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The Norwegian River Monitoring Programme

Priority substances and emerging contaminants in selected Norwegian rivers

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REPORT

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Summary

Riverine inputs and direct discharges to Norwegian coastal waters in 2020 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. Levels observed were compared with annual average environmental quality standards (AA-EQS). 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 2020 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. Observerte konsentrasjonsnivåer ble sammenlignet med grenseverdier for årlig gjennomsnitt (AA-EQS). En mer detaljert analyse av nye miljøgifter ble gjennomført i Alna.

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3. Emerging contaminants	3. Nye miljøgifter
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The Norwegian River Monitoring Programme

Priority substances and emerging contaminants in selected Norwegian rivers

Preface

The Norwegian River Monitoring Programme
Besides NIVA, involved collaborating partners include the Norwegian Water Resources and Energy Directorate (NVE) and the Norwegian Institute for Air Research (NILU). Contact persons at the Norwegian Environment Agency (NEA) has been Gunn Lise Haugestøl, Preben Danielsen and Eivind Farmen.

Hans Fredrik Veiteberg Braaten (NIVA) was project lead for the river monitoring programme in 2020, whereas Øyvind Kaste has been project lead in 2021. 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 chemistry analyses).

NVE has been responsible for the hydrological modelling, Eurofins has carried out the mercury analyses, and NILU has analysed selected priority substances and emerging contaminants. Water samples were collected by NVE's local fieldworkers. NIVA has been responsible for the urban river sampling of fish, sediment and water in Alna and training of NVE's local fieldworkers in water filtration for samples from Alta, Målelva, Pasvikelva, Tana and Vefsna.

Quality assurance of the report has been carried out by Sondre Meland, NIVA.
is carried out by the Norwegian Institute for Water Research in collaboration with consortium partners. Results from the 2020 monitoring activities are presented in four 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 under the main programme.

Oslo, November 2021

Ian Allan

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Summary

The monitoring of rivers as part of the Norwegian River Monitoring Programme (NRMP) is conducted annually 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 2017-2020, the programme was modified by increasing the number of monitored rivers from three to 20 (five main rivers per year in a four-year cycle). In addition, the number of contaminants was increased (increased focus on WFD priority substances) and changes in the matrices selected for analysis were conducted. Hence, the relevance of the programme's results to fulfil monitoring objectives of the EU Water Framework Directive (WFD) was enhanced.

For five rivers, the monitoring of priority substances and river basin specific substances was performed by bottle sampling with a sampling frequency of four times per year. One sampling location per river (usually the NRMP 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 (i.e. with no separation of liquid and particulate phases). For metals, these refer to filtered concentrations (0.45 µm).

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. It included composite water sampling, suspended particulate matter sampling, and biomonitoring of brown trout (*Salmo trutta*). Sampling was undertaken on two occasions, in June and September 2020 with multiple samples collected on each occasion.

The concentrations of priority substances in water were below EQS for most riverine sampling locations. Bottle sampling resulted in a significant amount of data below limits of quantification (LOQ), i.e. left-censored data. In most cases LOQs fulfilled WFD method performance criteria. Bottle sampling in the rivers Alta, Målselva, Pasvikelva, Tana and Vefsna showed that concentrations of polycyclic aromatic hydrocarbons (PAHs) were slightly higher (and closest to WFD AA-EQS) for the sampling site of the River Tana. The mean whole water concentration of benzo[a]pyrene was close to or above AA-EQS at the selected monitoring locations for this river. The Σ_7PCBs 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 not found above LOQ in any of the samples collected from the five rivers. Similar results were obtained for HBCDD isomers with no HBCDD found above LOQ in any of the samples. However, the LOQ is close to the EQS. Metal concentrations were mostly well below AA-EQS for all rivers. Elevated concentrations of Ni and Cu observed for the river Pasvikelva were close to or above EQS level. Emissions from the smelters in Russian settlements close to the border are the main source for these high concentrations.

MCCP concentrations were mostly below AA-EQS, except for the Målselva where one sample resulted in an average concentration above AA-EQS. Data for SCCPs, alkylphenols, chlorfenvenphos, cybutryne and DEHP were mostly low or below LOQ and below EQS. For 2020, LOQ values for 4-tert-octylphenol were well below EQS level and allowed LOQ well below EQS.

The programme of monitoring of the distribution of emerging contaminants in the Alna river for 2020 was similar to that for 2019 and simplified compared with 2017. Sampling in 2020 focussed essentially on water, suspended particulate matter (SPM) and fish (brown trout). UV filters were consistently found both in suspended particulate matter and water samples. Fish monitoring showed variable results.

SPM remained the matrix of choice for the detection and quantification of OPs in 2020. Organophosphorus compounds consistently detected in SPM were TiBP (126-71-6), TnBP (126-73-8), and TBEP (78-51-3), TCEP (115-96-8), TCPP (13674-87-8), sumTCP (1330-78-5), TPP (115-86-6), TnBP (126-73-8), TDCPP (13674-87-8), TXP (25155-23-1), TEHP (78-42-2) and EHDP (1241-94-7). TCPP, TPP, TiBP, TBEP and sumTCP were consistently detected in all fish samples analysed but concentrations did not exceed 6 ng g^{-1} w.w.

As for data from previous years, the bisphenols BPA, BPS and BPF were all found in water samples with BPA (4,4'-BPA) present in highest concentrations, approximately an order of magnitude above the concentrations of the other ones. BPA and BPF were the only bisphenols found above LOQ in brown trout samples.

Estimated $logK_{oc}$ values for UV filters and OPs tend to show equilibrium distribution between suspended organic carbon and water, although there was more spread of the data for 2020 than in previous years. $LogK_{ow}$ does not appear to be as good a predictor as $logK_{oc}$ for certain OPs (TCEP, TCPP), bisphenols and BP3.

The list of PFAS compounds detected in water samples/SPM is similar to that obtained in 2017-2019. In general, the identity and relative levels of PFAS compounds above LOQ in Alna river water agree with stormwater data from the monitoring programme "Environmental Contaminants in an Urban Fjord", indicating stormwater runoff from impervious areas may be a non-negligible source of PFAS chemicals to River Alna. A slightly higher number of PFAS compounds were found above LOQ in fish liver samples compared with previous years. PFOS showed the highest concentrations of all PFAS compound monitored. Logarithm of brown trout bioconcentration factors (logBCF) could be calculated for selected PFAS compounds.

Sammendrag

Tittel: Vannrammedirektivets prioriterte stoffer og nye miljøgifter i et utvalg norske elver
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Elveovervåkingsprogrammet estimerer årlige tilførsler av miljøgifter til norske havområder, som en del av Norges forpliktelser under Oslo-Paris konvensjonen. I perioden 2013-2016 ble konsentrasjoner og tilførsler av miljøgifter målt og beregnet i Alna, Drammenselva og Glomma, som en del av *Elvetilførselsprogrammet*. I perioden 2017-2020 er programmet utvidet fra tre til 20 elver (fem hovedelver per år i løpet av en syklus på fire år), samt at resultater skal innfri målsetningene for overvåking i henhold til Vannforskriften. Økt fokus på Vannforskiftens prioriterte stoffer betyr at flere miljøgifter bestemmes, i ulike medier som vann, biota og partikulært materiale.

For fem elver; Alta, Målselva, Pasvikelva, Tana og Vefsna, ble overvåking av prioriterte stoffer og andre vannregionspesifikke forbindelser gjennomført ved innsamling av vannprøver. Prøvene ble i 2020 samlet fra én stasjon per elv (hovedstasjonene i Elveovervåkingsprogrammet) fire ganger per år, og resultatene ble sammenlignet med vannforskriftens miljøkvalitetsstandarder (EQS). For prioriterte organiske forbindelser er EQS-verdiene oppgitt som totalkonsentrasjon i ufiltrerte vannprøver, mens verdiene for metaller er basert på filtrerte vannprøver (0,45 µm).

Det ble også gjennomført en mer detaljert analyse av utvalgte nye miljøgifter i Alna, inkludert bestemmelse av UV-stoffer, organofosfater, bisfenoler og perfluorerte forbindelser (PFAS). Siden disse forbindelsene varierer i fysisk-kjemiske egenskaper, ble ulike prøvetakingsmetoder benyttet: innsamling av blandprøver av vann, samt prøvetaking av suspendert partikulært materiale (SPM) og fisk (brunørret, *Salmo trutta*). Feltarbeidet i Alna ble gjennomført ved to anledninger, i juni og september 2020.

Konsentrasjonene av prioriterte stoffer var lavere en vanndirektivets grenseverdier (AA-EQS) for de fleste prøvelokalitetene som ble undersøkt i 2020. Stikkprøver av vann ga stort sett konsentrasjoner under gjeldende analytiske kvantifiseringsgrenser (LOQ), som i de fleste tilfeller innfridde vannforskriftens krav til analyseusikkerhet. Prøvene fra Alta, Målselva, Pasvikelva, Tana og Vefsna viste at konsentrasjonene av polysykliske aromatiske hydrokarboner (PAH) var høyest og nærmest grenseverdiene i Tana. Her var konsentrasjonen av benzo[a]pyren i vann var i nærheten av- eller over grenseverdien på utvalgte stasjoner. Summen av syv polyklorerte bifenyler (Σ_7PCB) var under LOQ i alle de undersøkte elvene, men det er verdt å merke seg at summen av kvantifiseringsgrensene (LOQ) for enkeltforbindelsene er signifikant høyere enn grenseverdien for Σ_7PCB på 0.0024 ng L^{-1}. Polybrominerte difenyletere (PBDE) og summen av isomerer av heksabromocyklododekan (HBCDD) ble ikke detektert i noen av elvene, men det bemerkes av kvantifiseringsgrensene er i nærheten av grenseverdiene for disse stoffene. Konsentrasjonen av filtrerte metaller var stort sett lavere enn grenseverdiene for alle de fem elvene. I Pasvikelva var konsentrasjoner av Ni og Cu nær- eller i overkant av grenseverdiene. Utslipp fra smelteverket på den andre siden av grensen mot Russland er sannsynligvis hovedkilden til de forhøyete konsentrasjonene.

Nivåer av mellomkjedete klorerte parafiner (MCCP) var for det meste under grenseverdiene, unntatt i Målselva hvor en av prøvene resulterte i en gjennomsnittskonsentrasjon som lå over AA-EQS. Data for kortkjedete klorerte parafiner (SCCP), alkylfenoler, klorfenvinfos, cybutryne og ftalater (DEHP) var stort sett under både kvantifiseringsgrensene og AA-EQS. I 2020 var LOQ for 4-tert-octylfenol lavere enn EQS, noe som muliggjorde en kvantifisering av forbindelsen i forhold til AA-EQS.

Overvåkingsprogrammet for nye miljøgifter i Alna var i 2020 tilsvarende som i 2019, dvs. forenklet i forhold til programmet som ble gjennomført i 2017. Programmet i 2020 var fokusert på prøver av vann, SPM og fisk (brunørret). UV-stoffene ble konsekvent funnet i prøver av SPM og vann, mens overvåking av disse stoffene i biota viste mer varierende resultater.

Som i tidligere år, var SPM å foretrekke ved kvantifisering av organofosfater (OP). Organofosfater som ble detektert i SPM inkluderte TiBP (126-71-6), TnBP (126-73-8), TBEP (78-51-3), TCEP (115-96-8), TCPP (13674-87-8), sumTCP (1330-78-5), TPP (115-86-6), TnBP (126-73-8), TDCPP (13674-87-8), TXP (25155-23-1), TEHP (78-42-2) og EHDP (1241-94-7). TCPP, TPP, TiBP, TBEP og sumTCP ble detektert i alle fiskeprøver, men ingen konsentrasjoner var høyere enn 6 ng g^{-1} (våtvekt).

Slik som tidligere år ble bisfenolene BPA, BPS og BPF funnet i vannprøver, med høyest nivåer av BPA (4,4’-BPA). BPA og BPF var de eneste bisfenolene som ble funnet i konsentrasjoner høyere enn LOQ i fiskeprøver.

Selv om det var mer variasjon i resultatene i 2020 sammenlignet med tidligere år, viser estimerte fordelingskoeffisienter ($logK_{OC}$) for UV-stoffer og organofosfater at forbindelsene er likevektsfordelt mellom suspendert organisk karbon og vann. $LogK_{OW}$ virker å være en mindre god prediktor enn $logK_{OC}$ for enkelte organofosfater (TCEP, TCPP), bisfenoler og BP3.

