead and its compounds | n.a. | 7.2 |
| **21** | 7439-97-6 | Mercury and its compounds | 0.07 | 0.05 |
| **22** | 91-20-3 | Naphthalene | n.a. | 2.4 |
| **23** | 7440-02-0 | Nickel and its compounds | n.a. | 20 |
| **24** | 25154-52-3 | Nonylphenols | 2.0 | 0.3 |
| | 104-40-5 | (4-nonylphenol) | n.a. | 0.1 |
| **25** | 1806-26-4 | Octylphenols | n.a. | 0.007 |
| | 140-66-9 | (4-(1,1',3,3'-tetramethylbutyl)-phenol) | 1 | 0.4 |
| **26** | 608-93-5 | Pentachlorobenzene | n.a. | n.a. |
| **27** | 87-86-5 | Pentachlorophenol | 0.1 | 0.05 |
| **28** | not applicable | Polycyclic aromatic hydrocarbons | n.a. | $\Sigma$ = 0.03 |
| | 50-32-8 | (Benzo(a)pyrene) | n.a. | |
| | 205-99-2 | (Benzo(b)fluoranthene) | n.a. | $\Sigma$ = 0.002 |
| | 191-24-2 | (Benzo(g,h,i)perylene) | n.a. | |
| | 207-08-9 | (Benzo(k)fluoranthene) | 4 | 1 |
| | 193-39-5 | (Indeno(1,2,3-cd)pyrene) | 0.0015 | 0.0002 |
| **29** | 122-34-9 | Simazine | n.a. | 0.4 |
| **30** | not applicable | Tributyltin compounds | n.a. | 2.5 |
| | 36643-28-4 | (Tributyltin-cation) | n.a. | 0.03 |
| **31** | 12002-48-1 | Trichlorobenzenes | 1.4 | 0.4 |
| **32** | 67-66-3 | Trichloromethane (chloroform) | 0.3 | 0.1 |
| **33** | 1582-09-8 | Trifluralin | 0.1 | 0.03 |

## 1.2 Emerging contaminants

Human development and anthropogenic processes result in the emission of a wide range of chemicals to the natural environment. While the European Water Framework Directive focuses initially on a restricted list of priority (hazardous) substances and river basin-specific substances, emerging contaminants are defined as chemicals that are not currently regulated but can impact on human or ecological health (Richardson, 2009). These substances can be found in aquatic environments all over the world, including freshwaters and the marine environment (Loos et al., 2009; Schwarzenbach et al., 2010; Schwarzenbach et al., 2006). Examples of emerging contaminants include industrial chemicals, plastic additives, disinfection

by-products, pharmaceutical and personal care products and their degradation products or persistent organic chemicals. In this report we specifically focus on substances identified in the past in the Norwegian environment through the screening programme[11]:

- **Bisphenols:** Bisphenols are commonly used in production of plastics and paint, and in Norway occurring typically in important products of plastic. Data on releases of bisphenols to the Norwegian environment is very limited, only reported for bisphenol A. Estimations suggest that the use of bisphenol A in chemicals are reduced from approximately 60 tons in 2000 to 11 tons in 2015.
- **UV-filters:** UV-filters are typically used to stabilise paint, rubber, and plastics to protect the material against sunlight. The substances are found several places in the Norwegian environment, including water (Atlantic cod liver (*Gadus morhua*)) of the Oslo fjord, sediments in Lake Mjøsa, and are also documented in human breastmilk). The use of UV-filters is declining in Norway, estimated at 1.19 tons in 2009 and 0.39 tons in 2015.
- **PFAS (Per- and Polyfluoroalkyl Substances):** PFAS have been used in industrial processes and consumer products since the 1950s, examples including textile impregnation, food packaging, firefighting foam, kitchen equipment coating, and ski wax. PFAS are shown to accumulate in food chains.
- **Organophosphates:** Organophosphates are commonly used in plastic products as flame retardants and softeners, and in paint products. Releases of organophosphates to the Norwegian environment is difficult to estimate and data is very limited. These substances are documented at high levels in organisms in the Arctic, including the Arctic fox, birds, seals, and fish and have been found in Arctic river water (Allan et al., 2018).

The abovementioned groups of emerging contaminants have been, and still are, regulated differently. Different PFAS have been regulated in Norway since 2002, and several organophosphorus compounds (OPs) have been regulated since 2012. UV-filters have been on the Norwegian priority list since 2017, targeted to be phased out by 2020. UV-filters are not regulated in the EU, but are on the candidate list of substances of very high concern[12]. Of the bisphenols, only Bisphenol-A is regulated, and have been on the Norwegian priority list since 2007, targeted to be phased out by 2020.

## 1.3 Project aims

The main purpose of the Norwegian RMP is to document levels of contaminants and nutrients in Norwegian rivers; document and provide information on effects of climate change; and to classify rivers per the WFD. In this report, contaminants data is presented, focusing on the WFD priority substances and the emerging contaminants. The following three of the RMP's main objectives will be answered in this report:

1. Measure concentrations of contaminants in Norwegian rivers, including the WFD priority substances and selected emerging contaminants;
2. Contribute to a strengthening of the knowledge on emerging contaminants and their fate in the Norwegian natural environment;

[11] http://www.miljodirektoratet.no/Documents/publikasjoner/M176/M176.pdf

[12] https://echa.europa.eu/web/guest/candidate-list-table

3. Estimate loads of selected contaminants to the coastal waters for an estimation of the contribution of pollution from terrestrial to coastal areas.

Objective 1 is answered by investigating concentrations of priority substances and emerging contaminants in water samples from five selected study rivers every third month. For 2017, the five study rivers include Glomma, Alna, Drammenselva, Numedalslågen, and Skienselva.
Objective 2 is answered by focusing on Alna as a study case, by sampling three levels of the food chain (i.e. algae, invertebrates, and fish), water, and particles at two events (spring and summer). Additionally, emerging contaminants were investigated in fish from five additional rivers, Snarumselva, Eidselva, Stryneelva, Stjørdalselva, and Reiselva. Objective 3 is answered by using relevant concentrations obtained to answer aim 1 in combination with hydrology data to calculate loads of selected contaminants to the sea for the five study rivers.

# 2. Materials and methods

## 2.1 Sampling methodologies

### 2.1.1 Sampling for priority substances in five rivers

Water samples were collected four times in 2017 in the five rivers Glomma, Alna, Drammenselva, Numedalslågen and Skienselva (Figure 1) for the measurement of "whole water" concentrations of priority substances. The term "whole water" concentration refers to the total concentration of the substance in the whole water sample and is used in the WFD to separate from the dissolved concentration of the metals Pb, Ni, Hg and Cd where the water has undergone pre-treatment such as filtration before analysis. In each river and at every sampling event 4 amber glass bottles (2.5 L) were filled with river water sampled approximately 0.5 m below the water surface. In addition, one set of blanks containing ultrapure water (4x 2.5 L bottles) were opened at one of the sites (Skienselva) for the duration of the sampling event (about 30 minutes) to control for potential contamination during sampling and sample preparation (Table 3). Before sampling the amber glass bottles were cleaned by heating in the muffle furnace at 550 °C before being rinsed with appropriate solvents.

Filtered and unfiltered water for metals and mercury were sampled at the same time. Sampling of water for filtered metal analysis (Lead (Pb), Nickel (Ni), Cadmium (Cd)) was undertaken using acid washed 60 ml Nalgene bottles (in a protective ziplock plastic bags to reduce contamination). The bottles were filled with ion-exchanged water containing 1% $HNO_3$. At sampling the bottle was emptied of the diluted acid downstream the sampling point and rinsed trice with ion-exchanged water. Disposable 0,45 µm Millipore membrane filters and 20 or 50 ml disposable syringes were used to filter the water. The membrane filter was initially rinsed by passing through 20 mL ion-exchanged water and then with 5-10 mL of the sample water. After this the filtrated sample water was taken.
Water for Mercury (Hg) analysis was sampled in 60 mL amber glass bottles. For the filtered Hg samples, the same procedure for rinsing the bottle and filtration was conducted. Bottles for unfiltered water samples were rinsed trice in river water before the samples were collected.

Only data from the filtered water samples will be presented in this report. The unfiltered metals are sampled more frequently and are presented in the main RMP. Additional information on the sampling stations can be found in the main RMP (M-1168|2018)[13].

**Table 3: Location of the 5 rivers and water sampling dates for the EU Water Framework Directive (WFD) priority substances and emerging contaminants in 2017.**
**Location given in UTM 33.**

| River* | River number** | x-coord. | y-coord. | Sampling date 1 | Sampling date 2 | Sampling date 3 | Sampling date 4 |
|---|---|---|---|---|---|---|---|
| **2-Glomma** | 002-1519-R | 279849 | 6577800 | 17.02.2017 | 02.05.2017 | 02.08.2017 | 02.10.2017 |
| **6-Alna** | 006-71-R | 264767 | 6648471 | 17.02.2017 | 02.05.2017 | 03.08.2017 | 02.10.2017 |
| **12-Drammenselva** | 012-2399-R | 219720 | 6634619 | 17.02.2017 | 03.05.2017 | 02.08.2017 | 03.10.2017 |
| **15-Numedalslågen** | 015-33-R | 217880 | 6561957 | 16.02.2017 | 03.05.2017 | 03.08.2017 | 03.10.2017 |
| **16-Skienselva** | 016-769-R | 192340 | 6575434 | 16.02.2017 | 03.05.2017 | 03.08.2017 | 03.10.2017 |
| **Blank** | | | | 16.02.2017 | 03.05.2017 | 03.08.2017 | 03.10.2017 |

* River number in NVE database. **Vann-nett ID

[13] The Norwegian river monitoring programme – water quality status and trends 2017 (M-1168|2018)

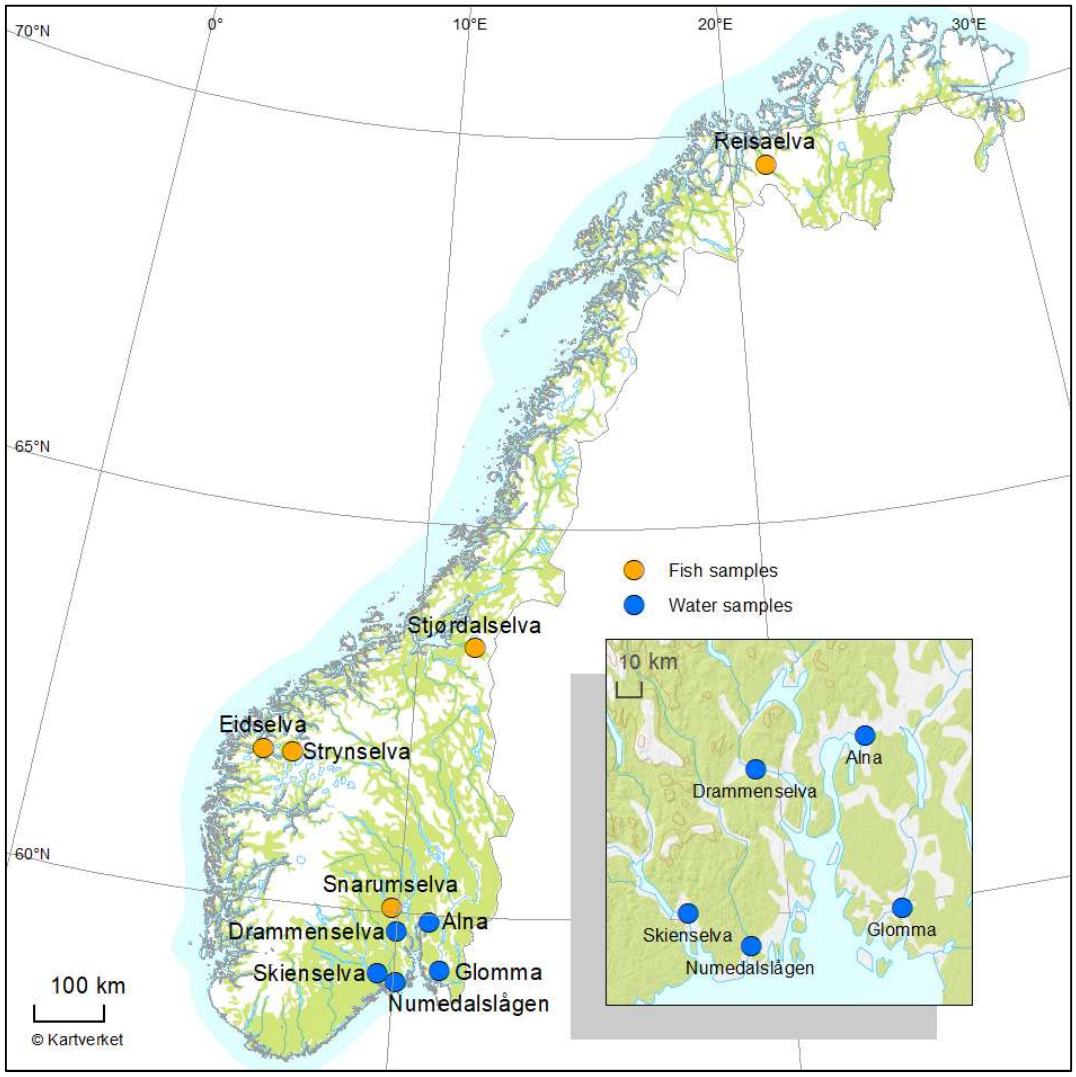


*Figure 1.* Location of the water sampling stations in Glomma, Alna, Drammenselva, Numedalslågen and Skienselva and the rivers Reisaelva, Stjørdalselva, Eidselva, Stryneelva and Snarumselva sampled for fish.

### 2.1.2 Suspended particulate matter sampling for emerging contaminants

Suspended particulate matter (SPM)-associated contaminants were sampled in the Alna using *continuous flow centrifugation* (CFC) twice a year. Deployment of the CFC at a secure site (with electrical power supply) near the river allowed for the continuous collection of SPM for a period of 7 days (Table 4). The SPM samples collected were stored at -20 °C. More details of sampling with CFC can be found in earlier reports (Allan et al., 2009; Allan et al., 2010). The same sampling site were used for the time-proportional water sampling (Table 4) and the Alna grab water samples (Table 3, Figure 1, Figure 2) (and the sensor monitoring (M-1168|2018).

**Table 4. Deployment periods for the time proportional water sampling and continuous flow centrifuge in river Alna in 2017**

| | |
|---|---|
| Sampling event 1 | 14-21.06.2017 (7 days) – 2 samples |
| Sampling event 2 | 4-11.10.2017 (7 days) – 2 samples |

### 2.1.3 Time-proportional water sampling for emerging contaminants

Representative and time integrated water sampling for emerging contaminants was done using automatic water sampling (Teledyne ISCO Avalanche automatic water sampler (ISCO sampling)) Automatic water sampling made it possible to do replicate sampling collected as mixed samples over a longer time period.

The ISCO sampling was conducted twice in 2017, for seven days in June and for seven days in October at the same time as the CFC was in the river (Table 4).

Eight bottles for replicate samples for 4 analyses were installed in the ISCO-sampler. Sampling approximately 700 mL water per sample over 7 days. Each bottle holds 950 mL, which leaves space for liquid-liquid extraction in the bottle. The ISCO-sampler were programmed to conduct five sampling events of 20 ml per 24 hours. The bottles were refrigerated (3 °C) in the ISCO sampler during the sampling event. In addition, 4 blank bottles filled with ultrapure water for 2 replicate analyses were included. The distilled water of the blanks was sampled through the ISCO avalanche system and tubing to expose the blanks to the same condition at the samples. All bottles were left open in the ISCO avalanche during the sampling period. After retrieval the samples were kept cold or stored at -20 °C until they were thawed for extraction and analysis for the contaminants of interest.

The system's tubing was rinsed in spring water and ultrapure water before use. In addition, the ISCO-sampling system was rinsed on site in river water with maximum flushing for about 10 minutes before the program was started. The sample bottles and blank bottles were cleaned before sampling. The bottle cleaning procedure were as follows:

The bottles and lids were washed in warm alkaline soap water (washing machine) then:
- Rinsed in RO-water (washing machine)
- Rinsed in methanol (manually)
- Rinsed twice in distilled water (manually)
- Rinsed twice in distilled water containing 2% acetic acid (manually)
- Rinsed in ultrapure water (manually)

### 2.1.4 Sampling of fish for priority contaminants in five rivers

Brown trout (*Salmo trutta*), Atlantic salmon (*Salmo salar*) and arctic char (*Salvelinus alpinus)* were sampled by electrofishing in the five rivers Eidselva, Stjørdalselva, Stryneelva, Reisa and Snarumselva for the analysis of priority substances. Sampled stations and information are shown in Table 5 and 6. The fish selected for analysis for each station of the same river were as homogenous as possible with respect to size. After capture the fish were wrapped in clean aluminium foil and kept frozen until arrival at the NIVA lab. The electrofishing was done according to the international standard NS-ISO-14011 and Norwegian standard NS-9455. Details on the methodology can be found in the companion biology report (M-1167|2018)[14].

The length and weight of each fish were measured. Species, sex and maturity stage were noted, and shells and otoliths were saved for potential future age determination. The fish that were captured were generally small. Thus, to get sufficient material to carry out the analyses

[14] Classification of ecological and chemical status in Norwegian rivers according to the Water Framework Directive. River Monitoring Programme 2017 (M-1167 | 2018)

whole fish were used in the pooled samples for the rivers Eidselva, Stjørdalselva, Stryneelva and Reisa. In Snarumselva, the fish were larger, so muscle tissue and liver samples were taken. For each river, three pooled samples containing five to six fish were homogenised and sent for analysis. For Snarumselva, the fish were grouped according to fish length as only one station was available. In Reisa the same was done for samples 2 and 3. The composition of the samples for the rest of the rivers were determined by the sampling stations. Information on the composition of the pooled samples can be found in Table 5 and 6, and information on individual fish in Appendix 6.1. The location of the rivers can be found in Figure 1.

