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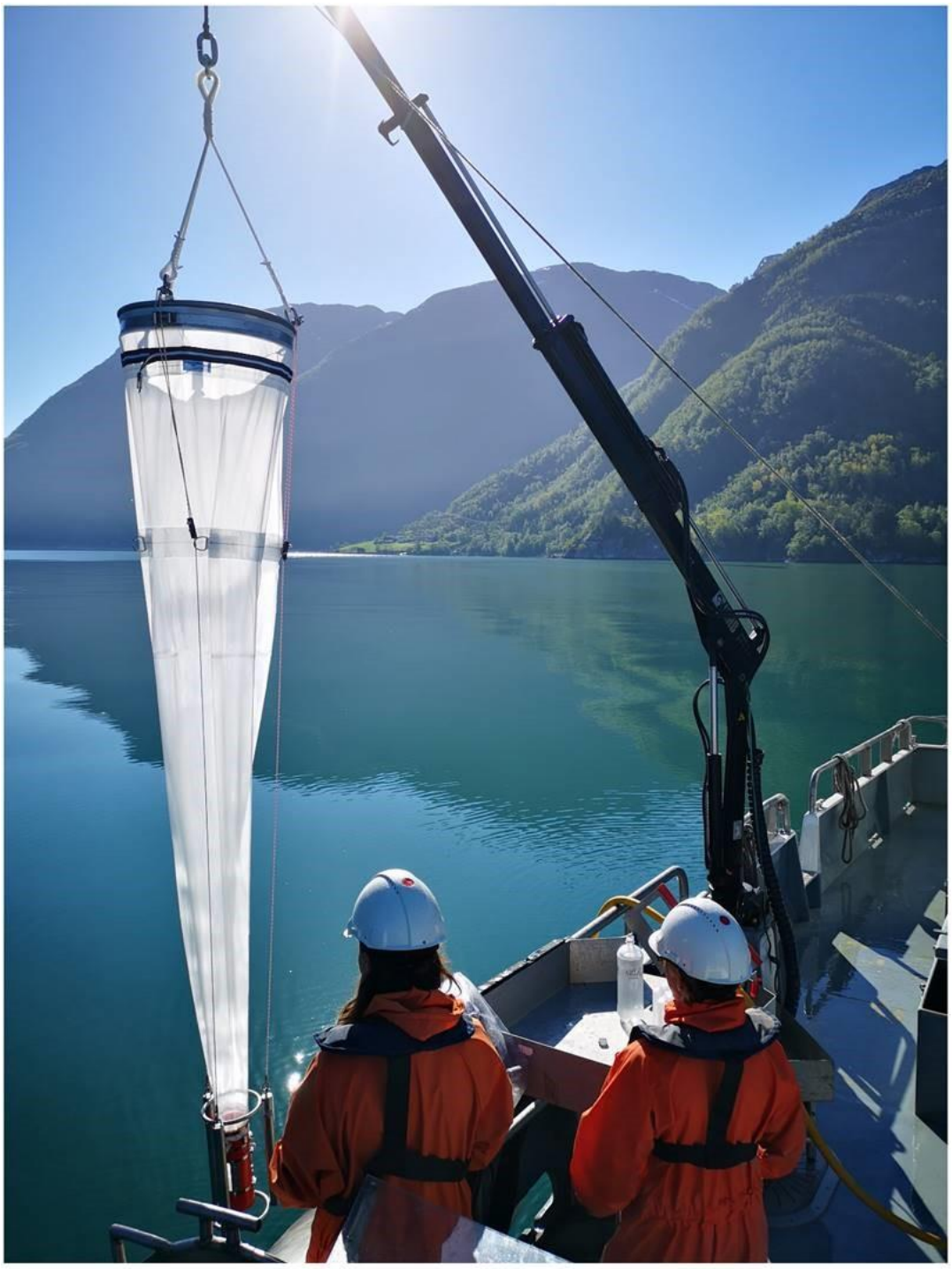
Microplastics in Norwegian coastal areas, rivers, lakes and air

(MIKRONOR1)



Norwegian Institute for Water Research

REPORT

Main Office
Økernveien 94
NO-0579 Oslo, Norway
Phone (47) 22 18 51 00

NIVA Region South
Jon Lilletuns vei 3
NO-4879 Grimstad, Norway
Phone (47) 22 18 51 00

NIVA Region East
Sandvikaveien 59
NO-2312 Ottestad, Norway
Phone (47) 22 18 51 00

NIVA Region West
Thormøhlensgate 53 D
NO-5006 Bergen Norway
Phone (47) 22 18 51 00

NIVA Denmark
Njalsgade 76, 4th floor
DK 2300 Copenhagen S, Denmark
Phone (45) 39 17 97 33

Internet: www.niva.no

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Author(s) Bert van Bavel, Amy Lusher, Chiara Consolaro, Sverre Hjelset, Cecilie Singdahl-Larsen, Nina Buenaventura, Laura Röhler, Svetlana Pakhomova, Espen Lund, David Eidsvoll, Dorte Herzke and Inger-Lise Nerland Bråte.	Topic group Environmental monitoring	Distribution Open
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Miljødirektoratet/Norwegian Environment Agency	Eivind Farmen
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The Norwegian Environment Agency (Miljødirektoratet, NEA) tasked the Norwegian Institute for Water Research (NIVA) to initiate Norway's National microplastic monitoring program. The program "Microplastics in Norwegian coastal areas, rivers, lakes and air (MIKRONOR)", was designed to target the multitude of environments in the Norwegian coastal, freshwater and terrestrial ecosystems. The primary aim is to provide information on levels and types of microplastics in aquatic environments as well as in air and build on the baseline data already generated for a number of these environments on previous assignments by NEA.
This report contains the first results of coastal sites, open marine waters, lakes, rivers and air including high-volume water samples (freshwater and marine, n=48), Ferrybox samples (marine, n=20), blue mussels (marine, n=71), vertical plankton net samples (marine, n=29) and 24 air samples (precipitation n= 12 and active air sampling n = 12).

Four keywords	Fire emneord
1. Environmental monitoring	1. Miljøovervåking
2. Microplastics	2. Mikroplast
3. Water samples	3. Vannprøver
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MIKRONOR1

Microplastics in Norwegian coastal areas, rivers, lakes and air

Preface

On behalf of the Norwegian Environment Agency (Miljødirektoratet), the Norwegian Institute for Water Research (NIVA) organised the sampling and carried out the analysis for MIKRONOR 1.

Coordinator at the Norwegian Environment Agency (Miljødirektoratet) was Eivind Farmen, and the project was started by project manager Inger-Lise Nerland Bråte. Project management was taken over by Bert van Bavel in 2022.

Sampling was carried out by several on-going monitoring programmes including ØKOKYST, Urbanfjord, MILFERSK, the Ocean Acidification program, MILKYS, the Screening Programme and the national measurement programme of long-range transported air pollutants for main components in air and precipitation. Coordination of sampling equipment and logistics were carried out by Sverre Hjelset, Cecilie Singdahl-Larsen, Chiara Consolaro and Nina Buenaventura.

Microplastic analysis were performed Sverre Hjelset, Cecilie Singdahl-Larsen, Chiara Consolaro and Svetlana Pakhomova using µFTIR and optical methods. Mass based measurement were performed by Laura Röhler (water and biota samples) and Dorte Herzke, NILU (air samples).

Data analyses and data storage was performed by Espen Lund, Dag Hjermann and Jemmima Knight. Scientific quality assurance was performed by Amy Lusher. The report was written by Bert van Bavel, Amy Lusher, Chiara Consolaro, Sverre Hjelset, Cecilie Singdahl-Larsen, David Eidsvoll, Laura Röhler, Svetlana Pakhomova, Espen Lund, Dorte Herzke and Inger-Lise Nerland Bråte.

This report focuses on phase 1 of the project.

Oslo, 28 November 2022

Bert van Bavel
Project manager
NIVA

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Sammendrag

Tittel: Mikroplast i norske kystområder, elver, innsjøer og luft (MIKRONOR)
År: 2022
Forfatter(e): Bert van Bavel, Amy Lusher, Chiara Consolaro, Sverre Hjelset, Cecilie Singdahl-Larsen, Nina Buenaventura, Laura Röhler, Svetlana Pakhomova, Espen Lund, David Eidsvoll, Dorte Herzke and Inger-Lise Nerland Bråte.
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Norsk institutt for vannforskning (NIVA) har på oppdrag fra Miljødirektoratet igangsatt Norges første nasjonale overvåkingsprogram for mikroplast i norsk natur. Programmet "Mikroplast i norske kystområder, elver, innsjøer og luft (MIKRONOR)" har som hovedmål å skaffe informasjon om nivåer og typer av mikroplast i miljøet. MIKRONOR genererer viktig kunnskap om overvåking av mikroplast i norsk natur, og bidrar til kunnskap inn mot både nasjonalt og internasjonalt samarbeid (f.eks. OSPAR og AMAP).

Innsamling av ulike prøvetyper i 2021. Programmet har dels mottatt prøver gjennom eksisterende nasjonale overvåkingsprogrammer som dekker et bredt geografisk område innenfor det norske miljøet (bl.a. Urban fjord, MILFERSK, ØKOKYST), dels foretatt egen prøvetaking. Materialet inkluderer prøver fra kystområder, åpent hav, innsjøer, elver og luft. I denne rapporten presenteres analytiske data fra de to første årene av prosjektet. Totalt er 316 prøver rapportert for den første fasen av MIKRONOR, inkludert følgende prøvetyper:

- Høyvolumsvannprøver (ferskvann og sjøvann, n = 48),
- Vannprøver samlet inn fra farvannet mellom Oslo og Kiel ved hjelp av automatiske prøvetakere ombord på Color Line (FerryBox) (sjøvann, n = 20),
- Blåskjell (n = 71),
- Vannprøver fra vertikale planktonnettprøver (sjø, n = 29),
- 24 luftprøver (nedbør n = 12 og aktiv luftprøvetaking n = 12).
- Blankprøver inkludert feltblanker (n = 78) og laboratorieblanker (n = 46).

Prøvetakingsstedene var i henhold til pågående overvåkingsprogram og prøvetakingsmetodene som ble brukt tilsvarte de som allerede er brukt i programmene, med spesifikke modifikasjoner for prøvetaking med tanke på mikroplastbestemmelse. Overvåkingslokalitetene representerer et generelt utvalg for norske vannforekomster. I tillegg ble noen spesifikke prøvetakingssteder valgt basert på potensielle kilder til mikroplast som f.eks. avløpsrenseanlegg og store veger.

Prøvebehandling i laboratoriet har fulgt anbefalte protokoller og analytisk kvantifisering (antall, form, plasttyper) ble utført gjennom en kombinasjon av skanning mikro-Fourier-transform infrarød spektroskopi (µFTIR) og pyrolyse-GC/MS.

Mikroplast (>50 µm – 5 mm) ble identifisert i nesten alle prøver, men nivåene i det norske miljøet er relativt lave og ofte rundt de analytiske deteksjonsgrensene (LoD) eller tilsvarende nivåene målt i feltblanker samlet inn sammen med de faktiske prøvene.

Undervannsprøver ble tatt kontinuerlig i et transekt gjennom Oslofjorden og Skagerrak ved hjelp av Ferrybox' mikroplastprøvetakingsmodul ombord MS Color Fantasy i rute mellom Oslo og Kiel. Antall

mikroplastpartikler funnet i FerryBox-prøvene var relativt lavt og maksimalt 2 partikler per m^3. Disse nivåene er sammenlignbare med nivåene funnet i både blankprøver fra laboratoriet og atmosfæriske feltblankprøver tatt ombord i båten. Konsentrasjonen av mikroplastpartikler var som regel under deteksjonsgrensen (LoD) basert på blanknivåer, men i samsvar med tilsvarende måling publisert i litteraturen.

Kort konklusjon

• Overflateprøver av vann (ca 1 m^3) ble samlet inn ved hjelp av en høyvolumspumpe i både sjø- og ferskvann og prøvene viste konsentrasjoner 1,3 – 4,3 MPs/m^3 for >200 µm-prøvene og 5,7 – 16,7 MPs/m^3 for >50 µm-prøvene. Antall mikroplastpartikler på lokalitetene var lavt og omtrent på samme nivå som konsentrasjoner i feltblankene.

• MP-nivåene for de vertikale håvtrekkprøvene langs norskekysten (Ca 11 m^3 vann) var lave med et maksimalt middelnivå på 3,14 partikler per m^3. Nivåene er nær metodens deteksjonsgrense (LoD) basert på atmosfæriske feltblanker.

• Blåskjell (10 individer pr lokalitet) fra alle de syv lokalitetene inneholdt lave nivåer av mikroplast, fra 0 - 10 MPs per individ, med et samlet gjennomsnitt på 1,15 MP per individ. Dette tilsvarer gjennomsnittlig 7,96 MP per g tørrvekt. Det ble ikke påvist signifikante forskjeller mellom lokalitetene.

• Mikroplastkonsentrasjonene i luft (ca 1000 m^3) og nedbørsprøver ved Birkenes var omtrent fire ganger høyere enn ved Zeppelin, sannsynligvis forårsaket av mer nedbør og større påvirkning fra luftmasser som kommer fra kontinentet. Høyere nivåer av mikroplast ble også funnet i nedbørsprøver sammenlignet med aktive luftprøver. Alle de ni undersøkte polymertypene ble påvist over deteksjonsnivåer i nedbørsprøver og/eller aktive luftprøver fra én eller begge stasjonene.

1 Executive summary

1.1 Short background and organisation of sampling

Norwegian Institute for Water Research (NIVA) have, on behalf of the Norwegian Environment Agency (NEA), carried out the first execution/round of Norway's National microplastic (MP) monitoring program, together with Norwegian Institute for Air Research (NILU). The program, Microplastics in Norwegian coastal areas, rivers, lakes and air (MIKRONOR1) started in 2021 with organisation of sampling for different matrices and the sampling will continue until 2023. This is the first report in the program, with a focus on water samples, mussels and air, and it will be followed by a report in 2023 with the rest of the analysis data (marine and freshwater sediments, duck mussels, polychaetes and blue mussels, wastewater effluent, riverine and marine waters).

1.2 Key findings

1.2.1 Microplastics in water samples

1.2.1.1 Subsurface water (Oslofjord, Skagerrak).

Subsurface samples were taken as a continuous transect through the Oslofjord and Skagerrak in Norwegian waters and data was collected for two size fractions (200 - 500 µm, 100-200 µm). Microplastic contamination was low to very low (0 – 1.94 MPs per m^3) for the 200 – 500 µm and even less so for the 100 - 200 µm fraction (0.41-1.06 MPs per m^3) with the exception of one sample where a large number of polytetrafluoroethylene (PTFE) particles were found. This is illustrated in ***Figure 1*** where the influence of PTFE particles is clearly visible. Despite sampling more than 8 m^3 per sample, the low levels of microplastics are very close to the levels found in the blank samples or the analytical limit of detection (LoD) based on the laboratory blanks.

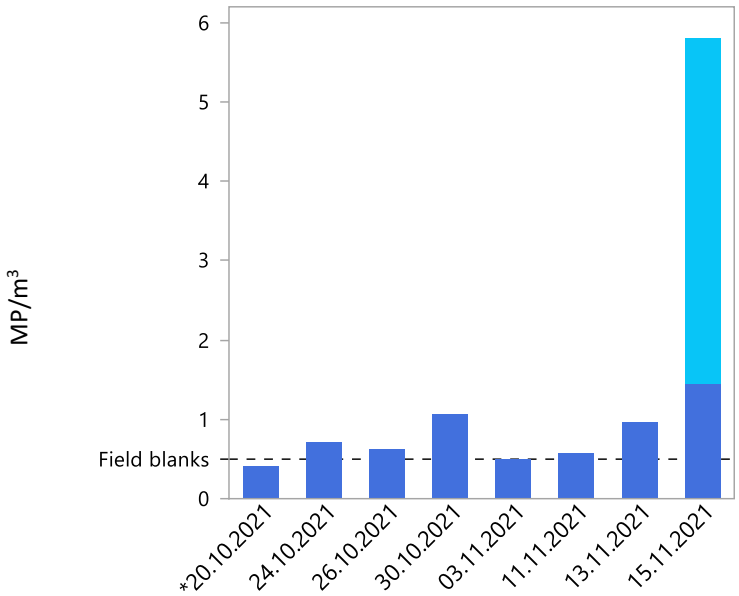


Figure 1. Number of microplastics (MPs/m^3) in subsurface samples (100-200 µm) collected as continuous transect samples covering the Oslofjord and Skagerrak. PTFE particles highlighted light blue. The average number of particles identified in the field blanks are indicated with the dashed line.

1.2.1.2 Surface water samples - High volume pump samples

Large volume surface samples taken were taken at different sites using a high-volume pump. The number of microplastics at all sites were low and in similar concentrations to the field blanks. Microplastics were found in mean concentrations ranging from 1.3 – 4.3 MPs/ m^3 for the > 200 µm samples and 5.7 – 16.7 MPs/m^3 for the > 50 µm samples for each sampling site. This is included in ***Figure 2*** which shows the sampling sites as taken at increasing distances from different point sources. It was expected that a gradient might be visible when sampling close to point sources (WWTPs, Oslo city centre, heavily trafficked bridge), although no trend could be detected. This was lower than expected although very little data exists for comparison. The gradient from the different point sources (WWTPs, Oslo city center, a heavy trafficked bridge, and a rural reference lake) did not show a decreasing trend, or rather the opposite due to small number of particles found. The low number of microplastics found in all samples highlights the importance of field blanks and avoiding the risk of contamination during sampling.

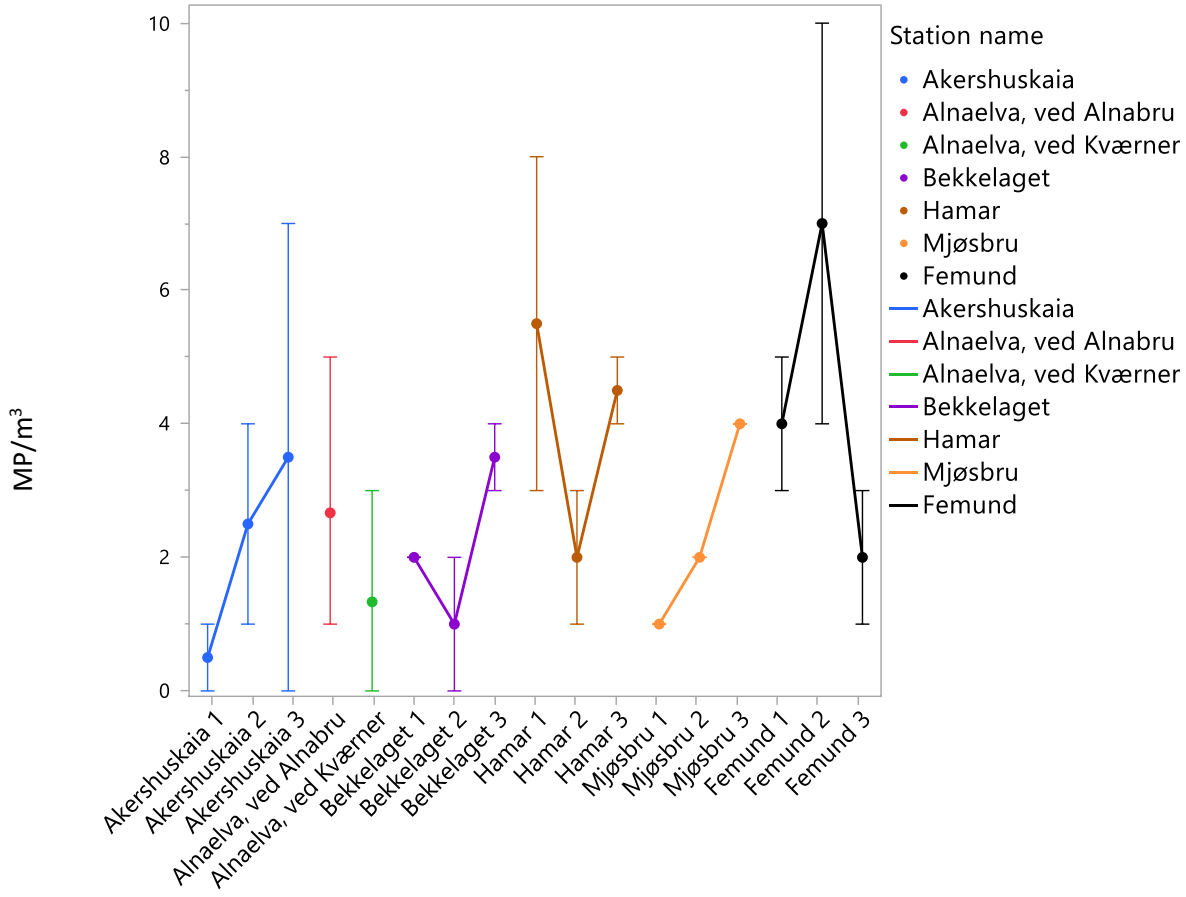


Figure 2. Number of microplastics (MP/m^3) in the high-volume samples (>200 µm), given by mean and range, at seven locations, including transects from the potential point sources.