Listen over PFAS-forbindelser som ble detektert i vannprøver og SPM i Alna i 2020 var lik den som ble funnet i 2017-2019. Identifiserte PFAS-forbindelser og målte konsentrasjoner over LOQ i 2020 stemmer godt overens med data for overvannsprøver fra overvåkingsprogrammet *Miljøgifter i en urban fjord*, noe som er en indikasjon på at overvann er en viktig kilde til PFAS i Alna. Sammenlignet med tidligere år ble det funnet et noe høyere antall PFAS-forbindelser over LOQ i fiskelever. Av alle PFAS-forbindelser som ble bestemt, var det høyest konsentrasjoner av PFOS. Biokonsentrasjonsfaktorer (som logBCF) var mulig å beregne for utvalgte PFAS-forbindelser.

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[1]. 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 2020 where five of these were prioritised for the determination of WFD priority substances (PS), river basin-specific pollutants and emerging contaminants (Table 1).

Table 1. Parameters investigated in the Norwegian River Monitoring Programme 2020

A summary table of groups of parameters investigated in the Norwegian River Monitoring Program (RMP). Rivers Driva, Nausta, Nidelva, Orkla and Vosso were investigated for EU Water Framework Directive (WFD) priority substances and emerging contaminants in 2020.

River	Group of parameters estimated (n=yearly sampling events)			
	General water chemistry*	**Metals****	**WFD priority substances**	**Emerging contaminants**
Alta	n = 12	n = 4	n = 4	n = 4
Målselva	n = 12	n = 4	n = 4	n = 4
Pasvikelva	n = 12	n = 4	n = 4	n = 4
Tana	n = 12	n = 4	n = 4	n = 4
Vefsna	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, total), lead (Pb, dissolved), cadmium (Cd, dissolved), chromium (Cr, total), copper (Cu, total), mercury (Hg, dissolved), nickel (Ni, dissolved) and zinc (Zn, total).

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 adopted in 2000. The Norwegian Environment Agency has since worked on the application of the WFD in Norway through the development of EQS[2,3] at national-level and guidelines for monitoring[4]. The framework aims to protect and restore clean waters across Europe and ensure its

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

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

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

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

long-term, sustainable use, including river basins[5]. 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[6]. 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”[7].

Currently, the list of priority substances consists of 45 compounds for which EQSs have been derived[8] (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) 0.45 (class 2) 0.6 (class 3) 0.9 (class 4) 1.5 (class 5)	< 0.08 (class 1) 0.08 (class 2) 0.09 (class 3) 0.15 (class 4) 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
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

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

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

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

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

Number	**CAS number**	**Name of priority substance**	**MAC ($\mu g\ L^{-1}$)**	**AA ($\mu g\ L^{-1}$)**
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.	Σ = 0.03
	50-32-8	(Benzo(a)pyrene)	n.a.	
	205-99-2	(Benzo(b)fluoranthene)	n.a.	Σ = 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
34	115-32-2	Dicofol	-	
35	1763-23-1	Perfluorooctylsulphonate acid (PFOS)	36	0.00065
36	124495-18-7	Quinoxyfen	2.7	0.15
37	See footnote[a]	Dioxin and dioxin-like compounds	-	
38	74070-46-5	Aclonifen	0.12	0.12
39	42576-02-3	Bifenox	0.12	0.012
40	28159-98-0	Cybutryne	0.016	0.0025
41	52315-07-8[b]	Cypermethrin	0.0006	0.000008
42	62-73-7	Dichlorvos	0.0007	0.0006
43	See footnote[c]	Hexabromocyclododecane	0.5	0.0016
44	76-44-8/1024-57-3	Heptachlor and heptachlor epoxide	0.0003	0.0000002
45	886-50-0	Terbutryne	0.34	0.065

[a] This includes: 7 polychlorinated dibenzo-*p*-dioxins: 2,3,7,8-T4CDD (CAS 1746-01-6), 1,2,3,7,8-P5CDD (CAS 40321-76-4), 1,2,3,4,7,8-H6CDD (CAS 39227-28-6), 1,2,3,6,7,8-H6CDD (CAS 57653-85-7), 1,2,3,7,8,9-H6CDD (CAS 19408-74-3), 1,2,3,4,6,7,8-H7CDD (CAS 35822-46-9), 1,2,3,4,6,7,8,9-O8CDD (CAS 3268-87-9) 10 polychlorinated dibenzofuran: 2,3,7,8-T4CDF (CAS 51207-31-9), 1,2,3,7,8-P5CDF (CAS 57117-41-6), 2,3,4,7,8-P5CDF (CAS 57117-31-4), 1,2,3,4,7,8-H6CDF (CAS 70648-26-9), 1,2,3,6,7,8-H6CDF (CAS 57117-44-9), 1,2,3,7,8,9-H6CDF (CAS 72918-21-9), 2,3,4,6,7,8-H6CDF (CAS 60851-34-5), 1,2,3,4,6,7,8-H7CDF (CAS 67562-39-4), 1,2,3,4,7,8,9-H7CDF (CAS 55673-89-7), 1,2,3,4,6,7,8,9-O8CDF (CAS 39001-02-0) 12 dioxin-like polychlorinated biphenyls: 3,3',4,4'-T4CB (PCB 77, CAS 32598-13-3), 3,3',4',5-T4CB (PCB 81, CAS 70362-50-4), 2,3,3',4,4'-P5CB (PCB 105, CAS 32598-14-4), 2,3,4,4',5-P5CB (PCB 114, CAS 74472-37-0), 2,3',4,4',5-P5CB (PCB 118, CAS 31508-00-6), 2,3',4,4',5'-P5CB (PCB 123, CAS 65510-44-3), 3,3',4,4',5-P5CB (PCB 126, CAS 57465-28-8), 2,3,3',4,4',5-H6CB (PCB 156, CAS 38380-08-4), 2,3,3',4,4',5'-H6CB (PCB 157, CAS 69782-90-7), 2,3',4,4',5,5'-H6CB (PCB 167, CAS 52663-72-6), 3,3',4,4',5,5'-H6CB (PCB 169, CAS 32774-16-6), 2,3,3',4,4',5,5'-H7CB (PCB 189, CAS 39635-31-9).[b] CAS 52315-07-8 relates to a mixture of isomers of cypermethrin; alpha-cypermethrin (CAS 67375-30-8), beta-cypermethrin (CAS 65731-84-2), theta-cypermethrin (CAS 71697-59-1) og zeta-cypermethrin (52315-07-8); [c]This includes 1,3,5,7,9,11-hexabromocyclododecane (CAS 25637-99-4), 1,2,5,6,9,10-hexabromocyclododecane (CAS 3194-55-6), α-hexabromocyclododecane (CAS 134237-50-6), β-hexabromocyclododecane (CAS 134237-51-7) and γ- hexabromocyclododecane (CAS 134237-52-8).

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 WFD 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[9]:

- **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 and 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.
- **Per- and Polyfluoroalkyl Substances (PFAS):** 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.
- **Organophosphorus flame retardants (OPFRs):** OPs 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 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[10]. 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, contaminant 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 a Norwegian urban riverine environment;

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

[10] 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.
Objective 2 is answered by focusing on Alna as a study case, by sampling fish, water, and particles at two events (spring and summer). Objective 3 is answered by using relevant concentrations obtained to answer objective 1 in combination with hydrology data to calculate loads of selected contaminants to the sea for the five study rivers.

2 Methods

2.1 Sampling methodologies

2.1.1 Sampling for priority substances in five rivers

Water samples were collected four times in 2020 in the five rivers Vefsna, Målselv, Alta, Tanavassdraget and Pasvikelva (Figure 1, Table 3) 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 lead (Pb), nickel (Ni), mercury (Hg) and cadmium (Cd) where the water has undergone 0.45 µm 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 for organic pollutants. Before sampling, the amber glass bottles were cleaned by heating in a muffle furnace at 550 °C or rinsed with appropriate solvents.
Filtered and unfiltered water for metals and mercury were sampled at the same time. NIVA personnel trained local samplers to perform on site water filtration during the first of the four sampling rounds in February. Sampling of water for filtered metal analysis Pb, Ni, 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% ultrapure/suprapure 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 river water prior to sampling.
Water for 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-1508|2019)[11].

[11] The Norwegian river monitoring programme – water quality status and trends 2018 (M-1508|2019)

Table 3: Location of the 5 rivers and water sampling dates for the EU Water Framework Directive (WFD) priority substances and emerging contaminants in 2020.

River	River number**	Latitude(N)	Longitude (E)	Sampling date 1	Sampling date 2	Sampling date 3	Sampling date 4
Vefsna	151-36-R	65,74245589	13,22661775	07.02.2020	05.05.2020	03.08.2020	05.10.2020
Målselv	196-61-R	69,13720652	18,60181192	06.02.2020	04.05.2020	03.08.2020	05.10.2020
Alta	212-63-R	69,93012506	23,26123667	05.02.2020	04.05.2020	03.08.2020	05.10.2020
Tanavassdraget	234-124-R	70,22984774	28,16465349	04.02.2020	04.05.2020	10.08.2020	05.10.2020
Pasvikelva	246-65242-L	69,47172441	30,11008439	03.02.2020	03.05.2020	10.08.2020	05.10.2020

*Vann-nett ID

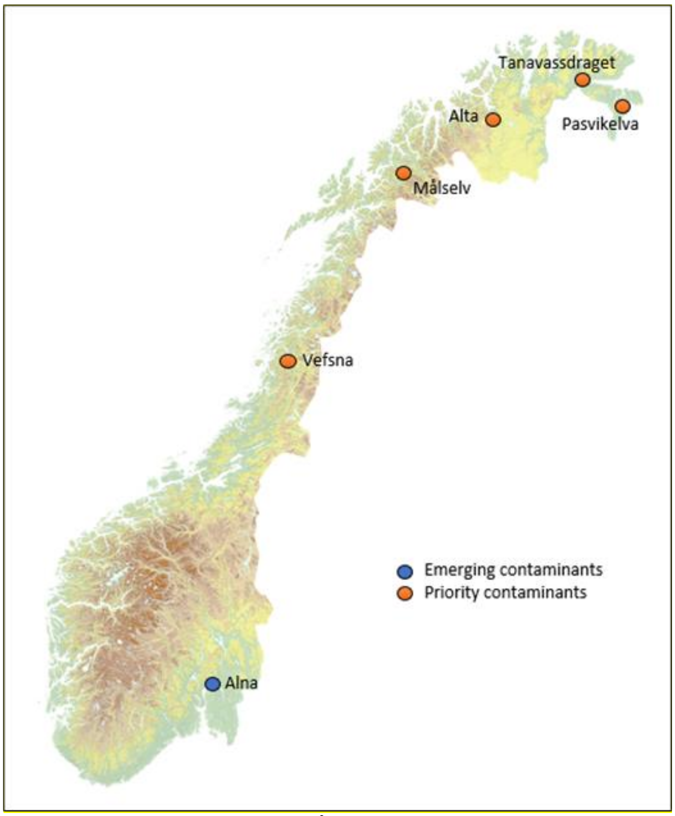

Figure 1. Location of the water sampling stations in Vefsa, Målselv, Alta, Tanavassdraget and Pasvikelva and the Alna sampling station (Background map from Kartverket/Geonorge.no).

2.1.2 Suspended particulate matter sampling for emerging contaminants

Suspended particulate matter (SPM)-associated contaminants were sampled in the Alna river (Figure 1, 2, Table 5) using *continuous flow centrifugation* (CFC) in spring and autumn, with three sampling events each time. 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 between 7-8 days at each sampling event

(Table 4). The collected SPM samples were stored at -20 °C. More details of sampling with CFC can be found in earlier reports (Allan et al., 2009; Allan et al., 2011). The same sampling site were used for water sampling (Table 4). Table 4 also shows the weekly rainfall for each sampling event.

Table 4. Deployment periods for the time proportional water sampling and continuous flow centrifuge and water sampling in river Alna in 2020

Sampling event	SPM	Water samples	Rainfall (mm)
Spring - 1	20.05-27.05.2020	27.05.2020	11.5
Spring - 2	27.05-03.06.2020	03.06.2020	0
Spring - 3	03.06-10.06.2020	10.06.2020	39.1
Autumn - 4	10.09-16.09.2020	16.09.2020	4.9
Autumn - 5	16.09-23.09.2020	23.09.2020	0
Autumn - 6	23.09-30.09.2020	30.09.2020	59.2

2.1.3 Water sampling for emerging contaminants in Alna

Water sampling for emerging contaminants in Alna were conducted at the end of each SPM event. Hence three times in spring and three times in autumn (Table 5, Figure 2)

At each sampling event water was sampled in 2, 2.5 L amber bottles for emerging contaminants, 1 L plastic bottle for PFAS and 0.5L plastic bottle for STS. The Alna river water was sampled approximately 0.5 m below the water surface. One of the amber glass bottles were cleaned by heating in a muffle furnace at 550 °C the other was rinsed with appropriate solvents. The plastic bottles were rinsed trice in the river water before sampling.