**Table 5. Overview of the five rivers that were sampled for fish for priority contaminants**

The coordinates are given in UTM33. The coordinates gives downstream startpoint for electrofishing

| County | River name | Sampling date | X-coordinate | Y-coordinate | Station ID |
|---|---|---|---|---|---|
| **Sogn og Fjordane** | Eidselva | 11.09.2017 | 29561 | 6897244 | EID-1 |
| | Eidselva | 11.09.2017 | 30599 | 6896992 | EID-2 |
| | Eidselva | 11.09.2017 | 32590 | 6896953 | EID-3 |
| | Stryneelva | 12.09.2017 | 71213 | 6892498 | STR-1 |
| | Stryneelva | 12.09.2017 | 72191 | 6892938 | STR-2 |
| | Stryneelva | 12.09.2017 | 69888 | 6892096 | STR-3 |
| **Buskerud** | Snarumselva | 02.11.2017 | 212243 | 6669311 | SNA-1 |
| **Trøndelag** | Stjørdalselva | 21.09.2017 | 331923 | 7039330 | STJ-1 |
| | Stjørdalselva | 21.09.2017 | 317445 | 7041787 | STJ-2 |
| | Stjørdalselva | 21.09.2017 | 305222 | 7043053 | STJ-3 |
| **Troms** | Reisaelva | 11.09.2017 | 745383 | 7729447 | REI-1 |
| | Reisaelva | 06.10.2017 | 744379 | 7735817 | REI-2 |

**Table 6: Overview of the five river stations that were sampled for fish for priority contaminants and the composition of the pooled fish samples.**

**The table shows species, sampled tissues (muscle (MU), liver (LI) and whole organism (WO)), subsamples (Fish ID) and mean lengths (cm) and weights(g) with standard deviation (SD) for each pooled sample**

| River name | St.ID | Sample nr | Species* | Tissue | Fish Ids | Mean length (SD) | Mean weight (SD) |
|---|---|---|---|---|---|---|---|
| **Eidselva** | EID-1 | 1 | *Salmo trutta* | WO | 2,4,5,6,7 | 11.0 (0.3) | 12(1) |
| **Eidselva** | EID-2 | 2 | *Salmo trutta* | WO | 8,9,12,15,16 | 11.0 (0.3) | 12(1) |
| **Eidselva** | EID-3 | 3 | *Salmo trutta* | WO | 19,20,22,24,25 | 12.1 (0.5) | 18(3) |
| **Stryneelva** | STR-1 | 1 | *Salmo trutta, Salmo salar* | WO | 2,4,5,7,8 | 11.7(0.5) | 18(2) |
| **Stryneelva** | STR-2 | 2 | *Salmo salar* | WO | 10,11,14,16,17 | 11.5(0.3) | 15(0.5) |
| **Stryneelva** | STR-3 | 3 | *Salmo trutta* | WO | 19,20,22,26,27 | 12.0(0.4) | 17(2) |
| **Snarumselva** | SNA-1 | 1 | *Salmo trutta* | MU, LI | 3,9,11,12,14 | 18.4(1.0) | 64(14) |
| **Snarumselva** | SNA-1 | 2 | *Salmo trutta* | MU, LI | 2,5,8,10,15 | 20.2(0.4) | 88(12) |
| **Snarumselva** | SNA-1 | 3 | *Salmo trutta* | MU, LI | 1,4,6,7,13 | 21.9(1.1) | 117(26) |
| **Stjørdaalselva** | STJ-1 | 1 | *Salmo trutta, Salmo salar* | WO | 3,5,6,7,8 | 11.6(1.2) | 17(5) |
| **Stjørdaalselva** | STJ-2 | 2 | *Salmo salar* | WO | 9,10,11,12,13 | 10.7(0.5) | 12(3) |
| **Stjørdaalselva** | STJ-3 | 3 | *Salmo trutta* | WO | 16,17,18,19,20 | 12.6(0.9) | 22(5) |
| **Reisaelva** | REI-1 | 1 | *Salvelinus alpinus, Salmo trutta* | WO | 1,2,3,4,5 | 14.9(1.0) | 32(6) |
| **Reisaelva** | REI-2 | 2 | *Salmo salar* | WO | 6,7,9,10,11,12 | 10.4(0.3) | 10(1) |
| **Reisaelva** | REI-3 | 3 | *Salmo salar* | WO | 13,15,16,17,18 | 12.2(0.8) | 16(4) |

*Brown trout (*Salmo trutta*); Atlantic salmon (*Salmo salar*); Arctic char (*Salvelinus alpinus*)

### 2.1.5 Biota sampling for emerging contaminants in River Alna

The Alna river, situated in Oslo was chosen as the urban river site. The river is highly affected by human activity, e.g. the catchment is affected by for example industrial emissions, stormwater, sewage water, pollution from old industrial sites and leakage from discarded landfills. The presence of emerging contaminants such as organophosphorus compounds, fragrances or UV filters has been documented (Allan et al., 2013; Pintado-Herrera et al., 2016).

Collection and sampling of biological material followed the guidelines of the Norwegian environmental specimen bank[15] . This implies stricter demands regarding use of personal care products and other potential contaminant sources during capture and later handling of the samples.

**Sampling of brown trout**

Brown trout from Alna were collected for emerging contaminants by electrofishing in May and September 2017 (Table 7, Figure 2). On both occasions the aim was to collect five fish from three different size groups. The fish were packed in clean aluminum foil after capturing and kept cool until frozen at –20°C.

Fish were thawed and dissected on clean aluminum foil. Nitrile gloves were used during handling. Glass containers was sealed with aluminum foil and burnt at 550 °C before use. The length, weight, sex and maturity stage were recorded. Shells and otoliths were removed for potential future age determination. Muscle tissue was taken, and liver was dissected out for analyses of PFAS. In total 28 fish were sampled, totaling to 11 samples. Fish smaller than 15 cm (pooled sample 3 and 4) were kept whole, thus all the analytes were done in whole fish. For the May fish samples all three samples were composed of five fish of as equal size as possible. The September samples had three pooled samples of 5,3 and 2 fish. In addition, the five largest fish were analyzed individually. The average length of the fish in each mixed sample ranged from 10,1 -35 cm. An overview of sample composition can be found in Table 8, and details on individual fish in Appendix, 6.1. The sampled were kept frozen (-20 °C) until homogenization and analysis.

**Sampling of benthic macroinvertebrates, periphyton and fountain moss**

Sampling of benthic macroinvertebrates, periphyton and fountain moss was undertaken at three stations in Alna in September 2017 (Alna-1, Alna-2 and Alna-3) (Table 7, Figure 2). Glass containers was sealed with aluminum foil and burnt at 550 °C before use. The samples were kept cold and frozen (-20 °C) until homogenization and analysis. The periphyton and fountain moss, and some of the larger invertebrates were handpicked in the river. Macroinvertebrates were obtained by using kick-net sampling (mesh size 0,25 mm). Only low amounts of biological material were available in the river. There were especially low yields of benthic macroinvertebrates at the chosen stations. Because of the high demands for sample size for the analyses, most of the samples were therefore grouped together from more than one station. The composition of the samples can be found in Table 9. The macroinvertebrate samples consisted of species from several different groups and trophic levels, including e.g. *Asellus aquaticus*, chironomids, oligochaetes, plecoptera, caddisflies, mayflies and leeches. The samples were also fouled by periphyton and fine river sediment, which could impact the usability of the results.

[15] Miljøprøvebanken, 2015. Procedure 001: Collection and sampling of freshwater fish, ver.1.1. Can be downloaded from: https://mpbank.files.wordpress.com/2018/04/mpb-eng-procedure-1-freshwater-fish.pdf

| Table 7. Location of the Alna sampling stations<br>The coordinates are given in UTM33 | | | |
|---|---|---|---|
| **Station ID** | **Area** | **X-coordinate** | **Y-coordinate** |
| **Alna-1** | Svartdalsparken | 264697 | 6648270 |
| **Alna-2** | Alfaset | 267723 | 6651091 |
| **Alna-3** | Fossumbekken | 270290 | 6652710 |
| **Alna-1,2,3** | Indicate that the sample derives from more than one of the stations | | |

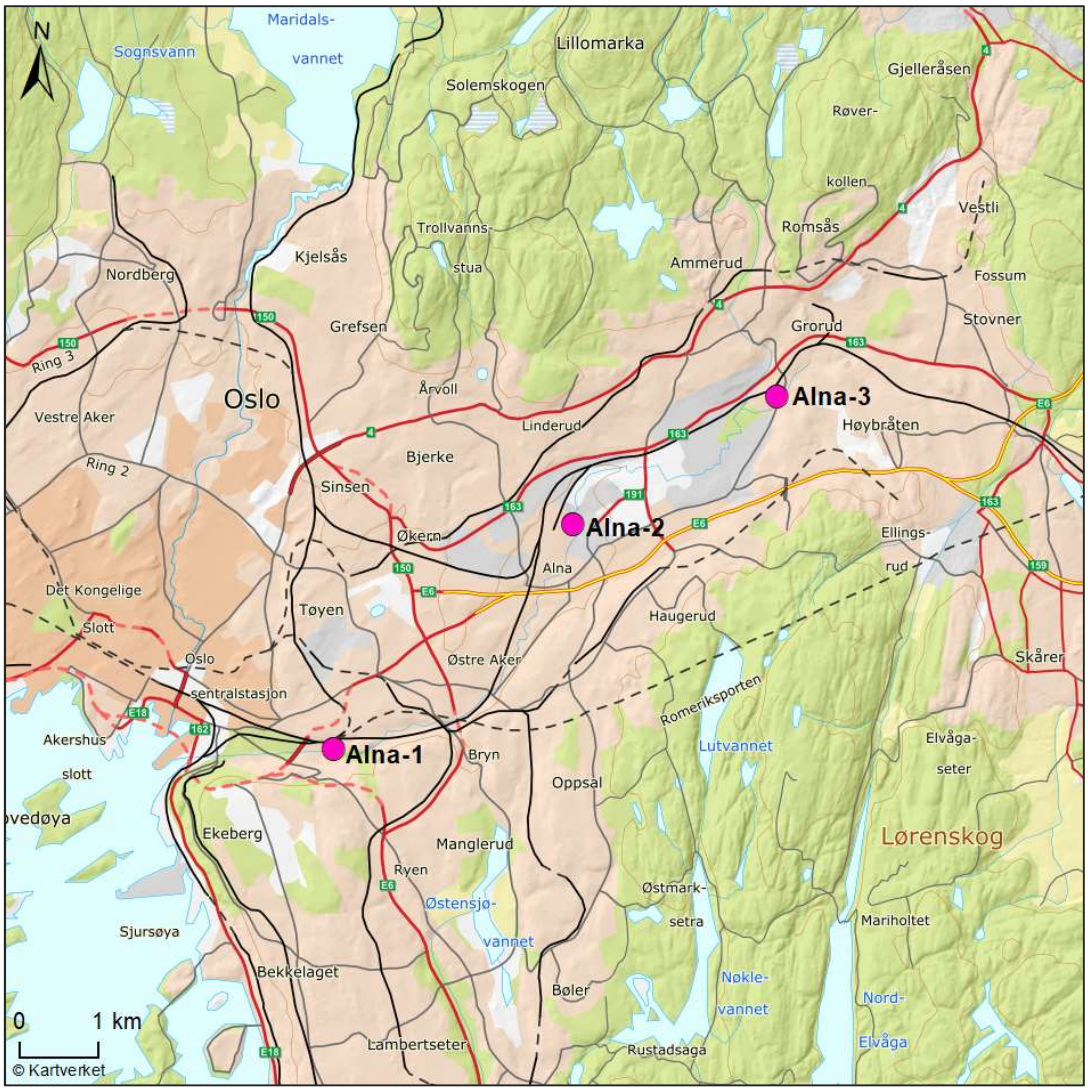


*Figure 2*. Location of the sampling stations in river Alna. One brown trout (*Salmo trutta*) was sampled at Alna-1, the rest of the brown trout were collected at Alna-2. The SPM and water were sampled at Alna-1. Benthic macroinvertebrates, periphyton and fountain moss were collected at Alna-1, Alna-2 and Alna-3.

**Table 8. Overview of the Alna pooled fish samples**

The table shows species, sampled tissues (muscle (MU), liver (LI) and whole organism (WO)), subsamples (Fish ID) and mean lengths (cm) and weights(g) with standard deviation (SD) for each pooled sample

| Station ID | Sample nr | Sampling date | Species | Tissue | Fish Ids | Mean (SD) length (cm) | Mean (SD) weight (g) |
|---|---|---|---|---|---|---|---|
| **Alna-2** | 1 | 24.05.2017 | *Salmo trutta* | MU, LI | 1,2,3,6,7 | 16.8(0.6) | 58.2(9.1) |
| **Alna-1,2** | 2 | 24.05.2017 | *Salmo trutta* | MU, LI | 4,5,8,9,10 | 21.1(3.1) | 123.8(57.0) |
| **Alna-2** | 3 | 24.05.2017 | *Salmo trutta* | WO | 11,12,13,14,15 | 10.12(0.1) | 13.62(0.7) |
| **Alna-2** | 4 | 25.09.2017 | *Salmo trutta* | WO | 19,20,21 | 13.7(0.4) | 32.0(3.7) |
| **Alna-2** | 5 | 25.09.2017 | *Salmo trutta* | MU, LI | 24,25,26 | 18.3(0.8) | 82.3(23.5) |
| **Alna-2** | 6 | 25.09.2017 | *Salmo trutta* | MU, LI | 27,29 | 21.8(1.1) | 131.5(4.2) |
| **Alna-2** | 7 | 25.09.2017 | *Salmo trutta* | MU, LI | 28 | 23.2 | 146.7 |
| **Alna-2** | 8 | 25.09.2017 | *Salmo trutta* | MU, LI | 30 | 23.5 | 167.7 |
| **Alna-2** | 9 | 25.09.2017 | *Salmo trutta* | MU, LI | 31 | 27 | 273.1 |
| **Alna-2** | 10 | 25.09.2017 | *Salmo trutta* | MU, LI | 32 | 27.2 | 296.4 |
| **Alna-2** | 11 | 25.09.2017 | *Salmo trutta* | MU, LI | 33 | 35 | 596.8 |

**Table 9. Overview over the of benthic macroinvertebrates, periphyton, and fountain moss samples collected in Alna.**

| Station ID | Sample nr | Sampling date | Specimen |
|---|---|---|---|
| **Alna-1,2,3** | 1 | 25.09.2017 | Benthic macroinvertebrates |
| **Alna-1,2,3** | 2 | 25.09.2017 | Benthic macroinvertebrates |
| **Alna-1** | 3 | 25.09.2017 | Periphyton+fountain moss |
| **Alna-2** | 5 | 25.09.2017 | Periphyton+fountain moss |
| **Alna-2** | 6 | 25.09.2017 | Periphyton+fountain moss |
| **Alna-3** | 7 | 25.09.2017 | Periphyton |
| **Alna-3** | 8 | 25.09.2017 | Fountain moss |

## 2.2 Chemical analysis and quality assurance

### 2.2.1 Priority substances in water and fish samples

**Polybrominated diphenyl ethers (PBDEs), hexabromocyclododecane (HBCDD) chlorfenvinphos, cybutryne, DEHP, PAHs and organochlorinated compounds**

The priority organic substances PBDEs, hexachlorobenzene (HCB), HBCDD, pentachlorobenzene (PeCB), lindane/hexachlorocyclohexane (γ-HCH), PAHs, chlorfenvinphos, cybutryne, DEHP, polychlorinated biphenyls (PCBs) and DDTs were analysed at NIVA. These substances were analysed in biota and water samples.

For the determination of concentrations of the priority substances in water, a mixture of recovery standards was added directly in the bottles used for sampling before the liquid-liquid extraction began. The internal standards consist mainly of isotope labeled standards that follows both extraction and pre-concentration of the samples and are used to quantify the analytes. The water samples were then extracted using an organic solvent to ensure good yields of the analytes. The extraction was done directly in the water bottles to reduce possible contamination of the samples and to ensure as little loss of analytes as possible. The method did to a large degree follow the guidelines given in ISO 28581 "*Water quality - Determination of selected non-polar substances –Method using gas chromatography with mass spectrometric detection (GC-MS)*".

Before extraction, biota samples were homogenized. A mixture of recovery standards, consisting primarily of isotopically-labelled standards were then added to the samples. These follows both extraction and pre-concentration and were used to quantify the analytes. Biota samples were extracted twice with an organic solvent to ensure good yields. After extractions both water and biota samples where cleaned up using gel permeation chromatography (GPC), concentrated sulphuric acid and/or primary-secondary amine (**PSA**) sorbent.

HBCDD was analysed on a LC-qToF, this is a full-scan instrument enabling identification of more substances. The remaining analytes were quantified on a GS-MS (GC-EI-MS and GC-NCI-MS).

For all the NIVA analyses in this report the limits of detection (LOD) and quantification (LOQ) were calculated for each sample, using the accepted standard method; three times the signal/noise ratio (z/n) and nine times the z/n ratio, respectively.

NIVA's laboratory is accredited by Norwegian Accreditation for ISO/IEC 17025. NIVA is not accredited for any of the organic compounds in this report, but to the extent possible, documentation, preparation, analysis and calculations are performed in accordance with accredited methods. NIVA participates in intercalibrations where possible. Samples were analysed in groups with at least one additive standard sample and a blank control.

**Short- and medium chained chlorinated paraffins (S/MCCP)**

The short- and medium chained chlorinated paraffins (S/MCCP) were determined at the Norwegian Institute for Air Research (NILU). Prior to extraction, a mixture of isotope labelled standards were added to the samples for quantification purposes. The water-, sediment- and biota samples were extracted with organic solvents and concentrated under nitrogen flow, followed by a clean-up procedure with concentrated sulfuric acid on a SPE column to remove

lipids and other interferences prior to analysis. The samples were analysed on a GC-HRMS (Waters Autospec or Agilent GC-qTof 7200) in ECNI mode.

For all the NILU analyses in this report the limits of detection (LOD) and quantification (LOQ) were calculated for each sample, using the accepted standard method, i.e. the average of blanks plus 3 and 10 times the standard deviation for blanks, for LOD and LOQ, respectively.

NILU's laboratories are accredited by Norwegian Accreditation for ISO/IEC 17025. NILU is not accredited for the analysis for of the organic compounds in this report, but as far as possible, the documentation, sample preparation, analysis and calculation procedures were conducted according to the accredited methods.

**Alkylphenols and bisphenols**

Alkylphenols and bisphenols (octylphenol, nonylphenol, bisphenols A, S, F and bisphenols-AF, AB, B, E, FL, M and Z) were analysed at NILU. Bisphenols are described here as a part of the analysis for alkylphenols, though the compounds belong under the emerging contaminant section (**2.2.2**)

Prior to extraction, the biota and SPM samples were added a mixture of isotope labelled bisphenols and alkylphenols for quantification purposes. The SPM and biota-samples were extracted with organic solvents and concentrated under nitrogen flow, followed by a cleaning procedure on a SPE column to remove lipids and other interferences prior to analysis. Water samples were concentrated and purified on a SPE column. After elution from the SPE column, the water sample extracts were further concentrated under nitrogen and subjected to instrumental analysis.

The samples were analysed by LC-QToF (Agilent 65/50) or LC-ToF (Waters Premier). For the emerging bisphenols the analysis was performed in full scan mode. This was done to be able to use the raw data in future retrospective non-target screening.

Due to the lack of specific isotopically-labelled standards, relevant to additional bisphenols (Bispenols AF, AB, B, E, FL, M and Z), the results are likely less accurate than those for which these labelled standards are used.

**Lead (Pb), Nickel (Ni), Cadmium (Cd) and mercury (Hg) in filtrated water samples**

Filtered water samples were preserved in nitric acid ($HNO_3$) before analyses. Cd, Ni and Pb were determined at NIVA according to analytical method NS-EN ISO 17294-1 and NS EN ISO 17294-2 modified. The level of detection and level of quantification (LOD/LOQ) were 0.0010/0.0030, 0.013/0.040 and 0.017/0.005 µg/L for Cd, Ni and Pb respectively. NIVA is accredited for the analytical method (NS-EN ISO/IEC 17025, Test 009). Hg was analysed at Eurofins according to method NS-EN ISO 12846 modified. The level of detection was 0.0003 µg Hg/L and level of quantification was 0.001 µgHg/L. Eurofins is accredited for the analytical method (NS-EN ISO/IEC 17025, Test 003).

### 2.2.2 Emerging contaminants in water, SPM and biota from Alna

**Bisphenols**

Bisphenol A, S, F and the extra compounds bisphenol-AF, -AB, -B, -E, -FL, -M and -Z were analysed in SPM, water and biota by NILU. The analysis of Bisphenols is described as part of the analysis for alkylphenols in the section above.