1.2.1.3 Plankton net samples

The MP levels of the vertical haul samples along the Norwegian coast were low with a maximum of mean level of 3.14 particles per m^3, in line with the samples taken by the FerryBox transect through the Oslofjord and Skagerrak and the large volume samples in the Oslofjord. These levels are close to the LoD based on atmospheric field blanks, and below the LoQ based on the sample equipment rinse blanks.

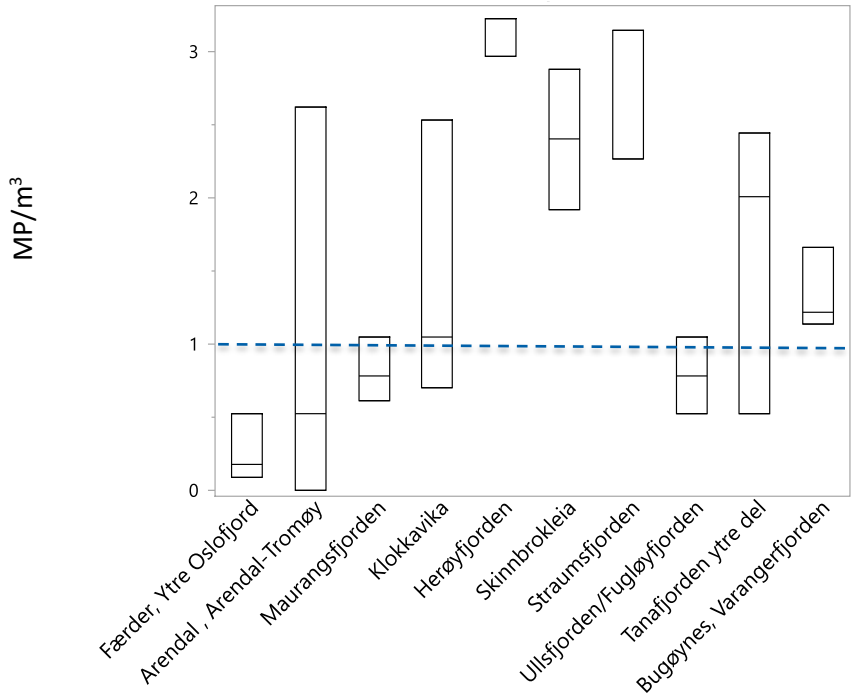


Figure 3. Number of microplastics (per m^3) identified in vertical plankton hauls from 10 sites along the Norwegian coast fraction 200 – 1000 µm. Data has been compiled for all size fractions with results are displayed as medians with minimum and maximum (LoD blue line).

1.2.2 Blue mussels

Mussels from all seven sites contained low levels of microplastics, ranging from 0 - 10 MPs/individual, with an overall average of 1.15 MP per individual. This corresponds to an average 7.96 MP per g d.w. No significant differences were seen between the sites (Figure 4). The largest variation and the highest number of microplastics were observed in mussels close to a WWTP in Oslofjord. Most of the microplastics were fragments, which dominated at all sites.

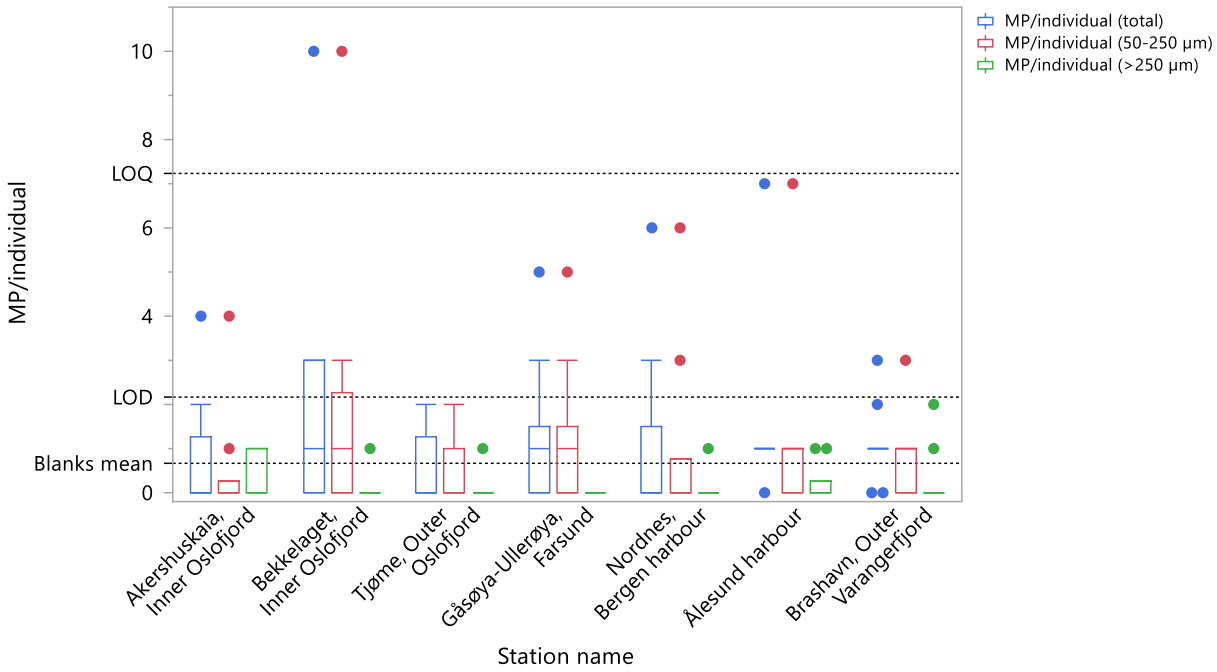


Figure 4. Number of microplastics per individual (MP/individual) for the blue mussels collected from seven sites. Data is displayed as box plots with median (centre line), 25 and 75 percentiles (top/bottom of box) and outliers (dots), as well as the average number of particles in the procedural blanks, the limit of detection (LOD) and the limit of quantification (LOQ).

1.2.3 Microplastics in air samples

Air samples were collected from mainland Norway (Birkenes) and the Arctic (Svalbard, Zeppelin). Two types of samples, precipitation samples and active air sampler, were taken between October and December 2021 (Figure 5). Microplastic concentrations in Birkenes were approximately four times higher than at Zeppelin, probably caused by more precipitation and greater influence from continental air masses. Higher levels of microplastics were also found, not unexpectedly, in precipitation samples compared to active air samples. All nine polymer types examined were detected above detection levels in precipitation samples and / or active air samples from one or both stations. Overall, it appears that polyurethane (PU) and polypropylene (PP) dominated in the precipitation samples, while polyethylene terephthalate (PET) and polyethylene (PE) dominated in the active air samples. These are common polymers, both in production volume and use with many applications.

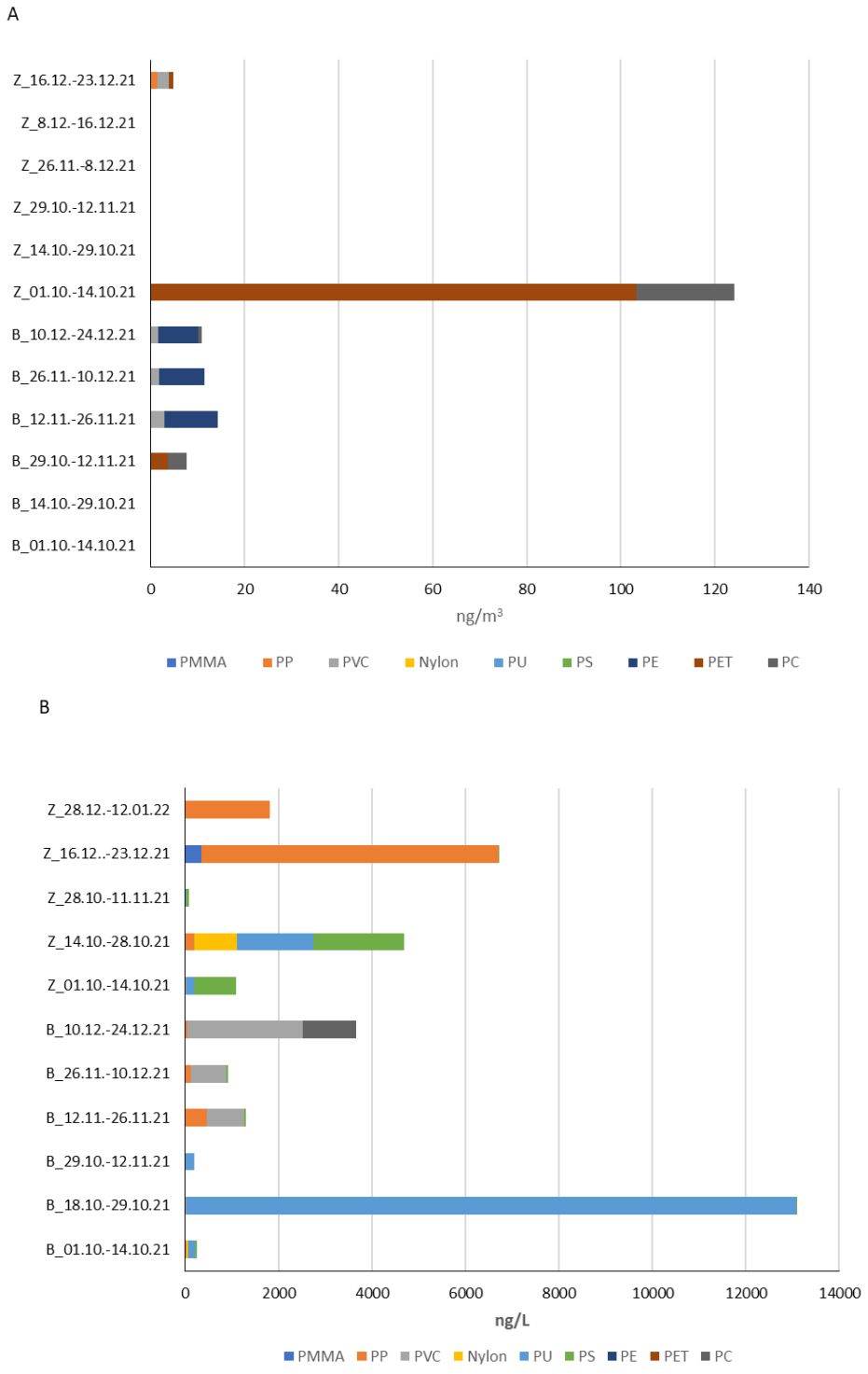


Figure 5. Results of air sampling carried out at Birkenes (B_dd.mm.yy) and Zeppelin (Z_dd.mm.yy) in 2021, divided by (A) active sampling (ng/m^3) and (B) precipitation sampling (ng/L).

1.2.4 Polymer composition

The levels of MPs in all samples were relatively low and often very close to the LoDs of the methods based on field blanks. A large variety of different MPs polymer categories were found when all MPs were combined (Figure 6). For the air samples only 9 polymers were analysed, and the distribution is based on mass. Here more polyester was found in the air samples while more polyurethane in precipitation. In fresh water more polycarbonate was found compared to the marine water samples which contained more polyester particles or fibres. The blue mussel samples contained more polypropylene particles.

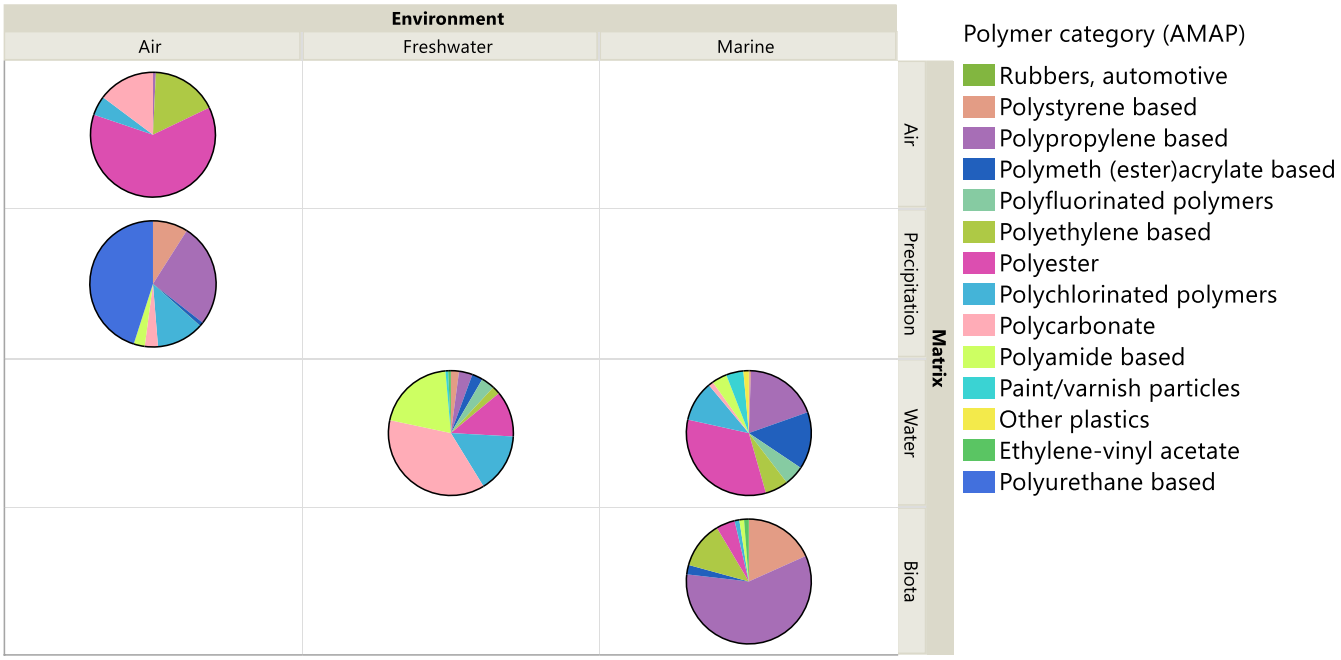


Figure 6. Distribution of the different polymer categories for the different sample categories. For the air samples only 9 polymer categories were analysed by pyr-GC/MS based on mass, for all other sample categories the distribution is based on the number of MPs.

1.3 Recommendations

- As expected, field blanks levels or contamination in the field play a major role and need to be reduced as much as possible.

- Larger sample volumes might result in levels above the field blanks, but these may require more extensive sample pre-treatment and analysis.

- The use of individual mussel samples results in close to the analytical LOD levels due to the low number of MPs in the samples. Individuals could be pooled in future investigations to avoid this.

- The use of trans-reflectance as opposed to transmittance µFTIR allows for the analysis of the same sample on µFTIR (number of microplastics) and pyrolysis-GC/MS (mass of polymers) which is more effective but is more sensitive for interference from other material including biological and organic material.

2 Introduction

2.1 Microplastics in Norwegian coastal areas, rivers, lakes and air

Norwegian Institute for Water Research (NIVA) have, on behalf of the Norwegian Environment Agency (NEA), carried out the first execution/round of Norway's National microplastic (MP) monitoring program, together with Norwegian Institute for Air Research (NILU) based on several on-going monitoring programmes in Norway and along the Norwegian coast. The program, Microplastics in Norwegian coastal areas, rivers, lakes and air (MIKRONOR1) started in 2021 with organisation of sampling for different sample types and will continue until 2023. This is the first report of the program, with a focus on water samples, mussels and air, and it will be followed up by a second report in 2023 with the rest of the analysis data (marine and freshwater sediments, duck mussels, polychaetes and blue mussels, wastewater effluent, riverine and marine waters). The MIKRONOR2 program has started and runs in parallel with MIKRONOR1 from 2022-2024. The samples included in MIKRONOR1 in this first report are air, water and blue mussel samples.

2.2 Aim of the study

This report aims to contribute to increasing the knowledge of microplastic contamination in the Norwegian environment. This will be accomplished in MIKRONOR by:

- **Documenting the levels and types of microplastics** in different Norwegian water bodies and air
- **Document any differences between matrices and spatial trends**
- Give a **baseline for further investigating of temporal trends** and possible impact from measures
- Contribute to **knowledge of sources and pathways of microplastics** into the Norwegian environment
- Contribute to **international harmonization** of microplastic monitoring through EU and OSPAR
- Give a foundation for **further national monitoring of microplastics**

2.3 Definitions used in this report

The MIKRONOR programme acknowledges that the definition of microplastics (and the terminology for plastic pollution in general) have evolved and are used interchangeably depending on the sector and context around the world. To reflect the focus of the project, which will be to eventually support Norway's reporting under OSPAR obligations, the following definition of microplastics is used:

Synthetic material (primarily oil-based polymers) identified in the environment in the size range 50 µm to 5mm, the lower cut-off of 50 µm is in accordance with the equipment and instrumentation limitations employed in the programme.

The definition is according to EU DIRECTIVE 2019/904[1] of plastics whereby they are materials consisting of a polymer to which additives or other substances may have been added, and which can function as a main structural component of final products, with the exception of natural polymers that have not been chemically modified. The EU Directive on Single Use Plastics exempts paints, inks and adhesives. The Guidelines further clarify especially the terms 'natural polymer' and 'chemical

[1] https://eur-lex.europa.eu/eli/dir/2019/904/oj

modification' to ensure a consistent implementation across the EU. According to ISO 472:2013[2]: plastic is a "*material which contains as an essential ingredient a high molecular weight polymer and which, at some stage in its processing into finished products, can be shaped by flow*".

Inconsistencies between these definitions:

(1) EU Directive excludes coatings/paints;
(2) ISO 472:2013 excludes some elastomers (e.g., rubbers).

For further discussion of definitions readers are referred to Hartmann et al., (2019).

Many technical reports and guidelines have introduced subcategories for size, usually to accommodate operational (sampling) or analytical (detection) limits**. In this report we use the Arctic Monitoring and Assessment Programme (AMAP) guidelines for size categories of 5-1 mm, 1 mm-0.3 mm, 0.3 – LOD mm** (AMAP, 2021). The lower size limit of MPs reported in this study is defined by the sampling and processing method, such that: Plankton samples were collected with both 180 and 200 µm meshes. The Ferrybox samples were collected using stacked filters with mesh sizes 100, 200 and 500 µm. Only samples collected with the 100 and 200 µm are included in this report. High-volume water samples were collected independently with 50 and 200 µm filters. The blue mussels were processed with a sieve with mesh size 50 µm to have a lower size limit for the particles that were detected using pyrolysis.

2.4 Standardisation and harmonisation considerations

To date, a lack of standardised procedures and guidelines for collection, preparation and analysis has made it challenging to carry out monitoring of microplastics in the environment. A draft ISO/CEN standard[3] is under development for microplastics in water samples, using reference materials developed by NIVA which were also used for QA/QC and recovery studies for the MIKRONOR project. However, there are still no established methods or indicators for microplastic monitoring. The topic is being worked on in various expert groups (e.g., ICES, OSPAR, AMAP, and TGML/MSFD) and there have been several proposed guidelines for monitoring microplastics released (e.g. GESAMP, 2019; Hanke et al., 2013; Michida et al., 2019; AMAP, 2021). The Arctic Monitoring and Assessment Programme (AMAP) has also recently published its recommendations for prioritising water, sediment, beach and coastline as well as seabirds for trend analysis (AMAP, 2021). For the current MIKRONOR report, water samples were collected with a high-volume pump, a vertical haul of a plankton net, Ferrybox, benthic animals (blue mussels) and air (precipitation and large volume) were included.

[2] ISO 472:2013: Plastics — Vocabulary, 2013-02, 406p.
[3] ISO/AWI: 16094: https://www.iso.org/standard/84463.html

3 Sample types and sampling programmes

3.1 Sample types and environmental compartments

Table 1. Overview of the sample types included in MIKRONOR1.

Environment	Matrix	Sample types (sample code)	Sample equipment	Mesh size of equipment (µm)	Position in water column (m)
Marine	Water	Sub-surface water samples (FB)	Ferrybox microplastic samples	100 - 200, 200 - 500	0 to 5
		Surface water samples (HW)	High-volume water sample pump	> 200 > 50	0 to 3
		Water column (WAT)	Vertical plankton haul	> 180 > 200	50 to 0
	Biota	Blue mussels (BM)	Hand picking	0	0 to 1
Freshwater	Water	Surface water samples (HW)	High-volume water sample pump	> 200 > 50	0 to 3
Air	Air	Air - active (dry)	Active air sampler	10	na
		Air - precipitation (rain)	Rain sampler	10	na

3.2 Sampling programmes and sample sites

The marine water samples were taken by the Urban Fjord and ØKOKYST program and supplemented by the MIKRONOR1 project. The freshwater samples were acquired through MILFERSK program and completed by the MIKRONOR1 project. The location of these large volume pump and vertical plankton haul samples are given in Figure 8.