2.1.4 Fish 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 from various impervious areas (e.g. roads, streets, roofs), sewage water, pollution from old industrial sites and leakage from discarded landfills. The presence of emerging contaminants such as OPs, fragrances or UV filters has been documented previously in the Alna river (Allan et al., 2013; Pintado-Herrera et al., 2016).

Collection and sampling of biological material followed the guidelines of the Norwegian environmental specimen bank[12] . 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 June and September 2020 (Table 5,6, Figure 2). On both occasions the aim was to collect five fish from three different size groups. Captured brown trout were packed in clean aluminium foil and kept cool after sampling until frozen at –20°C.

The fish were thawed and dissected on clean aluminium foil. Nitrile gloves were used during handling. Glass containers was sealed with aluminium foil and burnt at 550 °C before use. The length, weight, sex and maturity stage were recorded if possible. Scales, otoliths and bile were removed for potential future age determination and analysis. In total 30 fish were sampled, totaling to 6 pooled samples (Table 6). The size of the brown trout in pooled sample 1 and 4 were small, thus whole fish was used instead of muscle. The average length of the fish in the 6 samples ranged from 9.7 – 29.9 cm. An overview of sample composition can be found in Table 6, and details on individual fish in Attachment 1. The samples were kept frozen (-20 °C) until homogenization and analysis.

[12] 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

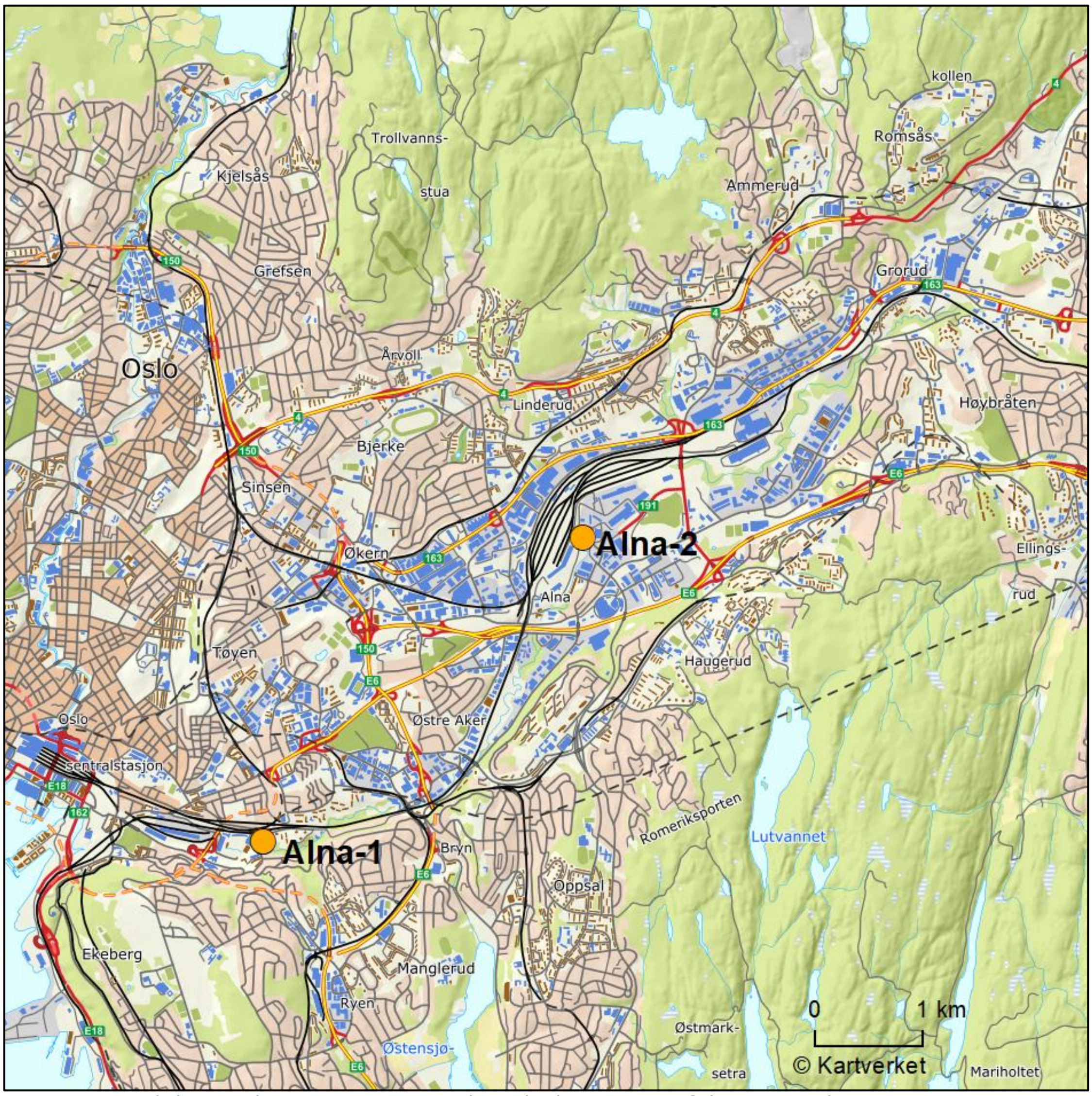

Figure 2. Location of the sampling stations in river Alna. The brown trout (*Salmo trutta*) for emerging contaminants were sampled at Alna-1 and Alna-2. The SPM and water were collected at Alna-1.

Table 5. Location of the Alna sampling stations in 2020 (GPS coordinates in decimal degrees)

Station ID	Area	Latitude (North)	Longitude (East)
Alna-1, SPM	Svartdalsparken	59.9045007	10.7923461
Alna-2	Alfaset	59.93159274	10.84242296

Table 6. Overview of the Alna pooled fish samples in 2020 (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 no.	Sampling date	Species	Tissue	Fish Ids	Mean (SD) length (cm)	Mean (SD) weight (g)
Alna-2	1	16.06.2020	*Salmo trutta*	WO, LI	1-5	13.2(1.0)	31.4(6.6)
Alna-2	2	16.06.2020	*Salmo trutta*	MU. LI	6-10	20,1(2,2)	114,2(34,1)
Alna-2	3	16.06.2020	*Salmo trutta*	MU, LI	11-15	28,0(1,9)	301,1(83,9)
Alna-2	4	22.09.2020	*Salmo trutta*	WO, LI	16-20	9,7(0,3)	11,7(1,1)
Alna-2	5	22.09.2020	*Salmo trutta*	MU, LI	21-25	23,9(2,3)	178,4(54,8)
Alna-2	6	22.09.2020	*Salmo trutta*	MU, LI	26-30	29,9(2,7)	349,9(112,2)

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 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 labelled 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 no loss of analytes. 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)*". After extractions the water 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) or GC-MS/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 was added to the samples for quantification purposes. The water 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

Alkylphenols (octylphenol, nonylphenol) were analysed at NILU. 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).

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

Filtered water samples were preserved in supra-pure 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). Mercury 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 µg Hg/L. Eurofins is accredited for the analytical method (NS-EN ISO/IEC 17025, Test 003).

Lipid content in biological samples was determined gravimetrically after extraction, before clean up together with the determination of PBDEs at NIVA.

2.2.2 Emerging contaminants in water, Suspended Particulate Matter (SPM) and brown trout 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 fish by NILU. Prior to extraction, the fish and SPM samples were added a mixture of isotope labelled bisphenols and alkylphenols for quantification purposes. The SPM and fish-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). 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.

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 fish samples were homogenized. The extraction of the UV-chemicals from water samples, suspended material and homogenized fish 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 in fish liver, SPM and water. 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 OPs were determined by NILU. Prior to extraction, a mixture of isotope labelled OP-standards were added to the sample for quantification. All samples, including fish, 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 OPs were quantified using GC-MS (Waters Quattro micro GC/MSMS) and LC-MS/MS (Thermo Vantage). Lipid content in biological samples was determined gravimetrically after extraction with organic solvent at NILU.

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. Hence, 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 3x 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

Table 7 presents the detection frequencies for all chemicals of this monitoring programme.

Table 7. Detection frequencies for all chemicals of interest of this monitoring programme for the different matrices sampled (water samples, suspended particulate matter and brown trout). The colour scheme is explained at the bottom of the table.

Chemical	% Detection in "Whole water"	% Detection in water samples of the River Alna	% Detection in suspended particulate matter of the River Alna	% Detection in brown trout (muscle/liver and whole fish) sampled in River Alna
Naphthalene	60	N/A	N/A	N/A
Acenaphthylene	0	N/A	N/A	N/A
Acenaphthene	25	N/A	N/A	N/A
Fluorene	35	N/A	N/A	N/A
Phenanthrene	20	N/A	N/A	N/A
Anthracene	0	N/A	N/A	N/A
Fluoranthene	20	N/A	N/A	N/A
Pyrene	25	N/A	N/A	N/A
Benz[a]anthracene	0	N/A	N/A	N/A
Chrysene	10	N/A	N/A	N/A
Benzo[b,j]fluoranthene	10	N/A	N/A	N/A
Benzo[k]fluoranthene	5	N/A	N/A	N/A
Benzo[a]pyrene	5	N/A	N/A	N/A
Indeno[1,2,3-cd]pyrene	10	N/A	N/A	N/A
Dibenzo[ac/ah]anthracene	0	N/A	N/A	N/A
Benzo[ghi]perylene	10	N/A	N/A	N/A
Pentachlorobenzene	0	N/A	N/A	N/A
Hexachlorobenzene	0	N/A	N/A	N/A
g-HCH	0	N/A	N/A	N/A
PCB28/31	0	N/A	N/A	N/A
PCB52	0	N/A	N/A	N/A

PCB101	0	N/A	N/A	N/A
PCB118	0	N/A	N/A	N/A
PCB153	0	N/A	N/A	N/A
PCB138	0	N/A	N/A	N/A
PCB180	0	N/A	N/A	N/A
p,p'-DDE	0	N/A	N/A	N/A
p,p'-DDD	0	N/A	N/A	N/A
p,p'-DDT	0	N/A	N/A	N/A
PBDE28	0	N/A	N/A	N/A
PBDE47	0	N/A	N/A	N/A
PBDE100	0	N/A	N/A	N/A
PBDE99	0	N/A	N/A	N/A
PBDE154	0	N/A	N/A	N/A
PBDE153	0	N/A	N/A	N/A
α-HBCDD	0	N/A	N/A	N/A
β-HBCDD	0	N/A	N/A	N/A
γ-HBCDD	0	N/A	N/A	N/A
SCCP	45	N/A	N/A	N/A
MCCP	40	N/A	N/A	N/A
Nonylphenol	0	N/A	N/A	N/A
Octylphenol	0	N/A	N/A	N/A
4-tert-octylphenol	0	N/A	N/A	N/A
Chlorfenvinfos	0	N/A	N/A	N/A
Cybutryne	0	N/A	N/A	N/A
DEHP	75	N/A	N/A	N/A
Benzophenone	N/A	100	100	0
EHMC-Z	N/A	83	100	33
EHMC-E	N/A	100	100	50
Octocrylene	N/A	100	100	100
UV-327	N/A	100	100	67

UV-328	N/A	100	100	100
UV-329	N/A	83	100	0
TEP	N/A	100	100	0
TCEP	N/A	100	100	0
TPrP	N/A	0	0	0
TCPP	N/A	100	100	0
TiBP	N/A	100	100	100
BdPhP	N/A	0	50	0
TPhP	N/A	100	100	100
DBPhP	N/A	0	0	0
TnBP	N/A	100	100	0
TDCPP	N/A	100	50	67
TBEP	N/A	100	100	100
TCP	N/A	0	100	100
EHDPP	N/A	0	100	0
TXP	N/A	0	50	33
TEHP	N/A	50	100	0
2,4'-BPA	N/A	0	0	0
4,4'-BPA	N/A	50	100	17
2,4'-BPS	N/A	33	0	0
4,4'-BPS	N/A	100	50	0
2,2'-BPF	N/A	0	0	0
2,4'-BPF	N/A	0	0	0
4,4'-BPF	N/A	0	0	17
BP-AF	N/A	0	0	0
BP-AP	N/A	0	0	0
BPB	N/A	0	0	0
BPE	N/A	0	0	0
BP-FL	N/A	0	0	0
BPM	N/A	0	0	0

BPZ	N/A	0	0	0
Perfluoropentanoate	N/A	100	0	0
PFHxA	N/A	100	33	0
PFHpA	N/A	100	17	0
Perfluorooctanoate	N/A	100	50	17
Perfluorononanoate	N/A	67	17	67
Perfluorodecanoate	N/A	17	0	100
PFUdA	N/A	0	0	100
PFDoA	N/A	0	0	100
PFTrDA	N/A	0	0	100
PFTeDA	N/A	0	0	100
PFPeDA	N/A	0	0	0
PFHxDA	N/A	0	0	0
Perfluorobutane sulfonate	N/A	100	0	0
Perfluoropentane sulfonate	N/A	0	0	0
PFHxS	N/A	100	0	100
PFHpS	N/A	17	0	67
Perfluorooctane sulfonate	N/A	100	100	100
Perfluorononane sulfonate	N/A	0	0	0
Perfluorodecane sulfonate	N/A	0	50	0
PFDoS	N/A	0	0	0
PFOSA	N/A	0	0	100
meFOSA	N/A	0	0	0
etFOSA	N/A	0	0	0
meFOSE	N/A	0	0	0
etFOSE	N/A	0	0	0
FOSAA	N/A	0	0	0
me- FOSAA	N/A	0	0	0
et- FOSAA	N/A	0	0	0
4:2 FTS	N/A	0	0	0

6:2 FTS	N/A	0	0	0
8:2 FTS	N/A	0	0	0
10:2 FTS	N/A	0	0	0
12:2 FTS	N/A	0	0	0

Note that the colour scheme is for visual effect only.