**UV filters**

UV chemicals (octocrylene, benzophenone and ethylhexylmethoxycinnamate, UV-327, UV-328 and UV-329) were determined by NIVA. A mixture of isotope labelled internal standards were added to the samples, following both the extraction and pre-concentration steps. Before extraction SPM were freeze-dried and biota samples were homogenized. The extraction of the UV-chemicals from water samples, suspended material and homogenized biota samples were similar to that described for PBDEs, HCB, HBCDD, QCB, HCH, HBCDD, PAHs, chlorfenvinphos, cybutryne, DEHP, PCBs and DDT above. All samples were cleaned up using GPC, before analysis. Some of the samples were also purified using PSA.

UV chemicals were analysed using GC-MS/MS (Agilent).

**Per and polyfluorinated substances (PFAS)**

PFAS were determined by NIVA. Prior to extraction, a mixture of isotope labelled PFAS were added to the samples following the sequence of both extraction and pre-concentration with organic solvents and used in the quantification of the analytes. Samples of suspended particulate material (SPM) and biota were extracted using acetonitrile and buffers for pH-control. The water samples were pre-concentrated and cleaned on a SPE column. All extracts were pre-concentrated under nitrogen before analysis. PFAS were determined using a LC-qToF-MS. As it is a full-scan instrument, it gives the possibility to identify more compounds later.

**Chlorinated and non-chlorinated organophosphorus compounds**

Chlorinated and non-chlorinated organophosphates were determined by NILU. Prior to extraction, a mixture of isotope labelled OP-standards were added to the sample for quantification. All samples, including biota, water, and sediment, were extracted using organic solvents. The extracts were reduced under a stream of nitrogen followed by a clean-up using silica column to ensure good recovery and removal of fat and other interferences. The organophosphates were quantified using GC-MS (Waters Quattro micro GC/MSMS) and LC-MS/MS (Thermo Vantage).

### 2.2.3 Stable Isotopes

The ratio between the stable nitrogen isotopes $^{14}N$ and $^{15}N$ ($\delta^{15}N$), the carbon isotopes $^{12}C$ and $^{13}C$ ($\delta^{13}C$), and the sulfur isotopes $^{32}S$ and $^{34}S$ were determined by IFE (Institute for Energy Technology), based on Vander Zanden and Rasmussen (2001). Analyses were performed according to standard protocols without removing lipids nor carbonates prior to analysis. Important steps of the method include combustion in an element analyzer, reduction of $NO_x$ in a Cu-oven, separation of $N_2$ and $CO_2$ on a GC-column followed by determination of $^{15}N$, $^{13}C$, and $^{34}S$ on an Isotope Ratio Mass Spectrometer (IRMS).

LOD and LOQ was calculated from analysis of international reference materials distributed by the IAEA (International atomic energy agency), USGS (U.S. Geological Survey) and NIST (National Institute of Standards and Technology) as well as in house laboratory standards. This

was done for each sequence and can vary somewhat. Typically, IFE need 5 mg sample to achieve the accuracy and precision needed.

Standards with known values were analyzed in all sequences as unknown samples. The results of these analyses were followed closely and was used as parameters to determine if the sequences were approved or not. They were also used to track if the results were stable over time. IFEs internal trout standard was used for $\delta^{13}C$ and $\delta^{15}N$, and NBS 127 ($BaSO_4$) reference material from IAEA for $\delta^{34}S$.

IFE is certified after the demands in ISO9001:2008 and ISO14001:2004.

## 2.3 Calculation procedures

Since in many cases, datasets included censored data (i.e. data below limits of quantification), a common procedure was used for dealing with these data. The following procedure was used to calculate means and standard deviations for priority substances concentrations in water samples from 5 rivers:

- When all 4 data points from one river were above LOQ, the mean and standard deviation (SD, n = 4) were estimated.
- When some of the data were below LOQ, these were given a value of half the LOQ, before the mean and SD were calculated.
- When all data were below LOQ, data was reported as below mean LOQ.
- When the data from the blanks were above LOQ, data from samples that were below x3 the blank value were given the value <3xblank.

This procedure was employed for all types of samples where multiple replicates data were available.

For the calculation of fluxes or discharges to sea, considering the low number of samples or litres of water sampled, no attempts were done to calculate discharge-weighed concentrations or fluxes.

# 3. Results and discussion

## 3.1 EU WFD Priority substances and other relevant chemicals in water of five rivers

In this section, we report estimates of annual average concentrations calculated from four "whole water" samples collected at one sampling site per river per year. We compare these estimates with annual average EQS published by the Norwegian Environment Agency in 2016[16].

### 3.1.1 Polycyclic Aromatic Hydrocarbons (PAHs)

Annual average concentrations of individual PAHs based on four water samples collected in 2017 are given in Table 10. PAHs are above LOQ most regularly in water samples from rivers Alna, Numedalslågen and Skienselva. Concentrations were generally highest for the Alna, followed by those from Skienselva and lowest for river Glomma. "Whole water" concentrations of naphthalene and anthracene were well below WFD AA-EQS for all rivers. For fluoranthene, the estimated annual average concentration in Alna exceeds the AA-EQS by a factor of three. The annual average concentration of 22 ng $L^{-1}$ is in the same range as estimates from previous years (16 and 8 ng $L^{-1}$) estimated with a combination of passive sampling and suspended particulate matter sampling[17]. For the Skienselva, this value is only a factor of four below AA-EQS. For the other rivers, estimated annual average concentrations were close to an order of magnitude below EQS. Estimates of annual average concentrations of fluoranthene in rivers Drammenselva and Glomma are lower than those obtained in previous years[18]. For benzo[a]pyrene, while most mean concentrations in the table below suffer from large standard deviations, most are close to or above EQS. For river Glomma, data are consistently below limits of quantification with limits of quantifications close to EQS.

[16] http://www.miljodirektoratet.no/Documents/publikasjoner/M608/M608.pdf
[17] http://www.miljodirektoratet.no/Documents/publikasjoner/M862/M862.pdf
[18] http://www.miljodirektoratet.no/Documents/publikasjoner/M862/M862.pdf

## Table 10. "Whole water" concentrations of PAHs

"Whole water" concentrations* of polycyclic aromatic hydrocarbons in five rivers (ng $L^{-1}$) and comparison with WFD AA-EQS. Values above the AA-EQS are presented in red-coloured cells.

| Chemical | Alna | Drammenselva | Glomma | Numedalslågen | Skienselva | AA-EQS |
|---|---|---|---|---|---|---|
| **Naphthalene** | 6.0 (3) | 2.5 (1.7) | 2.7 (2.1) | 2.5 (1.6) | 8 (13) | **2000** |
| **Acenaphthylene** | 1.8 (0.7) | <0.5 | <0.5 | <5 | 1.2 (2) | 1280 |
| **Acenaphthene** | 6.0 (5) | 0.71 (0.5) | 0.49 (0.37) | 0.9 (0.9) | 4.5 (8) | 3800 |
| **Fluorene** | 3.7 (2.4) | 0.25 (0.15) | 0.18 (0.13) | 0.45 (0.4) | 2 (4) | 1500 |
| **Phenanthrene** | 12 (15) | <1.5 | <1.5 | <1.5 | 2 (4) | 500 |
| **Anthracene** | 5.2 (9) | <0.2 | <0.2 | 0.15 (0.1) | 0.6 (1) | **100** |
| **Fluoranthene** | 22 (35) | 0.72 (0.4) | 0.57 (0.23) | 0.74 (0.4) | 1.4 (2) | **6.3** |
| **Pyrene** | 28 (45) | <0.5 | <5 | 0.8 (0.6) | 2 (4) | 23 |
| **Benz[a]anthracene** | 9.1 (17) | 0.19 (0.14) | 0.18 | 0.13 (0.12) | 0.24 (0.3) | 18 |
| **Chrysene** | 9.3 (16) | 0.26 (0.18) | 0.15 (0.1) | 0.23 (0.16) | 0.3 (0.4) | 70 |
| **Benzo[b,j]fluoranthene** | 13 (23) | 0.34 (0.28) | 0.16 (0.1) | 0.38 (0.3) | 0.4 (0.4) | |
| **Benzo[k]fluoranthene** | 4.3 (7) | 0.13 (0.07) | <0.2 | 0.18 (0.09) | 0.25 (0.3) | |
| **Benzo[a]pyrene** | 7.3 (13) | 0.12 (0.08) | <0.15 | 0.12 (0.11) | 0.20 (0.2) | **0.17** |
| **Indeno[1,2,3-cd]pyrene** | 5.8 (10) | 0.12 (0.08) | <0.18 | 0.17 (0.15) | 0.4 (0.6) | |
| **Dibenzo[ac/ah]anthracene** | 1.4 (2.5) | <0.15 | <0.15 | 0.13 (0.12) | <0.2 | 14 |
| **Benzo[ghi]perylene** | 9.0 (16) | 0.13 (0.1) | 0.093 (0.03) | 0.21 (0.2) | 0.26 (0.35) | |

*Yearly average (with standard deviation in brackets; n = 4 bottle samples); in ng $L^{-1}$; Note that original WFD AA-EQS are given in bold.

### 3.1.2 Organochlorinated compounds (PCBs and pesticides)

In most cases, no organochlorinated compounds were found above limits of quantification in water samples collected from any of the five rivers (Table 11). Hexachlorobenzene was detected and quantified in river Alna only. Based on these measurements, levels are well below WFD AA-EQS for pentachlorobenzene, lindane (γ-HCH). While *p,p'*-DDT and sum of DDTs are below limits of quantification, these are within a factor of two of WFD AA-EQS (a factor of three below is a performance requirement for the analysis for priority substances). The limit of quantification for the sum of concentrations of seven indicator PCBs is close to three orders of magnitude higher than the annual proposed average threshold of 2.4 pg $L^{-1}$.

**Table 11. "Whole water" concentrations of organochlorinated compounds**

"Whole water" concentrations* of polychlorinated biphenyls and other chlorinated organic compounds in five rivers (ng $L^{-1}$) and comparison with WFD AA-EQS.

| Chemical | Alna | Drammenselva | Glomma | Numedalslågen | Skien | WFD AA-EQS |
|---|---|---|---|---|---|---|
| **Pentachlorobenzene** | <0.7 | <0.2 | <0.2 | <0.2 | <0.2 | **7** |
| **Hexachlorobenzene** | 0.29 (*0.17*) | <0.25 | <0.2 | <0.2 | <0.2 | |
| **γ-HCH** | <2 | <1 | <1 | <1 | <1 | **20** |
| **PCB28/31** | <1 | <1 | <1 | <1 | <1 | |
| **PCB52** | <1 | <1 | <1 | <1 | <1 | |
| **PCB101** | <1 | <1 | <1 | <1 | <1 | |
| **PCB118** | <1 | <1 | <1 | <1 | <1 | |
| **PCB153** | <1 | <1 | <1 | <1 | <1 | |
| **PCB138** | <1 | <1 | <1 | <1 | <1 | |
| **PCB180** | <1 | <1 | <1 | <1 | <1 | |
| **$\Sigma_7$PCBs** | <7 | <7 | <7 | <7 | <7 | 0.0024 |
| ***p,p'*-DDE** | <2 | <2 | <2 | <2 | <2 | |
| ***p,p'*-DDD** | <4 | <4 | <4 | <4 | <4 | |
| ***p,p'*-DDT** | <7 | <7 | <7 | <7 | <7 | **10** |
| **$\Sigma_3$DDTs** | <13 | <13 | <13 | <13 | <13 | **25** |

*Yearly average (n = 2 bottle samples, except for pentachlorobenzene, hexachlorobenzene and γ-HCH for which n = 4); in ng $L^{-1}$; Note that original WFD AA-EQS are given in bold.

### 3.1.3 Polybrominated diphenyl ethers (PBDEs)

Estimated annual average concentrations of PBDEs in water of the five selected rivers are reported in the table below (Table 12). Only PBDE congeners 47, 100, 99 and 153 were relatively consistently detected above limits of quantification in river Alna. The sum of concentrations of 5 congeners (47, 100, 99, 154, and 153) is 0.32 ng $L^{-1}$. This value is well below the maximum acceptable EQS (MAC-EQS) of 140 ng $L^{-1}$ set by the WFD. No PBDEs were found above limits of quantification in "whole water" samples collected from the four other rivers. Considering the

hydrophobicity of PBDEs and their solubility in water, concentrations in the hundreds of ng per litre would be expected to be encountered only in contaminated effluents rather than in natural river water. While PBDE concentrations are well below the proposed EQS in water samples, the sum of PBDEs is consistently found above the $EQS_{biota}$ in freshwater fish. This may mean that the $EQS_{biota}$ is more protective than the EQS for water and that EQS values for different matrices are not internally consistent. The $EQS_{biota}$ may also be relevant from a secondary poisoning perspective. However, PBDE metabolism in fish can affect whether PBDE level in fish can be used to estimate the environmental quality of a water body.

**Table 12. "Whole water" concentrations of PBDEs**

"Whole water" concentrations* of polybrominated diphenyl ethers in five rivers (ng $L^{-1}$) and comparison with WFD AA-EQS

| Chemical | Alna | Drammenselva | Glomma | Numedalslågen | Skien | WFD AA-EQS |
|---|---|---|---|---|---|---|
| **PBDE28** | <0.06 | <0.06 | <0.06 | <0.06 | <0.06 | |
| **PBDE47** | 0.05 (0.06) | <0.03 | <0.03 | <0.03 | <0.03 | |
| **PBDE100** | 0.02 (0.01) | <0.03 | <0.03 | <0.03 | <0.03 | |
| **PBDE99** | 0.18 (0.1) | <0.28 | <0.28 | <0.28 | <0.28 | |
| **PBDE154** | <0.03 | <0.03 | <0.025 | <0.025 | <0.03 | |
| **PBDE153** | 0.02 (0.01) | <0.04 | <0.035 | <0.035 | <0.04 | |
| **$\Sigma_5$PBDEs** | 0.32 | <0.46 | <0.46 | <0.46 | <0.46 | **1.6** |

*Yearly average (standard deviation in brackets; n = 4 bottle samples); in ng $L^{-1}$; Note that original WFD AA-EQS are given in bold.

### 3.1.4 Hexabromocyclododecane (HBCDD)

As for PBDEs, hexabromocyclododecane isomers were only found above limits of quantification in water samples from river Alna (Table 13). The sum of concentrations of the three congeners of 1.71 ng $L^{-1}$ is above the WFD AA-EQS value of 1.6 ng $L^{-1}$ for continental waters. Note that there are large standard deviations associated with concentration estimates for river Alna. For all other rivers, concentrations are below AA-EQS, however limits of quantifications are close to EQS.

**Table 13. "Whole water" concentrations of HBCDD**

"Whole water" concentrations* of hexabromocyclododecane in five rivers (ng $L^{-1}$) and comparison with WFD AA-EQS. Values above the AA-EQS are presented with red colour.

| Chemical | Alna | Drammenselva | Glomma | Numedalslågen | Skien | WFD AA-EQS |
|---|---|---|---|---|---|---|
| **α-HBCDD** | 0.82 (*1.2*) | <0.5 | <0.5 | <0.5 | <0.5 | |
| **β-HBCDD** | 0.58 (*0.7*) | <0.5 | <0.5 | <0.5 | <0.5 | |
| **γ-HBCDD** | 0.31(*0.12*) | <0.5 | <0.5 | <0.5 | <0.5 | |
| **$\Sigma_3$HBCDD** | 1.7 | <1.5 | <1.5 | <1.5 | <1.5 | **1.6** |

*Yearly average (n = 4 bottle samples); in ng $L^{-1}$

### 3.1.5 Short and medium chain chlorinated paraffins (S/MCCPs)

As shown in Table 14, the concentrations of SCCPs and MCCPs below limits of quantification in all rivers except for the Alna where annual average concentrations of 53 and 50 ng $L^{-1}$ were estimated. Reported limits of quantification are in most cases due to non-negligible levels found in blanks. While there are large standard deviations associated with these estimates, estimated concentrations of SCCP remain close to an order of magnitude below WFD AA-EQS. However, SCCP concentrations for the remaining four rivers are well under AA-EQS. A slight detection of MCCPs above LOQ was observed for river Drammenselva. Estimated concentrations of MCCPs in rivers Alna and Drammenselva relatively close to the annual average threshold of 50 ng $L^{-1}$.

**Table 14. "Whole water" concentrations of S/MCCPs**

"Whole water" concentrations* of short and medium chain chlorinated paraffins in five rivers (ng $L^{-1}$) and comparison with WFD AA-EQS. Values above the AA-EQS are presented with red colour.

| Chemical | Alna | Drammenselva | Glomma | Numedalslågen | Skien | AA-EQS |
|---|---|---|---|---|---|---|
| **SCCP** | 53 (*98*) | <26 | <26 | <26 | <26 | **400** |
| **MCCP** | 50 (*65*) | 37 (*37*) | <28 | <28 | <28 | 50 |

*Yearly average (n = 4 bottle samples); in ng $L^{-1}$; Note that original WFD AA-EQS are given in bold.

### 3.1.6 Alkylphenols

Three alkyphenolic compounds were analysed for in the four water samples collected in 2017. Data are shown in Table 15. 4-n-Octylphenol and 4-n-nonylphenol were not found above limits of quantification in any of the samples including those for river Alna. Limits of quantification are two orders of magnitude below the WFD AA-EQS for 4-n-nonylphenol. The relatively high limits of quantification are the result of the quantification of 4-tert-octylphenol in one of the four blank samples. An annual average concentration of 1212 ng $L^{-1}$ was estimated for river Alna, which a factor of 10 above the AA-EQS of 100 ng $L^{-1}$. Concentrations for all other rivers were not above limits of quantification.

**Table 15. "Whole water" concentrations of alkylphenols**

"Whole water" concentrations* of nonylphenol, octylphenol and 4-tert-octylphenol in five rivers (ng $L^{-1}$) and comparison with WFD AA-EQS

| Chemical | Alna | Drammenselva | Glomma | Numedalslågen | Skien | AA-EQS |
|---|---|---|---|---|---|---|
| **Nonylphenol** | <2 | <3 | <1.3 | <3 | <1.4 | **300** |
| **Octylphenol** | <7 | <8 | <5 | <10 | <7 | |
| **4-tert-octylphenol** | 1212 (122) | <1037 | <1037 | <1037 | <1037 | **100** |

*Yearly average (standard deviation in brackets; n = 4 bottle samples); in ng $L^{-1}$; Note that original WFD AA-EQS are given in bold.

### 3.1.7 Others

The pesticide chlorfenvinphos and the biocide cybutryne were not found above limits of quantification in any of the water samples collected from the fiver rivers of interest (Table 16). For chlorfenvinfos, these limits of quantification were a factor of 50 below the WFD AA-EQS, while they were an order of magnitude lower for cybutryne. We previously were able to detect irgarol/cybutryne in River Alna at a freely dissolved concentration of about 1.4 ng $L^{-1}$ with

silicone rubber based passive sampling (Pintado-Herrera et al., 2016). For DEHP, overall limits of quantification are relatively higher due to the constant detection of DEHP in blank samples. An annual average concentration of 320 ng $L^{-1}$ was estimated for river Alna while concentrations were below 200 ng $L^{-1}$ for the remaining rivers.