The large volume microplastic samples taken on the transect in the Oslo fjord and Norwegian waters were taken by the Ocean Acidification program and acquired using the Ferrybox microplastic sampling module between latitude 57.745 and 59.905 on the MS Color Fantasy. The transect in Norwegian waters is given in Figure 9.

The air samples were taken by active air samplers and precipitation samplers in the Atmospheric Pollutants program in a remote area (Svalbard) and a close to a more populated area (Birkenes). The blue mussel samples were acquired through the MILKYS program. The locations of the air and blue mussel samples are given in Figure 7.

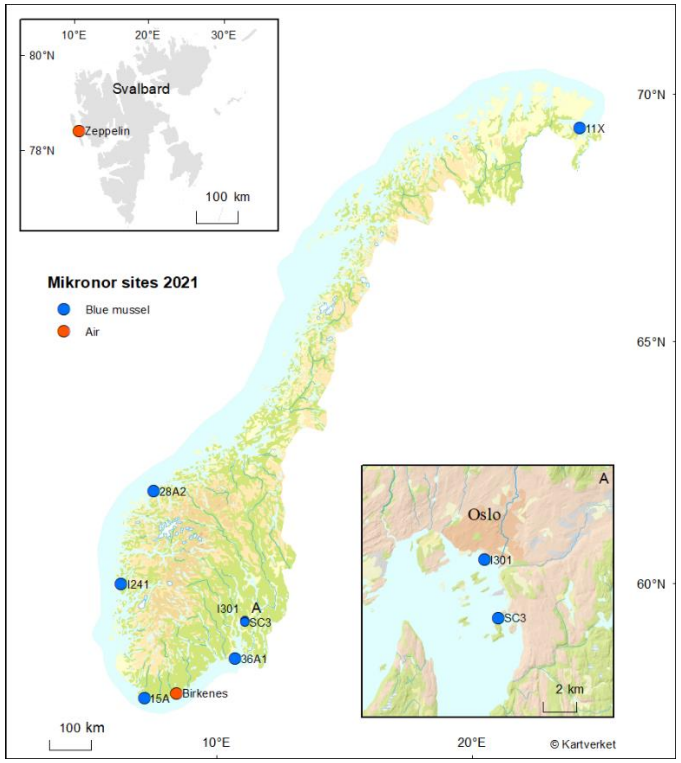


Figure 7. Locations of air and biota samples collected as part of the MIKRONOR project in 2021.

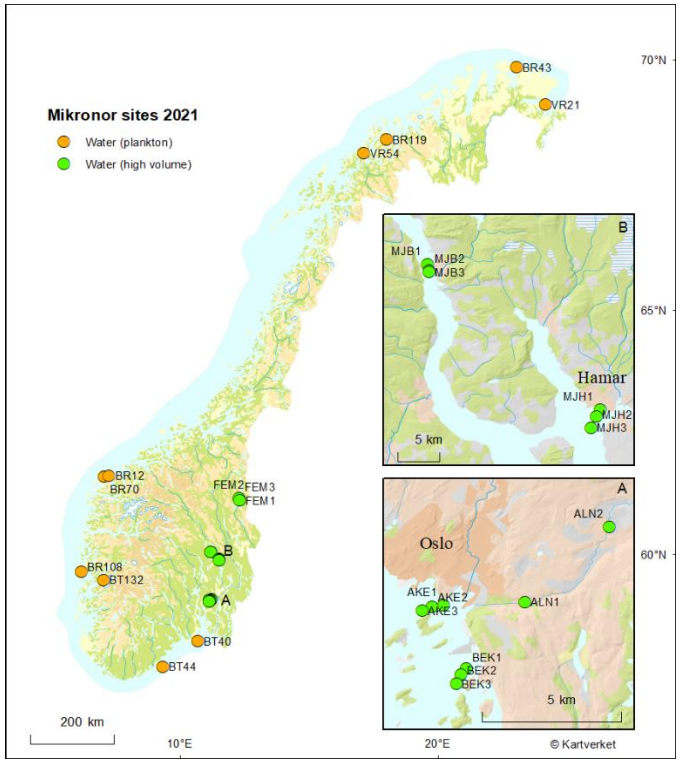


Figure 8. Locations of the large volume pump and vertical plankton haul water samples.

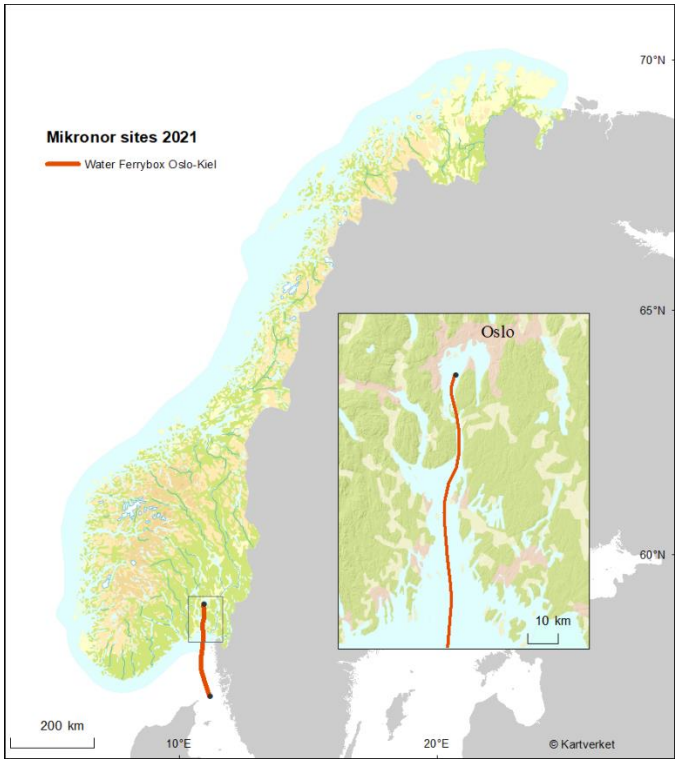


Figure 9. Sampling transect of the Ferrybox samples taken by the MS ColorLine Fantasy.

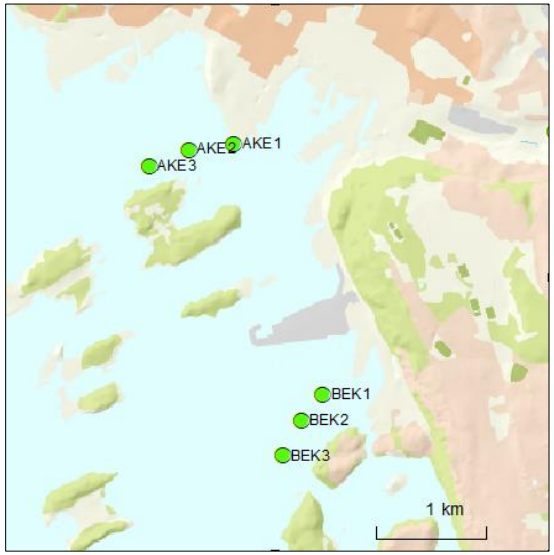


Figure 10. Locations of large volume samples showing the gradient samples taken from two point sources (WWTP and urban location Oslo)

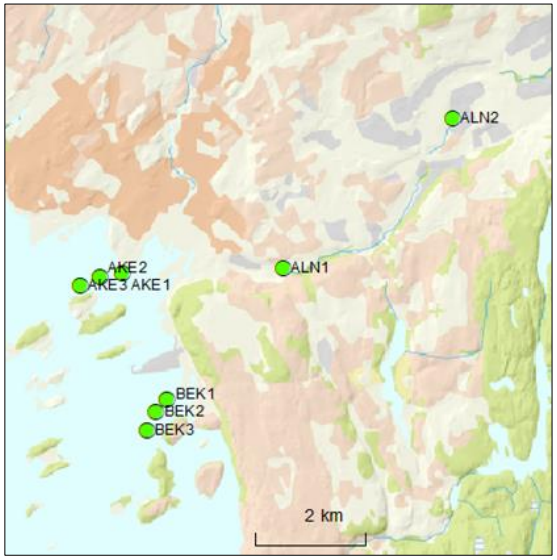


Figure 11. Locations of large volume samples showing the gradient samples and the samples taken at from the Alna river

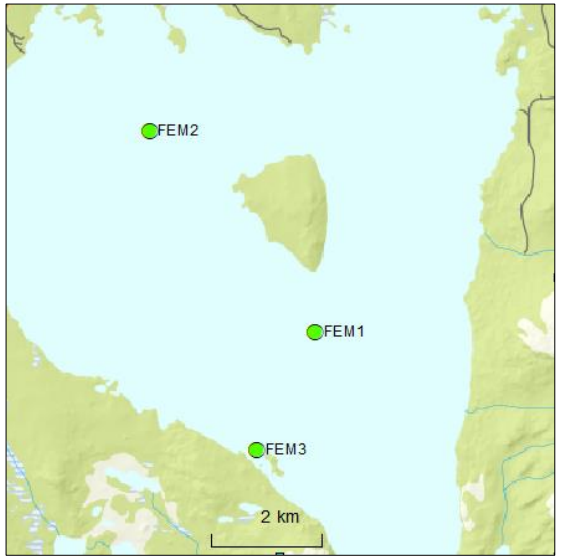


Figure 12. Locations of large volume samples taken in Lake Femund to represent a remote location (Lake Femund)

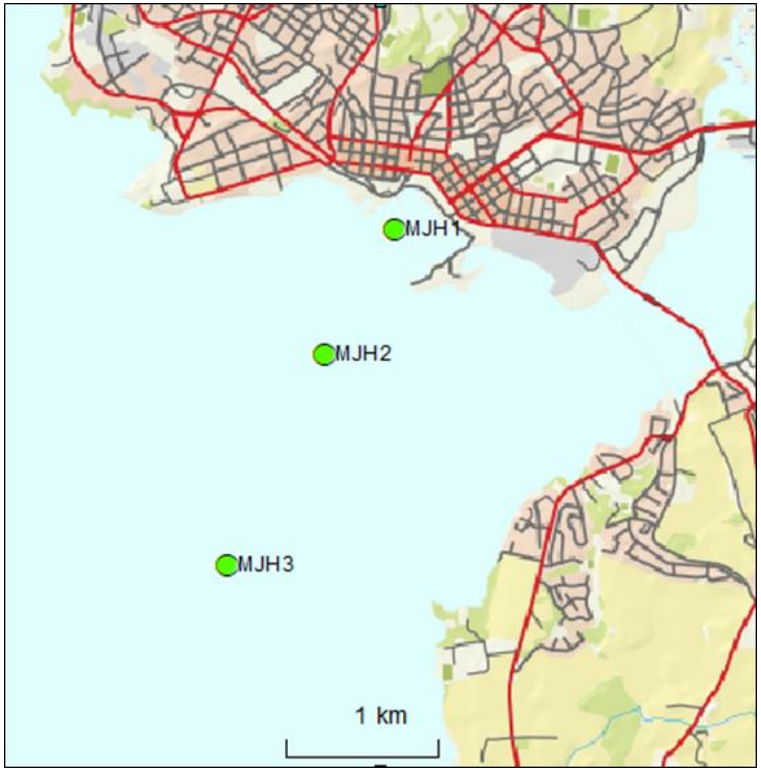


Figure 13. Locations of large volume samples showing the gradient samples taken from a point sources (urban, Hamar) at Lake Mjøsa.

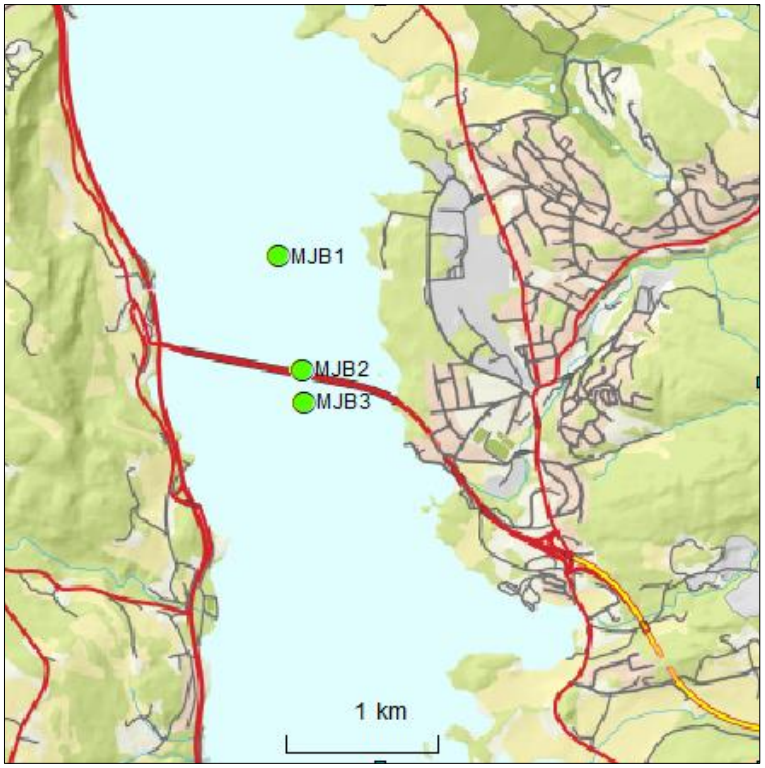


Figure 14. Locations of large volume samples showing the gradient samples taken close to a heavy trafficked bridge (E6), crossing Lake Mjøsa.

3.3 Microplastic analytical methods applied in MIKRONOR1

In total 286 samples were analysed in the first phase of the MIKRONOR1 project using three different detection methods **Table 2**, including visual detection in combination with ATR-FTIR, µFTIR using a diamond compression cell in the transition mode or automatic scanning using the trans reflectance mode. In addition, the high-volume samples collected on the 50 µm filters were run both on the µFTIR and the pyrolysis GC/MS, acquiring both number of particles and mass of the polymers on the same sample. The air samples were analysed by pyrolysis GC/MS only, and the fraction larger than 10 µm was analysed.

Table 2. Overview of analytical methods used for microplastic analysis of different samples types.

Sample type	Microplastic Analysis		
	Visual + FTIR (200 - 1000 µm)	µFTIR (50 µm-200 µm)	Pyrolysis (50 µm-200 µm)
Ferrybox water samples (FB)	x		
Vertical plankton haul	x		
High-volume pump (200 µm)	x		
High-volume pump (50 µm)	x	x	x
Blue mussels	x	x	x
Air precipitation (Rain)			x*
Active air samples			x*

* Air samples taken and analysed 10 µm -1000 µM.

4 Materials and Methods

4.1 Sample collection

Sample collection for MIKRONOR1 was carried out between May and December 2021. Each sampling campaign was provided with a field SOP containing the list of equipment and the metadata needed for each sample.

4.2 General contamination prevention during field sampling

To avoid contamination during field sampling:

- Potential sources of contamination were collected to act as a reference, including the clothing worn by samplers and any plastics used in the vicinity during sampling, as well as vessel paint.
- Samplers were asked to avoid synthetic clothing where practically possible. If synthetic materials could not be avoided the samplers recorded all potential possible sources in their field notes.
- Plastic equipment was avoided as far as practically possible. Sample collection containers were made of glass or metal. Any potential plastic materials which came in contact with the sample or sampling device were recorded in field notes.
- All sampling equipment was thoroughly cleaned before sampling, i.e., flushing with high volumes of filtered RO water.
- Samples were handled for the shortest possible time to limit unnecessary exposure to air.
- Field blanks were included in at all station, with the exception of mussels. Further details are provided per sample type in this document.

4.3 Field blanks:

Two different kind of field blanks were taken: A filtered water rinse of a sampling device (i.e. a net, Michida et al., 2019) or an atmospheric sample (e.g., filtered water in sample container/ clean sample device) open for the same duration samples are handled. Both types of field samples were collected for MIKRONOR1 at different occasions.

Vertical plankton samples: Before collecting the sample, the net was rinsed from the outside of the with seawater without the cod end attached. The cod-end was attached, and the net was flushed again with seawater. RO water was used to transfer the contents into a sample bottle. These field blanks were stored and treated in the same way as environmental samples. Due to local and weather conditions not all plankton stations did correctly collect field net blanks but instead collected atmospheric blanks.

High volume pump samples: Before the sample was collected at each site, the pump was turned on without a filter for 10 minutes to remove any remaining contamination from storage. Then the hose was disconnected from the pump, the filter was attached, and the hose were flushed with 2 L of filtered RO water, this sample was collected as the field blank. The material from the hose has been tested in order to be able to identify potential fragment from the hose in blanks and samples.

Ferrybox samples: The field blank on board the MS Color Fantasy was a sieve that is exposed to air for the same period of time as the samples were exposed to air during removal from the closed Ferrybox microplastic module. The sieves were treated in the same way as the sieve from the sampling unit.

Mussel samples: No field blanks were collected for mussels as they were closed during collection, but the samples were rinsed with filtered water before processing in the laboratory.

Air samples: 1 field blank and one transport blank was collected for each sample batch.

4.4 Sample collection - Water samples

4.4.1 Plankton samples (200 and 180 μm mesh)

Vertical plankton samples were provided to MIKRONOR1 through the programme ØKOKYST. An SOP was developed to ensure synergies with the sampling activities already being performed. The methods used for plankton net sampling are based on available international guidelines (GESAMP, 2019; AMAP, 2021; Michida et al., 2019) as well as contamination and quality control procedures (e.g., Brander et al., 2020). The net was rinsed before use by deploying the net without the cod-end attached and flushing it from the outside of the net with seawater. This was followed by the collection of the net field blank. A cod-end was attached, and the net was flushed again using RO water to transfer the contents into a sample bottle.

When the sample was taken, a plankton net (area of opening: 0.25 m^2, length of net 165 cm, with a mesh size of 200 μm) was whilst the vessel was stationary at one position to a depth of 0-50 m and slowly hauled to the surface at a speed of (0.5 m/s) resulting in a volume of 11.45 m^3. A flow meter was used to control and to calculate the volumes of water which passed through the net. The range measured by the flow meter agreed with the theoretical calculated volumes and ranged from 10.57 to 11.95 m^3. The average volume of 11.45 m^3 was used for all samples which was very close to the theoretical volume of 12.5 m^3. When the net was returned to the surface the outside of the net was flushed to ensure all particles moved to the cod-end. The concentrated sample in the cod-end was rinsed into a 1L glass jar with RO. All samples were kept in the dark and refrigerated after collection and sent to NIVA to carry out the analyses as quickly as possible after completed field work.

Figure 15. The plankton net used for the large volume haul samples from the ØKOKYST program.

4.4.2 High-volume water pump system (200 and 50 μm mesh)

High-volume water samples were provided to MIKRONOR1 through the programmes Urbanfjord, MILFERSK and MIKRONOR. An SOP was developed to ensure synergies with the sampling activities already being performed in each programme, and comparison between the programmes. The methods used for high-volume sampling are based on available international guidelines (GESAMP, 2019; AMAP, 2021) as well as contamination and quality control procedures (e.g., Brander et al., 2020).
The high-volume pump system was adapted using an existing pump system (KCDenmark, Silkeborg, Denmark) which was redesigned to allow the collection of water samples (freshwater and marine) at a maximum speed of 200L/min). The high-volume sampler takes samples in the surface water and can use filters (Axium, Swansea, UK) with different mesh sizes for different purposes. A filter is also fitted at the water intake so that particles larger than 5 mm do not enter the system. A volume of 1000 L was filtered for each sample. A flow meter was in place to ensure the correct measurement of the water volume was collected.

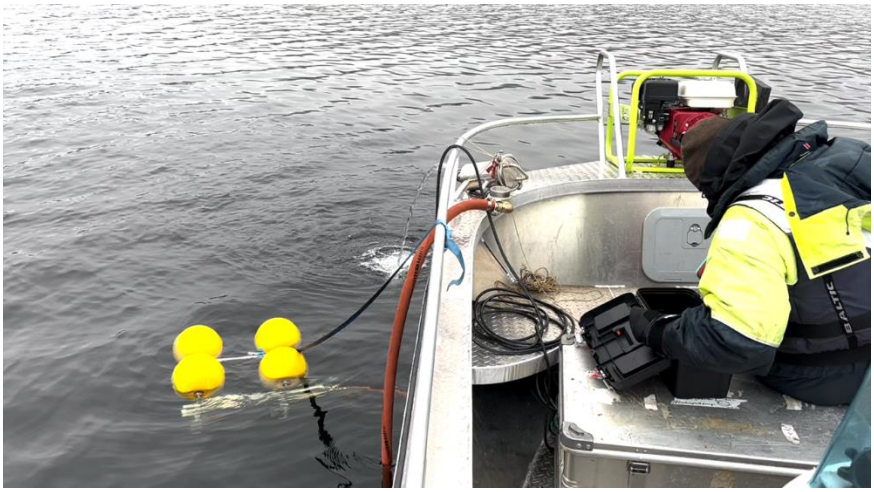


Figure 16. Deployment of the large volume microplastic pump and filter system by the Urbanfjord and Milfersk program.