Detection
0%
1-49%
50-99%
100%

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[13].

3.1.1 Polycyclic Aromatic Hydrocarbons (PAHs)

Annual average concentrations of individual PAHs based on four water samples collected in 2020 are given in Table 8. PAHs are above LOQ most frequently in water samples from rivers Pasvikelva and Tanaelva. This was found mostly for one out of the four samples collected in May. This could be linked to snow melt and higher suspended particulate matter levels (and sorbed PAHs). Between 2 and 6 PAHs were found above LOQ in two of four samples from the three other rivers. "Whole water" concentrations of naphthalene and anthracene were well below WFD AA-EQS for all rivers. Two samples from River Tana exhibited naphthalene concentrations in the range 20-50 ng L^{-1}. For fluoranthene, the annual average concentrations in all five rivers are a factor of 10 or more below the AA-EQS of 6.3 ng L^{-1}. These values are in line with concentrations measured in the 15 rivers monitored in the period from 2017 to 2019. For benzo[a]pyrene, the average concentration in River Tana is close to WFD AA-EQS. The average concentration of benzo[a]pyrene calculated from the four sampling events at the Tana river sampling site was 0.14 ng L^{-1} (SD= 0.08) is close to the EQS value of 0.17 ng L^{-1}. The generally higher annual average PAH concentrations in the Tana river are the result of one sample with much higher concentrations. Data for the three other samples are low or below LOQ. As a result, these data need to be interpreted carefully. Data from the three remaining rivers are below LOQ, however, as for previous years, these LOQs are at EQS level, rendering the comparison with EQS difficult.

Table 8. "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.

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

Chemical	Alta	Målselva	Pasvikelva	Tana	Vefsna	AA-EQS
Naphthalene	<3.5	<3.5	<3.5	17 (22)	<3.5	**2000**
Acenaphthylene	<0.25	<0.25	<0.25	0.62 (1.0)	<0.25	1280
Acenaphthene	0.47 (0.3)	0.74 (0.77)	0.47 (0.28)	0.54 (0.39)	0.63 (0.55)	3800
Fluorene	0.15	0.20 (0.13)	0.10 (0.04)	0.16 (0.19)	0.12 (0.03)	1500
Phenanthrene	0.28 (0.1)	0.28 (0.1)	0.58 (0.56)	2.3 (3.1)	0.28 (0.09)	500
Anthracene	<0.2	<0.2	<0.2	<0.2	<0.2	**100**
Fluoranthene	<0.15	0.48 (0.82)	0.48 (0.51)	0.42 (0.7)	<0.15	**6.3**
Pyrene	<0.2	0.80 (1.4)	0.29 (0.26)	0.30 (0.40)	0.12 (0.05)	23
Benz[a]anthracene	<0.2	<0.2	<0.2	<0.2	<0.2	18
Chrysene	<0.2	<0.2	0.18 (0.16)	0.18 (0.16)	<0.2	70
Benzo[b,j]fluoranthene	<0.2	<0.2	0.18 (0.16)	0.27 (0.35)	<0.2	
Benzo[k]fluoranthene	<0.2	<0.2	<0.2	0.14 (0.09)	<0.2	
Benzo[a]pyrene	<0.2	<0.2	<0.2	0.14 (0.08)	<0.2	**0.17**
Indeno[1,2,3-cd]pyrene	<0.2	<0.15	0.14 (0.14)	0.16 (0.2)	<0.15	
Dibenzo[ac/ah]anthracene	<0.2	<0.2	<0.2	<0.2	<0.2	14
Benzo[ghi]perylene	<0.2	<0.15	0.13 (0.12)	0.17 (0.2)	<0.15	

***Yearly average (with standard deviation in brackets; n = 4 bottle samples); in ng L^{-1}; WFD AA-EQS for priority/priority hazardous substances are given in bold while those for river basin-specific substances are not.**

3.1.2 Organochlorinated compounds (PCBs and pesticides)

In all cases, no organochlorinated compounds were found above LOQ in water samples collected from any of the five rivers sampled in 2019 (Table 9). Based on these measurements, levels measured at thee sampling sites are well below WFD AA-EQS for pentachlorobenzene, lindane (γ-HCH). While data for *p,p'*-DDT and Σ_3DDTs remained under LOQ, these are now approximately a factor of 5 below EQS. As for data from 2017-2019, the limit of quantification for the sum of concentrations of seven indicator PCBs is significantly higher than the annual proposed average threshold of 2.4 pg L^{-1}.

Table 9. "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	Alta	Målselva	Pasvikelva	Tana	Vefsna	WFD AA-EQS
Pentachlorobenzene	<0.075	<0.075	<0.075	<0.075	<0.075	**7**

Hexachlorobenzene	<0.1	<0.1	<0.1	<0.1	<0.1	
γ-HCH	<0.1	<0.1	<0.1	<0.1	<0.1	**20**
PCB28/31	<0.15	<0.15	<0.15	<0.15	<0.15	
PCB52	<0.1	<0.1	<0.1	<0.1	<0.1	
PCB101	<0.1	<0.1	<0.1	<0.1	<0.1	
PCB118	<0.1	<0.1	<0.1	<0.1	<0.1	
PCB153	<0.1	<0.1	<0.1	<0.1	<0.1	
PCB138	<0.1	<0.1	<0.1	<0.1	<0.1	
PCB180	<0.1	<0.1	<0.1	<0.1	<0.1	
Σ_7PCBs	<0.8	<0.8	<0.8	<0.8	<0.8	0.0024
p,p′-DDE	<0.1	<0.1	<0.1	<0.1	<0.1	
p,p′-DDD	<0.3	<0.5	<0.3	<0.3	<0.3	
p,p′-DDT	<0.1	<0.1	<0.1	<0.1	<0.1	**10**
Σ_3DDTs	<0.5	<0.5	<0.5	<0.5	<0.5	**25**
***Yearly average (n = 4 bottle samples); in ng L^{-1}; WFD AA-EQS for priority/priority hazardous substances are given in bold while those for river basin-specific substances are not.**						

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 10). PBDEs were not found above limits of quantification in “whole water” samples collected from any of the five rivers sampled in 2020. This is in line with data from rivers sampled in 2018 or 2019. Limits of quantification for 2019 are in line with those obtained in 2018 and this means that LOQ for the sum of PBDEs for comparison with WFD AA-EQS is approximately one order of magnitude below EQS. Considering the hydrophobicity of PBDEs and their very low solubility in water, concentrations in the hundreds of ng per litre would be expected to be encountered only in contaminated effluents rather in natural river water.

Table 10. “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	**Alta**	**Målselva**	**Pasvikelva**	**Tana**	**Vefsna**	**WFD AA-EQS**
PBDE28	<0.015	<0.015	<0.015	<0.015	<0.015	
PBDE47	<0.015	<0.015	<0.015	<0.015	<0.015	
PBDE100	<0.015	<0.015	<0.015	<0.015	<0.015	

PBDE99	<0.015	<0.015	<0.015	<0.015	<0.015	
PBDE154	<0.015	<0.015	<0.015	<0.015	<0.015	
PBDE153	<0.015	<0.015	<0.015	<0.015	<0.015	
Σ_5PBDEs	<0.09	<0.09	<0.09	<0.09	<0.09	**1.6**
*Yearly average (standard deviation in brackets; n = 4 bottle samples); in ng L^{-1}; WFD AA-EQS for priority/priority hazardous substances are given in bold while those for river basin-specific substances are not.						

3.1.4 Hexabromocyclododecane (HBCDD)

As for PBDEs, hexabromocyclododecane isomers were not found above LOQ in any of the water samples from the five rivers sampled in 2019 (Table 11). However, limits of quantifications for the sum of HBCDD isomers of 1.5 ng L^{-1} is close the WFD AA-EQS value of 1.6 ng L^{-1}.

Table 11. "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	Alta	Målselva	Pasvikelva	Tana	Vefsna	WFD AA-EQS
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	
Σ_3HBCDD	<1.5	<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 12, the concentrations of SCCPs and MCCPs in all five rivers sampled in 2020 are below 20 and 200 ng L^{-1}, respectively. LOQ are improved compared with those reported in previous years. MCCP data from Målselva and Vefsna are close to or above the WFD AA-EQS of 50 ng L^{-1}. Standard deviations for the mean MCCP concentrations for these two rivers are large. The standard deviation for the mean of 4 samples is high for both compounds. S/MCCPs concentration are below limits of detection for half of the water samples. For the Målselva, the high annual average is the result of one sample with a much higher concentration than all the others. One must be careful when interpreting this result.

Table 12. "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	Alta	Målselva	Pasvikelva	Tana	Vefsna	AA-EQS
SCCP	3.2 (4.8)	4.2 (6)	4.2 (7)	5.8 (11)	14 (17)	**400**

MCCP	11 (13)	102 (200)	13 (23)	14 (24)	37 (58)	50
*Yearly average (n = 4 bottle samples); in ng L^{-1}; Note that original WFD AA-EQS are given in bold. Standard deviations in brackets ().						

3.1.6 Alkylphenols

Three alkyphenolic compounds were analysed for in the four water samples collected in 2020 as was undertaken in previous years. Data are shown in Table 13. As for data from other rivers, none of the three alkylphenols were found above limits of quantification in any of the samples from the five rivers under study in 2020. For nonylphenol, LOQs are over a factor of ten below the AA-EQS. The LOQs for 4-tert-octylphenol for this year's monitoring are similar to those from 2019 and well under the WFD AA-EQS value of 100 ng L^{-1} with LOQ in the range 4-5 ng L^{-1}.

Table 13. "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	Alta	Målselva	Pasvikelva	Tana	Vefsna	AA-EQS
Nonylphenol	<18	<18	<20	<18	<18	**300**
Octylphenol	<10	<10	<10	<10	<10	
4-tert-octylphenol	<4.4	<4.8	<4.3	<4.3	<5.1	**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 in 2020 (Table 14). This mimicks data from 2017-2019. For chlorfenvinphos, these limits of quantification were close to a factor of 1000 below the WFD AA-EQS, while they were over a factor of ten below the WFD AA-EQS level 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). DEHP was found above LOQ in most water samples but at concentrations well below WFD AA-EQS. Concentrations were slightly higher and in the range 20-50 ng L^{-1} in Rivers Målselva, Pasvikelva and Tana than in Rivers Alta and Vefsna (Table 14).

Table 14. "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	Alta	Målselva	Pasvikelva	Tana	Vefsna	AA-EQS
Chlorfenvinfos	<0.25	<0.25	<0.25	<0.25	<0.25	**100**

Cybutryne	<0.25	<0.25	<0.25	<0.25	<0.25	**2.5**
DEHP	8.1 (*2.8*)	37 (*32*)	23 (*32*)	44 (*76*)	6.4 (*2.7*)	**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.