**Table 16. "Whole water" concentrations of other selected PS**

"Whole water" concentrations* of chlorfenvinfos, cybutryne and DEHP in five rivers (ng $L^{-1}$) and comparison with WFD AA-EQS

| Chemical | Alna | Drammenselva | Glomma | Numedalslågen | Skien | AA-EQS |
|---|---|---|---|---|---|---|
| **Chlorfenvinfos** | <2 | <2 | <2 | <2 | <2 | **100** |
| **Cybutryne** | <0.3 | <2 | <0.3 | <0.3 | <0.3 | **2.5** |
| **DEHP** | 320 (410) | <187 | <190 | <190 | <190 | **1300** |

*Yearly average (standard deviation in brackets; n = 4 bottle samples); in ng $L^{-1}$; Note that original WFD AA-EQS are given in bold.

### 3.1.8 Metals

Trace metals (As, Cd, Cr, Cu, Hg, Ni, Pb and Zn) were sampled four times a year in the Rivers Alna, Drammenselva, Glomma, Numedalslågen and Skienselva. For the purpose of comparison with WFD AA-EQS, filtered concentrations (0.45 μm) were measured. Estimates of annual average concentrations were calculated from these four datapoints and are compared with WFD AA-EQS values in Figure 3. Estimates of annual average concentrations of As, Cd, Cr, Cu, Ni, Pb and Zn in the Rivers Drammen, Glomma, Numedalslågen and Skienselva are below proposed AA-EQS values. For elements such as As and Zn, concentrations are slightly closer to EQS than for the other elements. For Cd, Cr, Cu, Ni and Pb, filtered concentrations are approximately an order of magnitude below AA-EQS values. For the River Alna, filtered concentrations of As, Cu, Cr and Zn are substantially higher and more variable than for the samples from the other rivers. They are also close to or above AA-EQS values. For Cd, Ni and Pb, filtered concentrations are closer to those found in in the other rivers. Estimates of annual average filtered concentrations of Hg were well below the EQS of 47 ng $L^{-1}$. Some of the samples from the Rivers Alna and Drammen were above LOQ. Much of the data from the other rivers was below the LOQ of 1 ng $L^{-1}$.

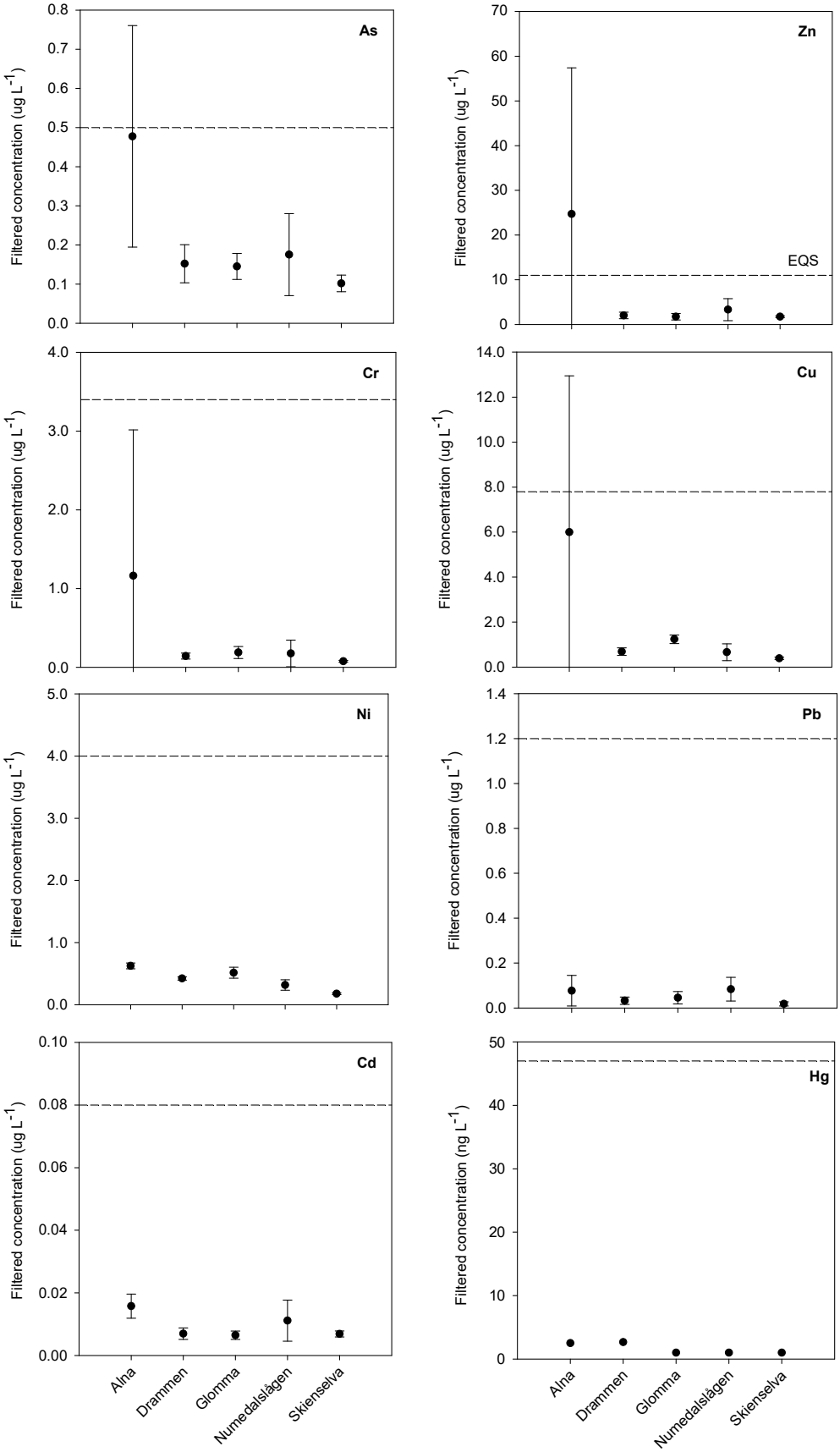


*Figure 3.* Annual average filtered metal concentrations (and standard deviation, n=4) in five rivers. The dotted reference line represents the AA-EQS for specific elements. For Hg, note that the unit is ng $L^{-1}$ and datapoints for the last three rivers represent the LOQ at 1 ng $L^{-1}$.

### 3.1.9 Yearly discharge of selected chemicals for the Alna, Drammenselva, Glomma, Numedalslågen and Skienselva for 2017

Yearly fluxes or discharges were estimated for these five rivers based on bottle sampling conducted four times in 2017, and data for selected chemicals or classes of chemicals are shown in Table 17. The estimate of yearly discharge of 16 U EPA PAHs of 4.8 kg in 2017 is relatively close to the value of 2.1 kg estimated for 2016 (Skarbovik et al., 2016). A slightly larger difference in yearly fluxes of PAHs was observed for rivers Drammenselva and Glomma with lower fluxes found in 2017 than in 2016. Yearly discharges of 7 indicator PCB congeners could not be estimated for 2017. Fluxes are likely to be lower than 235 g $y^{-1}$ for river Alna and lower than 83 and 188 kg $y^{-1}$ for rivers Drammenselva and Glomma, respectively. Estimates for these three rivers for 2016 were 8-10, 700-1200 and 2100-2900 g $y^{-1}$. Detailed fluxes are given in Tables A1 to A7 in Appendix 6.2.

**Table 17. Estimates of yearly discharge of selected chemicals or sets of chemicals in five rivers for 2017**

| Chemical | Alna | Drammenselva | Glomma | Numedalslågen | Skien |
|---|---|---|---|---|---|
| $\Sigma_{16}$PAHs | 4847 | 65-88 | 128-186 | 27-31 | 294-297 |
| Pentachlorobenzene | <24 | <2.4 | <5.4 | <0.76 | <2.5 |
| Hexachlorobenzene | 9.6 | <3.0 | <5.4 | <0.76 | <2.5 |
| γ-HCH | <59 | <12 | <27 | <3.8 | <13 |
| *p,p'*-DDE | <67 | <24 | <54 | <7.5 | <25 |
| *p,p'*-DDT | <235 | <83 | <188 | <27 | <87 |
| $\Sigma_7$PCBs | <235 | <83 | <188 | <26 | <87 |

*Data in g/year for River Alna and kg/year for the other rivers; Considering the relative standard deviations of estimates of annual average concentrations of individual chemicals that span 50-180 %, the uncertainty in the fluxes reported here to be a factor of 2-3.

## 3.2 EU WFD Priority substances and other relevant chemicals in fish from 5 rivers

Fish (*Salmo trutta* or *Salmo salar* in most cases) were sampled from each of the five rivers. The data reported below are for triplicate whole fish composite samples (except for Snarumselva for which samples comprises pooled liver and muscle samples).

Table 18 shows the whole fish concentrations measured for organochlorinated compounds. Pentachlorobenzene was not found in any fish from the five rivers with LOQs a factor of 10 below $EQS_{biota}$. Hexachlorobenzene was found at concentrations ranging from 0.16 to 0.61 ng $g^{-1}$ ww in whole fish, aver an order of magnitude below $EQS_{biota}$. The sum of concentrations for the seven indicator PCBs were in the range 0.83-2.25 ng $g^{-1}$ ww. These values are above the proposed $EQS_{biota}$ of 0.6 ng $g^{-1}$ ww for $\Sigma_7$PCBs. Although it is not appropriate to compare nonpolar non-ionized organic chemical concentrations in fish from different rivers without at least a

normalisation to the lipid content of the samples, in general it can be observed that the concentration DDTs in fish from Stryneelva are a factor of 10-20 higher than for fish from the other rivers. This is substantially more than what could be explained by differences in lipid content of the fish and possibly indicates a source of DDTs to that river. Values remain well below the proposed human health based $EQS_{biota}$ of 610 ng total-DDT/g fish[19]

**Table 18. Concentrations of polychlorinated biphenyls and other chlorinated organic compounds in fish from five rivers**

| Chemical | Stryneelva | Stjørdalselva | Eidselva | Reisa | Snarumselva | $EQS_{biota}$ |
|---|---|---|---|---|---|---|
| **Pentachlorobenzene** | <3 | <3 | <3 | <3 | <0.7 | 50 |
| **Hexachlorobenzene** | 0.47 (0.04) | 0.27 (0.06) | 0.61 (0.27) | 0.41 (0.07) | 0.16 (0.04) | 10 |
| **γ-HCH** | <3 | <3 | <3 | <3 | <0.6 | 61 |
| **PCB28/31** | <0.5 | <0.5 | <0.5 | <0.5 | <0.1 | |
| **PCB52** | <0.1 | <0.10 | 0.09 (0.04) | <0.10 | 0.06 (0.02) | |
| **PCB101** | 0.19 (0.05) | 0.13 (0.02) | 0.21 (0.11) | <0.10 | 0.11 (0.06) | |
| **PCB118** | 0.16 (0.06) | 0.11 (0.02) | 0.22 (0.12) | 0.07 (0.04) | 0.16 (0.09) | |
| **PCB153** | 0.69 (0.25) | 0.40 (0.07) | 0.79 (0.41) | 0.20 (0.04) | 0.37 (0.17) | |
| **PCB138** | 0.41 (0.17) | 0.25 (0.07) | 0.43 (0.23) | 0.13 (0.02) | 0.22 (0.09) | |
| **PCB180** | 0.27 (0.08) | 0.15 (0.04) | 0.26 (0.11) | <0.10 | 0.13 (0.017) | |
| **$\Sigma_7$PCBs** | 2.0 (0.60) | 1.4 (0.22) | 2.3 (1.0) | 0.83 (0.05) | 1.1 (0.47) | 0.6 |
| ***p,p'*-DDE** | 11.3 (3.0) | 0.72 (0.16) | 1.8 (1.0) | 0.27 (0.06) | 0.37 (0.11) | |
| ***p,p'*-DDD** | 1.0 (0.2) | <0.2 | 0.13 (0.06) | <0.2 | 0.37 (0.11) | |
| ***p,p'*-DDT** | 4.2 (1.7) | <0.5 | 0.38 (0.22) | <0.5 | <0.2 | |
| **$\Sigma_3$DDTs** | 16.5 (4.2) | 1.1 (0.16) | 2.3 (1.3) | 0.62 (0.06) | 0.55 (0.13) | |

*Data shown as the average (and standard deviation in brackets, n = 3) of contaminant measurements in triplicate composite whole fish samples expressed in ng $g^{-1}$ wet weight.

The results of the monitoring of brominated flame retardants in fish from the five selected rivers is presented in Table 19. A comparison with $EQS_{biota}$ is shown for the sums of PBDE congeners and HBCDD isomers. The $\Sigma_5$PBDEs ranging from 0.07 ng $g^{-1}$ ww for fish from Reisa to 0.42 ng $g^{-1}$ ww for Eidselva is above the $EQS_{biota}$ of 0.0085 ng $g^{-1}$ ww for all rivers. The sum of concentrations of HBCDD isomers is over two orders of magnitude below $EQS_{biota}$. These results are similar to those found in other countries. PBDE concentrations in fish from the German specimen bank (1995-2014) were all above $EQS_{biota}$ while those for HBCDD were mostly below $EQS_{biota}$ (Fliedner et al., 2016). In the data reviewed by Eljarrat and Barcelo (2018), most PBDE

[19] http://www.miljodirektoratet.no/Documents/publikasjoner/M241/M241.pdf

concentrations in European and North American fish exceeded the WFD EQS. Comparatively, a much lower number of exceedances were found for HBCDD.

**Table 19. Concentrations of brominated flame retardants compounds in fish from five rivers**

| Chemical | Stryneelva | Stjørdalselva | Eidselva | Reisa | Snarumselva | $EQS_{biota}$ |
|---|---|---|---|---|---|---|
| **PBDE28** | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | |
| **PBDE47** | 0.047 (0.012) | 0.043 (0.015) | 0.11 (0.10) | 0.023 (0.006) | 0.039 (0014) | |
| **PBDE100** | 0.033 (0.006) | 0.03 (0.00) | 0.063 (0.032) | 0.01 (0.00) | 0.019 (0.008) | |
| **PBDE99** | 0.25 (0.24) | 0.14 (0.03) | 0.17 (0.10) | <0.05 | 0.15 (0.02) | |
| **PBDE126** | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | |
| **PBDE154** | 0.027 (0.012) | 0.017 (0.006) | 0.043 (0.032) | <0.01 | 0.007 (0.003) | |
| **PBDE153** | 0.023 (0.006) | 0.020(0.00) | 0.037 (0.021) | <0.01 | 0.007 (0.003) | |
| **PBDE183** | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | |
| **$\Sigma_5$PBDEs** | 0.38 (0.22) | 0.25 (0.04) | 0.42 (0.29) | 0.07 (0.01) | 0.22 (0.04) | 0.0085 |
| **α-HBCDD** | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 | |
| **β-HBCDD** | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 | |
| **γ-HBCDD** | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 | |
| **$\Sigma_3$HBCDD** | <1.5 | <1.5 | <1.5 | <1.5 | <1.5 | 167 |

*Data shown as the average (and standard deviation given in brackets; n = 3) of contaminant measurements in triplicate composite whole fish samples expressed in ng $g^{-1}$ wet weight.

As shown in Table 20, the concentrations of short and medium chain chlorinated paraffins in brown trout from the five selected rivers are well below $EQS_{biota}$.

**Table 20. Concentrations of short and medium chain chlorinated paraffins in fish from five rivers**

| Chemical | Stryneelva | Stjørdalselva | Eidselva | Reisa | Snarumselva | $EQS_{biota}$ |
|---|---|---|---|---|---|---|
| **SCCP** | 44 (27) | 38 (6) | 34 (2) | 19 (1.5) | 33 (36) | 6000 |
| **MCCP** | 21 (23) | 26 (18) | 12 (3) | 15 (5) | 33 (13) | 170 |

*Data shown as the average (and standard deviation given in brackets, n = 3) of contaminant measurements in triplicate composite whole fish samples expressed in ng $g^{-1}$ wet weight.

Concentrations of selected alkylphenols and DEHP are reported in the table below (Table 21). No 4-n-octylphenol or 4-n-nonylphenol could be found above LOQ in any of the fish samples from the five selected rivers. For 4-n-nonylphenol, LOQs are at least two orders of magnitude below $EQS_{biota}$ of 3000 ng $g^{-1}$ ww. The limit of quantification for 4-tert-octylphenol is set relatively high (350 ng $g^{-1}$ ww), most likely as a result of blank and contamination problems during sample preparation. LOQs are therefore very high particularly considering the proposed $EQS_{biota}$ of 0.004 ng $g^{-1}$ ww. Only the data for fish from Snarumselva are above LOQ and five orders of magnitude above $EQS_{biota}$.

| Table 21. Concentrations of alkylphenols and DEHP in fish from five rivers | | | | | | |
|---|---|---|---|---|---|---|
| **Chemical** | **Stryneelva** | **Stjørdalselva** | **Eidselva** | **Reisa** | **Snarumselva** | **$EQS_{biota}$** |
| **4-n-octylphenol** | <2 | <2 | <2 | <2 | <2 | |
| **4-n-nonylphenol** | <8 | <13 | <21 | <15 | <8 | 3000 |
| **4-tert-octylphenol** | <350 | <350 | <350 | <350 | 466 (45) | 0.004 |
| **DEHP** | <40 | 47 (47) | 48 (30 | <40 | <30 | 2900 |

*Data shown as the average (and standard deviation in brackets, n = 3) of contaminant measurements in triplicate composite whole fish samples expressed in ng $g^{-1}$ wet weight.

# 3.3 Emerging contaminants in River Alna

Emerging contaminants including a series of UV filters, organophosphorus flame retardants, bisphenols and perfluoro chemicals were quantified in a range of matrices from river Alna. These included composite water samples, suspended particulate matter samples (SPM), periphyton/moss and brown trout (*Salmo trutta*).

## 3.3.1 Stable isotopes

Results of the stable isotope analysis is presented in Figure 4. Stable isotopes of carbon and nitrogen are useful indicators of food origin and trophic level for organisms in freshwater or marine environments. $\delta^{13}C$ (and to a lesser extent $\delta^{15}N$) provides an indication of carbon source in the diet of a food web. $\delta^{15}N$ has been shown to increase in organisms of higher trophic levels because of greater retention of the heavier isotope, with an expected increase of 3-5 ‰ per trophic level (Layman et al., 2012; Post, 2002). $\delta^{13}C$ tends to have more negative values for land-based/allochthonous carbon/energy sources. As shown on Figure 4, these values range from -39 to -25 and as expected correspond primarily to land-based energy sources. As an example, $\delta^{13}C$ for a marine/Oslo fjord foodweb exhibit lower values, ranging from -16 to -22 (Ruus et al., 2016). It should be noted that the C/N ratios for most samples were >3.5 indicating the presence of lipids which can affect the interpretation of $\delta^{13}C$ results (lipids are depleted in $^{13}C$ isotope relative to proteins). A calculation of trophic level (TL) for brown trout indicates a TL of 2.2. The TL for benthic invertebrates was 1.2.