4.4.3 Ferrybox (100-200 μm fraction and 200-500 μm fraction)

Ferrybox samples were provided to MIKRONOR1 through the programme Ocean Acidification program. The SOP used follows previously published methods (Lusher et al., 2021; van Bavel et al., 2020).

A three-stage sampling tool which enables the sampling of relatively high numbers of microplastic particles (improving the limit of detection, LOD) and accurately measures of the volume of seawater (improving the accuracy of concentration reporting) connected to NIVA Ferrybox system on the MS Color Fantasy was used for the large volume transect sampling. The Ferrybox system is set up to collect water from a seawater intake situated at 5 m depth on the starboard side of 'M/S Color Fantasy'. The system is remotely operated to start sampling and to stop again at designated positions along the vessels transect. The NIVA microplastic sampling module connected to the Ferrybox enables the sampling of relatively large volumes of sea water in the area of interest (5000-15000 L) with low limit of detection (LOD numbers of microplastic particles/L). The system also accurately measures the volume of seawater improving the accuracy of the microplastic concentration (flow precision < 0.2%).

Each sample was collected over the south bound (Oslo-Kiel) and the north bound (Kiel-Oslo) resulting in two time periods and volumes (*Table 3*) collected on the same standard system set-up with three filters: 500 µm, 200 µm and 100 µm. These are stacked sequentially for size fractionation and subsequent analysis in the laboratory. The volume of water filtered was measured by the built-in flow meter allowing all samples to be standardised to "per cubic metre filtered (m^3)". Following each sample period, the filters were removed from the Ferrybox and the samples were processed on the same day, under controlled laboratory conditions.

Table 3. Sampling dates, duration and volumes of the Ferrybox transect samples in 2021.

	South Bound			North Bound			Combined	
#	Date	Duration (hr)	Volume (L)	Date	Duration (hr)	Volume (L)	Duration (hr)	Volume (L)
1	18 Oct	6.9	3688	20 Oct	7.2	3528.3	14.1	7216
2	20 Oct	7.1	3677	22 Oct	7.1	3655.5	14.2	7333
3	22 Oct	7.1	3892	24 Oct	7.0	4139.3	14.1	8032
4	24 Oct	7.1	4119	26 Oct	7.3	4244.4	14.4	8363
5	26 Oct	7.1	4073	28 Oct	7.0	3980.0	14.1	8053
6	28 Oct	7.2	4307	30 Oct	7.1	4194.0	14.3	8501
7	30 Oct	7.2	4256	01 Nov	7.2	4219.0	14.4	8475
8	01 Nov	7.5	4378	03 Nov	7.3	4180.7	14.8	8559
9	03 Nov	7.1	4055	05 Nov	7.1	4059.8	14.2	8115
10	05 Nov	6.9	3913	07 Nov	7.2	4023.3	14.1	7936
11	07 Nov	7.0	3966	09 Nov	9.0	4606.5	16.0	8572
12	09 Nov	10.7	5414	11 Nov	7.3	4574.9	18.0	9989
13	11 Nov	6.9	4247	13 Nov	7.3	4464.3	14.2	8712
14	13 Nov	6.6	4014	15 Nov	7.2	4287.6	13.8	8301
15	15 Nov	n.a*	n.a*	17 Nov	7.0	4125.5	7.0	4126

* the south bound transect was not sampled due to logistical constraints on the vessel

Figure 17. Ferrybox microplastic sampler on board MS Color Fantasy.

4.5 Sample collection - Blue mussels (> 50 μm)

Blue mussel (*Mytilus* spp.) samples were provided to MIKRONOR1 through the programme MILKYS and Screening Programme. The SOP used follows previously published methods (Bråte et al., 2018).

Mussels were collected in August 2021 (Table 4). For MIKRONOR1, a minimum of 10 individuals per site were collected from natural substrate (i.e. avoiding those individuals growing on nylon ropes, plastic buoys etc.). Only living individuals (3-6 cm in size) with no visible signs of damage were collected and wrapped in aluminium foil before storage. Individuals were frozen (- 20 °C) whole (in their shell) as soon as possible after collection until sample processing and analyses.

Table 4. Summary of Locations and metadata for mussels collected for the MIKRONOR project. All data for length and weight are presented as averages.

Station name	Station code	N	Length (mm)	Weight (g, w.w)	Weight (g, d.w)
Akershuskaia, Inner Oslofjord	I301	10	45.23	1.59	0.28
Bekkelaget, Inner Oslofjord	SC3	10	39.06	0.68	0.13
Tjøme, Outer Oslofjord	36A1	10	52.45	1.84	0.30
Gåsøya-Ullerøya, Farsund	15A	10	40.13	0.59	0.07
Nordnes, Bergen harbour	I241	10	61.40	4.58	0.75
Ålesund harbour	28A2	10	57.65	3.86	0.67
Brashavn, Outer Varangerfjord	11X	11	35.03	0.78	0.12
Total		**71**	**47.10**	**1.99**	**0.33**

4.6 Sample collection - Air

The monitoring programme for long-range transported atmospheric contaminants is designed to study long- and short-term time trends and spatial distribution of regulated persistent organic pollutants (POPs), organic contaminants of emerging concern, and heavy metals. Since 2021, it is also responsible to collect samples for microplastics, conducted by NILU on the behalf of the Norwegian Environment Agency. The analyses of the samples were covered by the program MIKRONOR and conducted by NILU on the behalf of the NEA.

The number of observatories and the geographical distribution are selected in order to represent different parts of Norway, and areas that receive air from different source regions globally. The observatories included in this monitoring programme are to a large extent coordinated and thereby the same ones as those within “the national measurement programme of long-range transported air pollutants for main components in air and precipitation”, which like this monitoring programme is conducted by NILU on behalf of NEA, and the Ministry of Climate and Environment (Aas et al., 2019). The two observatories used for the monitoring of microplastics and additives in air; Birkenes in southern Norway, and Zeppelin, located on Svalbard, an archipelago in the Arctic Ocean.

Table 5. Monitoring stations for air samples for both air and precipitation

Monitoring station	Birkenes	Zeppelin
Station code (EBAS)	NO0001R NO0002R	NO0042G
Latitude	58 23 N	78 54 N
Longitude	8 15 N	11 53 E
Height above mean sea level	190/219 m	475 m
Sample matrix	Air & Precipitation	Air & Precipitation
Precipitation	01.10. - 14.10.21 18.10.- 29.10.21 29.10.- 12.11.21 12.11.- 26.11.21 26.11.- 10.12.21 10.12.- 24.12.21	01.10.-14.10.21 14.10.-28.10.21 28.10.-11.11.21 26.11.-16.12.21 16.12.-23.12.21 28.12.-12.01.22
Air	01.10.-14.10.21 14.10.-29.10.21 29.10.-12.11.21 12.11.-26.11.21 26.11.-10.12.21 10.12.-24.12.21	01.10.-14.10.21 14.10.-29.10.21 29.10.-12.11.21 26.11.-08.12.21 08.12.-16.12.21 16.12.-23.12.21

Samples of wet and dry deposition, as well as particulate phase of air were collected from the Birkenes and Zeppelin observatory. Collection of wet and dry deposition took place over 14 days. Sampling of air must take place by actively pumping air through a suitable type of filter over 14 days at a flow of 2-2.5 m^3/h to reach a total volume of 700-900 m^3 air. During the time period for handling filters from the air sampler, open containers must be used as blank samples to control airborne dust during handling.

Active air sampling

Air samples for microplastics and related additives were collected using active air samplers at both stations. The active air samples were collected on a bi-weekly basis throughout the fall using full-metal filter holders, equipped with 10 µm steel filters and collected TSP (total suspended particles) down to 10 µm size with a sampling rate of 3 m^3/hour.

Wet and dry precipitation

The precipitation samples were collected on bi-weekly basis using full metal bulk precipitation samplers (Innovation nilu's Atmospheric Microplastic Collector) with no microplastic size limitation, for a period of 14 days per period at both stations.

Active air samples and precipitation samples were extracted, analysed and quantified at NILU under strict quality control using the isotopic dilution method.

4.7 Sample preparation and filtration

Considering the array of different samples handled within the MIKRONOR1 programmes a variety of methods were employed to process and prepare them for plastic analysis. The steps are briefly described below and summarised in Table 6. All reagents and RO water used in the sample preparation steps were filtered through a membrane filter (Merck Millipore, pore size of 0.22 µm) before use.

4.7.1 Water samples

All water samples (plankton, high-volume pump, Ferrybox) contained a high amount of organic material. They required oxidative digestion with potassium hydroxide (KOH). This followed the method a modified approach as published in Bråte et al., 2018; Lusher et al., 2020; Pakhomova et al., 2022.

The samples were rinsed through a sieve to remove the fractions below the LOD (50 µm sieve for high-volume pump 50 µm samples; 90 µm sieve for Ferrybox 100 µm samples; 180 µm sieve for vertical plankton net, Ferrybox 200 µm, and high-volume pump 200 µm samples). The residue on the sieves was then rinsed into a 250 ml Erlenmeyer flask with filtered RO-water. A pre-filtered solution of 47% KOH was then added to the samples and diluted until a 10% KOH solution was obtain. The samples were then put in an incubator at 40°C with continuous agitation (100 rpm) for about 24 hours, before filtration onto glass fibre filters (GF/A; 47 mm in diameter, pore size of 1.6 µm). Filter papers were allowed to dry in a covered petri dish before visual before being visually inspected for the presence of suspected microplastics followed by single point µFTIR.

There was one exception with the filtering, the high-volume pump 50 µm samples were filtered onto silver membrane filters (13 mm in diameter, pore size of 3 µm) and allow to dry in a covered glass holder before analysis with µFTIR scanning imaging mode, followed by pyrolysis- GC/MS.

Table 6. Summary of sample treatment and analytical detection technology.

Sample type	Size fractionation (µm)	Treatment (digestion)	Filters	Visual analysis	µFTIR	Pyrolysis
Vertical plankton nets	>180/200 µm	10% KOH	GFA	Yes	Transmittance	No
High-volume pump	>50 µm	10% KOH	Silver	No	Reflectance, scanning	Yes
High-volume pump	>200 µm	10% KOH	GFA	Yes	Transmittance	No
Ferrybox	100-200 µm 200-500 µm	10% KOH	GFA	Yes	Transmittance	No

4.7.2 Blue mussels

The sample pre-treatment is outlined in Figure 18. Ten individuals of *Mytilus* spp. were processed per site, except Site 7 where 11 mussels have been processed. All samples were store frozen and then defrosted. Their lengths were measured (mm) with callipers before rinsing with DO water. Shells were opened and the soft tissue was dissected out, weighed (g, w.w.), and placed in a pre-rinsed, clean glass beaker.

A pre-filtered solution of 10% KOH was added to each beaker in a ration of 1:10 (biota: KOH, v/v) in order to digest the soft tissues. Beakers were sealed with aluminium foil and placed in an incubator for 48 h at 40 °C with continuous agitation (100 rpm). A pre-filtered solution of 10% acetic acid was then added to the samples in a 1:1 ratio (10% acetic acid: 10% KOH) for a final concentration of 5% acetic acid, in order to dissolve $CaCO_3$ shell residues that might disturb visual and µFTIR analysis, and then placed in an incubator for a minimum of 4 h at 40°C with continuous agitation (100 rpm) (Bråte et al. 2020).

The samples were then size fractionated through 50 µm and 250 µm sieves. The larger fraction (>250 µm) was filtered onto glass microfibre filter papers (GF/A, 47 mm diameter, 1.6 µm pore size) and allowed to dry in a covered petri dish. Filters were visually inspected for the presence of suspected microplastics, they were confirmed as plastic using by single-point- µFTIR. The smaller fraction (50-250 µm) was filtered onto a silver membrane filters (13 mm in diameter, pore size of 3 µm) for analysis with µFTIR scanning imaging mode followed by pyrolysis- GC/MS.

Mytilus spp. dry weight was calculated using 3-4 additional individuals not previously analysed for microplastics. After the calculation of average dry weight % for each site, the dry weight was calculated for each individual. For one site (Nordnes, Bergen harbour), the measured dry weight was not available, so the overall mean of the dry weight % of all sites was calculated and used to covert the wet weight of the individuals to dry weight.

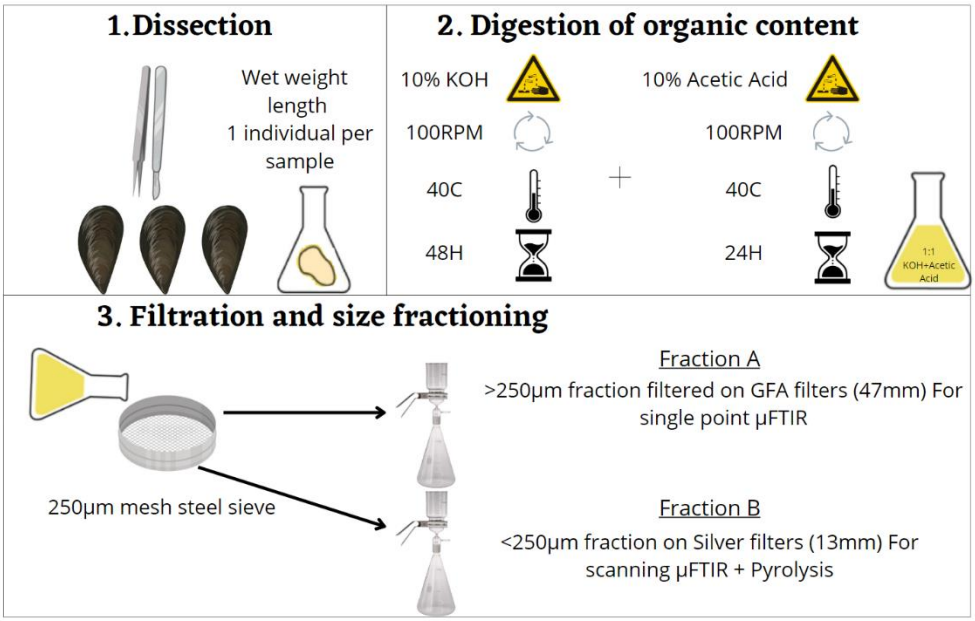


Figure 18. Overview of sample processing for blue mussel samples. 1. Samples were dissected and wet weight + length (from each apex of the shell) were recorded. 2. The organic content was digested using 10% KOH followed by 10% Acetic Acid. 3. Each sample was then split into two different fractions: >250 µm and <250 µm.

4.8 Analytical procedures used for microplastic analysis

4.8.1 Larger size fraction (visual identification and μFTIR)

The larger size fractions (100, 200, or 250 μm) of all samples types were visually examined under a stereomicroscope (Nikon SMZ745T, 20× magnification), measured (at their longest, length and shortest, width, μm) and photographed (using Infinity 1-3C/INFINITY 1 Lumenera camera and INFINITY ANALYZE and CAPTURE software). Visual identification followed the methods and standards presented in Lusher et al. (2020) regarding microplastics categorisation by shape, size, and colour.

Visual identification was supported by μFTIR (Spotlight 400, PerkinElmer) to determine the type of plastics recovered. Before analysis, the particles were transferred to a diamond compression cell (DCC) to squash the particles and provide a thin and even surface for spectra analysis. The analysis was performed in transmission mode with a resolution of 4 cm^{-1} and wavelength 4000 to 600 cm^{-1}. Background scanning was performed before each analysis. The instrument is used together with the Spectrum 10 software (v. 10.6.2), and each spectrum is compared to several different libraries: PerkinElmer ATR Polymers library, STJapan Polymers ATR library, BASEMAN library (Primpke et al., 2018), and in-house libraries including reference material, various textiles, and potential sources of contamination from the lab. All spectra were manually inspected to ensure that each library match is acceptable. Particles were accepted as plastics if they fell into the categories as assigned by AMAP. The full list of polymers included in this reporting are in the Appendix.

4.8.2 Smaller size fraction (combined μFTIR and pyrolysis)

Smaller size fractions of each sample type were analysed with μFTIR imaging reflectance mode directly on silver membrane filters using a Perkin Elmer Spotlight 400.

For the blue mussels, there were only a few suspected microplastics identified in the 50 – 250 μm size fraction. The suspected plastic particles were first identified under the stereomicroscope, photographed, described and measured in a similar way as for the larger size fraction samples (see previous section), but without physically handling the particles. The whole silver filter was then placed under the μFTIR microscope without disturbing the particles, and each particle was analysed in reflectance mode using the same software (Spectrum IR) in the same way as for the larger size fraction samples (see previous section). All spectra were manually checked to ensure a good match with the library and a reliable identification of the plastic polymers.

The high-volume pump (50 μm) samples contained many more particles compared to the blue mussels, therefore they were analysed using μFTIR imaging scanning mode on the whole silver membrane filters. This method is more sensitive in that it is possible to analyse smaller sized particles, and human bias linked to subjectivity in the visual preselection step is avoided. The method also limits particle loss linked to the physical handling of particles.

In short, μFTIR imaging involves analysing spectra for each defined pixel within a defined area, and building a chemical map of the entire sample, i.e. all identified particles. Automatic scanning of particles >50 μm was done using a Perkin Elmer Spotlight 400. The resulting FTIR spectra were further analysed using siMPle software where after loading the data and reference spectra, the spectral were fit a Pearson correlation for the untreated data, the first derivative and the second derivative, resulting in several correlation factors. siMPle identifies the recorded spectra based on the results of the Pearson correlation factors. The procedure siMPle is using is outlined in Figure 19. In short, the sample is collected on a silver membrane filter (A), scanned using the μFTIR and processing in simple with a

heat map is generated during the identification process (B), and final identification completed after applying a threshold value (C). An example of spectral matching is presented for library and transmittance spectra (D). Once scanning was complete, filter papers were processed using pyrolysis.

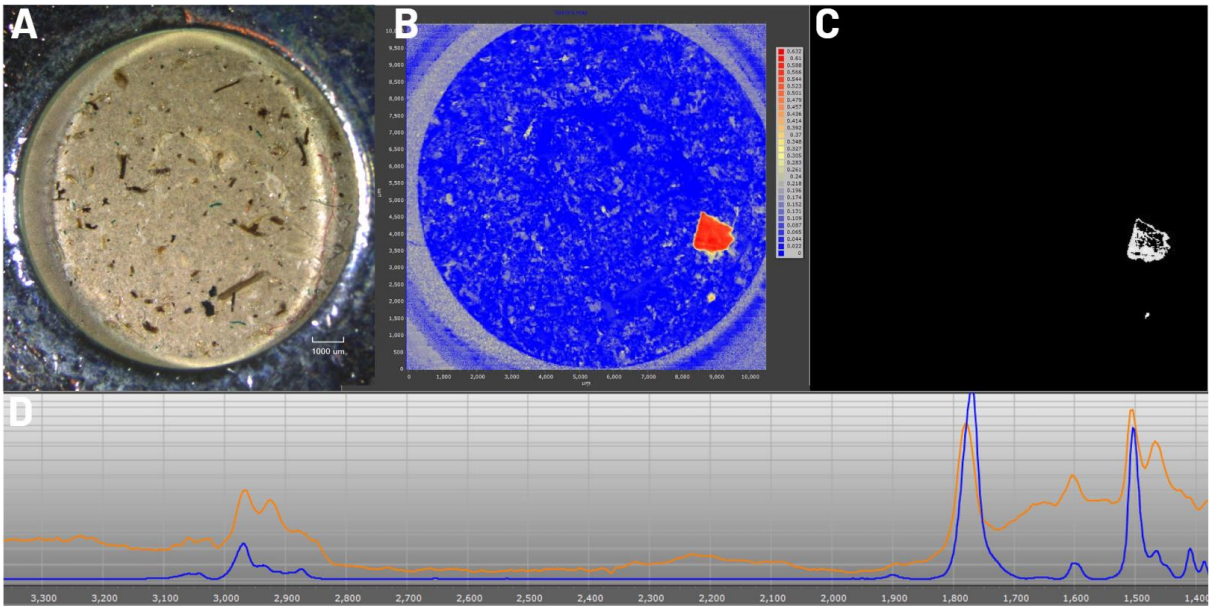


Figure 19. Workflow using siMPle for polymer identification. The sample is collected on a silver membrane filter (A), a heat map is generated by the software (B) and a final image generated after threshold value correction (C). Transmittance spectra area produced (D) showing the reference (blue) and sample (orange). A polycarbonate fragment is identified in this example.