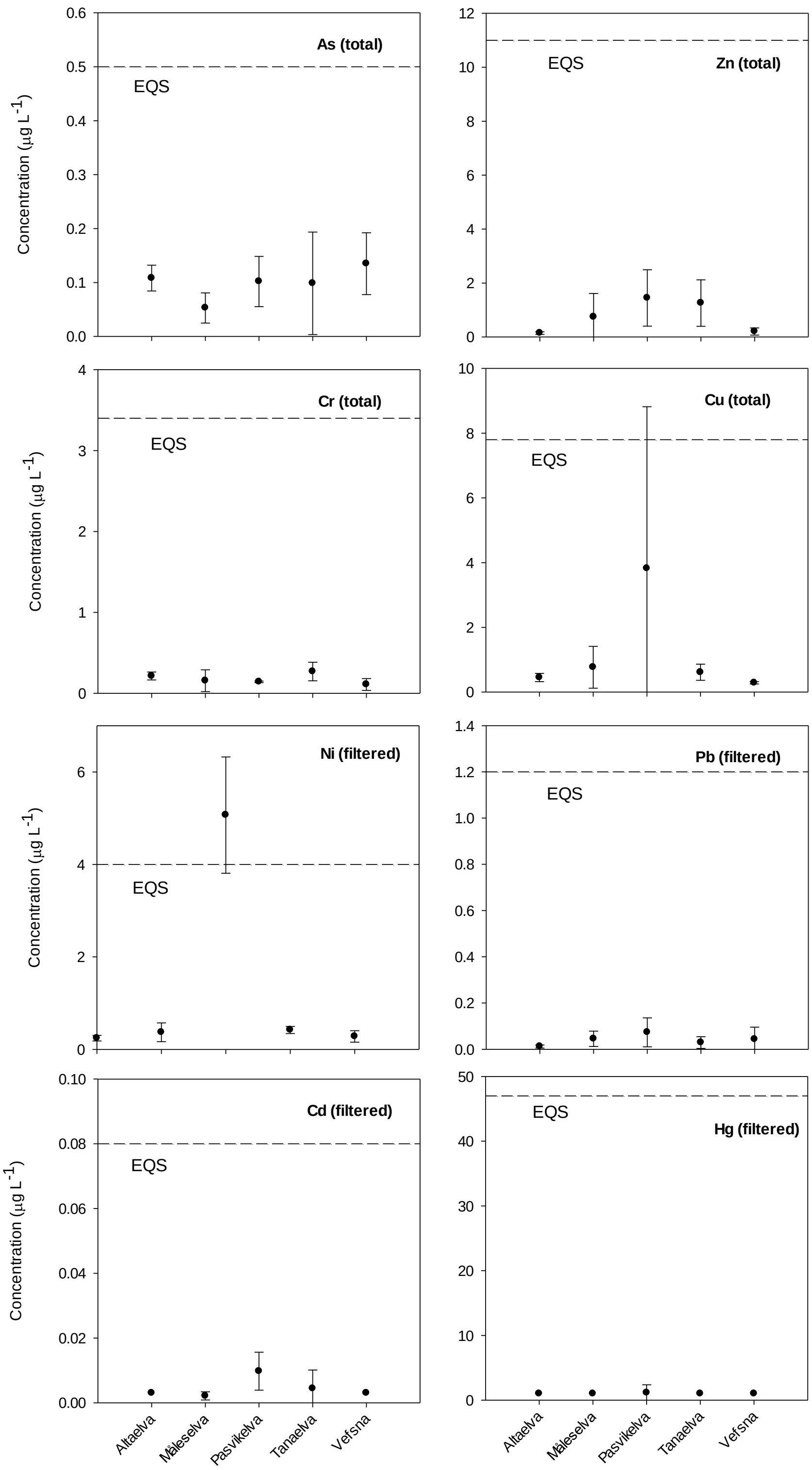

Figure 3. Annual average filtered metal concentrations (and standard deviation, n=4) in five rivers. The dotted reference line represents the AA-EQS for specific elements. For Hg, note that the unit is ng L^{-1} and datapoints for the last three rivers represent the LOQ at 1 ng L^{-1}.

3.1.8 Metals

Trace metals (As, Cd, Cr, Cu, Hg, Ni, Pb and Zn) were sampled four times a year in the Rivers Altaelva, Målselva, Pasvikelva, Tana and Vefsna in 2020. For the purpose of comparison with WFD AA-EQS, filtered concentrations (0.45 µm) were measured for Cd, Hg, Ni, and Pb. 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, Hg, Pb and Zn in all five rivers are below proposed AA-EQS values. The river Pasvikelva shows elevated levels of Cu and Ni. The average concentration for Ni of approximately 5 µg L^{-1} is above the AA-EQS of 4 µg L^{-1}. The mean value for the concentration of Cu in the Pasvikelva is approximately half of the AA-EQS value of 8 µg L^{-1}. Concentrations of Cd, Pb and Zn in the Pasvikelva are slightly higher than in the other rivers. These elevated Cu and Ni concentrations in the Pasvikelva can be explained by the emission of these metals from the smelters located in the towns of Zapolyarny and Nikel near the Russian-Norwegian border (Puro-Tahvanainen et al. 2011). Estimates of annual average filtered concentrations of Hg were well below the EQS of 47 ng L^{-1}. Most data were below the LOQ of 1 ng L^{-1}.

3.1.9 Yearly discharge of selected chemicals for the Alta, Målselva, Pasvikelva, Tana, and Vefsna for 2020

Yearly fluxes or discharges were estimated for these five rivers based on bottle sampling conducted four times in 2020 and data for selected chemicals or classes of chemicals are shown in Table 15.

The highest flux of PAHs was found for the river Tana and yearly discharge estimate of 216 kg y^{-1} is mostly the result of higher concentrations in 2 samples, especially for the PAH naphthalene. For the other rivers, PAH discharges are in the range of 17-38 kg y^{-1}. Since samples taken in the Spring tend to show the highest concentrations, these may be linked to snow melt and PAH associated to SPM. As for data from 2017-2019, yearly discharges of 7 indicator PCB congeners could not be estimated for 2020. Fluxes are likely to be under 3 kg g y^{-1} for the river Alta to under 7.6 kg y^{-1} for the river Tana. Detailed fluxes are given in Tables A1 to A7 in Appendix 2.

Table 15. Estimates of yearly discharge (kg/year) of selected chemicals or sets of chemicals in five rivers for 2020

Chemical	**Alta**	**Målselva**	**Pasvikelva**	**Tana**	**Vefsna**
Σ_{16}PAHs	17	37	38	216	28
Pentachlorobenzene	<0.28	<0.44	<0.38	<0.65	<0.41
Hexachlorobenzene	<0.39	<0.56	<0.56	<1.0	<0.58
γ-HCH	<0.39	<0.56	<0.56	<1.0	<0.58
p,p'-DDE	<0.39	<0.56	<0.56	<1.0	<0.58
p,p'-DDT	<0.39	<0.56	<0.56	<1.0	<0.58
Σ_7PCBs	<3.0	<4.2	<4.3	<7.6	<4.4

3.2 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) and brown trout. For each sampling period of 2020, three consecutive samples were collected both for bottle samples as well as for continuous flow centrifugation. Data for each sampling period are reported as a mean of triplicate measurements.

3.2.1 UV filters in River Alna

All substances were found well above LOQs in the 6 SPM samples. As for SPM samples from 2017-2019, OC was found in highest concentrations in 2020. Most of these substances are relatively hydrophobic and distribute favorably 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). BP3, OC, UV-327, and UV-328 were found above LOQ in all water samples. UV-329 and EHMC-Z were detected in all but one water sample. Results from water and SPM sampling are provided in Table 16. There are no major differences in the average SPM concentrations of UV filters between June and October. Standard deviations generally range from 10 % to under 50 % and are only higher than this on a few occasions. Whole water concentrations of UV filters are highest for OC with concentrations of 11 and 178 ng L^{-1}. The latter results from one very high value, hence the large reported standard deviation (See Table 16). As for previous years, higher concentrations in water are found for most of the substances for the October sampling in water. This difference, however, is not clear for the SPM analysis. Relative levels of the different UV filters found in 2020 are in line with data from 2018-19.

Table 16. UV filter concentrations in water and suspended particulate matter of the River Alna

Chemical	CAS number	Water concentration (ng/L)		SPM concentration (ng/g dry weight)	
		June	September	June	September
Benzophenone (BP3)	119-61-9	0.17 (0.01)	4.12 (4.6)	38 (14)	33 (19)
2-ethyl-hexyl-4-trimethoxycinnamate (EHMC-Z)	5666-77-3	0.02 (0.01)	0.19 (0.28)	7.6 (2.6)	3.7 (2.0)
EHMC-E	5466-77-3	0.1 (0.04)	0.56 (0.8)	34 (14)	20 (11)
Octocrylene (OC)	6197-30-4	11 (7)	178 (287)	1967 (404)	1600 (100)
2-(2'-Hydroxy-3',5'-di-tert-butylphenyl)-5-chlorobenzotriazole (UV-327)	3864-99-1	0.31 (0.03)	0.63 (1.1)	0.24 (0.02)	0.22 (0.06)

2-(2H-Benzotriazol-2-yl)-4,6- ditert pentylphenol (UV-328)	25973-55-1	0.72 (0.3)	3.8 (6.0)	0.94 (0.07)	1.3 (0.5)
2-(2'-hydroxy-5'-tert-octyllphenyl)benzotriazole (UV-329)	3147-75-9	0.2 (0.1)	1.4 (2.3)	5.9 (0.5)	7.6 (3.3)
Mean of triplicate measurements (standard deviation in brackets)					

As shown in Table 17, EHMC was only found above LOQ in the whole fish samples from June and September. In 2020, BP3 and UV-329 were not found above LOQ in any of the fish samples (LOQ = 0.4-0.7 ng g^{-1}). Remaining compounds were consistently detected in all fish samples. OC was found in highest concentrations (2-6 ng g^{-1}). This is in line with relative concentrations of UV filters in water and suspended particulate matter from River Alna. These compounds with logP values above 3 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 favored bioaccumulation.

Table 17. UV filter concentrations in brown trout (muscle/liver and whole fish) sampled in River Alna in June and September 2020

Chemical	CAS number	June 2020 (16.06.2020)		September 2020 (22.09.2020)	
		Whole fish conc. (ng g^{-1} ww)[a]	Muscle conc. (ng g^{-1} ww)[b]	Whole fish conc. (ng g^{-1} ww)[a]	Muscle conc. (ng g^{-1} ww)[b]
Benzophenone (BP3)	119-61-9	<0.7	<0.7	<0.7	<0.07
2-ethyl-hexyl-4-trimethoxycinnamate (EHMC-Z)	5666-77-3	0.097	<0.04	0.056	<0.04
EHMC-E	5466-77-3	0.22	0.05	0.14	<0.07
Octocrylene (OC)	6197-30-4	5.9	2.3 (30)	5.0	3.4 (10)
2-(2'-Hydroxy-3',5'-di-tert-butylphenyl)-5-chlorobenzotriazole (UV-327)	3864-99-1	0.033	0.015 (68)	0.021	0.016 (73)
2-(2H-Benzotriazol-2-yl)-4,6- ditert pentylphenol (UV-328)	25973-55-1	0.21	0.11 (71)	0.15	0.12 (40)
2-(2'-hydroxy-5'-tert-octylphenyl)benzotriazole (UV-329)	3147-75-9	<0.4	<0.4	<0.4	<0.4
[a]Data from one sample; [b]Mean of two samples (relative percent difference %)					

3.2.2 Organophosphorus compounds in the River Alna

Table 18 shows, as for previous years, that a slightly higher number of OPs could be seen in SPM samples than in water samples.
Full names, abbreviations and CAS numbers of the OPFRs are given in Tables 17 and 18. TEHP showed the highest level in SPM with concentration approaching the µg g^{-1} g range but remaining lower than in 2019. TCPP and TBEP were also in some of the highest amounts in SPM (140-287 ng g^{-1} dw) with concentrations in a similar range as those measured the previous year (2017-2019). They also exhibit the highest concentrations in whole water samples with concentrations in the range 74 to 1524 ng L^{-1}. Compounds detected in SPM samples and to a lesser extent in water samples included TCEP, TiBP, TPP, TDCPP, TnBP, and TBEP. TCEP, TCPP, sum TCP and EHDP and TXP were consistently detected in sediment and to a lesser extent in water sample.