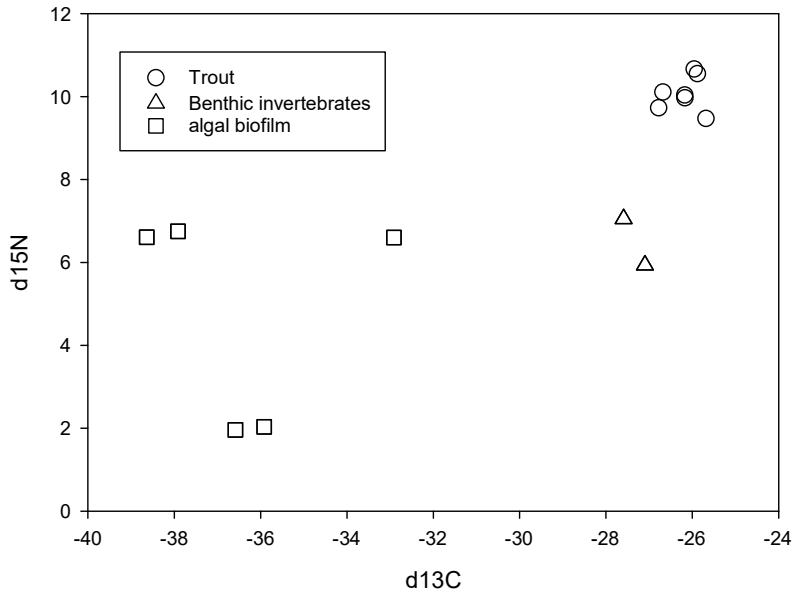


*Figure 4.* $\delta^{13}C$ plotted against $\delta^{15}N$ in algal biofilm, benthic invertebrates, and trout from river Alna.

### 3.3.2 UV filters in River Alna

All substances were found well above LOQs in the two SPM samples. OC was found in highest concentrations. Most of these substances are relatively hydrophobic and distribute favourably to particulate organic carbon. In past studies, substances such as BP3 and OC were also quantified at concentrations of hundreds of ng per litre in River Alna (Pintado-Herrera et al., 2016).

Results from automated composite water sampling (with ISCO autonomous sampling unit) and SPM sampling are provided in Table 22. Composite water sampling is not necessarily ideal for sampling of certain UV filters. Because of the sampling process with the automated sampler, there is generally more manipulation of the water samples than with one grab sample, and hence more possibilities of contact of the water being sampled with plastic tubing and other parts of the automated sampling unit resulting in contamination. Limits of quantification are set relatively high for certain compounds because of blank issues. BP3 and UV-328 were found above LOQ at concentrations in the range 1-3 ng $L^{-1}$.

**Table 22. UV filter concentrations in water and suspended particulate matter of the River Alna**

| Chemical | Abbreviation | Water concentration (ng/L) | | SPM concentration (ng/g dry weight) | |
|---|---|---|---|---|---|
| | | Sample 1 | Sample 2 | Sample 1 | Sample 2 |
| Benzophenone | BP3 | <7 | 2.5 | 17 | 18 |
| 2-ethyl-hexyl-4-trimethoxycinnamate | EHMC | <9 | <15 | 54 | 54 |
| Octocrylene | OC | <24 | <651 | 1280 | 1305 |
| 2-(2'-Hydroxy-3',5'-di-tert-butylphenyl)-5-chlorobenzotriazole | UV-327 | <1 | <2 | 23 | 17 |
| 2-(2H-Benzotriazol-2-yl)-4,6- ditert pentylphenol | UV-328 | 1.0 | 1.9 | 53 | 39 |
| 2-(2'-hydroxy-5'-tert-octyllphenyl)benzotriazole | UV-329 | <0.5 | <2 | 6.5 | 7.0 |

As shown in the table below (Table 23), only UV-327 was found in benthic organisms in River Alna. A more consistent detection of all UV filter can be observed for periphyton/moss samples. The relative concentrations (or distribution) of these UV filters are similar to those found in SPM samples (Table 22). This is perhaps not surprising since it was difficult to sample periphyton and avoid or remove associated SPM. So, it remains difficult to be certain these chemicals were indeed sorbed to periphyton or associated with SPM within the samples.

**Table 23. UV filter concentrations in lower trophic organisms sampled in River Alna**

| Chemical | Benthic macroinvertebrate concentration (ng $g^{-1}$ ww)[a] | Benthic macroinvertebrate concentration (ng $g^{-1}$ ww)[b] | Moss and periphyton concentration (ng $g^{-1}$ ww)[c] | Moss and periphyton concentration (ng $g^{-1}$ ww)[d] | Moss/periphyton concentration (ng $g^{-1}$ ww)[e] |
|---|---|---|---|---|---|
| BP3 | <7 | <2 | 4.2 | 3.4 | 3.4 |
| EHMC | <13 | <5 | <10 | <10 | 17.4 |
| OC | <13 | <5 | <240 | <200 | 628 |
| UV-327 | 1.7 | 0.67 | 3.4 | 2.3 | 6.1 |
| UV-328 | <2 | <1 | 14 | 7.4 | 17.7 |
| UV-329 | <2 | <1 | <3 | <3 | <3 |

[a]Composite sample (oligochaete); [b]Composite sample (Asellus, mayfly, ephmeroptera…); [c]Periphyton and moss sampled at the RID sampling location; [d]Mean of two samples of periphyton and moss sampled at Station 2 ("Bring Alfaset"); [e]Mean of two samples of moss sampled at Station 3 (Fossumbekken)

As shown in Table 24, BP3, EHMC and OC were not found above LOQ in whole fish or fillet/muscle samples from the two sampling events. This is despite being found in SPM samples collected at the RID monitoring station. These compounds have logP values above 3 and have been shown to accumulate in fish (Gago-Ferrero et al., 2015). The authors concluded from biota-sediment accumulation factors, that levels of excretion were low and favoured

bioaccumulation. UV-327, UV-328 and UV-329 were more consistently found at sub ng $g^{-1}$ wet weight in whole fish and muscle samples.

**Table 24. UV filter concentrations in brown trout (muscle/liver and whole fish) sampled in River Alna in May and September 2017**

| Chemical | Abbreviation | May 2017 | | September 2017 | |
|---|---|---|---|---|---|
| | | Whole fish conc. (ng $g^{-1}$ ww) | Muscle/liver conc. (ng $g^{-1}$ ww)[a] | Whole fish conc. (ng $g^{-1}$ ww) | Muscle/liver conc. (ng $g^{-1}$ ww)[b] |
| **Benzophenone** | BP3 | <1 | <0.5 | <4 | <1 |
| **2-ethyl-hexyl-4-trimethoxycinnamate** | EHMC | <3 | <2 | <4 | <3 |
| **Octocrylene** | OC | <6 | <4 | <4 | <4 |
| **2-(2'-Hydroxy-3',5'-di-tert-butylphenyl)-5-chlorobenzotriazole** | UV-327 | <0.4 | <0.3 | 0.3 | 0.4 (0.3) |
| **2-(2H-Benzotriazol-2-yl)-4,6- ditert pentylphenol** | UV-328 | 0.7 | 0.44 | 0.7 | 0.48 (0.19) |
| **2-(2'-hydroxy-5'-tert-octyllphenyl)benzotriazole** | UV-329 | <0.5 | <0.4 | <0.7 | <0.5 |

[a]Mean of two samples; [b]Mean of 7 samples and standard deviation give in brackets

### 3.3.3 Organophosphorus compounds in the River Alna

Table 25 shows that slightly more organophosphorus compounds could be seen in SPM samples than in composite water samples. One issue with composite water sampling with the ISCO sampler was the level of contamination in the blanks. The two blank samples were relatively similar both in terms of identity and concentration. Highest concentrations in the blanks were for TCPP (180 and 285 ng $L^{-1}$), TEP (107 and 167 ng $L^{-1}$), TCEP (19 and 23 ng $L^{-1}$), DBPhP (5.5 and 6.7 ng $L^{-1}$), TnBP (2.9 and 3 ng $L^{-1}$) and EHDP (3.8 and 4.8 ng $L^{-1}$). This blank issue affected the measurements of TCPP in composite water samples. TCPP was in highest amounts in SPM (239 and 274 ng $g^{-1}$ dw). Compounds consistently detected in both matrices included TEP, TiBP, TnBP, and TBEP. TCEP, TCPP, sum TCP and TEHP were consistently detected in sediment and to a lesser extent in water sample. Other compounds such as TPrP, BdPhP, TXP, TIPP, TTBPP and TEHP were not detected in any of the composite water or SPM samples.

**Table 25. Organophosphorus flame retardant concentrations in water and suspended particulate matter of the River Alna**

| Chemical | Abbreviation | Water concentration (ng/L) | | SPM concentration (ng/g dry weight) | |
|---|---|---|---|---|---|
| | | Sample 1 | Sample 2 | Sample 1 | Sample 2 |
| Tri ethylphosphate | TEP | 738 | 475 | 87 | 38 |
| Tri(2-chloroethyl)phosphate | TCEP | 78 | <70 | 3.7 | 3.3 |
| Tripropylphosphate | TPrP | <0.2 | <0.2 | <0.01 | <0.02 |
| tri(1-chloro-2-propyl)phosphate | TCPP | <855 | <541 | 239 | 274 |
| Tri-iso-butylphosphate | TiBP | 12 | 10 | 1.3 | 1.1 |
| Butyl diphenylphosphate dibutylphenylphosphate | BdPhP | <0.03 | <0.03 | <0.03 | <0.01 |
| Triphenylphosphate | TPP | <0.05 | <0.05 | 123 | <0.02 |
| Dibutyl phenyl phosphate | DBPhP | <17 | <21 | <0.01 | 38 |
| Tri-n-butyphosphate | TnBP | 12 | 9.6 | 1.7 | 1.5 |
| tri(1,3-dichloro-2-propyl)phosphate | TDCPP | 21 | 11 | <0.02 | 7.0 |
| tri(2-butoxyethyl)phosphate | TBEP | 200 | 145 | 436 | 415 |
| Tricresylphosphate | SumTCP | <0.1 | <0.1 | 25 | 38 |
| 2-ethylhexyl-diphenyl phosphate | EHDP | <0.4 | 11 | 25 | 51 |
| Trixilylphosphate | TXP | <0.14 | <0.14 | <0.02 | <0.06 |
| tris(isopropylphenyl) phosphate isomers | TIPPP | <0.03 | <0.03 | <0.01 | <0.01 |
| tris(p-tert-butylphenyl) phosphate | TTBPP | <0.04 | <0.04 | <0.02 | <0.02 |
| tris(2-ethylhexyl) phosphate | TEHP | <0.10 | <0.1 | 463 | 494 |

The contamination picture from the analysis of lower trophic organisms (periphyton and benthic macroinvertebrates) shows a generally similar picture of contamination (Table 26). TCPP, TiBP, DBPhP, TnBP, TDCPP, TBEP, sumTCP, EHDP and TEHP were consistently detected both in benthic invertebrates and periphyton in concentrations ranging from < 1 ng $g^{-1}$ ww to 50 ng $g^{-1}$ ww. Concentrations of many organophosphorus compounds are higher in periphyton samples than in macroinvertebrate samples (on a wet weight basis). TXP was only detected in periphyton samples. There are wide variations in concentrations in the different periphyton samples. For example, the concentration on a wet weight basis for TCPP varies by an order of magnitude between the different samples. As mentioned above for the UV filters, it was difficult to separate the periphyton from the associated sediment. The relative distribution of organophosphorus compounds in the periphyton samples appear similar to those in suspended particulate matter samples in Table 25.

**Table 26. Organophosphorus flame retardant concentrations in lower trophic organisms sampled in River Alna in September 2017**

| Chemical | Benthic macroinvertebrate concentration (ng $g^{-1}$ ww)[a] | Benthic macroinvertebrate concentration (ng $g^{-1}$ ww)[b] | Moss and periphyton concentration (ng $g^{-1}$ ww)[c] | Moss and periphyton concentration (ng $g^{-1}$ ww)[d] | Moss and periphyton concentration (ng $g^{-1}$ ww)[e] |
|---|---|---|---|---|---|
| TEP | <0.1 | <0.1 | 12 | 0.7 | 12.0 |
| TCEP | <0.1 | <0.1 | 1.4 | 0.3 | 0.4 |
| TPrP | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| TCPP | 7.9 | 2.8 | 88 | 9.1 | 29.1 |
| TiBP | 0.7 | 2.6 | 0.5 | 0.4 | 0.3 |
| BdPhP | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| TPP | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| DBPhP | 5.3 | 4.0 | 29.0 | 4.2 | 5.9 |
| TnBP | 1.1 | 1.1 | 1.1 | 0.6 | 0.5 |
| TDCPP | 1.9 | 1.3 | 1.8 | 1.3 | 1.5 |
| TBEP | 5.0 | 4.3 | 35 | 6.0 | 24 |
| SumTCP | 5.0 | 2.9 | 24.0 | 6.1 | 9.9 |
| EHDP | 8.9 | 10 | 21 | 11 | 16 |
| TXP | <0.02 | <0.02 | 8.8 | 2.4 | 3.8 |
| TIPPP | <0.02 | <0.02 | <0.02 | <0.02 | <0.02 |
| TTBPP | <0.02 | 18.1 | <0.02 | <0.02 | <0.02 |
| TEHP | 14 | 5.7 | 55 | 47 | 38 |

[a]Composite sample (oligochaete); [b]Composite sample (Asellus, mayfly, ephmeroptera…); [c]Periphyton and moss sampled at the RID sampling location; [d]Mean of two samples of periphyton and moss sampled at Station 2 ("Bring Alfaset"); [e]Mean of two samples of moss sampled at Station 3 (Fossumbekken)

The concentrations of organophosphorus compounds in whole fish and muscle samples of brown trout from River Alna are shown in Table 27. TCPP, TnBP, sumTCP, and EHDP were consistently detected in all fish samples analysed. TEP was only detected in muscle samples. Notably, while TPP was not detected in other samples, it was consistently found in fish samples.

**Table 27. Organophosphorus flame retardant concentrations in brown trout (muscle and whole fish) sampled in River Alna in May and September 2017**

| Chemical | Abbreviation | May 2017 | | September 2017 | |
|---|---|---|---|---|---|
| | | Whole fish conc. (ng $g^{-1}$ ww) | Muscle/liver conc. (ng $g^{-1}$ ww)[a] | Whole fish conc. (ng $g^{-1}$ ww) | Muscle/liver conc. (ng $g^{-1}$ ww)[b] |
| Tri ethylphosphate | TEP | <0.12 | 0.12 | <0.12 | 0.13 (0.04) |
| Tri(2-chloroethyl) phosphate | TCEP | <0.01 | <0.04 | <0.01 | <0.04 |
| Tripropylphosphate | TPrP | <0.01 | <0.01 | <0.01 | <0.01 |
| tri(1-chloro-2-propyl)phosphate | TCPP | 0.72 | 0.31 | 0.33 | 0.25 (0.07) |
| Tri-iso-butylphosphate | TiBP | <0.2 | <0.2 | <0.2 | <0.2 |
| Butyl diphenylphosphate dibutylphenylphospha te | BdPhP | <0.01 | <0.01 | <0.01 | <0.01 |
| Triphenylphosphate | TPP | 1.49 | 1.0 | 3.6 | 3.1 (1.0) |
| Dibutyl phenyl phosphate | DBPhP | <0.01 | <0.01 | <0.01 | <0.01 |
| Tri-n-butyphosphate | TnBP | 0.20 | 0.14 | 0.18 | 0.13 |
| tri(1,3-dichloro-2-propyl)phosphate | TDCPP | <0.12 | <0.12 | <0.12 | <0.12 |
| tri(2-butoxyethyl)phosphat e | TBEP | 0.18 | 0.11 | 0.14 | <0.2 |
| Tricresylphosphate | SumTCP | 0.18 | 0.11 | 0.29 | 0.17 (0.04) |
| 2-ethylhexyl-diphenyl phosphate | EHDP | 3.4 | 0.94 | 1.5 | 0.70 (0.2) |
| Trixilylphosphate | TXP | <0.01 | <0.01 | <0.01 | <0.01 |
| tris(isopropylphenyl) phosphate isomers | TIPPP | <0.01 | <0.01 | <0.01 | <0.01 |
| tris(p-tert-butylphenyl) phosphate | TTBPP | <0.01 | <0.01 | <0.01 | 0.015 (0.01) |
| tris(2-ethylhexyl) phosphate | TEHP | 0.14 | <0.05 | <0.1 | <0.05 |

[a]Mean of two samples; [b]Mean of 7 samples and standard deviation give in brackets

### 3.3.4 Bisphenols in River Alna

The concentration of a wide range of bisphenols in composite water samples and SPM from the River Alna are given in Table 28. BPA was not found above LOQ in water samples but was detected in both SPM samples. No other bisphenols were found above LOQs in water samples. A few bisphenols were detected in the first SPM (4,4', BPA, 4,4'-BPS, 2,2'-BPF, 2,4'-BPF, and 4,4'-BPF). Most bisphenols, except for BPE were found above LOQ in the second SPM sample.

**Table 28. Bisphenol concentrations in water and suspended particulate matter of the River Alna**

| Chemical | Water concentration (ng/L) | | SPM concentration (ng/g dry weight) | |
|---|---|---|---|---|
| | Sample 1 | Sample 2 | Sample 1 | Sample 2 |
| ***2,4'*-BPA** | <6 | <6 | <3.5 | 244 |
| ***4,4'*-BPA** | <219 | <288 | 216 | 305 |
| ***2,4'*-BPS** | <2 | <2 | <3.5 | 3.7 |
| ***4,4'*-BPS** | <19 | <18 | 1.1 | 4.9 |
| ***2,2'*-BPF** | <4 | <2 | 5.0 | 6.7 |
| ***2,4'*-BPF** | <11 | <23 | 22 | 42 |
| ***4,4'*-BPF** | <8 | <20 | 14 | 49 |
| **BP-AF** | <1 | <1 | <3.5 | 2.0 |
| **BP-AP** | <3 | <2 | <1.6 | 4.6 |
| **BPB** | <4 | <4 | <3.2 | 0.97 |
| **BPE** | <49 | <107 | <3.5 | <18 |
| **BP-FL** | <7.7 | <6 | <1.7 | 2.3 |
| **BPM** | <1 | <1 | <3.3 | 2.5 |
| **BPZ** | <2 | <7 | <8.8 | 4.7 |

The concentration of bisphenols in benthic macroinvertebrates and periphyton are presented in Table 29. The data from these matrices are relatively variable with some compounds found above LOQ in some samples and not others. BPA (4,4'-BPA) was consistently found in all samples with concentrations in the range 1-23 ng $g^{-1}$ wet weight. Other bisphenols such as 4,4'-BPS, 2,4'BPF, and 4,4'-BPF were also found in higher amounts than other bisphenols in these lower trophic level samples. This is consistent with the SPM data above.