4.8.3 Pyrolysis GC/MS

***Water samples*:** The silver membrane filters used for µFTIR are suited for use on pyr-GC/MS and the same samples can first be imaged using a non-destructive approach through IR spectroscopy, followed by more precise quantification of total polymer content for a range of common polymer types using pyr-GC/MS (destructive approach). A Frontier lab multi shot pyrolizer EGA/PY 3030D connected to a Frontier lab AS 1020E Auto shot sampler with a MFS 2015E multi-functional splitless sampler was connected to an Agilent 8860 GC with an Agilent 5977B GC/MSD was used for sample analysis. The analytical method, adapted from Ishimura et al. 2021 and Matsueda et al. 2021, using calcium carbonate as a catalyst for the simultaneous quantification of 10 different polymers. In addition to these polymers, the samples were scanned for rubber, originated from tires. With the adapted method it is possible to quantify PMMA (poly methyl methacrylate), Nylon-6 (polycaproamide), Nylon-6,6 (poly hexamethylene adipamide), PP (polypropylene), PVC (poly vinyl chloride), PC (polycarbonate), PET (polyethylene terephthalate), PE (polyethylene), ABS (acetonitrile-butadiene-styrene copolymer) as well as PS (polystyrene) containing microplastics.

***Air samples*:** For both air sample types, after filtration on a GF/F filter, polymer determination by pyr-GC/MS was carried out. The 9 main polymer types in use were measured (PE, PP, PET, PS, PVC, PMMA, Nylon, PC, PU) in addition to BSR for car tire particles. This provides the opportunity to determine trace amounts of polymer particles, unavailable for other techniques (> 10 µm). Chromeleon was used for quantification. An external calibration curve for each polymer was used in addition to isotopic labelled PS. UV compounds in the organic filtrate were analysed by GC/Orbitrap MS by using the isotopic dilution method.

5 Results

5.1 QA/QC of MIKRONOR1

5.1.1 Results of recovery tests

Recovery tests were carried out for two types of matrix, water and biota, where water was sampled with three different ways: plankton net, Ferrybox and high-volume pump. These three have different size ranges and processing procedures. Therefore, recovery tests were made for four different cases. For samples with lower size limit 50-100 µm (Ferrybox, high-volume pump and biota) standard reference material of MPs (SRM) in form of soda tablets were used. These SRM contains plastic particles made of three polymer types: PS, PVC and PE in size range 125-350 µm (Table 7). For plankton net samples, 10 PE particles with size 450 µm were manually added in addition, as particles < 180 µm from SRM (PVC and PE) will pass through sieves under processing. SRMs were added to the water samples before processing and to the biota samples at the first step under processing. The same processing for each type of samples was carried out as described in the project (Chapter 4.7). Since the particles in SRM have a specific shape/size, only visual analysis under a microscope was needed to identify SRM particles.

All tests shown recovery rates above 90% for total number of particles. Specifically, the methods applied in the laboratory to digest biological material returned a high extraction efficiency, 93%, when processing mussels (*Table 8*). Processing large volume water samples had a 100%, 95% and 92% recovery rate, for plankton nets, Ferrybox and high-volume pump respectively (*Table 9-Table 11*). These results confirmed that the protocols used were suitable for the monitoring programme.

Table 7. Overview of polymers and size fractions used for recovery tests in MIKRONOR1.

	Number of particles added	Plankton net (200 µm)	Ferrybox (100 µm)	High-volume pump (50 µm)	Biota (50 µm)
PVC (150-250 µm)	36 ±3		x	x	x
PS (250-355 µm)	35 ±5	x	x	x	x
PE (125-150 µm)	29 ±5		x	x	x
PE (425-500 µm)	10 ±0	x			

Table 8. Results of recovery tests for processing biota (blue mussel) samples (50 µm).

	Test 1	Test 2	Test 3	Mean	Stdev, ±	%RSD	SRM
PVC	43	40	38	40	3	6	36 ±3
PS	27	30	31	29	2	7	35 ±5
PE (125-150)	28	29	31	29	2	5	29 ±5
total	98	99	100	99	1	1	106 ±9
Recovery rate							**93%**

Table 9. Results of recovery tests for processing large volume plankton net (200 µm) water samples

	Test 1	Test 2	Test 3	Mean	Stdev, ±	%	SRM
PS	42	31	32	35	6	17	35 ±5
PE (425-500)	10	10	10	10	0	0	10 ±0
Recovery rate							**100%**

Table 10. Results of recovery tests for processing Ferrybox (100 µm) samples

	Test 1	Test 2	Test 3	Mean	Stdev, ±	%	SRM
PVC	35	38	50	41	8	19	36 ±3
PS	33	33	36	34	2	5	35 ±5
PE (125-150)	19	21	26	22	4	16	29 ±5
total	87	92	112	97	13	14	106 ±9
Recovery rate							**92%**

Table 11. Results of recovery tests for processing high-volume pump samples (50 µm).

	Test 1	Test 2	Test 3	Mean	Stdev, ±	% RSD	SRM
PVC	46	32	40	39	7	18	36 ±3
PS	28	40	36	35	6	18	35 ±5
PE (125-150)	27	21	31	26	5	19	29 ±5
total	101	93	107	100	7	7	106 ±9
Recovery rate							**95%**

5.1.2 Results of laboratory procedural controls

Mussel samples

The laboratory procedural controls showed a consistent, low level, of procedural contamination. Across all corresponding laboratory procedural blanks (n = 28), the number of microplastics ranged from 0 – 2 (average: 0.67 ± 0.72). In total, 10 particles were identified corresponding to 80% fragments and 20% fibres. This level of background is not dissimilar to previous works. No blank corrections were performed on the data. Therefore, the results of the blue mussel analysis are presented with the average of all blanks (0.67 ± 0.72), LOD (2.17) and LOQ (7.24) **(Table 12).**

Water samples

All water samples were processed in the same way and in parallel (Chapter 4.7). Therefore, the laboratory procedural controls are combined for all sample types. Similar to blue mussels, the procedural controls showed a consistent, low level, of procedural contamination. Across all corresponding laboratory/procedural blanks (n = 18), the number of microplastics ranged from 0 - 1 (average: 0.11 ± 0.32), with 0.97 as LOD and 3.23 as LOD. In total, 2 microplastics were identified corresponding to 100% fragments. This level of background is not dissimilar to previous works, no blank corrections have been performed on the data.

Table 12. Summary of particles identified in procedural (laboratory) blanks. Number of blanks (N).

	N	Total	% Fragments	% Fibres	Average (± SD)	LOD	LOQ
Blue mussels	28	10	80	20	0.67 (± 0.72)	2.17	7.24
Water samples	18	2	100	0	0.11 (± 0.32)	0.97	3.23

5.2 Blue Mussels

5.2.1 QA/QC measures for mussels

No field blanks were collected for blue mussels because the shells close and act as a natural barrier from field contamination. Procedural blanks were included once laboratory processing began.

5.2.2 Size of mussels

Mussels ranged in size from 30.4 mm to 66.0 mm (average: 47.1 ± 10.2 mm) across the 7 sites included in this report. There was quite a significant difference in mussel size between sites, with the smallest individuals found at Site 7 (Brashavn, Outer Varangerfjord: 35.03 mm average) and the largest individuals found at Site 5 (Nordnes, Bergen harbour: 61.4 mm average). The wet weight varied between 0.31 and 6.5 g, and when this was standardised to dry weight (d.w.), this varied between 0.042 and 1.14 g (average: 0.33 ± 0.028). Considering the variations between mussel size and wet weight, results are presented as per individual, and standardised to MP/ g d.w., in the Appendix (7.1.2).

5.2.3 Occurrence of microplastics in blue mussels from the Norwegian coast

Mussels (30.4 – 55.0 mm) from all 7 sites contained microplastics, with an overall average of 1.15 MP/individual^{-1} (range: 0 - 10/individual, Figure 20) corresponding to 7.96 MP/$^{-1}$ g d.w (range: 0 – 73.5 MP/$^{-1}$ g d.w (Appendix, 7.1.2). There was no significant difference between the sites. None of the sample sites exceeded the LOD (and subsequently LOQ) of the blanks for this current study. This is further explored in the discussion. When the number of microplastics per individual is divided into the two size categories (50-250 µm, >250 µm) more microplastics were observed in the smaller size fraction compared to the large size fraction. Most of the particles were fragments, which dominated at all sites (Figure 21.A). Mussels from Ålesund had the most diversity in particle morphology. However, when focusing on the larger particles (>250 µm), fibres dominated across all sides with the exception of Akeshuskia which was dominated by fragments (Appendix, 7.1.2). The polymer composition found a dominance of PP at all sites (Figure 21).

The results of the pyrolysis analysis of the individual blue mussel samples were all under the LOD for PMMA (< 025 µg), N66 (< 1.1 µg) and N6 (<0.6 µg) (polyamide based), PP (<1.3 µg), PC (<0.3 µg), PET (<0.8 µg) , PE (< 4.6 µg), ABS <0.3 µg) with the exception of 4 stations (Tjøme Outer Oslofjord, Gåsøya - Ullerøya Farsund, Nordness Bergen and Ålesund Harbour) were small amounts of PVC were found (0.6-6.5 ug per blue mussel). Small amount of PS (LOD <0.1 µg) were found at all locations ranging between <0.1 to 6.7 ug per blue mussel sample. However, PS was also found at similar levels in several of the blank samples.

Depending on the particle seize, many particles < 250 µm or 1 particle > 200 µm, it is difficult to compare the results from the from the pyr-GC/MS and the µFTIR. The results showed here do not show good agreement between the two analysis, but the material is too small draw further conclusions.

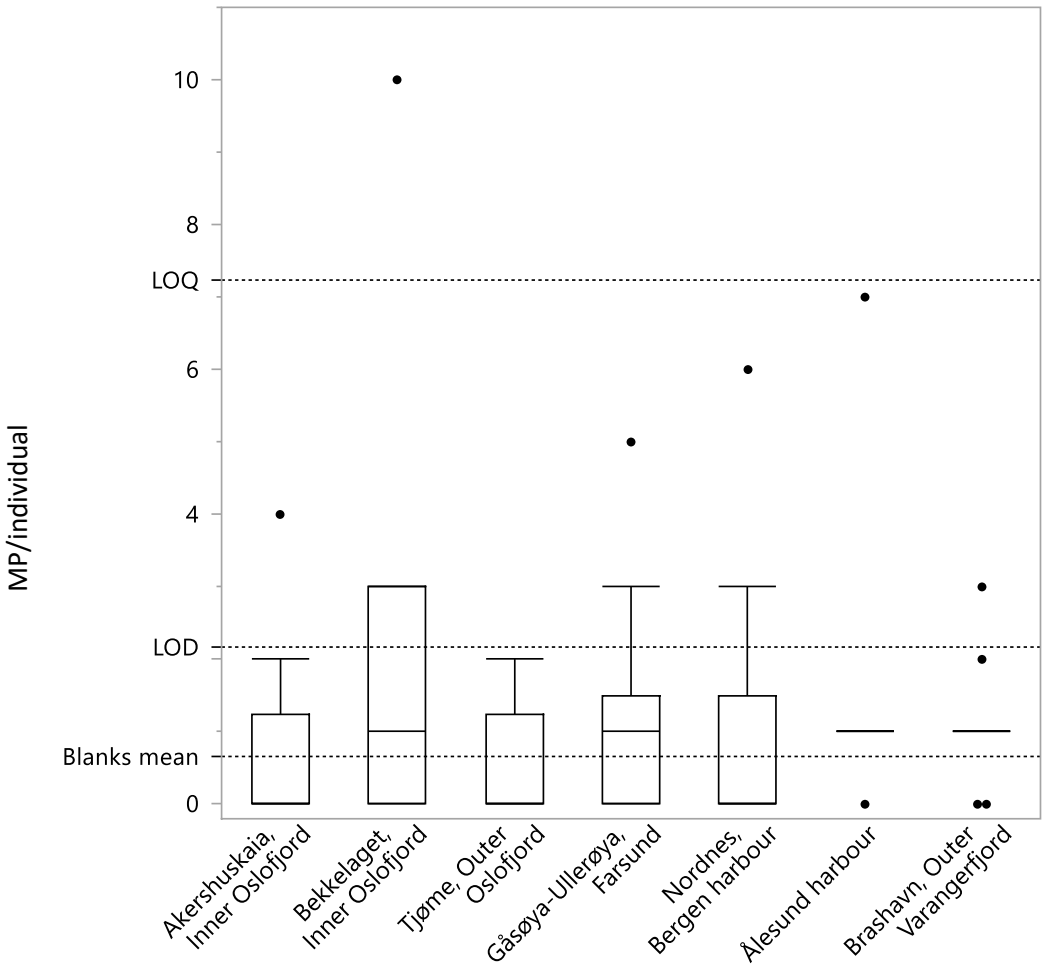


Figure 20. Number of microplastics identified in blue mussels from seven sites on the Norwegian coast as MP count/individual. Data has been compiled for all size fractions. Data is displayed as box plots with median (centre line), 25 and 75 percentiles (top/bottom of box) and outliers (dots). The dashed lines represent the mean, LOD and LOQ of the blanks. The corresponding size fraction specific data is presented in the results appendix.

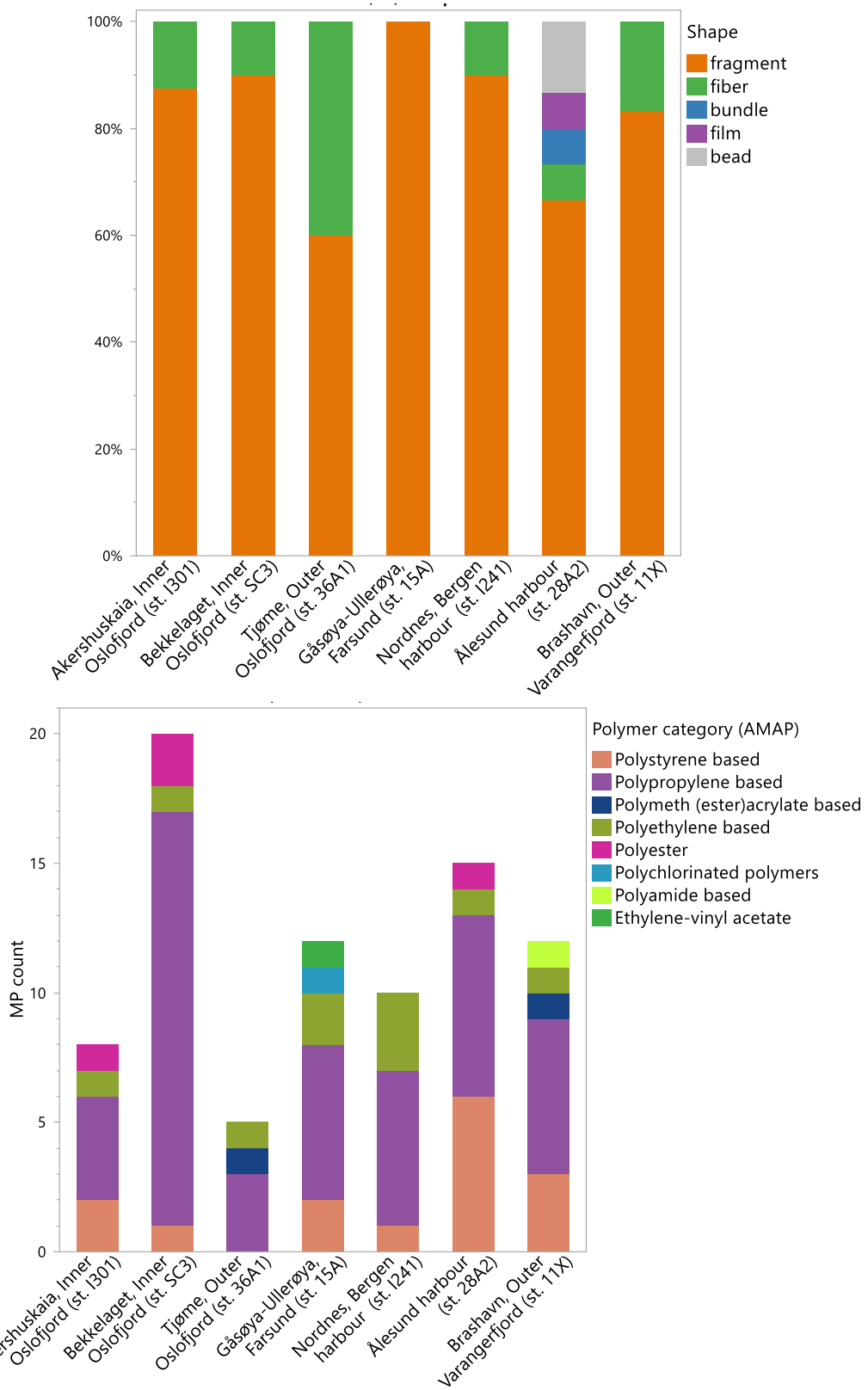


Figure 21. Particle characteristics including shape (top) and polymer composition of microplastics found in blue mussels from seven sites on the Norwegian coast. Data displayed here are compiled for all size fractions. Corresponding size fraction specific data are presented in the appendix.

5.3 Transect samples Oslofjord and Skagerrak

5.3.1 QA/QC – field controls

The results from the atmospheric blank samples taken on a 100 µm filter while opening the Ferrybox microplastic module with the filters containing the two filters are given in **Table 13**. The number of particles on the blank filter varied from 1 to 9 microplastics, with the exception of one blank sample which contained a large number of polypropylene particles and subtracted from the number of particles because they were the result of improper handling of the filters. Most of the microplastic in the blank were polyester fibres, most likely coming from clothing of staff operating the engine room at the MS Color Fantasy. The distribution of the polymers and the morphology is given in **Figure 22**.

Table 13. Atmospheric blank samples collected on board the MS Color Fantasy, while opening the closed Ferrybox system.

Ferrybox Oslo-Kiel Blanks	Lower size detection (µm)	Date	Number of microplastics
FB.OK.1. Blank	100	18.10.2021	1
FB.OK.2. Blank	100	20.10.2021	3
FB.OK.4. Blank	100	24.10.2021	9
FB.OK.5. Blank	100	26.10.2021	9
FB.OK.6. Blank	100	28.10.2021	5
FB.OK.7. Blank	100	30.10.2021	2
FB.OK.8. Blank	100	01.11.2021	2
FB.OK.9. Blank	100	03.11.2021	1*
FB.OK.10. Blank	100	05.11.2021	1
FB.OK.13. Blank	100	11.11.2021	9
FB.OK.14. Blank	100	13.11.2021	1
FB.OK.15. Blank	100	15.11.2021	4

*Obvious polypropylene contamination removed

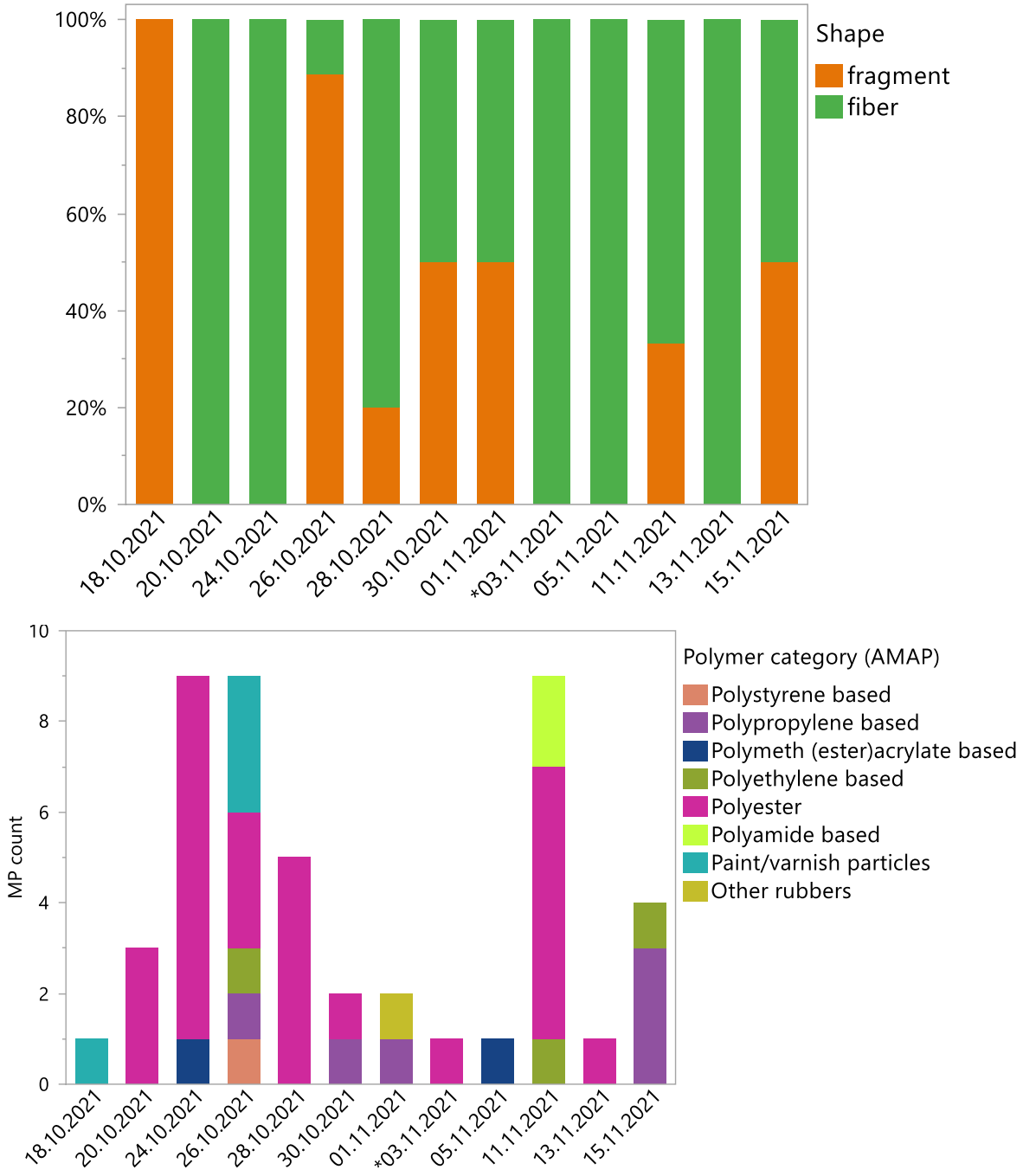


Figure 22. Composition of the on-board blank samples taken during the opening and changing of the filters in the Ferrybox microplastic sampler. The top graph presents the morphology and bottom graph presents the polymer composition.