Table 18. Organophosphorus flame retardant concentrations in water and suspended particulate matter of the River Alna in June and September 2020

Chemical	CAS number	Water concentration (ng/L)		SPM concentration (ng/g dry weight)	
		June	September	June	September
Tri ethylphosphate (TEP)	78-40-0	35 (8)	58 (23)	31 (11)	N/A
Tri(2-chloroethyl)phosphate (TCEP)	115-96-8	9.7 (1.3)	13 (6.4)	5.3 (1.3)	7.1 (2.5)
Tripropylphosphate (TPrP)	513-08-6	<0.2	<0.9	<0.01	<0.01
tri(1-chloro-2-propyl)phosphate (TCPP)	13674-87-8	74 (19)	265 (148)	203 (7)	287 (199)
Tri-iso-butylphosphate (TiBP)	126-71-6	15 (7.1)	28 (28)	3.0 (0.56)	176 (120)
Butyl diphenylphosphate (BdPhP)	2752-95-6	<0.4	<0.9	14 (6.4)	<0.3
Triphenylphosphate (TPP)	115-86-6	6.9 (4.5)	15 (8)	137 (172)	3.6 (1.6)
Dibutyl phenyl phosphate (DBPhP)	2528-36-1	<0.5	<0.9	<0.01	<0.03
Tri-n-butyphosphate (TnBP)	126-73-8	14 (2.5)	12.4 (1.3)	1.9 (0.5)	2.3 (0.9)

tri(1,3-dichloro-2-propyl)phosphate (TDCPP)	13674-87-8	9.6 (3.2)	19 (13)	<0.2	11 (5)
tri(2-butoxyethyl)phosphate (TBEP)	78-51-3	154 (215)	1524 (1389)	140 (72)	278 (184)
Tricresylphosphate (sumTCP)	1330-78-5	<1	<3	26 (9)	53 (29)
2-ethylhexyl-diphenyl phosphate (EHDP)	1241-94-7	<1.2	<0.8	62 (34)	171 (110)
Trixilylphosphate (TXP)	25155-23-1	<1.2	<1	<0.1	17 (7.5)
tris(isopropylphenyl) phosphate isomers (IPPP)	26967-76-0	<0.4	<1	27 (11)	47 (7)
tris(p-tert-butylphenyl) phosphate (TTBPP)	78-33-1	N/A	N/A	N/A	N/A
tris(2-ethylhexyl) phosphate (TEHP)	78-42-2	<1	1.7 (0.96)	582 (119)	757 (398)

N/A: Not analysed; mean of triplicate measurements, standard deviation in brackets

The concentrations of OPs in whole fish and muscle samples of brown trout from River Alna are shown in Table 19. TCPP was not detected in any of the fish samples from 2020. As found in previous years, TPP and sumTCP were consistently detected in all fish samples analysed. This is in agreement with TPP being consistently found in water and SPM of the river Alna. In 2020, TiBP was consistently found in all fish samples. TBEP and TXP were found above LOQ in some but not all of the fish samples and levels are close to LOQ. None of the concentrations exceeded 5 ng g^{-1} ww fish. In general, the pattern of chemicals found above LOQ in fish samples in 2020 is similar to that from 2019. OP compounds found in the highest amounts in fish were sumTCP and TPP at concentrations of 0.6-2.0 and 1.8-3.8 ng g^{-1} ww, respectively. These are in line with results reported for previous years.

Table 19. Organophosphorus flame retardant concentrations in brown trout (muscle and whole fish) sampled in River Alna in June and September 2020

Chemical (abbreviation)	CAS number	June 2020		September 2020	
		Whole fish conc. (ng g^{-1} ww)[a]	Muscle conc. (ng g^{-1} ww)[b]	Whole fish conc. (ng g^{-1} ww)[a]	Muscle conc. (ng g^{-1} ww)[b]
Tri ethylphosphate (TEP)	78-40-0	<0.4	<0.4	<0.4	<0.4
Tri(2-chloroethyl)phosphate (TCEP)	115-96-8	<0.1	<0.1	<0.1	<0.1

Tripropylphosphate (TPrP)	513-08-6	<0.3	<0.3	<0.3	<0.3
tri(1-chloro-2-propyl)phosphate (TCPP)	13674-87-8	<0.1	<0.1	<0.1	<0.1
Tri-iso-butylphosphate (TiBP)	126-71-6	0.44	0.20 (5)	0.22	0.18 (11)
Butyl diphenylphosphate (BdPhP)	2752-95-6	<0.1	<0.1	<0.1	<0.1
Triphenylphosphate (TPP)	115-86-6	2.5	1.8 (31)	2.2	3.8 (83)
Dibutyl phenyl phosphate (DBPhP)	2528-36-1	<0.2	<0.2	<0.2	<0.2
Tri-n-butylphosphate (TnBP)	126-73-8	<0.1	<0.1	<0.1	<0.1
tri(1,3-dichloro-2-propyl)phosphate (TDCPP)	13674-87-8	0.23	<0.1	0.24	0.18 (6)
tri(2-butoxyethyl)phosphate (TBEP)	78-51-3	0.62	0.32 (9.5)	0.67	0.45 (34)
Tricresylphosphate (sumTCP)	1330-78-5	2.0	0.96 (55)	1.51	0.6 (10)
2-ethylhexyl-diphenyl phosphate (EHDP)	1241-94-7	<0.2	<0.2	<0.2	<0.2
Trixilylphosphate (TXP)	25155-23-1	0.1	<0.1	0.74	<0.1
tris(isopropylphenyl) phosphate isomers (IPPP)	26967-76-0	<0.2	<0.2	<0.2	<0.2
tris(p-tert-butylphenyl) phosphate (TTBPP)	78-33-1	-	-	-	-
tris(2-ethylhexyl) phosphate (TEHP)	78-42-2	<2	<2	<2	<2
[a]Data from one sample; [b]Mean of two samples (Relative percent difference in %)					

3.2.3 Bisphenols in River Alna

The concentrations of a wide range of bisphenols in composite water samples and SPM from the river Alna are given in Table 20. BPA was found above LOQ both in water samples and SPM samples at concentration levels of hundreds of ng L^{-1} or ng g^{-1} dw. This is very consistent with data reported for

2018-2019. One other bisphenol, 4,4’-BPS was consistently found in water samples at concentration of 26-35 ng L^{-1} in line with data from 2018-2019 (8.3-26 ng L^{-1}). As result of slightly lower limits of quantification for 2,4’-BPS in 2020 compared with 2019, it is also possible to measure it in one water sample. While 4,4'-BPS, 2,2'-BPF, 2,4'-BPF, and 4,4'-BPF were detected in SPM samples in 2019, none of these were detected in SPM samples from 2020. BPA was in concentrations approximately one to two orders of magnitude higher than the other bisphenols in both water and SPM samples. Relative standard deviations of the triplicate measurements in SPM between 20 and 40 % are relatively low and consistent with OP and UV filter data. BPA concentrations in water are more variable than those in SPM.

Table 20. Bisphenol concentrations in water and suspended particulate matter of the River Alna in June and September 2020

Chemical	Water concentration (ng/L)		SPM concentration (ng/g dry weight)	
	June	**September**	**June**	**September**
2,4'-BPA (837-08-1)	<2	<2	<3.6	<3.1
4,4'-BPA (80-05-7)	509 (850)	46 (55)	124 (28)	156 (59)
2,4'-BPS (5397-34-2)	1.1 (0.64)	<1.6	<1	<1.1
4,4'-BPS (80-09-1)	26 (8)	35 (22)	6.8 (1.8)	<2.2
2,2'-BPF (2467-02-9)	<13	<7.9	<3.9	<4
2,4'-BPF (2467-03-0)	<65	<43	<22	<22
4,4'-BPF (620-92-8)	<59	<38	<19	<19
BP-AF (1478-61-19)	<0.8	<9.2	<5	<5
BP-AP (1571-75-1)	<2.8	<16	<5	<8.5
BPB (77-40-7)	<3.3	<25	<4	<11
BPE (2081-08-5)	<4.1	<27	<4	<8
BP-FL (3236-71-3)	<4.9	<28	<7.5	<11
BPM (3236-71-3)	<1.3	<5	<6.6	<4
BPZ (843-55-0)	<5.0	<36	<6.4	<16

Mean of triplicate measurements; standard deviations in brackets

The table below (Table 21) shows the bisphenol concentrations in whole fish and muscle samples of brown trout from the river Alna. Compounds such as 4,4'-BPA, 4,4'-BPS, 2,2'-BPF, 2,4'-BPF and 4,4'-BPF were consistently found in whole fish and fish muscle samples from 2019. However, almost none of these could be found above LOQ in fish samples from 2020. BPA (4,4’-BPA) was found above LOQ only once and this was in the whole fish sample from June 2020 (19.1 ng g^{-1} ww). The bisphenol 4,4’-BPF was found above LOQ in the fish muscle sample from September at a concentration of 5.7 ng g^{-1} ww. The concentration of remaining bisphenols were below LOQ in all samples. This is a much lower number of bisphenol compounds detected than in previous years. Levels found in previous years are at LOQ level and this could explain the lack of detection.

Table 21. Bisphenol concentrations in brown trout (muscle and whole fish) sampled in River Alna in May and October 2020

Chemical	**June 2020**		**September 2020**	
	Whole fish concentration (ng g^{-1} ww)[a]	**Muscle concentration (ng g^{-1} ww)[b]**	**Whole fish concentration (ng g^{-1} ww)[a]**	**Muscle concentration (ng g^{-1} ww)[b]**

2,4'-BPA (837-08-1)	<2	<2.2	<2.5	<2.4
4,4'-BPA (80-05-7)	19.1	<11	<11	<12
2,4'-BPS (5397-34-2)	<0.65	<0.8	<0.9	<0.94
4,4'-BPS (80-09-1)	<22	<22	<20	<22
2,2'-BPF (2467-02-9)	<0.66	<0.73	<0.76	<1.2
2,4'-BPF (2467-03-0)	<11	<10	<9.6	<11
4,4'-BPF (620-92-8)	<5.8	<5.5	<5.2	5.7 (4)
BP-AF (1478-61-19)	<5.5	<5.2	<5	<5.5
BP-AP (1571-75-1)	<2	<2.2	<2.3	<2.2
BPB (77-40-7)	<2.9	<3	<3.1	<3.0
BPE (2081-08-5)	<2.4	<2.9	<3.2	<3.3
BP-FL (3236-71-3)	<3.6	<3.4	<3.3	<3.6
BPM (3236-71-3)	<0.89	<0.89	<0.89	<0.89
BPZ (843-55-0)	<4.0	<4.0	<3.8	<4.1
[a]Data from one sample; [b]Mean of two samples (relative percent difference, %)				

3.2.4 Emergent contaminant distribution in River Alna

For compounds whose concentrations were above LOQ both in fish and in water or SPM, it was possible to calculate bioaccumulation factors (BAF in L kg^{-1}):

$$BAF = \frac{C_{Fish}}{C_w}$$

With C_{Fish} and C_w, contaminant concentrations in fish (ng g^{-1}) on a wet weight or lipid basis and in water (ng L^{-1}). The lipid content of fish samples was not available for 2020. It was therefore not possible to calculate lipid-based BAF as we have done in previous years.

The quantification of emerging contaminants both in water and in SPM means field-based organic carbon-normalised suspended particulate matter-water distribution coefficients (K_{oc}) can be estimated:

$$K_{oc} = \frac{C_{SPM,OC}}{C_w}$$

With $C_{SPM,OC}$ the OC-normalised SPM concentration and C_w the concentration in water. As shown on Figure 4, many logK_{oc} values for emerging contaminants of interest are close to the 1:1 relationship with logK_{ow} and demonstrate agreement between water and SPM concentrations measured for these compounds. LogK_{oc} values obtained in 2030 are generally in line with those reported in 2018. A wider discrepancy between logK_{oc} and logK_{ow} can be seen for bisphenols, TCPP, TCEP, UV327 and 328, and BP3. Values of logK_{oc} for some UV filters tend to be under the 1:1 line. LogK_{ow} values were obtained from the Pubchem database and since many these values are calculated values, some uncertainty can be expected with these. For comparison, logK_{oc} for PCBs from 2016 are also plotted on Figure 4. LogK_{oc} for OPFRs are generally in agreement with literature values (e.g. Zhang et al. 2018).

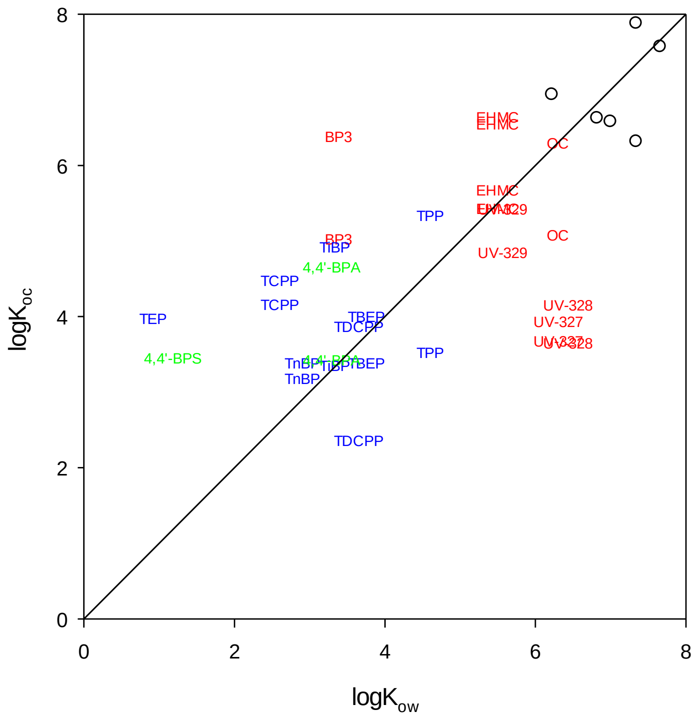

Figure 4. Field-based organic carbon-normalised SPM-water distribution coefficients (K_{oc}) for emerging contaminants in River Alna in 2020. Empty circles represent K_{oc} for PCBs.