**Table 29. Bisphenol concentrations in lower trophic organisms sampled in River Alna in September 2017**

| Chemical | Benthic macroinvertebrate concentration (ng $g^{-1}$ ww)[a] | Benthic macroinvertebrate concentration (ng $g^{-1}$ ww)[b] | Moss and periphyton concentration (ng $g^{-1}$ ww)[c] | Moss and periphyton concentration (ng $g^{-1}$ ww)[d] | Moss and periphyton concentration (ng $g^{-1}$ ww)[e] |
|---|---|---|---|---|---|
| ***2,4'*-BPA** | <2 | 7.9 | <2 | 5.9 | 3.8 |
| ***4,4'*-BPA** | 5.3 | 23 | 1.0 | 19 | 13 |
| ***2,4'*-BPS** | <0.3 | <3 | <0.7 | <3 | <2 |
| ***4,4'*-BPS** | 1.7 | 4.4 | <0.8 | 3.8 | 2.3 |
| ***2,2'*-BPF** | 2.5 | <0.7 | <0.2 | <0.7 | 0.3 |
| ***2,4'*-BPF** | 15.6 | 2.5 | <0.8 | 2.7 | 3.2 |
| ***4,4'*-BPF** | 14.0 | 2.0 | <0.6 | 2.6 | 2.2 |
| **BP-AF** | <0.3 | 1.6 | <1.1 | 1.4 | 1.0 |
| **BP-AP** | <1.3 | 0.2 | <0.2 | 0.1 | 0.1 |
| **BPB** | <3 | <2 | <1.4 | <1.6 | <1.4 |
| **BPE** | <10 | <18 | <21 | <18 | <14 |
| **BP-FL** | <0.6 | 0.4 | <0.5 | <0.4 | <0.5 |
| **BPM** | <1.2 | 0.9 | <0.2 | 0.5 | 0.8 |
| **BPZ** | <4 | <8 | <5 | <8 | <6 |

[a]Composite sample (oligochaete); [b]Composite sample (Asellus, mayfly, ephmeroptera…); [c]Periphyton and moss sampled at the RID sampling location; [d]Mean of two samples of periphyton and moss sampled at Station 2 ("Bring Alfaset"); [e]Mean of two samples of moss sampled at Station 3 (Fossumbekken)

The table below (Table 30) shows the bisphenol concentrations in whole fish and muscle samples of brown trout from the river Alna. No bisphenols were found above LOQ in whole fish samples collected during the two sampling periods. A similar set of bisphenols were found above LOQ in fish muscle as in benthic invertebrates and periphyton. It is not clear at present why this is the case. For the samples from May 2017, LOQs for whole fish analyses are close to bisphenol concentrations measured in the muscle. In general, these differences could be the result of extracting different equivalent masses of lipids. It could be that the size of the fish also affects bioaccumulation, however it is difficult from this dataset to conclude. These included 4,4'-BPA, 4,4'-BPS, 2,2'-BPF, 2,4'-BPF and 4,4'-BPF. Concentrations on a wet weight basis are in the same range as those observed for benthic macroinvertebrates. The relative concentrations of these bisphenols are similar for fish brown trout muscles from sampling in May and September 2017.

**Table 30. Bisphenol concentrations in brown trout (muscle and whole fish) sampled in River Alna in May and September 2017**

| Chemical | May 2017[a] | | September 2017[b] | |
|---|---|---|---|---|
| | Whole fish concentration (ng $g^{-1}$ ww) | Muscle concentration (ng $g^{-1}$ ww)[a] | Whole fish concentration (ng $g^{-1}$ ww) | Muscle concentration (ng $g^{-1}$ ww)[b] |
| ***2,4'*-BPA** | <7 | <0.9 | <2 | <0.7 |
| ***4,4'*-BPA** | <10 | 14 | <2.3 | 8.3 (5) |
| ***2,4'*-BPS** | <0.5 | <0.4 | <0.4 | <0.4 |
| ***4,4'*-BPS** | <0.6 | 0.54 | <0.5 | 0.42 (0.3) |
| ***2,2'*-BPF** | <7 | 0.44 | <0.5 | 4.5 (10) |
| ***2,4'*-BPF** | <30 | 26 | <2 | 29 (62) |
| ***4,4'*-BPF** | <20 | 25 | <1 | 26 (58) |
| **BP-AF** | <0.4 | <0.3 | <0.6 | <0.4 |
| **BP-AP** | <4 | <0.4 | <2 | <0.5 |
| **BPB** | <7 | <1 | <3 | <0.8 |
| **BPE** | <24 | <12 | <19 | <11 |
| **BP-FL** | - | <0.2 | <0.8 | <0.2 |
| **BPM** | - | <2 | <5 | <0.4 |
| **BPZ** | <5 | <2 | <2 | <3 |

[a]Mean of two samples; [b]Mean of 7 samples and standard deviation give in brackets

### 3.3.5 PFAS in River Alna

Concentrations of PFAS compounds in composite water and SPM samples are reported in Table 31. Data from the two composite water samples are very consistent and there were no issues of blanks/contamination for PFAS compounds. The concentrations of PFAS compounds found above LOQ were in the range 0.5-4 ng $L^{-1}$. PFOS, PFOA, 6:2 FTS, PFBS, PFPS, PFHxS, PFPA, PFHxA, PFHpA, PFNA and PFDA were found above LOQ in composite water samples from the Alna. Only PFOS was measured above limits of quantification in SPM samples.

**Table 31. PFAS concentration in water and suspended particulate matter of the River Alna**

| Chemical | Abbreviation | Water concentration (ng/L) | | SPM concentration (ng/g dry weight) | |
|---|---|---|---|---|---|
| | | Sample 1 | Sample 2 | Sample 1 | Sample 2 |
| **Perfluoropentanoate** | PFPA | 3.6 | 3.1 | <0.5 | <0.5 |
| **Perfluorohexanoate** | PFHxA | 3.2 | 3.3 | <0.5 | <0.5 |
| **Perfluoroheptanoate** | PFHpA | 2.0 | 1.7 | <0.5 | <0.5 |

**Table 31. PFAS concentration in water and suspended particulate matter of the River Alna**

| Chemical | Abbreviation | Water concentration (ng/L) | | SPM concentration (ng/g dry weight) | |
|---|---|---|---|---|---|
| | | Sample 1 | Sample 2 | Sample 1 | Sample 2 |
| Perfluorooctanoate | PFOA | 2.2 | 2.1 | <0.5 | <0.5 |
| Perfluorononanoate | PFNA | 0.63 | 0.69 | <0.5 | <0.5 |
| Perfluorodecanoate | PFDA | <0.5 | <0.5 | <0.5 | <0.5 |
| Perfluoroundecanoate | PFUdA | <0.4 | <0.4 | <0.4 | <0.4 |
| Perfluorododecanoate | PFDoA | <0.4 | <0.4 | <0.4 | <0.4 |
| Perfluorotridecanoate | PFTrDA | <0.4 | <0.4 | <0.4 | <0.4 |
| Perfluorotetradecanoate | PFTeDA | <0.4 | <0.4 | <0.4 | <0.4 |
| Perfluorobutane sulfonate | PFBS | 2.0 | 1.0 | <0.1 | <0.1 |
| Perfluoropentane sulfonate | PFPS | 0.16 | 0.13 | <0.1 | <0.1 |
| Perfluorohexane sulfonate | PFHxS | 0.69 | 0.65 | <0.1 | <0.1 |
| Perfluoroheptane sulfonate | PFHpS | <0.1 | <0.1 | <0.1 | <0.1 |
| Perfluorooctane sulfonate | PFOS | 3.5 | 3.3 | 0.42 | 0.46 |
| 8Cl-perfluorooctane sulfonate | 8Cl-PFOS | <0.2 | <0.2 | <0.2 | <0.2 |
| Perfluorononane sulfonate | PFNS | <0.2 | <0.2 | <0.2 | <0.2 |
| Perfluorodecane sulfonate | PFDS | <0.2 | <0.2 | <0.2 | <0.2 |
| Perfluorododecane sulfonate | PFDoS | <0.2 | <0.2 | <0.2 | <0.2 |
| Perfluorooctane sulphonamide | PFOSA | <0.1 | <0.1 | <0.1 | <0.1 |
| N-Methyl fluorooctane sulfonate | meFOSA | <0.3 | <0.3 | <0.3 | <0.3 |
| N-Ethyl fluorooctane sulfonate | etFOSA | <0.3 | <0.3 | <0.3 | <0.3 |
| N-Methyl fluorooctane sulfonamidoethanol | meFOSE | <5 | <5 | <5 | <5 |
| N-Ethyl fluorooctane sulfoamidoethanol | etFOSE | <5 | <5 | <5 | <5 |
| 4:2 fluorotelomer sulfonate | 4:2 FTS | <0.3 | <0.3 | <0.3 | <0.3 |
| 6:2 fluorotelomer sulfonate | 6:2 FTS | 0.54 | 0.61 | <0.3 | <0.3 |
| 8:2 fluorotelomer sulfonate | 8:2 FTS | <0.3 | <0.3 | <0.3 | <0.3 |
| 10:2 fluorotelomer sulfonate | 10:2 FTS | <0.3 | <0.3 | <0.3 | <0.3 |

**Table 31. PFAS concentration in water and suspended particulate matter of the River Alna**

| Chemical | Abbreviation | Water concentration (ng/L) | | SPM concentration (ng/g dry weight) | |
|---|---|---|---|---|---|
| | | Sample 1 | Sample 2 | Sample 1 | Sample 2 |
| Potassium 2-(4-chloro-1,1,2,2,3,3,4,4,5,5,6,6-dodecafluorohexyloxy)-1,1,2,2-tetrafluoroethane sulfonate | 4:2 F53B | <0.3 | <0.3 | <0.3 | <0.3 |
| Potassium 2-(6-chloro-1,1,2,2,3,3,4,4,5,5,6,6-dodecafluorohexyloxy)-1,1,2,2-tetrafluoroethane sulfonate | 6:2 F53B | <0.3 | <0.3 | <0.3 | <0.3 |
| N-Ethyl perfluorooctane sulfonamido acetic acid | me-FOASAA | <0.3 | <0.3 | <0.3 | <0.3 |
| N-Ethyl perfluorooctane sulfonamido acetic acid | et-FOSAA | <0.3 | <0.3 | <0.3 | <0.3 |

Concentrations of PFAS compounds in benthic invertebrates and periphyton samples collected from the river Alna are given in the table below (Table 32). Many of the PFAS compounds are also below LOQ in these samples. Some of these chemicals, i.e. PFNA, PFDA were found only in periphyton samples. PFDoA and PFOS were the only two PFAS compounds found in most benthic invertebrate and periphyton samples. PFTrDA, PFTeDA, PFBS, PFDS, 6:2 FTS and 10:2 FTS were sparsely found in benthic invertebrates.

**Table 32. PFAS concentration in lower trophic organisms sampled in River Alna in September 2017**

| Chemical | Benthic macroinvertebrate concentration (ng $g^{-1}$ ww)[a] | Benthic macroinvertebrate concentration (ng $g^{-1}$ ww)[b] | Moss and periphyton concentration (ng $g^{-1}$ ww)[c] | Moss and periphyton concentration (ng $g^{-1}$ ww)[d] | Moss and periphyton concentration (ng $g^{-1}$ ww)[e] |
|---|---|---|---|---|---|
| PFPA | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 |
| PFHxA | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 |
| PFHpA | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 |
| PFOA | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 |
| PFNA | <0.5 | <0.5 | 0.54 | <0.5 | 0.6 |
| PFDA | <0.5 | <0.5 | 0.53 | <0.5 | 1.1 |
| PFUdA | <0.4 | <0.4 | <0.4 | <0.4 | <0.4 |
| PFDoA | 1.17 | 0.42 | 0.44 | <0.4 | 0.41 |
| PFTrDA | 1.1 | <0.4 | <0.4 | <0.4 | <0.4 |
| PFTeDA | 1.09 | <0.4 | <0.4 | <0.4 | <0.4 |
| PFBS | <0.1 | 0.18 | <0.1 | <0.1 | <0.1 |

**Table 32. PFAS concentration in lower trophic organisms sampled in River Alna in September 2017**

| Chemical | Benthic macroinvertebrate concentration (ng $g^{-1}$ ww)[a] | Benthic macroinvertebrate concentration (ng $g^{-1}$ ww)[b] | Moss and periphyton concentration (ng $g^{-1}$ ww)[c] | Moss and periphyton concentration (ng $g^{-1}$ ww)[d] | Moss and periphyton concentration (ng $g^{-1}$ ww)[e] |
|---|---|---|---|---|---|
| PFPS | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 |
| PFHxS | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 |
| PFHpS | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 |
| PFOS | 4.1 | 1.02 | 2.62 | 1.8 | 4.4 |
| 8Cl-PFOS | <0.2 | <0.2 | <0.2 | <0.2 | <0.2 |
| PFNS | <0.2 | <0.2 | <0.2 | <0.2 | <0.2 |
| PFDS | 1.07 | <0.2 | <0.2 | <0.2 | <0.2 |
| PFDoS | <0.2 | <0.2 | <0.2 | <0.2 | <0.2 |
| PFOSA | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 |
| meFOSA | <0.3 | <0.3 | <0.3 | <0.3 | <0.3 |
| etFOSA | <0.3 | <0.3 | <0.3 | <0.3 | <0.3 |
| meFOSE | <5 | <5 | <5 | <5 | <5 |
| etFOSE | <5 | <5 | <5 | <5 | <5 |
| 4:2 FTS | <0.3 | <0.3 | <0.3 | <0.3 | <0.3 |
| 6:2 FTS | 0.41 | <0.3 | <0.3 | <0.3 | <0.3 |
| 8:2 FTS | <0.3 | <0.3 | <0.3 | <0.3 | <0.3 |
| 10:2 FTS | 0.91 | <0.3 | <0.3 | <0.3 | <0.3 |
| 4:2 F53B | <0.3 | <0.3 | <0.3 | <0.3 | <0.3 |
| 6:2 F53B | <0.3 | <0.3 | <0.3 | <0.3 | <0.3 |
| me-FOASAA | <0.3 | <0.3 | <0.3 | <0.3 | <0.3 |
| et-FOSAA | <0.3 | <0.3 | <0.3 | <0.3 | <0.3 |

[a]Composite sample (oligochaete); [b]Composite sample (Asellus, mayfly, ephmeroptera…); [c]Periphyton and moss sampled at the RID sampling location; [d]Mean of two samples of periphyton and moss sampled at Station 2 ("Bring Alfaset"); [e]Mean of two samples of moss sampled at Station 3 (Fossumbekken)

PFAS concentrations in brown trout sampled in May and September 2017 are given in Table 33 and on Figure 5. For each sampling period, "whole fish" and liver concentration were obtained. Consistently more PFAS chemicals were found above LOQ in liver samples than in whole fish analyses. On a wet weight basis, concentrations are consistently higher in liver. PFOA, PFNA, PFUdA, PFHxS and PFHpS were detected in the liver samples only and with concentration generally not exceeding 2 ng $g^{-1}$ wet weight. PFDA, PFDoA, PFTrDA, PFTeDA, PFOS, PFDS and PFOSA were measured above LOQ in all fish samples. For these chemicals, liver concentrations on a wet weight basis are consistently higher than those from whole fish analyses. The highest

concentrations were observed for PFOS with concentrations of 14.2 and 13.1 ng $g^{-1}$ wet weight in whole fish samples and 39 and 144 ng $g^{-1}$ wet weight for liver samples. In general, the liver data from the two sampling events in 2017 are consistent (Figure 5).

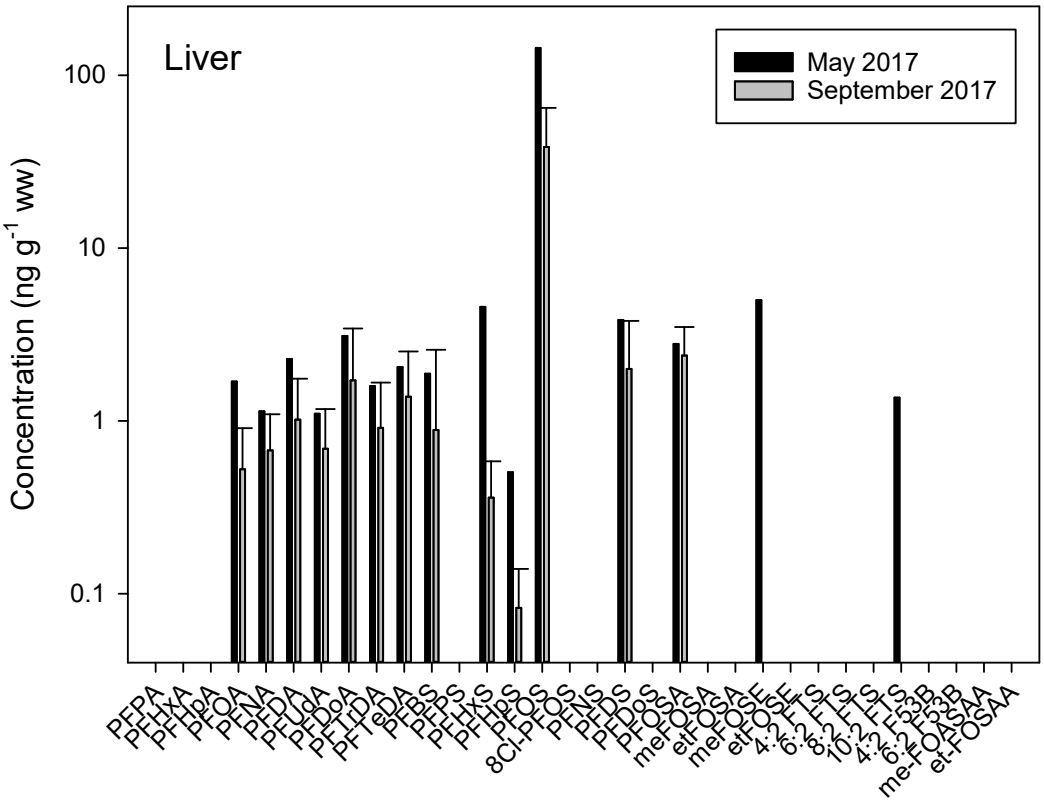


*Figure 5.* Concentrations of PFAS compounds in liver of brown trout (Salmo trutta) sampled on two occasions in 2017 in the River Alna. Note the log-scale.