5.3.2 MPs in water samples transect Oslofjord and Skagerrak

The results of sampling on the transect through the Oslofjord and Skagerrak in Norwegian waters are given in Table 14, where the sampling dates, the sample volume (sum of south and north bound sampling), the total number of particles and the number of particles per m^3 are presented. For the larger size fraction (500-200 µm), the number of particles varied from 0 to 8 particles per sample

resulting in normalised levels of 0 to 1.94 MPs per m^3. For the lower size fraction (100-200 µm), 3 to 9 particles were found with the exception of one sample containing 18 particles of PTFE. Although no obvious source of these particles within the equipment could be found, the tubing, connections and pump systems incorporated in the MS Color Fantasy's system might be a likely source. For another sample and one blanks sample, a high number of polypropylene particles were found due to a mistreatment of the filter, these clearly visible particles were not included in the results. This resulted in normalised levels ranging from 0.41 to 1.06 MP particles per m^3 for the 100-200 µm samples, with the exception of the sample with the large number of PTFE particles (5.82 MPs/m^3).

The polymer composition of the samples is given in Figure 23 apart from the high number of PTFE particles in one of the 100 -200 µm samples contained several polymers but no pattern was seen. For the larger size fraction (200 - 500 µm) relatively more polyester fibres were found which were also present in several blanks samples (Figure 22).

Ferrybox Oslo-Kiel Samples	Lower size detection (µm)	Date	N samples	Sample volume (m^3)	MP particles	MP per m^3
FB.OK.2.	100 - 200	20.10.2021	1	7.333	3*	0.41*
FB.OK.4.	100 - 200	24.10.2021	1	8.363	6	0.72
FB.OK.5.	100 - 200	26.10.2021	1	8.053	5	0.62
FB.OK.7.	100 - 200	30.10.2021	1	8.475	9	1.06
FB.OK.9.	100 - 200	03.11.2021	1	8.115	4	0.49
FB.OK.13.	100 - 200	11.11.2021	1	8.712	5	0.57
FB.OK.14.	100 - 200	13.11.2021	1	8.301	8	0.96
FB.OK.15.	100 - 200	15.11.2021	1	4.126**	24	5.82
FB.OK.1.	200 - 500	18.10.2021	1	7.216	0	0.00
FB.OK.2.	200 - 500	20.10.2021	1	7.333	1	0.14
FB.OK.4.	200 - 500	24.10.2021	1	8.363	4	0.48
FB.OK.5.	200 - 500	26.10.2021	1	8.053	8	0.99
FB.OK.6.	200 - 500	28.10.2021	1	8.501	3	0.35
FB.OK.7.	200 - 500	30.10.2021	1	8.475	1	0.12
FB.OK.8.	200 - 500	01.11.2021	1	8.559	0	0.00
FB.OK.9.	200 - 500	03.11.2021	1	8.115	5	0.62
FB.OK.10.	200 - 500	05.11.2021	1	7.936	3	0.38
FB.OK.13.	200 - 500	11.11.2021	1	8.712	2	0.23
FB.OK.14.	200 - 500	13.11.2021	1	8.301	7	0.84
FB.OK.15.	200 – 500	15.11.2021	1	4.126**	8	1.94

***Obvious polypropylene contamination removed. **Only one transect sample (North Bound)**

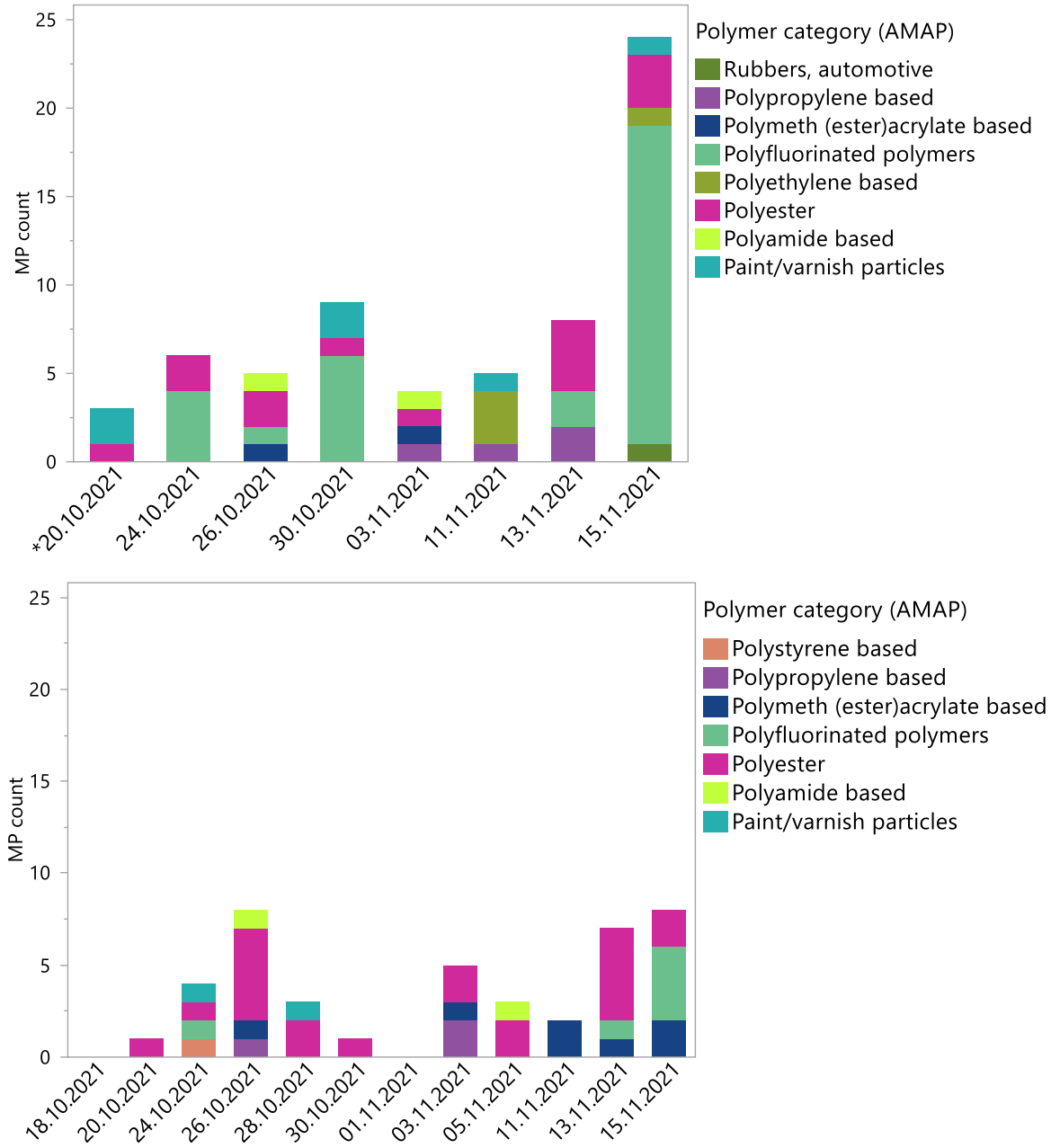


Figure 23. Composition of microplastics according to AMAP polymer categories in the 100 – 200 µm (top), and 200 – 500 µm (bottom) fractions of the Ferrybox samples.

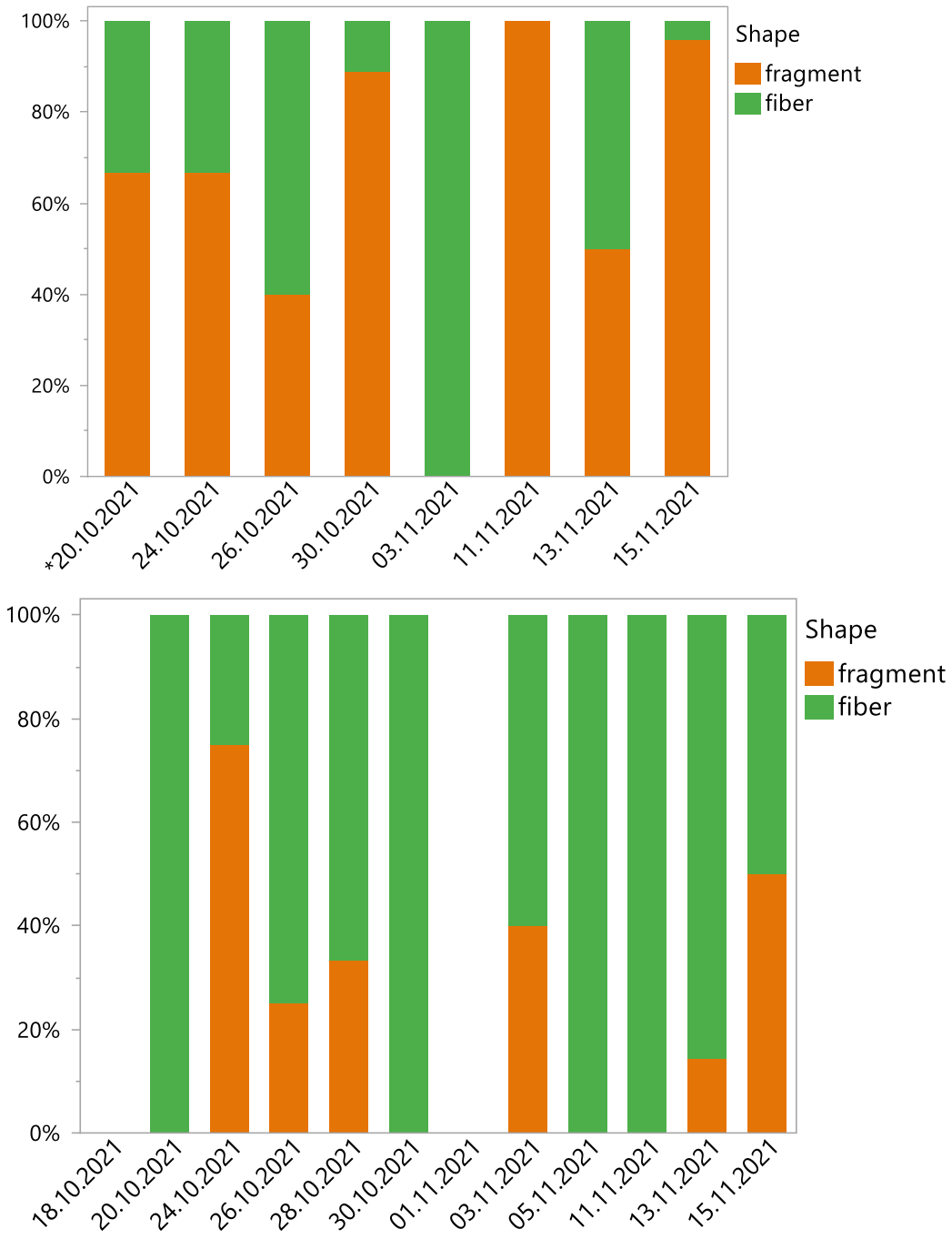


Figure 24. Morphology of microplastics in the 100 – 200 µm (top) and the 200 - 500 µm (bottom) fraction of the Ferrybox samples**.**

5.4 High-volume pump samples

5.4.1 QA/QC – field controls

During the sampling a lot of effort was put into acquiring representative field blank samples which would represent the sampling procedure. This turned out to be quite challenging under field conditions and the sampling teams had to compromise and adapt the procedures on-site. The field blank in many cases do not reflect the potential contamination of the samples but are an indication of possible contamination during the sampling and are given in **Table 15**. The polymer composition of both blanks and samples is given in **Figure 25**.

Table 15. The results from the field blanks taken at different occasion and procedures by the sampling teams for the high-volume pumps systems > 200 µm.

Station	N blanks	Total MP particles
Akershuskaia	6	10
Alnaelva, ved Alnabru	3	9
Alnaelva, ved Kværner	3	3
Bekkelaget	6	18
Hamar	6	15
Mjøsbru	6	21
Femund	3	10

5.4.2 MPs in high-volume surface water samples (number)

The total number of MPs in the samples and field blanks are very similar but above the LOD based on laboratory blanks (**Table 12**). The composition of MPs in the samples is somewhat different where there was more polypropylene present in the blank's samples and more polyethylene in the samples. In ***Figure 2*** in section 1.2.1.2 all individual samples are displayed, including the triplicate samples taken at different distances from potential point sources. The samples taken at different distances from point sources showed no clear trend for the three samples.

Table 16. MPs levels in the high-volume surface samples for the 200 -1000 µm fraction.

Station	N samples	Volume per sample (m^3)	Total volume (m^3)	Total MP particles	MP/m^3
Akershuskaia	6	1	6	13	**2.2**
Alnaelva, ved Alnabru	3	1	3	8	**2.7**
Alnaelva, ved Kværner	3	1	3	4	**1.3**
Bekkelaget	6	1	6	13	**2.2**
Hamar	6	1	6	24	**4.0**
Mjøsbru	6	1	6	14	**2.3**
Femund	6	1	6	26	**4.3**

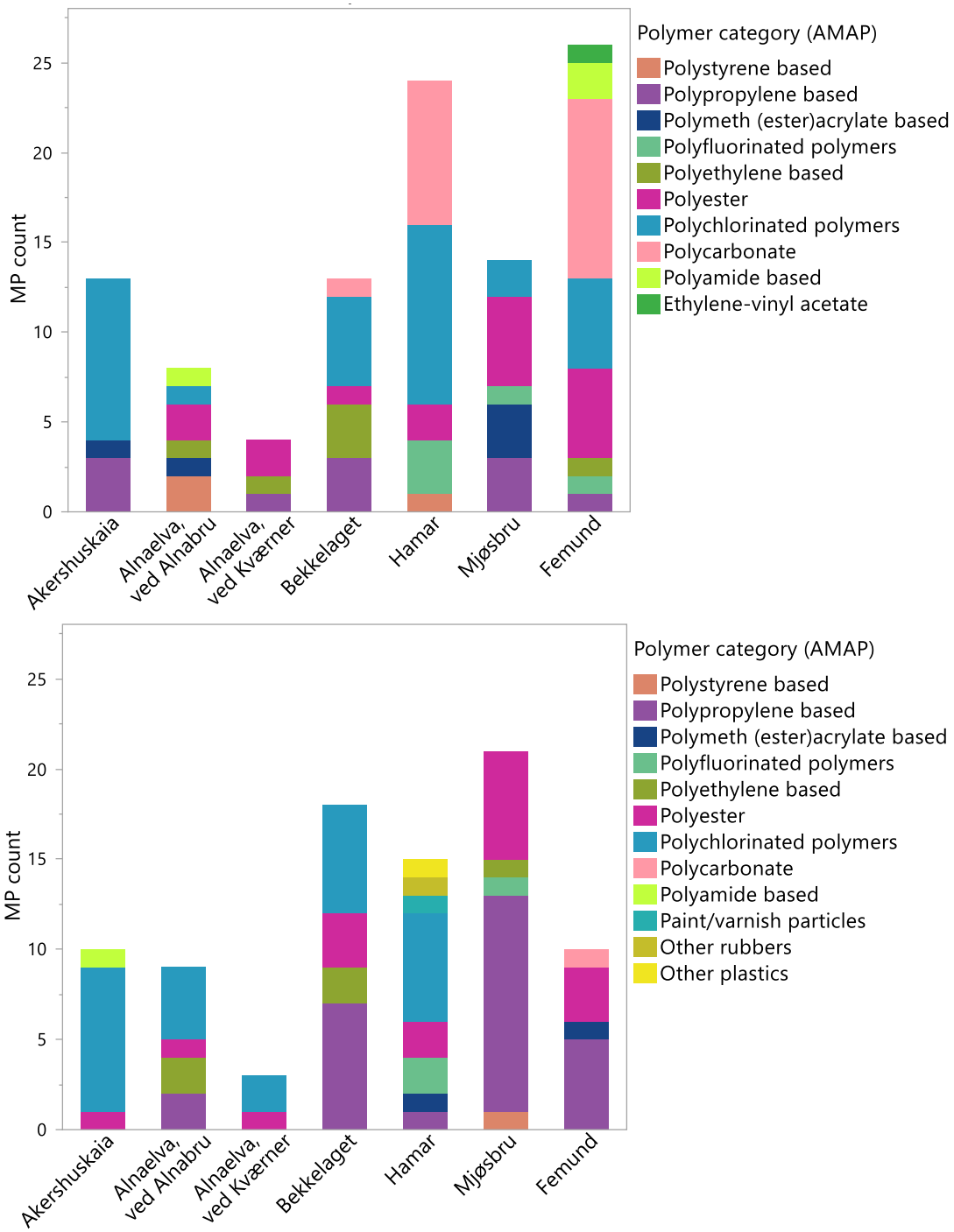


Figure 25. Polymer composition of the samples (top) and the blanks (bottom) taken at the same sampling occasions of the 200 - 500 µm fraction.

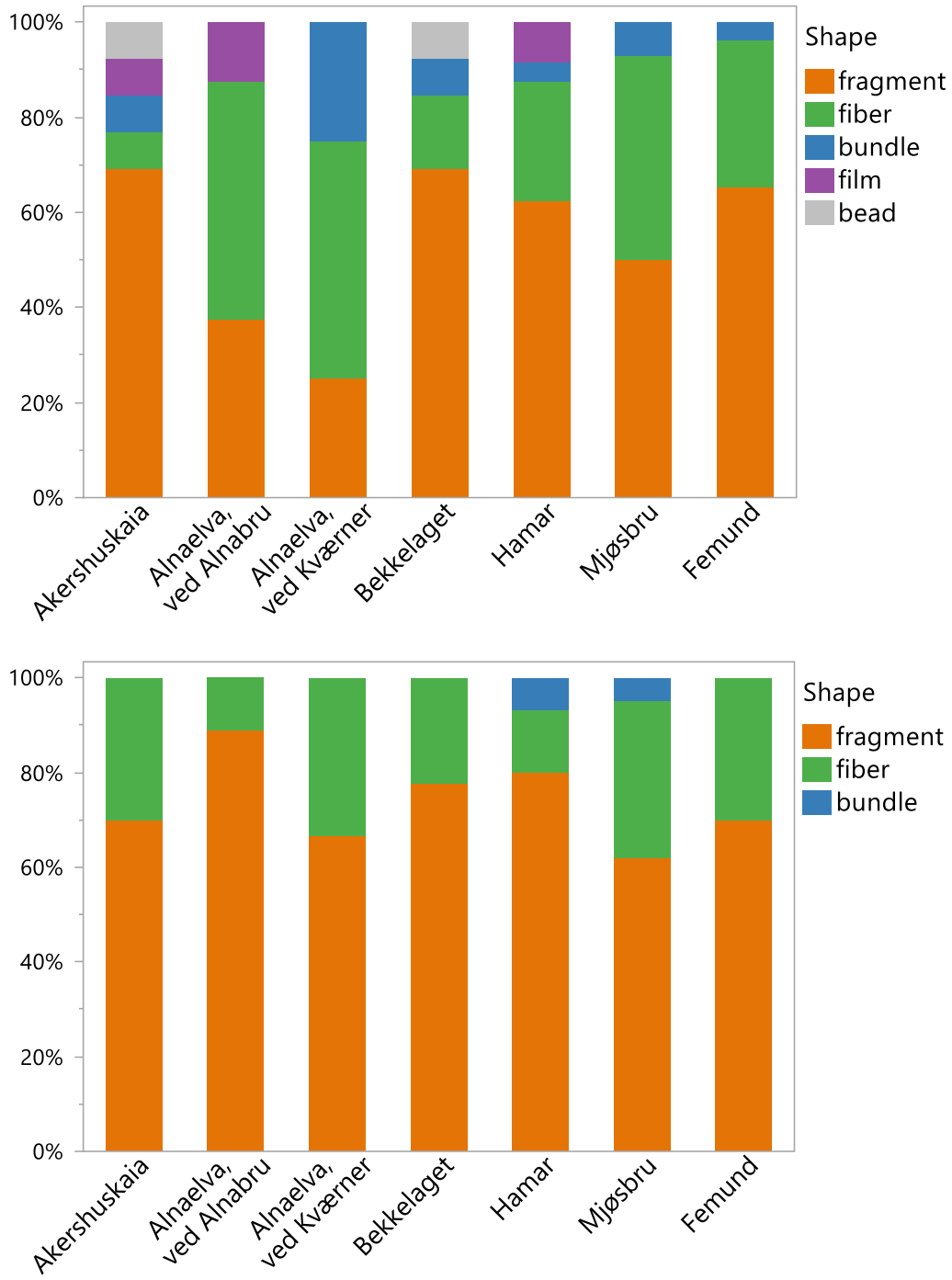


Figure 26. Morphology of the detected MPs in the 200 – 500 µm high-volume samples (top) and the blanks (bottom).