Finally, fish concentrations can also be compared with SPM concentrations through the calculation of biota-sediment accumulation factors (BSAF) (Burkhard, 2003):

$$BSAF = \frac{C_{Fish,lip}}{C_{SPM,OC}}$$

BSAF for emerging contaminants for 2020 could not be plotted for 2020 since lipid content of fish samples was not available.

3.2.5 PFAS in River Alna

The list of PFAS chemicals being investigated was similar to that reported in 2017. Mean concentrations of PFAS compounds in triplicate water and SPM samples collected in June and October 2020 are reported in Table 22. The concentrations of PFAS compounds found above LOQ were in the range 0.63-2.8 ng L^{-1}. As in 2019, PFOS, PFOA, PFBS, PFHxS, PFPA, PFHxA, PFHpA, and PFNA were found above LOQ in water samples from the Alna. In addition to PFOS, PFHxA, PFHpA, PFOA, PFNA and PFDS were measured above limits of quantification in (some) SPM samples. The list of PFAS compounds detected in River Alna from 2018 to 2020 are very similar and similar to that for PFAS chemicals found in stormwaters during monitoring in the programme “Environmental contaminants in an Urban fjord”[14]. In addition, a relatively good agreement between the relative distribution of PFAS compounds in Alna

[14] Environmental Contaminants in an Urban Fjord, 2017
https://www.miljodirektoratet.no/globalassets/publikasjoner/m1131/m1131.pdf

river water and in Oslo stormwaters can be seen in Figure 5. Since the sampling of stormwaters and river water was not coordinated, it is difficult to be more informative.

Table 22. PFAS concentration in water and suspended particulate matter of the River Alna (standard deviations in brackets)

Chemical	CAS number	Water concentration (ng/L)		SPM concentration (ng/g dry weight)	
		Sample 1	Sample 2	Sample 1	Sample 2
Perfluoropentanoate (PFPA)	356-42-3	1.7 (0.15)	2.2 (1.0)	<0.5	<0.5
Perfluorohexanoate (PFHxA)	307-24-4	1.5 (0.4)	2.8 (0.7)	0.63 (0.66)	0.53 (0.49)
Perfluoroheptanoate (PFHpA)	375-85-9	0.97 (0.25)	1.8 (0.5)	0.37 (0.20)	<0.5
Perfluorooctanoate (PFOA)	335-67-1	1.5 (0.4)	2.8 (1.0)	0.67 (0.21)	<0.5
Perfluorononanoate (PFNA)	375-95-1	0.77 (0.9)	0.97 (0.4)	0.33 (0.14)	<0.5
Perfluorodecanoate (PFDA)	335-76-2	<0.4	0.63 (0.8)	<0.4	<0.4
Perfluoroundecanoate (PFUdA)	2058-94-8	<0.4	<0.4	<0.4	<0.4
Perfluorododecanoate (PFDoA)	307-55-1	<0.4	<0.4	<0.4	<0.4
Perfluorotridecanoate (PFTrDA)	72629-94-8	<0.4	<0.4	<0.4	<0.4
Perfluorotetradecanoate (PFTeDA)	376-06-7	<0.4	<0.4	<0.4	<0.4
Perfluoropentadecanoate (PFPeDA)	1214264-29-5	<0.4	<0.4	<0.4	<0.4
Perfluorohexadecanoate (PFHxDA)	67905-19-5	<0.4	<0.4	<0.4	<0.4
Perfluorobutane sulfonate (PFBS)	375-73-5	0.50 (0.10)	0.73 (0.32)	<0.1	<0.1
Perfluoropentane sulfonate (PFPS)	2706-91-4	N/A	N/A	<0.1	<0.1
Perfluorohexane sulfonate (PFHxS)	355-46-4	0.33 (0.06)	0.40 (0.1)	<0.1	<0.1

Perfluoroheptane sulfonate (PFHpS)	21934-50-9	0.1 (0.1)	<0.1	<0.1	<0.1
Perfluorooctane sulfonate (PFOS)	1763-23-1	1.63 (0.21)	2.83 (0.55)	0.63 (0.15)	0.63 (0.12)
8Cl-perfluorooctane sulfonate (8Cl- PFOS)	N/A	N/A	N/A	N/A	N/A
Perfluorononane sulfonate (PFNS)	17202-41-4	<0.1	<0.1	<0.1	<0.1
Perfluorodecane sulfonate (PFDS)	67906-42-7	<0.2	<0.2	0.2 (0.1)	0.2 (0.17)
Perfluorododecane sulfonate (PFDoS)	85187-17-3	<0.2	<0.2	<0.2	<0.2
Perfluorooctane sulphonamide (PFOSA)	754-91-6	<0.1	<0.1	<0.1	<0.1
N-Methyl fluorooctane sulfonate (meFOSA)	250-665-8	<0.3	<0.3	<0.3	<0.3
N-Ethyl fluorooctane sulfonate (etFOSA)	4151-50-2	<0.3	<0.3	<0.3	<0.3
N-Methyl fluorooctane sulfonamidoethanol (meFOSE)	24448-09-7	<2	<2	<2	<2
N-Ethyl fluorooctane sulfoamidoethanol (etFOSE)	1691-99-2	<2	<2	<2	<2
Perfluorooctane Sulfonamidoacetic acid (FOSAA)	2806-24-8	N/A	N/A	<0.3	<0.3
N-methylperfluoro-1-octanesulfonamidoacetic acid (me- FOSAA)	2355-31-9	<0.3	<0.3	<0.3	<0.3
N- ethylperfluoro-1-octanesulfonamidoacetic acid (et- FOSAA)	2991-50-6	<0.3	<0.3	<0.3	<0.3
4:2 Fluorotelomer sulfonate (4:2 FTS)	414911-30-1	<0.3	<0.3	<0.3	<0.3
6:2 Fluorotelomer sulfonate (6:2 FTS)	27619-97-2	<0.3	<0.3	<0.3	<0.3
8:2 Fluorotelomer sulfonate (8:2 FTS)	481071-78-7	<0.3	<0.3	<0.3	<0.3
10:2 Fluorotelomer sulfonate (10:2 FTS)	N/A	<0.3	<0.3	<0.3	<0.3
12:2 Fluorotelomer sulfonate (12:2 FTS)	N/A	<0.3	<0.3	<0.3	<0.3

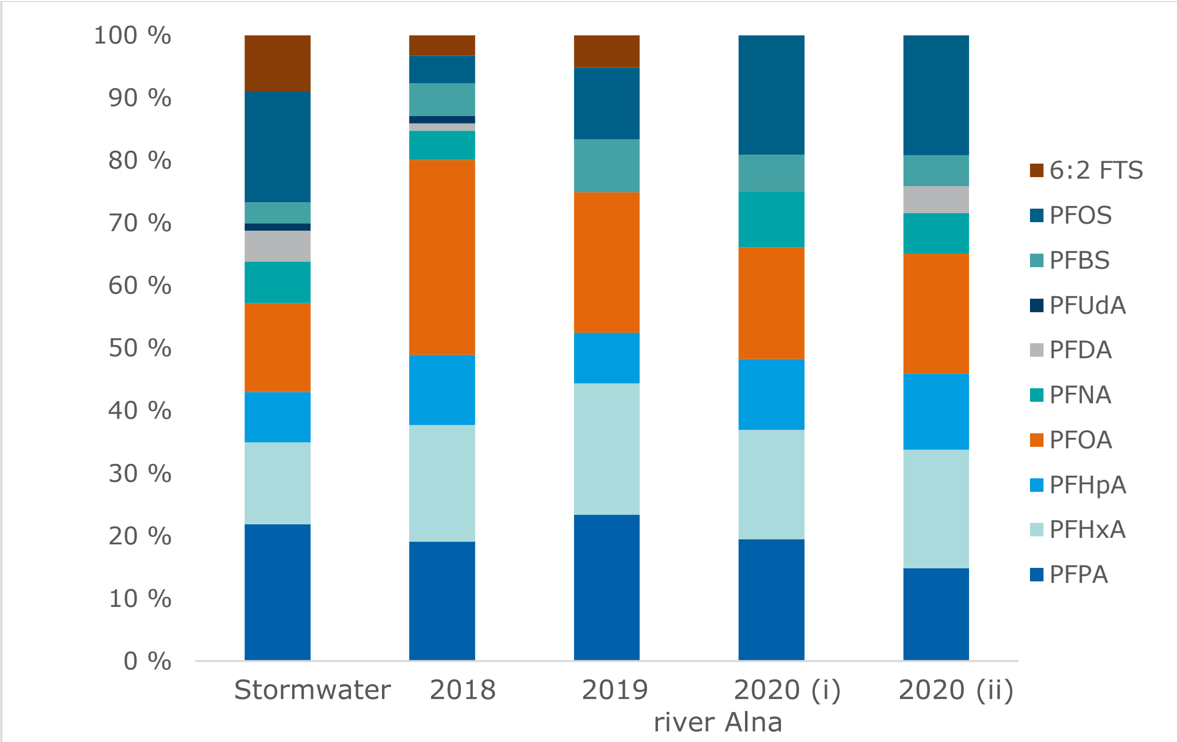

Figure 5. Comparison of the relative distribution of detected PFAS compounds in water of River Alna (2018, 2019 and 2020) and in Stormwater samples collected from drains in Oslo for the monitoring programme "Environmental contaminants in an Urban fjord".

PFAS concentrations in brown trout sampled in June and September 2020 are given in Table 23. Except for a couple of chemicals (PFBS and PFPS), the number of PFAS compounds measured in liver samples in 2020 is comparable with results from this monitoring programme from 2019. Highest PFAS concentrations in fish liver were found for PFOS. PFOS concentrations in fish liver from 2020 were 37 and 22 ng g^{-1} ww and were lower than those measured in 2019 (53 and 35 ng g^{-1} ww). PFOSA, PFDA, PFDoA, PFTrDA, PFTeDA, PFDS were found on average at concentrations in liver between 1 and 3 ng g^{-1} ww. Concentrations of other compounds that were detected in fish liver samples were below 1 ng g^{-1} ww. The relative pattern of PFAS chemicals in brown trout in 2019 and 2020 are similar.

TABLE 23. PFAS concentration in brown trout (liver) sampled in River Alna in May and October 2019 (standard deviation in brackets)

Chemical	CAS number	June 2020	September 2020
		Liver concentration (ng g^{-1} ww)[a]	Liver concentration (ng g^{-1} ww)[a]
Perfluoropentanoate (PFPA)	356-42-3	<0.5	<0.5
Perfluorohexanoate (PFHxA)	307-24-4	<0.5	<0.5
Perfluoroheptanoate (PFHpA)	375-85-9	<0.5	<0.5
Perfluorooctanoate (PFOA)	335-67-1	<0.5	0.4 (0.3)

Perfluorononanoate (PFNA)	375-95-1	0.52 (0.3)	0.62 (0.4)
Perfluorodecanoate (PFDA)	335-76-2	1.3 (0.4)	1.7 (0.2)
Perfluoroundecanoate (PFUdA)	2058-94-8	0.87 (0.12)	0.93 (0.2)
Perfluorododecanoate (PFDoA)	307-55-1	2.0 (0.2)	2.1 (0.5)
Perfluorotridecanoate (PFTrDA)	72629-94-8	1.3 (0.4)	1.2 (0.3)
Perfluorotetradecanoate (PFTeDA)	376-06-7	1.6 (0.5)	1.1 (0.3)
Perfluoropentadecanoate (PFPeDA)	1214264-29-5	<0.4	<0.4
Perfluorohexadecanoate (PFHxDA)	67905-19-5	<0.4	<0.4
Perfluorobutane sulfonate (PFBS)	375-73-5	<0.1	<0.1
Perfluoropentane sulfonate (PFPS)	2706-91-4	<0.1	<0.1
Perfluorohexane sulfonate (PFHxS)	355-46-4	0.8 (0.9)	0.3 (0.1)
Perfluoroheptane sulfonate (PFHpS)	21934-50-9	0.23 (0.15)	0.13 (0.06)
Perfluorooctane sulfonate (PFOS)	1763-23-1	37 (9)	22 (13)
8Cl-perfluorooctane sulfonate (8Cl-PFOS)	N/A	NA	NA
Perfluorononane sulfonate (PFNS)	17202-41-4	<0.1	<0.1
Perfluorodecane sulfonate (PFDS)	67906-42-7	2.3 (0.7)	2.0 (0.6)
Perfluorododecane sulfonate (PFDoS)	85187-17-3	<0.2	<0.2
Perfluorooctane sulphonamide (PFOSA)	754-91-6	2.6 (0.46)	2.6 (0.3)
N-Methyl fluorooctane sulfonate (meFOSA)	250-665-8	<0.3	<0.3
N-Ethyl fluorooctane sulfonate (etFOSA)	4151-50-2	<0.3	<0.3
N-Methyl fluorooctane sulfonamidoethanol (meFOSE)	24448-09-7	<2	<2
N-Ethyl fluorooctane sulfoamidoethanol (etFOSE)	1691-99-2	<2	<2
Perfluorooctane Sulfonamidoacetic acid (FOSAA)	2806-24-8	<0.3	<0.3
N-methylperfluoro-1-octanesulfonamidoacetic acid (me-FOSAA)	2355-31-9	<0.3	<0.3

N- ethylperfluoro-1-octanesulfonamidoacetic acid (et-FOSAA)	2991-50-6	<0.3	<0.3
4:2 Fluorotelomer sulfonate (4:2 FTS)	414911-30-1	<0.3	<0.3
6:2 Fluorotelomer sulfonate (6:2 FTS)	27619-97-2	<0.3	<0.3
[a] Mean and standard deviation in brackets for triplicate samples			

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. logBCF values for PFNA, PFDA, PFHxS, PFHpS, PFOA and PFOS, calculated as the logarithm of the concentration in the organism (wet weight basis) divided by that in water, are presented in Table 24. LogBCF estimated for PFOS in 2020 are in the range observed for samples from previous years. For PFOS, the log of SPM-water distribution coefficient of 2.40 in 2020 is slightly lower than the 2019 value of 3.00 for river Alna and is in agreement with literature values (e.g. Labadie and Chevreuil, 2011).