**TABLE 33. PFAS concentration in brown trout (liver) sampled in River Alna in May and September 2017**

| Chemical | Abbr. | May 2017 | | September 2017 | |
|---|---|---|---|---|---|
| | | Whole fish concentration (ng $g^{-1}$ ww) | Liver concentration (ng $g^{-1}$ ww)[a] | Whole fish concentration (ng $g^{-1}$ ww) | Liver concentration (ng $g^{-1}$ ww)[b] |
| Perfluoropentanoate | PFPA | <0.5 | <0.5 | <0.5 | <0.5 |
| Perfluorohexanoate | PFHxA | <0.5 | <0.5 | <0.5 | <0.5 |
| Perfluoroheptanoate | PFHpA | <0.5 | <0.5 | <0.5 | <0.5 |
| Perfluorooctanoate | PFOA | <0.5 | 1.7 | <0.5 | 0.52 (0.4) |
| Perfluorononanoate | PFNA | <0.5 | 1.1 | <0.5 | 0.67 (0.42) |
| Perfluorodecanoate | PFDA | 0.63 | 2.3 | <0.5 | 1.0 (0.74) |
| Perfluoroundecanoate | PFUdA | <0.4 | 1.1 | <0.4 | 0.69 (0.47) |

**TABLE 33. PFAS concentration in brown trout (liver) sampled in River Alna in May and September 2017**

| Chemical | Abbr. | May 2017 | | September 2017 | |
|---|---|---|---|---|---|
| | | Whole fish concentration (ng $g^{-1}$ ww) | Liver concentration (ng $g^{-1}$ ww)[a] | Whole fish concentration (ng $g^{-1}$ ww) | Liver concentration (ng $g^{-1}$ ww)[b] |
| Perfluorododecanoate | PFDoA | 1.04 | 3.1 | 1.1 | 1.7 (1.7) |
| Perfluorotridecanoate | PFTrDA | 0.7 | 1.6 | 0.77 | 0.91 (0.75) |
| Perfluorotetradecanoate | PFTeDA | 0.65 | 2.1 | 0.88 | 1.4 (1.2) |
| Perfluorobutane sulfonate | PFBS | 7.4 | 1.9 | <0.1 | 0.89 (1.7) |
| Perfluoropentane sulfonate | PFPS | <0.1 | <0.1 | <0.1 | <0.1 |
| Perfluorohexane sulfonate | PFHxS | <0.1 | 4.6 | <0.1 | 0.36 (0.22) |
| Perfluoroheptane sulfonate | PFHpS | <0.1 | 0.51 | <0.1 | 0.083 (0.056) |
| Perfluorooctane sulfonate | PFOS | 14.2 | 144 | 13.1 | 39 (26) |
| 8Cl-perfluorooctane sulfonate | 8Cl-PFOS | <0.2 | <0.2 | <0.2 | <0.2 |
| Perfluorononane sulfonate | PFNS | <0.2 | <0.2 | <0.2 | <0.2 |
| Perfluorodecane sulfonate | PFDS | 0.57 | 3.8 | 0.75 | 2.0 (1.8) |
| Perfluorododecane sulfonate | PFDoS | <0.2 | <0.2 | <0.2 | <0.2 |
| Perfluorooctane sulphonamide | PFOSA | 1.2 | 2.8 | 0.88 | 2.4 (1.1) |
| N-Methyl fluorooctane sulfonate | meFOSA | <0.3 | <0.3 | <0.3 | <0.3 |
| N-Ethyl fluorooctane sulfonate | etFOSA | <0.3 | <0.3 | <0.3 | <0.3 |
| N-Methyl fluorooctane sulfonamidoethanol | meFOSE | <5 | <5 | <5 | <5 |
| N-Ethyl fluorooctane sulfoamidoethanol | etFOSE | <5 | <5 | <5 | <5 |
| 4:2 fluorotelomer sulfonate | 4:2 FTS | <0.3 | <0.3 | <0.3 | <0.3 |
| 6:2 fluorotelomer sulfonate | 6:2 FTS | <0.3 | <0.3 | <0.3 | <0.3 |
| 8:2 fluorotelomer sulfonate | 8:2 FTS | <0.3 | <0.3 | <0.3 | <0.3 |
| 10:2 fluorotelomer sulfonate | 10:2 FTS | <0.3 | 1.4 | 0.44 | <0.3 |
| Potassium 2-(4-chloro-1,1,2,2,3,3,4,4,5,5,6,6-dodecafluorohexyloxy)-1,1,2,2-tetrafluoroethane sulfonate | 4:2 F53B | <0.3 | <0.3 | <0.3 | <0.3 |

**TABLE 33. PFAS concentration in brown trout (liver) sampled in River Alna in May and September 2017**

| Chemical | Abbr. | May 2017 | | September 2017 | |
|---|---|---|---|---|---|
| | | Whole fish concentration (ng $g^{-1}$ ww) | Liver concentration (ng $g^{-1}$ ww)[a] | Whole fish concentration (ng $g^{-1}$ ww) | Liver concentration (ng $g^{-1}$ ww)[b] |
| **Potassium 2-(6-chloro-1,1,2,2,3,3,4,4,5,5,6,6-dodecafluorohexyloxy)-1,1,2,2-tetrafluoroethane sulfonate** | 6:2 F53B | <0.3 | <0.3 | <0.3 | <0.3 |
| **N-Ethyl perfluorooctane sulfonamido acetic acid** | me-FOASAA | <0.3 | <0.3 | <0.3 | <0.3 |
| **N-Ethyl perfluorooctane sulfonamido acetic acid** | et-FOSAA | <0.3 | <0.3 | <0.3 | <0.3 |

[a]Mean of two samples; [b]Mean of 7 samples and standard deviation give in brackets

Since it was possible to measure concentrations both in fish and in water for selected PFAS compounds, bioconcentration factors (BCF) could be estimated for brown trout (*Salmo trutta*). logBCF values for PFNA, PFBS, PFHxS and PFOS, calculated as the logarithm of the concentration in the organism (wet weight basis) divided by that in water, are presented in Table 34.

**Table 34. Bioconcentration factors for selected PFAS compounds in the River Alna**

| Chemical | Bioconcentration factor (logBCF; L $kg^{-1}$)* | | | |
|---|---|---|---|---|
| | May 2017 | | September 2017 | |
| | Whole fish | Liver | Whole fish | Liver |
| **PFNA** | - | 3.26 | - | 2.99 |
| **PFBS** | 3.67 | 3.07 | - | 2.86 |
| **PFHxS** | - | 3.82 | - | 2.74 |
| **PFOS** | 3.61 | 4.61 | 3.60 | 4.07 |

*On a wet weight basis

# 4. Conclusions

**Monitoring based on water samples in the rivers Alna, Drammenselva, Glomma, Numedalslågen and Skienselva in 2017:**

- Polycyclic aromatic hydrocarbons concentrations were the closest or above WFD AA-EQS for the sampling location on River Alna (e.g. mean value of 4 measurements above AA-EQS for fluoranthene or benzo[a]pyrene for example). Annual average estimates of concentrations for selected monitoring sites on the other rivers were low but remained close to the AA-EQS for benzo[a]pyrene.

- Most organochlorinated priority substances were below LOQ in most water samples and below AA-EQS for pentachlorobenzene and γ-HCH. The $\Sigma_7$PCBs is below LOQ but the sum of LOQs is significantly higher than the proposed AA-EQS of 0.0024 ng $L^{-1}$.
- PBDEs were only found above LOQ in the River Alna and the mean concentration from four samples was a factor of five below AA-EQS. PBDEs were not found above LOQ in samples collected from the other rivers.
- The sum of isomers of HBCDD was above AA-EQS for the Alna, but no HBCDD could be found above LOQ in samples from the other rivers. The LOQ is however close to the EQS.
- Filtered metal concentrations were below AA-EQS for all rivers except for the River Alna, where annual average concentrations of As, Cu, Cr and Zn are close to or above EQS, and substantially higher and more variable than for the samples from the other rivers.
- Mean concentrations of MCCPs and 4-tert-octylphenol were at AA-EQS level or above for the river Alna. For the remaining rivers, all data for S/MCCPs, alkylphenols, chlorfenvenphos, cybutryne and DEHP were below LOQ and below EQS.
- The monitoring of priority substances with bottle sampling results in much data below limits of quantifications. While in many cases limits of quantification are sufficiently low (with respect to WFD analytical performance criteria), the data do not inform us on actual levels or on trends in concentrations. One of the next step in WFD monitoring programme is to establish robust methodologies to measure trends in concentrations with time. Options for this task for hydrophobic substances include the measured of SPM-associated concentrations, the use of passive sampling devices and perhaps biota.
- Estimated fluxes of $\Sigma_{16}$PAHs are in reasonable agreement with previous data from passive sampling and SPM sampling. For a river with high SPM content, most accurate estimates would however be obtained with specific monitoring of the SPM.

**Biota monitoring of Stryneelva, Stjørdalselva, Eidselva, Reisa and Snarumselva in 2017:**

- Concentrations of hexachlorobenzene, pentachlorobenzene, and γ-HCH in fish samples (*Salmo trutta* and *S. salar*) from the five rivers are well below $EQS_{biota}$ values.
- The sums of seven indicator PCBs are close to or above the $EQS_{biota}$ value of 0.6 ng $g^{-1}$ wet weight for all rivers.
- The concentration of DDTs in fish from Stryneelva are a factor of 10-20 above those observed in fish from the other rivers but remain below the proposed human health based $EQS_{biota}$ of 610 ng/g fish.
- The concentration of PBDEs in whole fish samples from the five selected rivers (Stryneelva, Stjørdalselva, Eidselva, Reisa and Snarumselva) are well above $EQS_{biota}$. These exceedances are in line with European and more generally worldwide data.
- Concentrations of the three HBCDD isomers are below LOQ and well below $EQS_{biota}$ for fish samples from all five rivers.
- Fish concentrations of S/MCCPs, 4-n-octylphenol, 4-n-nonyphenols and DEHP were well below $EQS_{biota}$ for all five rivers. LOQs for 4-tert-octylphenol were significantly higher than the $EQS_{biota}$ rendering the assessment difficult.

**Emerging contaminants in the River Alna in 2017:**

- UV filter were most consistently found in suspended particulate matter samples. Biota monitoring showed variable results. UV-327 and UV-328 were most consistently found across all matrices.

- SPM appeared generally more promising for sampling of organophosphorus compounds in the River Alna than composite water sampling. Organophosphorus compounds consistently detected in water and SPM were TEP, TiBP, TnBP, and TBEP. TCEP, TCPP, sum TCP and TEHP were consistently detected in SPM. Data from the analysis of lower trophic level organisms (benthic macroinvertebrates and periphyton) showed a similar pattern of contamination and with a concentration range of <1 to 50 ng $g^{-1}$ ww. TCPP, TnBP, sumTCP, and EHDP were consistently detected in all fish samples analysed. TEP was only detected in muscle samples. Notably, while TPP was not detected in other samples, it was consistently found in fish samples.
- A few bisphenols were detected in the first SPM sample (4,4', BPA, 4,4'-BPS, 2,2'-BPF, 2,4'-BPF, and 4,4'-BPF). Most bisphenols, except for BPE were found above LOQ in the second SPM sample. None were found above LOQ in the water samples. BPA (4,4'-BPA) was found in all lower trophic level samples with concentrations in the range 1-23 ng $g^{-1}$ wet weight. Other bisphenols such as 4,4'-BPS, 2,4'BPF, and 4,4'-BPF were also found in higher amounts than other bisphenols in these lower trophic level samples. With regards the fish sample analyses, bisphenols could only be found in muscle samples and at concentrations similar on a wet weight basis to those measured in lower trophic level organisms.
- PFOS, PFOA, 6:2 FTS, PFBS, PFPS, PFHxS, PFPA, PFHxA, PFHpA, PFNA and PFDA were found at concentrations of 1-4 ng $L^{-1}$ in composite water samples from the Alna while only PFOS was measured above LOQ in SPM. The detection of PFAS compounds in periphyton and benthic organisms was relatively erratic. Only PFDoA and PFOS were consistently found in these samples.
- A higher number of PFAS compounds were found in liver samples than in whole fish. On a wet weight basis, PFAS concentrations were consistently higher in liver samples. PFDA, PFDoA, PFTrDA, PFTeDA, PFOS, PFDS and PFOSA were measured above LOQ in all fish samples. PFOS showed the highest concentrations of all PFAS compound monitored. Logarithm of brown trout bioconcentration factors (logBCF) could be calculated for four PFAS compounds.
- Composite sampling with the ISCO sampler as performed here, is not perfectly suited to the monitoring of the selected list of emerging contaminants analysed in this project. These tend to increase the LOQ significantly for certain compounds (UV filter, organophosphorus compounds and bisphenols).

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# Attachment 1. Details of the fish samples collected from the Rivers Alna, Stryneelva, Stjørdalselva Eidselva, Reisa and Snarumselva in 2017

| ALNA | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Aquamonitorsta | Station ID | Fish ID | Date captured | Species | Length (cm) | Weight (g) | Otholiths | Scales | Sex | Stage | Muscle (g) | Liver (g) | Sample |
| EO-Alna-2 | ALN4 | 7 | 24.05.2017 | Salmo trutta | 17.5 | 66.8 | 2 | ok | F | 2 | 35.5 | 1 | 1 |
| EO-Alna-2 | ALN4 | 2 | 24.05.2017 | Salmo trutta | 17.4 | 67.5 | 1 | ok | M | 1-2 | 30.2 | 1.7 | 1 |
| EO-Alna-2 | ALN4 | 3 | 24.05.2017 | Salmo trutta | 16.5 | 48.1 | 2 | ok | F | 1-2 | 21.9 | 1.2 | 1 |
| EO-Alna-2 | ALN4 | 6 | 24.05.2017 | Salmo trutta | 16.4 | 49.8 | 2 | ok | F | 2 | 25.8 | 0.7 | 1 |
| EO-Alna-2 | ALN4 | 1 | 24.05.2017 | Salmo trutta | 16.4 | 58.6 | 1 | ok | F | 2-3 | 27.2 | 1.2 | 1 |
| EO-Alna-2 | ALN4 | 4 | 24.05.2017 | Salmo trutta | 17.7 | 77.2 | 2 | ok | M | 1-2 | 34.6 | 1.3 | 2 |
| EO-Alna-2 | ALN4 | 8 | 24.05.2017 | Salmo trutta | 19.4 | 82.2 | 2 | ok | F | 2 | 41.5 | 1.2 | 2 |
| EO-Alna-RID | ALN6 | 5 | 24.05.2017 | Salmo trutta | 22.5 | 141.2 | 2 | ok | M | 2 | 72.1 | 2.5 | 2 |
| EO-Alna-2 | ALN4 | 10 | 24.05.2017 | Salmo trutta | 25.6 | 215.3 | 2 | ok | F | 7 | 111.9 | 5.6 | 2 |
| EO-Alna-2 | ALN4 | 9 | 24.05.2017 | Salmo trutta | 20.3 | 103.3 | 2 | ok | M | 2 | 55.6 | 1.7 | 2 |
| EO-Alna-2 | ALN4 | 11 | 24.05.2017 | Salmo trutta | 10.1 | 13.1 | | | n.a | | Whole organism | | 3 |
| EO-Alna-2 | ALN4 | 12 | 24.05.2017 | Salmo trutta | 10 | 13 | | | n.a | | Whole organism | | 3 |
| EO-Alna-2 | ALN4 | 13 | 24.05.2017 | Salmo trutta | 10.2 | 14.6 | | | n.a | | Whole organism | | 3 |
| EO-Alna-2 | ALN4 | 14 | 24.05.2017 | Salmo trutta | 10.3 | 13.3 | | | n.a | | Whole organism | | 3 |
| EO-Alna-2 | ALN4 | 15 | 24.05.2017 | Salmo trutta | 10 | 14.1 | | | n.a | | Whole organism | | 3 |
| EO-Alna-2 | ALN4 | 19 | 22.09.2017 | Salmo trutta | 14.2 | 36.2 | | | n.a | | Whole organism | | 4 |
| EO-Alna-2 | ALN4 | 20 | 22.09.2017 | Salmo trutta | 13.5 | 30.3 | | | n.a | | Whole organism | | 4 |
| EO-Alna-2 | ALN4 | 21 | 22.09.2017 | Salmo trutta | 13.4 | 29.4 | | | n.a | | Whole organism | | 4 |
| EO-Alna-2 | ALN4 | 25 | 22.09.2017 | Salmo trutta | 18 | 75 | 2 | ok | M | 5 | 31.8 | 1.1 | 5 |
| EO-Alna-2 | ALN4 | 24 | 22.09.2017 | Salmo trutta | 17.9 | 69.3 | 1 | ok | F | 2 | 30.4 | 0.8 | 5 |
| EO-Alna-2 | ALN4 | 26 | 22.09.2017 | Salmo trutta | 19 | 102.6 | 2 | ok | M | 5 | 43 | 1.2 | 5 |
| EO-Alna-2 | ALN4 | 27 | 22.09.2017 | Salmo trutta | 21 | 128.5 | 2 | ok | M | 4-5 | 50.9 | 1.7 | 6 |
| EO-Alna-2 | ALN4 | 29 | 22.09.2017 | Salmo trutta | 22.5 | 134.5 | 2 | ok | F | 1-2 | 58.7 | 1.8 | 6 |
| EO-Alna-2 | ALN4 | 28 | 22.09.2017 | Salmo trutta | 23.2 | 146.7 | 1 | ok | F | 3 | 61 | 1.9 | 7 |
| EO-Alna-2 | ALN4 | 30 | 22.09.2017 | Salmo trutta | 23.5 | 167.7 | 2 | ok | M | 4-5 | 70.6 | 2.3 | 8 |
| EO-Alna-2 | ALN4 | 31 | 22.09.2017 | Salmo trutta | 27 | 273.1 | 2 | ok | F | 5-6 | 80 | 8.9 | 9 |
| EO-Alna-2 | ALN4 | 32 | 22.09.2017 | Salmo trutta | 27.2 | 296.4 | 2 | ok | F | 5-6 | 116.3 | 8 | 10 |
| EO-Alna-2 | ALN4 | 33 | 22.09.2017 | Salmo trutta | 35 | 596.8 | 2 | ok | F | 5-6 | 201.2 | 15.2 | 11 |

| Stjørdalselva | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Aquamonitorstation | Station ID | Fish ID | Date captured | Species | Length (cm) | Weight (g) | Otholiths | Scales | Sex | Stage | Muscle (g) | Liver (g) | Sample |
| EO-STJ-1 | STJ-1 | 3 | 21.09.2017 | Salmo trutta | 9.7 | 9.9 | 1 | ok | n.a | | Whole organism | | 1 |
| EO-STJ-1 | STJ-1 | 5 | 21.09.2017 | Salmo salar | 12 | 18.3 | 2 | ok | n.a | | Whole organism | | 1 |
| EO-STJ-1 | STJ-1 | 6 | 21.09.2017 | Salmo salar | 12.8 | 21.5 | 1 | ok | n.a | | Whole organism | | 1 |
| EO-STJ-1 | STJ-1 | 7 | 21.09.2017 | Salmo salar | 11.9 | 20 | 2 | ok | n.a | | Whole organism | | 1 |
| EO-STJ-1 | STJ-1 | 8 | 21.09.2017 | Salmo salar | 11.8 | 14.3 | 2 | ok | n.a | | Whole organism | | 1 |
| EO-STJ-2 | STJ-2 | 9 | 21.09.2017 | Salmo salar | 11.5 | 16.8 | 2 | ok | n.a | | Whole organism | | 2 |
| EO-STJ-2 | STJ-2 | 10 | 21.09.2017 | Salmo salar | 10.4 | 10.2 | 2 | ok | n.a | | Whole organism | | 2 |
| EO-STJ-2 | STJ-2 | 11 | 21.09.2017 | Salmo salar | 10.6 | 11.1 | 2 | ok | M | 1 | Whole organism | | 2 |
| EO-STJ-2 | STJ-2 | 12 | 21.09.2017 | Salmo salar | 10.4 | 9.6 | 2 | ok | F | 1 | Whole organism | | 2 |
| EO-STJ-2 | STJ-2 | 13 | 21.09.2017 | Salmo salar | 10.5 | 10.5 | 2 | ok | F | 1 | Whole organism | | 2 |
| EO-STJ-3 | STJ-3 | 16 | 21.09.2017 | Salmo trutta | 14.1 | 30.2 | 2 | ok | M | 1 | Whole organism | | 3 |
| EO-STJ-3 | STJ-3 | 17 | 21.09.2017 | Salmo trutta | 12.5 | 21.9 | 2 | ok | F | 1 | Whole organism | | 3 |
| EO-STJ-3 | STJ-3 | 18 | 21.09.2017 | Salmo trutta | 12.4 | 19.8 | 2 | ok | F | 1 | Whole organism | | 3 |
| EO-STJ-3 | STJ-3 | 19 | 21.09.2017 | Salmo trutta | 12.5 | 22.4 | 2 | ok | M | 1 | Whole organism | | 3 |
| EO-STJ-3 | STJ-3 | 20 | 21.09.2017 | Salmo trutta | 11.6 | 17.1 | 2 | ok | F | 1 | Whole organism | | 3 |