The results of the smaller size fraction (50 - 1000 µm) contained significantly more particles and the average of the three samples taken at the 4 locations varied from 5.7 to 16.7 MPs per m^3. The corresponding field blanks contained significantly higher numbed of MPs due to methodological challenges comparing blanks and real samples using µFTIR in the trans reflectance mode (***Table 17***). The polymer composition of the blank is somewhat different (Figure 27) but not conclusive to enable removal of polymers from the field blanks in the evaluation of the results.

Table 17. MPs levels in the high-volume surface samples for the 50 -1000 µm fraction. MP in blanks also given, these have different volumes.

Station name	N samples	Total sample volume (m^3)	Sum of MP particles in samples	MP/m^3 in samples	MP particles in blanks (different volume)
Akershuskaia	3	3	50	**16.7**	116
Bekkelaget	3	3	20	**6.7**	50
Hamar	3	3	17	**5.7**	47
Mjøsbru	3	3	50	**16.7**	281
		Sum	137		494

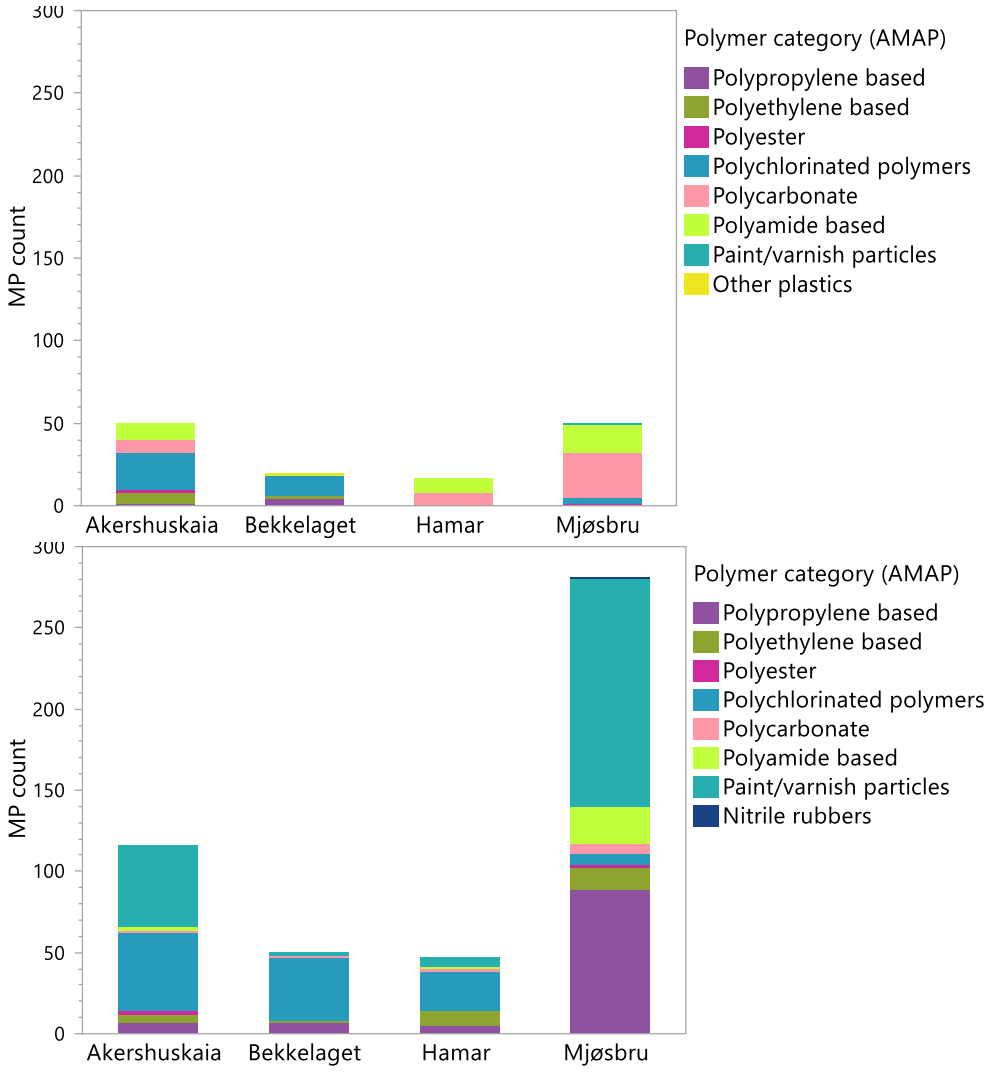


Figure 27. Polymer composition of the samples (top) and the blanks (bottom) taken at the same sampling occasions of the 50- 1000 µm fraction

5.4.3 MPs in high-volume surface water samples (mass).

In Table 18 the results from the pyr-GC/MS analysis of the same samples which were analysed using µFTIR are given. The results show that both PMMA (Polymethyl methacrylate), PVC, PP, PC and PS were found in both blanks and the samples. Especially PVC, PC and PS were found at significantly higher levels than were found in the blank samples in specific, in accordance with the uFTIR results no gradient was found in locations with different distances to potential points sources.

Table 18. Results from the pyr-GC/MS analysis of the high-volume samples (µg / sample 3 m^3)

Sampling Sites **Field Blanks**	**PMMA µg**	**Nylon 66 µg**	**PP µg**	**PVC µg**	**Nylon 6 µg**	**PC µg**	**PET µg**	**PE µg**	**ABS µg**	**PS µg**
Blank Mjosbru1	0.1	<2.1	10	3.1	<1.2	6.9	<1.6	<9.2	<0.5	6.3
Blank Mjosbru2	< 0.05	<2.1	13	1.3	<1.2	1.0	<1.6	<9.2	<0.5	2.0
Blank Mjosbru3	<0.5	<2.1	7.4	0.9	<1.2	<0.6	<1.6	<9.2	<0.5	0.1
Blank Mjoshavn1	1.1	<2.1	<2.5	26	<1.2	0.1	<1.6	<9.2	<0.5	1.1
Blank Mjoshavn2	<0.5	<2.1	14	1.2	<1.2	<0.6	<1.6	<9.2	<0.5	0.1
Blank Mjoshavn3	0.6	<2.1	<2.5	5.9	<1.2	0.1	<1.6	<9.2	<0.5	1.0
Blank Akershus1	0.5	<2.1	<2.5	3.5	<1.2	<0.6	<1.6	<9.2	<0.5	0.9
Blank Akershus2	0.7	<2.1	5.1	6.1	<1.2	<0.6	<1.6	<9.2	<0.5	1.5
Blank Akershus3	0.8	<2.1	13	12	<1.2	<0.6	<1.6	<9.2	<0.5	0.3
Blank Bekk1	0.6	<2.1	<2.5	7.7	<1.2	<0.6	<1.6	<9.2	<0.5	0.2
Blank Bekk2	0.6	<2.1	<2.5	6.9	<1.2	<0.1	<1.6	<9.2	<0.5	1.1
Blank Bekk3	0.7	<2.1	<2.5	9.3	<1.2	<0.6	<1.6	<9.2	<0.5	0.2
Samples										
Mjosbru1	1.7	<2.1	<2.5	> 48.5	<1.2	41	<1.6	<9.2	<0.5	54
Mjosbru2	0.6	<2.1	<2.5	9.1	<1.2	12	<1.6	<9.2	<0.5	38
Mjosbru3	0.6	5.7	3.9	12	<1.2	1.3	<1.6	<9.2	<0.5	3.3
Mjoshavn1	1.4	<2.1	<2.5	> 48.5	<1.2	0.9	<1.6	<9.2	<0.5	3.7
Mjoshavn2	0.7	<2.1	3.2	19	<1.2	36	<1.6	<9.2	<0.5	42
Mjoshavn3	1.1	<2.1	3.2	40	<1.2	1.6	<1.6	<9.2	<0.5	7.2
Akershus1	<0.5	<2.1	<2.5	2.8	<1.2	0.1	<1.6	<9.2	<0.5	1.1
Akershus2	1.4	<2.1	<2.5	> 48.5	<1.2	3.4	<1.6	<9.2	<0.5	6.4
Akershus3	0.9	<2.1	<2.5	24	<1.2	1.8	<1.6	<9.2	<0.5	2.7
Bekk1	0.6	<2.1	<2.5	13	<1.2	<0.1	<1.6	<9.2	<0.5	0.8
Bekk2	<0.5	4.7	<2.5	33	<1.2	<0.6	<1.6	<9.2	<0.5	2.5
Bekk3	0.5	<2.1	2.5	9.1	<1.2	0.6	<1.6	<9.2	<0.5	12
LOD / LOQ										
LOD	0.01	0.5	0.5	0.3	0.05	0.1	0.50	1.00	0.10	0.01
LOQ	0.5	2.1	2.5	1.2	1.2	0.6	1.6	9.2	0.5	0.8

5.4.4 Comparison estimated mass (µFTIR) and mass determined by pyr-GC/MS.

The same silver filter after sample pre-treatment was analysed both by the µFTIR (counting particles) and pyr-GC/MS (reporting mass). The µFTIR scanning data of the filter was treated by the software tool SimPle which allows automatic particle identification and seize determination. The SimPle software also estimate the mass of the polymers on the filter by using the Feret diameter. The pyr-GC/MS measures specific fragments after pyrolysis of the sample and calculates the mass of the polymers on the filters against a standard curve of virgin polymers.

As can be seen from *Table 19* where the results of three of the polymers which were both measured by the two different methods the results can vary largely. Although the same polymers were detected the amounts can differ significantly. There are several reasons for this including the assumption of spherical particles for the estimated mass from the µFTIR analysis and the uncertain amounts of additives in different plastics which are not measured with the pyr-GC/MS which generally reports lower mass of the polymers except for PVC. This was also described in the literature (Primpke et al. 2020) where the results from both methods were compared. This might indicate an interference while measuring PVC in samples with high background.

Table 19. Comparison of the amounts of MPs determined by pyr-GC/MS (µg) and the amounts estimated (µg) from the number of particles analysed by µFTIR.

Detection method	**pyr-GC/MS**			**uFTIR (estimated amounts)**		
Sampling Sites Field Blanks	**PP µg**	**PVC µg**	**PC µg**	**PP µg**	**PVC µg**	**PC µg**
Blank Mjosbru1	10	3.1	6.9	1.68	1.15	602
Blank Mjosbru2	13	1.3	1.0	26.2	0.46	404
Blank Mjosbru3	7.4	0.9	<0.6	11	0.72	0.14
Blank Mjoshavn1	<2.5	26	0.1	0.043	17	7.0
Blank Mjoshavn2	14	1.2	<0.6	2.2	4.6	
Blank Mjoshavn3	<2.5	5.9	0.1	0.008	2.1	
Blank Akershus1	<2.5	3.5	<0.6	0.12	4.7	0.076
Blank Akershus2	5.1	6.1	<0.6	0.25	8.6	
Blank Akershus3	13	12	<0.6	0.15	187	
Blank Bekk1	<2.5	7.7	<0.6	0.05	117	
Blank Bekk2	<2.5	6.9	<0.1	0.01	17.9	0.019
Blank Bekk3	<2.5	9.3	<0.6	7.0	4.9	
Samples					4.1	27
220930 HW50 Mjosbru1	<2.5	> 48.5	41	0.005		593
220930 HW50 Mjosbru2	<2.5	9.1	12			
220930 HW50 Mjosbru3	3.9	12	1.3			
220930 HW50 Mjoshavn1	<2.5	> 48.5	0.9			206
220930 HW50 Mjoshavn2	3.2	19	36			3.8
220930 HW50 Mjoshavn3	3.2	40	1.6	0.02		
220930 HW50 Akershus1	<2.5	2.8	0.1		2.0	0.66

220930 HW50 Akershus2	<2.5	> 48.5	3.4		2.7	13
220930 HW50 Akershus3	<2.5	24	1.8	0.05	0.97	
220930 HW50 Bekk1	<2.5	13	<0.1			
220930 HW50 Bekk2	<2.5	33	<0.6		1.39	
220930 HW50 Bekk3	2.5	9.1	0.6			
LOD	0.5	0.3	0.1	NA	NA	NA
LOQ	2.5	1.2	0.6	NA	NA	NA

5.5 Plankton net samples

5.5.1 QA/QC – field controls

Two types of field blanks were collected for the plankton samples, air blanks by deposition on a filter and a rinse of the equipment as described in section 4.3. The air blanks contained 0 to 2 MPs; these was very low in comparison to the MPs in the samples which varied from 0 to 37 MPs. The other field blanks were taken flushing the sampling equipment, these blank sample however were of varying quality and did contain relatively large amounts of MPs. These blanks were taken by different sampling teams and often under difficult field conditions. Further investigation of the field reports and type of MPs, these field blanks were found to be not representative of a true field sample and therefore excluded from analysis.

5.5.2 MPs in vertical plankton net samples

Microplastics were identified at all 10 stations using a vertical plankton net. The mean number of particles per station ranged from 0.26 to 3.14 /m^3, with an overall average of 1.54 (Table 20**Error! Reference source not found.**). A lot of fibres were found in the samples except for Færder, in the outer Osloford (Figure 28) where only fragments were found. The polymer composition varied between stations and field blanks.

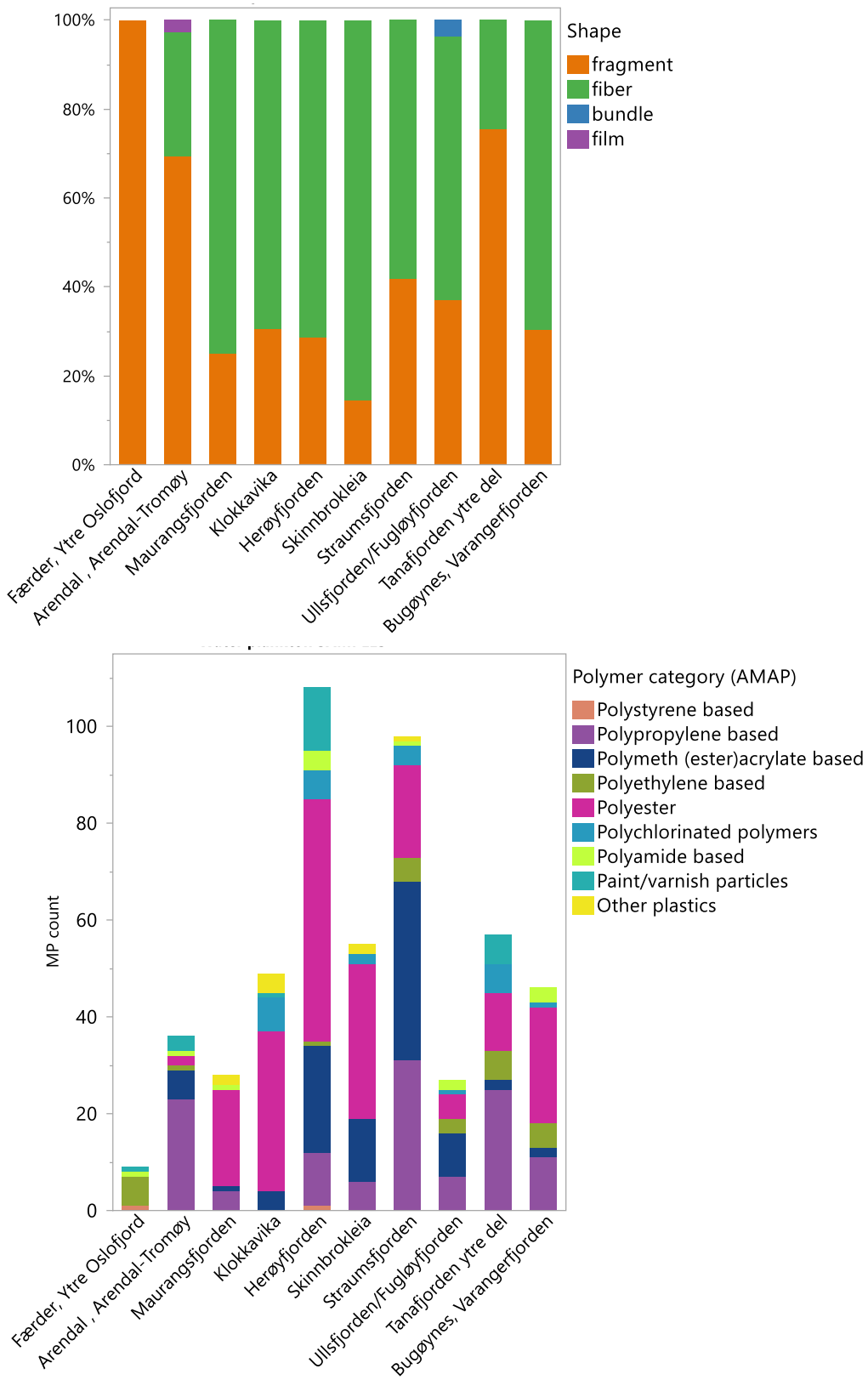


Figure 28. Particle characteristics including shape (top) and polymer composition of microplastics found vertical plankton hauls from 10 sites along the Norwegian coast. Data displayed here are compiled for all size fractions 200 -1000 µm.

Table 20. The results from the vertical plankton samples for the 200 – 1000 µm fraction.

Station	Station Code	Samples (n)	Sum (MP)	Volume (m^3)	Mean (MP/m^3)
Færder, Outer Oslofjord	BT40	3	9	34.35	0.26
Arendal , Arendal-Tromøy	BT44	3	36	34.35	1.05
Maurangsfjorden	BT132	3	28	34.35	0.82
Klokkavika	BR108	3	49	34.35	1.43
Herøyfjorden	BR70	3	108	34.35	3.14
Skinnbrokleia	BR12	2	55	22.9	2.40
Straumsfjorden	VR54	3	98	34.35	2.85
Ullsfjorden/Fugløyfjorden	BR119	3	27	34.35	0.79
Outer Tanafjorden	BR43	3	57	34.35	1.66
Bugøynes, Varangerfjorden	VR21	3	46	34.35	1.34

5.6 Air Samples

5.6.1QA/QC – field controls

The results of the mass-based analysis of the active air and deposition samples are given in Table 21. Field control samples were taken with each sampling batch, representing the complete handling process of the samples in the field. For active samples, filterholders were mounted on the sampling device for the same sampling period as the samples, with pumping air through them. After the end of the sampling period, the filterholders were closed in the field and shipped directly to the lab for processing. Field controls for deposition samples were taken by pouring water into empty sampling containers during handling of real samples, and subsequent collection of this water into clean glassbottles, shipped to the laboratory. All samples were blank corrected.