Table 24. Bioconcentration factors for selected PFAS compounds in the River Alna

Chemical	Bioconcentration factor (logBCF; $L\ kg^{-1}$)*			
	June 2020		September 2020	
	Whole fish	Liver	Whole fish	Liver
PFOA		-		2.15
PFNA		2.83		2.80
PFDA		-		3.43
PFHxS		3.38		2.88
PFHpS		3.37		-
PFOS		4.36		3.88

*On a wet weight basis; these logBCFs are for compounds detected both in brown trout and in the water phase.

4 Conclusions

Monitoring based on water samples in the rivers Altaelva, Målselva, Pasvikelva, Tana and Vefsna in 2020:

- Polycyclic aromatic hydrocarbon (PAH) concentrations were the highest and closest to WFD AA-EQS for the sampling location on the River Tana followed by the Pasvikelva. For the river Tana, benzo[a]pyrene was close to AA-EQS value of 0.17 ng L^{-1}. Annual average estimates of concentrations for the selected monitoring sites on the other rivers were below LOQ but remained at EQS level for benzo[a]pyrene.
- All organochlorinated priority substances were below LOQ in all water samples and below AA-EQS for pentachlorobenzene and γ-HCH. The Σ_7PCBs is below LOQ but the sum of LOQs is significantly higher than the proposed AA-EQS of 0.0024 ng L^{-1}.
- PBDEs were not found above LOQ in any of the samples collected from the five rivers. Similar results were obtained for HBCDD isomers with no HBCDD found above LOQ in any of the samples analysed in 2020. However, the LOQ is close to the EQS.
- Metal (filtered and/or total) concentrations were mostly well below AA-EQS for all rivers with the exception of Ni and Cu in the Pasvikelva. The annual average concentrations of Ni in the Pasvikelva was above the AA-EQS of 5 ng L^{-1} while the concentration of Cu reached half the EQS.
- Better limits of quantification for MCCPs helped with comparisons with AA-EQS. Most results were low or below LOQ except for one samples from the River Målselva which resulted in an annual average concentration above AA-EQS for that river. Data for SCCPs, alkylphenols, chlorfenvenphos, cybutryne and DEHP were mostly low or below LOQ and below EQS. LOQ values for 4-tert-octylphenol improved and concentrations in all rivers were 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 steps in WFD river monitoring programme is to establish robust methodologies to measure trends in concentrations with time. Options for this task for hydrophobic substances include the measurement of SPM-associated concentrations, the use of passive sampling devices and perhaps biota.

Emerging contaminants in the River Alna in 2020:

- UV filters were consistently found both in suspended particulate matter and water samples. Fish monitoring showed variable results. The four UV filters detected in brown trout were EHMC-E, OC, UV-327 and UV-328.
- As for the data from 2017-2019, SPM sampled in 2020 appeared generally more promising for sampling of organophosphorus compounds in the River Alna than composite water sampling. Most organophosphorus compounds were consistently detected in SPM except for TPrP, BdPhP, DBPhP, TDCPP and TXP. Concentrations ranged from 1.3 ng g^{-1} dw for TnBP up to over 1000 ng g^{-1} dw for TEHP. TPP, TiBP, TBEP and sumTCP, were consistently detected in all fish samples analysed with concentrations not exceeding a few ng g^{-1} ww except for TPP with concentrations between 1.5 and 5.4 ng g^{-1} ww.

- As for 2017-2019, a few bisphenols were detected in the SPM samples (4,4'-BPA and 4,4'-BPS only). All these compounds were also found in water samples. BPA (4,4'-BPA) is present in highest concentrations, at the ten to hundreds of ng L^{-1} or ng g^{-1} dw levels in water and SPM respectively. There were hardly any bisphenol detections in brown trout samples.
- For most substances found both in SPM and water samples, estimated $logK_{oc}$ tend to show equilibrium distribution between organic carbon and water. Data were more variable for 2020 with more data deviating from the 1:1 relationship with $logK_{ow}$ than in previous years.
- PFOS, PFOA, PFBS, PFHxS, PFPA, PFHxA, PFHpA, PFNA and PFDA were found at concentrations of 0.2-3.2 ng L^{-1} in water samples from the Alna while only PFOS was consistently measured above LOQ in SPM. This list of PFAS compounds detected in water samples is similar to the 2017-2019 data. In general, the identity and relative levels of PFAS compounds above LOQ in Alna river water are in agreement with stormwater data from the monitoring programme "Environmental contaminants in an urban fjord", indicating storm waters and surface runoff is a non-negligible source of PFAS chemicals to River Alna.
- A similar number of PFAS compounds were found in fish sample in 2020 compared with 2019. Out of 31 PFAS chemicals analysed for, 10 were measured above LOQ in most fish liver samples from the two sampling periods. PFOS showed the highest concentrations of all PFAS compound monitored. Logarithm of brown trout bioconcentration factors (logBCF) could be calculated for selected PFAS compounds.

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Appendix A.

Alna - Emerging contaminants sampling in fish

Stasjon	Sample ID	Lims-nr	Species	Date captured	Date dissected	Fish Ids	Muscle/Whole organism (g)	MU/WO, LI	Liver (g)	Mean (SD) length	Mean (SD) weight
EO-Alna-2 (Al	Alna Ø1	NR-2020-07339	*Salmo trutta*	16.06.2020	27.10.2020	1-5	146.4	WO + LI	2.2	13,2(1,0)	31,4(6,6)
EO-Alna-2 (Al	Alna Ø2	NR-2020-07340	*Salmo trutta*	16.06.2020	27.10.2020	6-10	138.2	MU + LI	8.7	20,1(2,2)	114,2(34,1)
EO-Alna-2 (Al	Alna Ø3	NR-2020-07341	*Salmo trutta*	16.06.2020	27.10.2020	11-15	153.8	MU + LI	31.9	28,0(1,9)	301,1(83,9)
EO-Alna-2 (Al	Alna Ø4	NR-2020-07342	*Salmo trutta*	22.09.2020	27.10.2020	16-20	53.6	WO + LI	0.7	9,7(0,3)	11,7(1,1)
EO-Alna-2 (Al	Alna Ø5	NR-2020-07343	*Salmo trutta*	22.09.2020	27.10.2020	21-25	133.7	MU + LI	19.9	23,9(2,3)	178,4(54,8)
EO-Alna-2 (Al	Alna Ø6	NR-2020-07344	*Salmo trutta*	22.09.2020	27.10.2020	26-30	147.9	MU + LI	32.7	29,9(2,7)	349,9(112,2)

Appendix B.

Yearly discharges of chemicals from the Rivers Driva, Nausta, Nidelva, Orkla and Vosso for 2019

TABLE A1

Yearly discharge of polycyclic aromatic hydrocarbons in five rivers

	Alta	Målselva	Pasvik	Tana	Vefsna
Naphthalene	8.9	12.4	13	138	13
Acenaphthylene	<1	<1.4	<1.5	14.3	<1.4
Acenaphthene	2.1	5.6	3.5	8.4	4.9
Fluorene	<0.6	1.4	0.51	3.1	0.65
Phenanthrene	<0.8	1.8	5.2	14.2	1.8
Anthracene	<0.8	<1.1	<1.1	<2	<1.1
Fluoranthene	<0.8	3.9	4.3	10	<0.9
Pyrene	<0.8	6.6	2.4	6.1	0.82
Benz[a]anthracene	<0.8	<1.1	<1.1	<2	<1.2
Chrysene	<0.8	<1.1	1.6	3.1	<1.2
Benzo[b,j]fluoranthene	<0.8	<1.1	1.6	5.6	<1.2
Benzo[k]fluoranthene	<0.8	<1.1	<1.1	2.1	<1.2
Benzo[a]pyrene	<0.8	<1.1	<1.1	2.0	<1.2
Indeno[1,2,3-cd]pyrene	<0.8	<1.1	1.2	3.2	<0.9
Dibenzo[ac/ah]anthracene	<0.8	<1.1	<1.1	<2	<1.2
Benzo[ghi]perylene	<0.8	<1.1	1.1	3.2	<0.9

*Data in kg/year

TABLE A2

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

	Alta	Målselva	Pasvik	Tana	Vefsna
Pentachlorobenzene	<0.28	<0.44	<0.38	<0.65	<0.41
Hexachlorobenzene	<0.39	<0.56	<0.56	<1.0	<0.58
g-HCH	<0.39	<0.56	<0.56	<1.0	<0.58
PCB28/31	<0.4	<0.8	<0.9	<1.7	<0.9
PCB52	<0.4	<0.6	<0.6	<1	<0.6
PCB101	<0.4	<0.6	<0.6	<1	<0.6
PCB118	<0.4	<0.6	<0.6	<1	<0.6
PCB153	<0.4	<0.6	<0.6	<1	<0.6
PCB138	<0.4	<0.6	<0.6	<1	<0.6
PCB180	<0.4	<0.6	<0.6	<1	<0.6
p,p'-DDE	<0.4	<0.6	<0.6	<1	<0.6
p,p'-DDD	<1.2	<1.6	<2	<4	<1.9
p,p'-DDT	<0.4	<0.6	<0.6	<1	<0.6

*Data kg/year

TABLE A3

Yearly discharge of polybrominated diphenyl ethers in five rivers

	Alta	Målselva	Pasvik	Tana	Vefsna
PBDE28	<0.06	<0.09	<0.08	<0.13	<0.08
PBDE47	<0.06	<0.09	<0.08	<0.13	<0.08
PBDE100	<0.06	<0.09	<0.08	<0.13	<0.08
PBDE99	<0.06	<0.09	<0.08	<0.13	<0.08
PBDE154	<0.06	<0.09	<0.08	<0.13	<0.08
PBDE153	<0.06	<0.09	<0.08	<0.13	<0.08
*Data in kg/year					

TABLE A4

Yearly discharge of hexabromocyclododecane in five rivers

	Alta	Målselva	Pasvik	Tana	Vefsna
α-HBCDD	<2	<3	<3	<1.3	<3
β-HBCDD	<2	<3	<3	<1.3	<3
γ-HBCDD	<2	<3	<3	<1.3	<3
*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

	Alta	Målselva	Pasvik	Tana	Vefsna
SCCP	12	23	24	58	82

MCCP	44	570	73	134	213

*Data in kg/year for all rivers

TABLE A6

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

	Alta	Målselva	Pasvik	Tana	Vefsna
Nonylphenol	<70	<99	<109	<177	<104
Octylphenol	<37	<53	<55	<95	<56
4-tert-octylphenol	<17	<27	<24	<43	<30

*Data in kg/year for all rivers

TABLE A7

Yearly discharge of chlorfenvinfos, cybutryne and DEHP in five rivers

	Alta	Målselva	Pasvik	Tana	Vefsna
Chlorfenvinfos	<0.9	<1.5	<1.2	<1.9	<1.4
Cybutryne	<0.9	<1.5	<1.2	<1.9	<1.4
DEHP	33	175	237	1055	39

*Data in kg/year for all rivers

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