| Strynselva | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Aquamonitorstation | Station ID | Fish ID | Date captured | Species | Length (cm | Weight (g) | Otholiths | Scales | Sex | Stage | Muscle (g) | Liver (g) | Sample |
| EO-STR-1 | STR | 4 | 12.09.2017 | Salmo trutta | 12.0 | 17.6 | 2 | ok | F | 1 | Whole organism | | 1 |
| EO-STR-1 | STR | 7 | 12.09.2017 | Salmo salar | 11.6 | 18.1 | 2 | ok | F | 1 | Whole organism | | 1 |
| EO-STR-1 | STR | 2 | 12.09.2017 | Salmo trutta | 12.3 | 19.6 | 2 | ok | F | 1 | Whole organism | | 1 |
| EO-STR-1 | STR | 5 | 12.09.2017 | Salmo salar | 11.0 | 15.6 | 2 | ok | F | 1 | Whole organism | | 1 |
| EO-STR-1 | STR | 8 | 12.09.2017 | Salmo trutta | 11.8 | 17.3 | 2 | ok | F | 1 | Whole organism | | 1 |
| EO-STR-1 | STR | 16 | 12.09.2017 | Salmo salar | 11.2 | 14.9 | 2 | ok | F | 1 | Whole organism | | 2 |
| EO-STR-1 | STR | 14 | 12.09.2017 | Salmo salar | 11.4 | 14.3 | 2 | ok | F | 1 | Whole organism | | 2 |
| EO-STR-1 | STR | 10 | 12.09.2017 | Salmo salar | 12.0 | 15.0 | 2 | ok | F | 1 | Whole organism | | 2 |
| EO-STR-2 | STR | 11 | 12.09.2017 | Salmo salar | 11.8 | 15.6 | 2 | ok | M | 1 | Whole organism | | 2 |
| EO-STR-2 | STR | 17 | 12.09.2017 | Salmo salar | 11.3 | 14.6 | 2 | ok | M | 5 | Whole organism | | 2 |
| EO-STR-2 | STR | 26 | 12.09.2017 | Salmo salar | 12.6 | 18.6 | 2 | ok | F | 1 | Whole organism | | 3 |
| EO-STR-2 | STR | 19 | 12.09.2017 | Salmo salar | 11.9 | 15.8 | 2 | ok | F | 1 | Whole organism | | 3 |
| EO-STR-2 | STR | 20 | 12.09.2017 | Salmo trutta | 12.0 | 19.2 | 2 | ok | M | 5 | Whole organism | | 3 |
| EO-STR-2 | STR | 22 | 12.09.2017 | Salmo trutta | 11.4 | 15.7 | 2 | ok | F | 1 | Whole organism | | 3 |
| EO-STR-2 | STR | 27 | 12.09.2017 | Salmo trutta | 12.2 | 16.3 | 2 | ok | F | 1 | Whole organism | | 3 |

| Eidselva | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Aquamonitorsta | Station ID | Fish ID | Date captured | Species | Length (cm) | Weight (g) | Otholiths | Scales | Sex | Stage | Muscle (g) | Liver (g) | Sample |
| EO EID-1 | EID-1 | 2 | 11.09.2017 | Salmo salar | 11.2 | 11.1 | 0 | ok | m | 1 | Whole organism | | 1 |
| EO EID-1 | EID-1 | 4 | 11.09.2017 | Salmo salar | 10.6 | 10.4 | 2 | ok | m | 1 | Whole organism | | 1 |
| EO EID-1 | EID-1 | 5 | 11.09.2017 | Salmo salar | 11.2 | 13 | 1 | ok | m | 1 | Whole organism | | 1 |
| EO EID-1 | EID-1 | 6 | 11.09.2017 | Salmo salar | 11.2 | 12.8 | 2 | ok | f | 1 | Whole organism | | 1 |
| EO EID-1 | EID-1 | 7 | 11.09.2017 | Salmo salar | 10.8 | 12.1 | 1 | ok | f | 2 | Whole organism | | 1 |
| EO EID-2 | EID-2 | 8 | 11.09.2017 | Salmo salar | 13.2 | 21.1 | 2 | ok | f | 1 | Whole organism | | 2 |
| EO EID-2 | EID-2 | 9 | 11.09.2017 | Salmo salar | 11.7 | 16.5 | 2 | ok | m | 5 | Whole organism | | 2 |
| EO EID-2 | EID-2 | 12 | 11.09.2017 | Salmo salar | 13.3 | 23.7 | 2 | ok | m | 5 | Whole organism | | 2 |
| EO EID-2 | EID-2 | 15 | 11.09.2017 | Salmo salar | 13.3 | 26.3 | 2 | ok | m | 5 | Whole organism | | 2 |
| EO EID-2 | EID-2 | 16 | 11.09.2017 | Salmo salar | 13.1 | 20.6 | 2 | ok | f | 1 | Whole organism | | 2 |
| EO EID-3 | EID-3 | 19 | 11.09.2017 | Salmo salar | 12.6 | 19.6 | 2 | ok | f | 1 | Whole organism | | 3 |
| EO EID-3 | EID-3 | 20 | 11.09.2017 | Salmo salar | 12.4 | 19.8 | 1 | ok | f | 1 | Whole organism | | 3 |
| EO EID-3 | EID-3 | 22 | 11.09.2017 | Salmo salar | 12 | 18.9 | 2 | ok | f | 1 | Whole organism | | 3 |
| EO EID-3 | EID-3 | 24 | 11.09.2017 | Salmo salar | 11.2 | 14.2 | 2 | ok | f | 1 | Whole organism | | 3 |
| EO EID-3 | EID-3 | 25 | 11.09.2017 | Salmo salar | 12.2 | 17.2 | 2 | ok | f | 1 | Whole organism | | 3 |

| Reisaelva | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Aquamonitorstation | Station ID | Fish ID | Date captured | Species | Length (cm) | Weight (g) | Otholiths | Scales | Sex | Stage | Muscle (g) | Liver (g) | Sample |
| EO-REI-1 | REI-1 | 1 | 11.09.2017 | Salmo trutta | 14.5 | 30.1 | 2 | ok | M | 1 | Whole organism | | 1 |
| EO-REI-1 | REI-1 | 2 | 11.09.2017 | Salmo trutta | 15.6 | 40.3 | 2 | ok | F | 1 | Whole organism | | 1 |
| EO-REI-1 | REI-1 | 3 | 11.09.2017 | Salvelinus alpinus | 16.3 | 33.3 | 2 | ok | F | 2 | Whole organism | | 1 |
| EO-REI-1 | REI-1 | 4 | 11.09.2017 | Salmo trutta | 13.7 | 25.9 | 2 | ok | F | 1 | Whole organism | | 1 |
| EO-REI-1 | REI-1 | 5 | 11.09.2017 | Salmo trutta | 14.6 | 34 | 2 | ok | M | 1 | Whole organism | | 1 |
| EO-REI-2 | REI-2 | 6 | 06.10.2017 | Salmo salar | 9.8 | 8.4 | 2 | ok | F | 2 | Whole organism | | 2 |
| EO-REI-2 | REI-2 | 7 | 06.10.2017 | Salmo salar | 10.5 | 8.7 | 2 | ok | F | 1 | Whole organism | | 2 |
| EO-REI-2 | REI-2 | 9 | 06.10.2017 | Salmo salar | 10.5 | 9.7 | 2 | ok | F | 2 | Whole organism | | 2 |
| EO-REI-2 | REI-2 | 10 | 06.10.2017 | Salmo salar | 10.3 | 10.8 | 2 | ok | F | 2 | Whole organism | | 2 |
| EO-REI-2 | REI-2 | 11 | 06.10.2017 | Salmo salar | 10.6 | 9.7 | 2 | ok | F | 2 | Whole organism | | 2 |
| EO-REI-2 | REI-2 | 12 | 06.10.2017 | Salmo salar | 10.5 | 10.9 | 2 | ok | F | 2 | Whole organism | | 2 |
| EO-REI-2 | REI-2 | 13 | 06.10.2017 | Salmo salar | 11.8 | 13.7 | 2 | ok | F | 2 | Whole organism | | 3 |
| EO-REI-2 | REI-2 | 15 | 06.10.2017 | Salmo salar | 11.2 | 13.1 | 2 | ok | F | 2 | Whole organism | | 3 |
| EO-REI-2 | REI-2 | 16 | 06.10.2017 | Salmo salar | 12.1 | 14 | 2 | ok | F | 2 | Whole organism | | 3 |
| EO-REI-2 | REI-2 | 17 | 06.10.2017 | Salmo salar | 12.9 | 19.5 | 2 | ok | M | 4 | Whole organism | | 3 |
| EO-REI-2 | REI-2 | 18 | 06.10.2017 | Salmo salar | 13.1 | 19.4 | 2 | ok | M | 4 | Whole organism | | 3 |

| Snarumselva | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Aquamonitorsta | Station ID | Fish ID | Date captured | Species | Length (cm) | Weight (g) | Otholiths | Scales | Sex | Stage | Muscle (g) | Liver (g) | Sample |
| EO-SNA-1 | SNA-1 | 14 | 02.11.2017 | Salmo trutta | 17.3 | 52.7 | 2 | Ok | f | 1 | 18.2 | 0.6 | 1 |
| EO-SNA-1 | SNA-1 | 9 | 02.11.2017 | Salmo trutta | 17.7 | 50.9 | 2 | Ok | m | 3 | 18.6 | 0.8 | 1 |
| EO-SNA-1 | SNA-1 | 12 | 02.11.2017 | Salmo trutta | 18.2 | 58.7 | 2 | Ok | m | 1 | 18.6 | 0.5 | 1 |
| EO-SNA-1 | SNA-1 | 3 | 02.11.2017 | Salmo trutta | 19.4 | 80.2 | 2 | Ok | f | 3 | 22.5 | 0.9 | 1 |
| EO-SNA-1 | SNA-1 | 11 | 02.11.2017 | Salmo trutta | 19.5 | 78.4 | 2 | Ok | f | 4 | 24.2 | 1.6 | 1 |
| EO-SNA-1 | SNA-1 | 15 | 02.11.2017 | Salmo trutta | 19.5 | 73.3 | 2 | Ok | m | 4 | 21.6 | 1.2 | 2 |
| EO-SNA-1 | SNA-1 | 10 | 02.11.2017 | Salmo trutta | 20.2 | 81 | 2 | Ok | f | 3 | 25.7 | 1.5 | 2 |
| EO-SNA-1 | SNA-1 | 8 | 02.11.2017 | Salmo trutta | 20.4 | 104.7 | 2 | Ok | m | 4 | 26.2 | 1.1 | 2 |
| EO-SNA-1 | SNA-1 | 2 | 02.11.2017 | Salmo trutta | 20.5 | 93.6 | 2 | Ok | m | 1 | 27.5 | 1.2 | 2 |
| EO-SNA-1 | SNA-1 | 5 | 02.11.2017 | Salmo trutta | 20.5 | 87.8 | 2 | Ok | m | 4 | 25.1 | 1 | 2 |
| EO-SNA-1 | SNA-1 | 7 | 02.11.2017 | Salmo trutta | 21.1 | 80.5 | 2 | Ok | f | 3 | 23.2 | 1.1 | 3 |
| EO-SNA-1 | SNA-1 | 4 | 02.11.2017 | Salmo trutta | 21.5 | 123.5 | 2 | Ok | m | 3 | 27.4 | 1.6 | 3 |
| EO-SNA-1 | SNA-1 | 6 | 02.11.2017 | Salmo trutta | 21.5 | 109.6 | 2 | Ok | m | 2 | 32.2 | 1.1 | 3 |
| EO-SNA-1 | SNA-1 | 1 | 02.11.2017 | Salmo trutta | 21.6 | 115.5 | 2 | Ok | m | 4 | 26.6 | 1.4 | 3 |
| EO-SNA-1 | SNA-1 | 13 | 02.11.2017 | Salmo trutta | 23.9 | 153.4 | 2 | Ok | m | 3 | 34.1 | 1.5 | 3 |

# Attachment 2. Yearly discharges of chemicals from the Rivers Alna, Drammenselva, Glomma, Numedalslågen and Skienselva for 2017

**TABLE A1**
**Yearly discharge of polycyclic aromatic hydrocarbons in five rivers**

| | Alna | Drammenselva | Glomma | Numedalslågen | Skienselva |
|---|---|---|---|---|---|
| Naphthalene | 201 | 30 | 74 | 9.3 | 98 |
| Acenaphthylene | 61 | <2.5 | <5.8 | <1 | 14 |
| Acenaphthene | 202 | 8.4 | 13 | 3.5 | 56 |
| Fluorene | 124 | 2.9 | 4.9 | 1.7 | 26 |
| Phenanthrene | 414 | <10 | <24 | <4 | 26 |
| Anthracene | 175 | <2.4 | <5.4 | 0.56 | 7.0 |
| Fluoranthene | 732 | 8.5 | 15 | 2.8 | 18 |
| Pyrene | 942 | <6 | <11 | 2.9 | 24 |
| Benz[a]anthracene | 305 | 2.2 | <5 | 0.47 | 2.9 |
| Chrysene | 312 | 3.1 | 4.0 | 0.87 | 3.8 |
| Benzo[b,j]fluoranthene | 447 | 4.0 | 4.4 | 1.4 | 5.0 |
| Benzo[k]fluoranthene | 143 | 1.6 | <5.4 | 0.67 | 3.1 |
| Benzo[a]pyrene | 246 | 1.5 | <4 | 0.45 | 2.3 |
| Indeno[1,2,3-cd]pyrene | 193 | 1.4 | <5 | 0.66 | 4.8 |
| Dibenzo[ac/ah]anthracene | 48 | <1.8 | <4.0 | 0.47 | <3 |
| Benzo[ghi]perylene | 304 | 1.5 | 2.5 | 0.80 | 3.2 |
| $\Sigma_{16}$PAHs | 4847 | 65-88 | 128-186 | 27-31 | 294-297 |

*Data in g/year for the Alna and kg/year for the other rivers.

**TABLE A2**
**Yearly discharge of polychlorinated biphenyls and other chlorinated organic compounds in five rivers**

| | Alna | Drammenselva | Glomma | Numedalslågen | Skien |
|---|---|---|---|---|---|
| Pentachlorobenzene | <24 | <2.4 | <5.4 | <0.76 | <2.5 |
| Hexachlorobenzene | 9.6 | <3.0 | <5.4 | <0.76 | <2.5 |
| γ-HCH | <59 | <12 | <27 | <3.8 | <13 |
| PCB28/31 | <34 | <12 | <27 | <3.8 | <12 |
| PCB52 | <34 | <12 | <27 | <3.8 | <12 |
| PCB101 | <34 | <12 | <27 | <3.8 | <12 |
| PCB118 | <34 | <12 | <27 | <3.8 | <12 |
| PCB153 | <34 | <12 | <27 | <3.8 | <12 |
| PCB138 | <34 | <12 | <27 | <3.8 | <12 |
| PCB180 | <34 | <12 | <27 | <3.8 | <12 |
| *p,p'*-DDE | <67 | <24 | <54 | <7.5 | <25 |
| *p,p'*-DDD | <135 | <47 | <108 | <15.1 | <49 |
| *p,p'*-DDT | <235 | <83 | <188 | <27 | <87 |
| $\Sigma_7$PCBs | <235 | <83 | <188 | <26 | <87 |

*Data in g/year for River Alna and in kg/year for the other rivers

**TABLE A3**
**Yearly discharge of polybrominated diphenyl ethers in five rivers**

| | Alna | Drammenselva | Glomma | Numedalslågen | Skien |
|---|---|---|---|---|---|
| PBDE28 | <2.1 | <0.71 | <1.6 | <0.23 | <0.74 |
| PBDE47 | 1.60 | <0.36 | <0.81 | <0.11 | <0.37 |
| PBDE100 | 0.76 | <0.36 | <0.81 | <0.11 | <0.37 |
| PBDE99 | 6.05 | <3.3 | <7.6 | <1.1 | <3.5 |
| PBDE154 | <0.9 | <0.30 | <0.67 | <0.09 | <0.31 |
| PBDE153 | 0.80 | <0.41 | <0.94 | <0.13 | <0.43 |
| $\Sigma_5$PBDEs | 10.7 | <5.5 | <13 | <1.8 | <5.7 |

*Data in g/year for River Alna and in kg/year for the other rivers

**TABLE A4**
**Yearly discharge of hexabromocyclododecane in five rivers**

| | Alna | Drammenselva | Glomma | Numedalslågen | Skien |
|---|---|---|---|---|---|
| α-HBCDD | 28 | <6 | <14 | <2 | <7 |
| β-HBCDD | 19 | <6 | <14 | <2 | <7 |
| γ-HBCDD | 10 | <6 | <14 | <2 | <7 |
| $\Sigma_3$HBCDD | 57 | <18 | <42 | <6 | <21 |

*Data in g/year for River Alna and in kg/year for the other rivers

**TABLE A5**
**Yearly discharge of short and medium chain chlorinated paraffins in five rivers**

| **Chemical** | Alna | Drammenselva | Glomma | Numedalslågen | Skien |
|---|---|---|---|---|---|
| SCCP | 1.8 | <210 | <460 | <36 | <250 |
| MCCP | 1.7 | 432 | <890 | <35 | <230 |

*Data in kg/year for all rivers

**TABLE A6**
**Yearly discharge of nonylphenol, octylphenol and 4-tert-octylphenol in five rivers**

| **Chemical** | Alna | Drammenselva | Glomma | Numedalslågen | Skien |
|---|---|---|---|---|---|
| Nonylphenol | <0.07 | <32 | <35 | <8.1 | <17 |
| Octylphenol | <0.22 | <87 | <130 | <38 | <90 |
| 4-tert-octylphenol | <15 | 9480 | <8250 | <1350 | <3100 |

*Data in kg/year for all rivers

**TABLE A7**
**Yearly discharge of chlorfenvinfos, cybutryne and DEHP in five rivers**

| **Chemical** | Alna | Drammenselva | Glomma | Numedalslågen | Skien |
|---|---|---|---|---|---|
| Chlorfenvinfos | <0.07 | <24 | <54 | <8 | <25 |
| Cybutryne | <0.09 | <4 | <9 | <2 | <4 |
| DEHP | 11 | <1000 | <100 | <165 | <1100 |

*Data in kg/year for all rivers

**Norwegian Environment Agency**
**Telephone:** +47 73 58 05 00 | Fax: +47 73 58 05 01
**E-mail:** post@miljodir.no
**Web:** www.environmentagency.no
**Postal address:** Postboks 5672 Torgarden, N-7485 Trondheim
**Visiting address Trondheim:** Brattørkaia 15, 7010 Trondheim
**Visiting address Oslo:** Grensesvingen 7, 0661 Oslo

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.

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

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.

Our principal functions include collating and communicating environmental information, exercising regulatory authority, supervising and guiding regional and local government level, giving professional and technical advice, and participating in international environmental activities.