5.6.2MPs in air samples

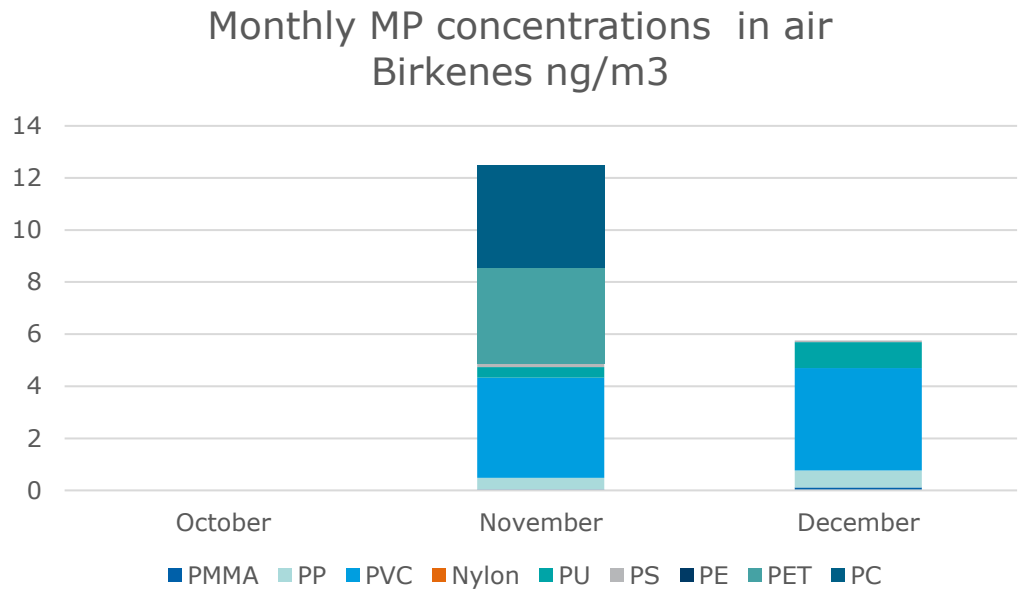
MP concentrations in air and deposition from Birkenes and Zeppelin on a monthly basis (December for Zeppelin could not be calculated due to interrupted sampling at the station). Detailed results are given in Table 21.

In general, pyr-GC/MS analyses resulted in sumMP concentrations in air of on average 3.04 ng/m^3 in Birkenes and on average 1.53 ng/m^3 at Zeppelin with the exception of one datapoint of 124 ng/m^3 (not included in the calculation of the average) for atmospheric suspended MPs. For precipitation samples, average an average MP concentration of 3276 and 2878 ng/L ere measured in Birkenes and Zeppelin over the period of sampling (n=6 per site and sampling type). While approximately 1000 m^3 of air were sampled per sampling period of 14 days, the precipitation varied between 0.6 and 4.8 l in Birkenes and none and 0.6 l at Zeppelin. Over the overall sampling period of 12 weeks, both dry and wet deposition was collected, with wet deposition consisting of both rain and snow.

A calculation of monthly atmospheric MP concentrations done for both sampling types and sites (Figure 29 and Figure 30). In deposition samples, and variety of plastic polymers could be found on both sites. Polymer patterns also changed between the sampling months, indicating a variety of possible sources. The deposition samples revealed much higher amounts of MPs, due to the

indiscriminately sampling in terms of particle size. In air samples, PVC and PET dominated the pattern at Birkenes with only trace levels of MP detectable at Zeppelin in November and December.

The elevated concentration found in air in October at Zeppelin, is caused by PET and PC, detected during the first 14-day deployment of the sampler, but not in the 2nd 14-day period, indicating an extraordinary event.



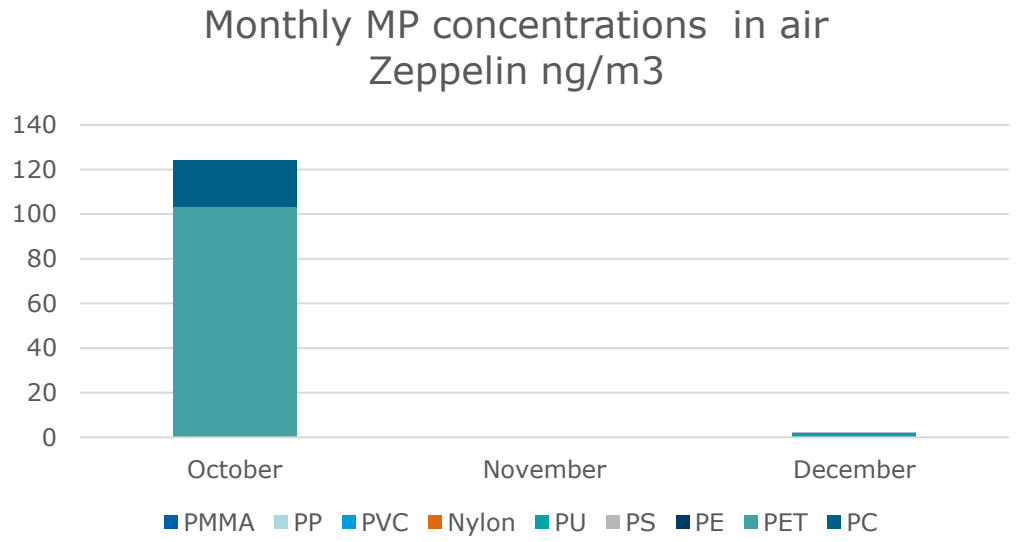


Figure 29. Comparison of MP concentrations in air from Birkenes and Zeppelin on a monthly basis. (December for Zeppelin could not be calculated due to interrupted sampling at the station)

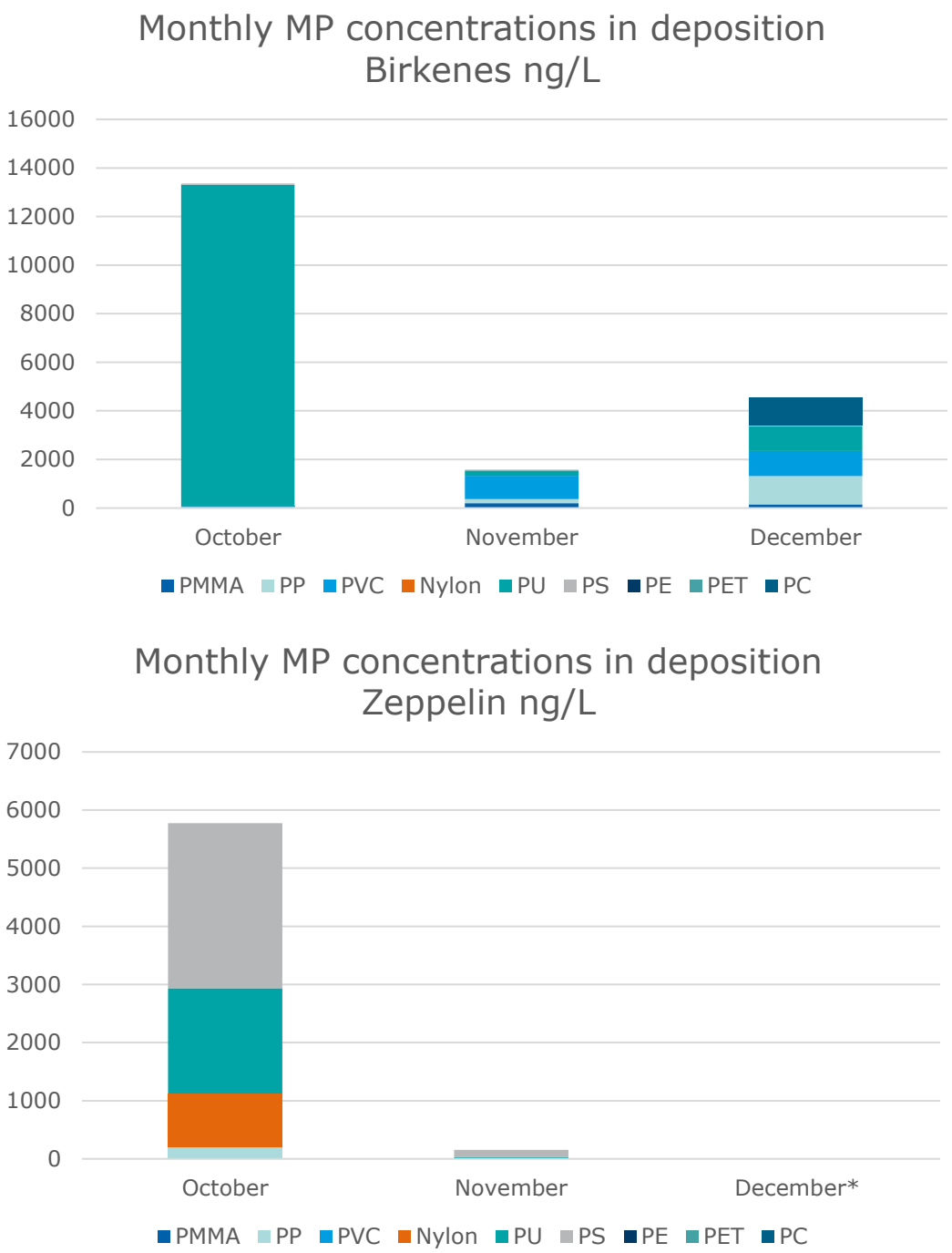


Figure 30. Comparison of MP concentrations in air and deposition from Birkenes and Zeppelin on a monthly basis. (December for Zeppelin could not be calculated due to interrupted sampling at the station)

Table 21. The results from the pyrolysis analysis of the air and deposition samples of 9 selected polymers.

	Station	*Type of sample*	*Sampling period*	*PMMA*	*PP*	*PVC*	*Nylon*	*PU*	*PS*	*PE*	*PET*	*PC*
ng/m^3	Birkenes	Air sample	B_01.10.-14.10.21	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
ng/m^3	Birkenes	Air sample	B_14.10.-29.10.21	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
ng/m^3	Birkenes	Air sample	B_29.10.-12.11.21	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	3.67	3.93
ng/m^3	Birkenes	Air sample	B_12.11.-26.11.21	<LOD	<LOD	2.88	<LOD	<LOD	<LOD	11.4	<LOD	<LOD
ng/m^3	Birkenes	Air sample	B_26.11.-10.12.21	<LOD	<LOD	1.67	<LOD	<LOD	<LOD	9.64	<LOD	<LOD
ng/m^3	Birkenes	Air sample	B_10.12.-24.12.21	<LOD	<LOD	1.63	<LOD	<LOD	<LOD	8.52	<LOD	0.75
ng/L	Birkenes	Deposition	B_01.10.-14.10.21	<LOD	15.3	8.05	39.1	158	33.5	<LOD	<LOD	<LOD
ng/L	Birkenes	Deposition	B_18.10.-29.10.21	<LOD	4.67	15.6	<LOD	13066	13.6	<LOD	<LOD	<LOD
ng/L	Birkenes	Deposition	B_29.10.-12.11.21	<LOD	4.00	<LOD	<LOD	191	<LOD	<LOD	<LOD	<LOD
ng/L	Birkenes	Deposition	B_12.11.-26.11.21	<LOD	452	813	<LOD	<LOD	35.2	<LOD	<LOD	<LOD
ng/L	Birkenes	Deposition	B_26.11.-10.12.21	<LOD	109	770	<LOD	<LOD	38.6	<LOD	<LOD	<LOD
ng/L	Birkenes	Deposition	B_10.12.-24.12.21	<LOD	32.1	2486	<LOD	<LOD	<LOD	<LOD	<LOD	1141
ng/m^3	Zeppelin	Air sample	Z_01.10.-14.10.21	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	103	20.8
ng/m^3	Zeppelin	Air sample	Z_14.10.-29.10.21	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
ng/m^3	Zeppelin	Air sample	Z_29.10.-12.11.21	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
ng/m^3	Zeppelin	Air sample	Z_26.11.-8.12.21	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
ng/m^3	Zeppelin	Air sample	Z_8.12.-16.12.21	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
ng/m^3	Zeppelin	Air sample	Z_16.12.-23.12.21	<LOD	1.30	2.51	<LOD	<LOD	<LOD	<LOD	0.89	<LOD
ng/L	Zeppelin	Deposition	Z_01.10.-14.10.21	<LOD	12.5	7.21	10.3	170	896	<LOD	<LOD	<LOD
ng/L	Zeppelin	Deposition	Z_14.10.-28.10.21	<LOD	191	<LOD	910	1641	1945	<LOD	<LOD	<LOD
ng/L	Zeppelin	Deposition	Z_28.10.-11.11.21	<LOD	<LOD	<LOD	<LOD	14.5	62.7	<LOD	<LOD	<LOD
ng/L	Zeppelin	Deposition	Z_26.11.-16.12.21*									
ng/L	Zeppelin	Deposition	Z_16.12.-23.12.21	352	6347	<LOD	<LOD	<LOD	20.9	<LOD	<LOD	<LOD
ng/L	Zeppelin	Deposition	Z_28.12.-12.01.22	<LOD	1812	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
ng/d	Zeppelin	Deposition	Z_26.11.-16.12.21*	0.025	0.007	<LOD	0.014	0.010	0.021	0.041	<LOD	0.026

6 Discussion

Microplastics result from many different sources, which contributes to a large heterogeneity in terms of polymer composition, type of additives, sizes, colour and shape. In Norway, microplastics have been detected in many different matrices (recently summarized in Lusher et al., 2021); e.g. in mussels and small sediment-dwelling clams (Lusher et al., 2017; Bråte et al., 2018, 2020), in sediments and multi-brush land from the seabed in the North Sea and in the Barents Sea (Arp et al., 2019; Jensen and Bellec, 2018; Knutsen et al., 2019; Møskeland et al., 2018; Bronzo et al., 2021), in urban marine sediments and water (Haave et al., 2019; Nerheim and Lusher, 2020), in sediments and water samples from Lake Mjøsa (Clayer et al., 2021) and in Arctic coastal waters (Lusher et al., 2015; Yakushev et al., 2021; Pakhomova et al., 2022), as well as effluent from wastewater treatment plants (Vogelsang et al., 2020).

6.1 Blue mussels

With the limited number of individuals and stations reported here it is difficult to draw any conclusions from the data. Currently the data shows that there were similar numbers of microplastics in the samples and the blanks. When compared to previous data, few sites also exceeded the LOD and LOQ (Bråte et al., 2020).

These results which may indicate that a modified approach is needed if continuing to use blue mussels as an indicator for microplastic pollution. Two approaches could be considered:

(A) More individuals per site
(B) Processing individuals pooled to ensure the recovery of particles is higher than the procedural blanks

Table 22. Results of similar studies reporting microplastics in Blue mussels. All samples were processed using the same method (10% potassium hydroxide digestion for 24 hours. There was a temperature difference in the earlier studies where 60 °C was used. The present study uses 40 °C. (N.R not reported)

Location	Number of sites	Minimum particle size	FTIR % of items	Average MP/individual (± SD)	Average MP/g w.w (± SD)	Average MP/g d.w (± SD)	Reference
Norwegian coastline	15	70 µm	25%	1.5 (±2.3)	0.97 (±2.61)	n.r.	Bråte et al., 2018
Norwegian coastline	11	34 µm	100%	na	n.r	na	Bråte et al., 2020
Nordic region	32	34 µm	100%	na	n.r	na	Bråte et al., 2020
Norwegian coastline	***7***	50 µm	100%	1.15 (±1.78)	1.14 (±2.17)	7.96 (±14.6)	***This study***

6.2 Microplastics in water samples

6.2.1 MPs in water samples transect Oslofjord and Skagerrak.

The levels of microplastic in the large volume samples for both the 100 - 200 µm and 200 – 500 µm fraction are low and in agreement with published data on large volume sampling using pump systems. For the 100 – 200 µm fraction the levels varied from 0.41 to 1.06 MPs per m^3 with an average of 1.33 MPs per m^3, except for one sample containing a large number of PTFE particles (5.82 MPs per m^3). This agrees with several studies listed in Table 23 in the same size range, but smaller size range and lower sampling volumes seem to result in higher counts of MPs. Also, the results for the larger size fraction (200 µm) are low ranging from no MPs present to 1.94 MP per m^3 with an average of 0.51 MPs per m^3, which again agrees with similar samples using similar sampling methods.

One of the major challenges in the current study/analyses(?) has been the contamination level during sampling and laboratory analysis and all results are (if measured in total number of particles) very close or below the LOD if we calculate the LOD on the blanks values. In addition, it is difficult to take larger sampling volumes resulting in the sampling of more organic and biological material which would need more sample pre-treatment in the laboratory.

Table 23. Studies of subsurface MPs in different regions with different of sampling and analysis

Region	Number of stations	Minimum size, µm	Average filtered volume, m^3	FTIR/Raman, % of items	Average abundance, items/m^3	Reference
Atlantic						
NE Atlantic	470	250	2	0.3	2.46	(Lusher et al., 2014)
NE and NW Atlantic	23	10	2.6	50	13-501	(Enders et al., 2015)
NE and SE Atlantic*	76	250	2	100	1.15	(Kanhai et al., 2017)
Oslo - Kiel	13	100	5.3	100	0.7	**(van Bavel et al., 2020)**
Arctic						
North Pole/Central Basin	13	63	0.07	25	44.3	(Ross et al., 2021)
	57	250	2	100	0.7	(Kanhai et al., 2018)
Eurasian Arctic	60	100	3.3	100	0.8	(Yakushev et al., 2021)
Canadian Arctic	34	63	0.07	33	21.1	(Ross et al., 2021)
North Atlantic/Fram	24	63	0.07	50	65.1	(Ross et al., 2021)
Fram strait	5	32	0.26	5-100	113-1287	(Tekman et al., 2020)
Greenland/Barents Sea*	75	250	2	1	2.68	(Lusher et al., 2015)
Greenland Sea**	7	80	1	100	2.4	(Morgana et al., 2018)

*included rayon

**without fibres, fragments only

6.2.2 High volume pump water samples

The levels of MPs for the 200 – 1000 µm samples were relatively low (1.3 – 4.3 MPs per m^3) but significantly higher for the 50 - 1000 µm size samples (5.7 – 16.7 MPs per m^3). This is relatively low or in line with similar samples. However, the field blanks taken by the sampling teams at the same locations showed similar levels of MPs as the large volume samples for the > 200 µm samples, for the smaller fraction >50 µm the number of MPs in the field blanks are even more than double the numbers found in the samples.

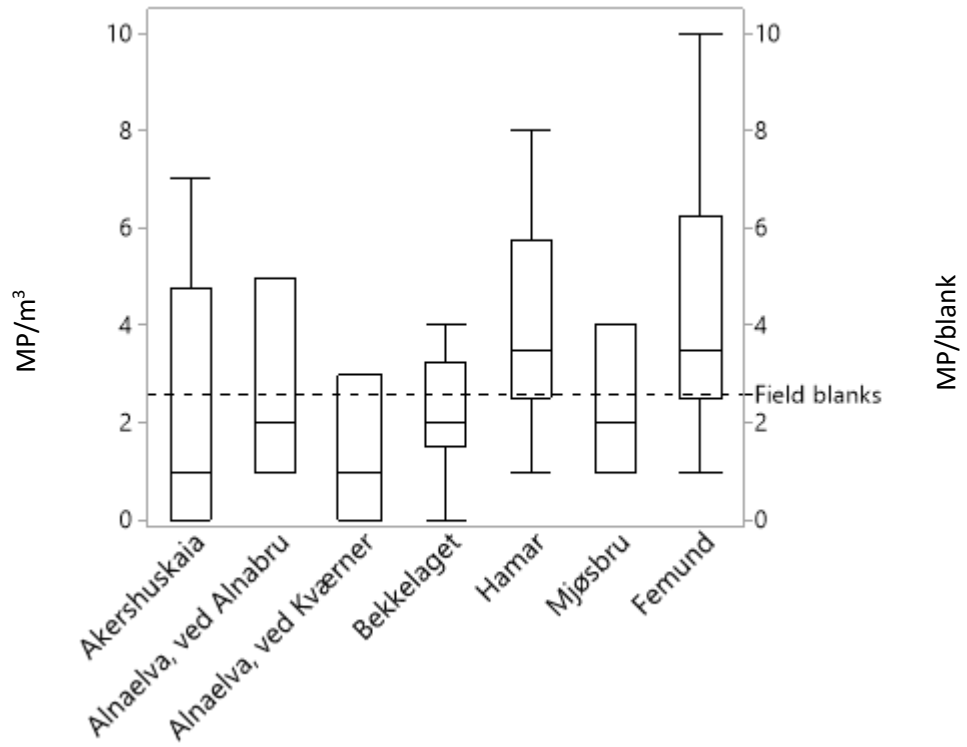


Figure 31. Levels of MPs in the high-volume samples > 200 µm at 7 locations and the average level found in the field blanks taken at the different sites (dashed line).

One of the reasons of the high field blanks samples are the challenges to get a representative field blanks according to the protocols and instruction on site, and a number of field blanks might have been compromised and contaminated on site. Another reason might be methodological, the large volume samples were automatically scanned using uFTIR and the data was subsequently analysed using the siMPle software. This is outlined in Figure 32 for a large volume sample where the sample is displayed (A) showing the difficulties to detect microplastics in a real sample, the matching of the trans reflectance spectra (B and D) and finally the identification (C). In this case polyamide particles, which can be seen as small white fragment in illustration C. The blanks samples contain often less interferences resulting in more positive identifications (Figure 19).

In conclusion, it is only possible to report that the levels of MPs in the large volume for the 200µm samples are below < 4.3 MPs per m^3 and for the 50 µm fraction are below < 16.7 MPs per sample.

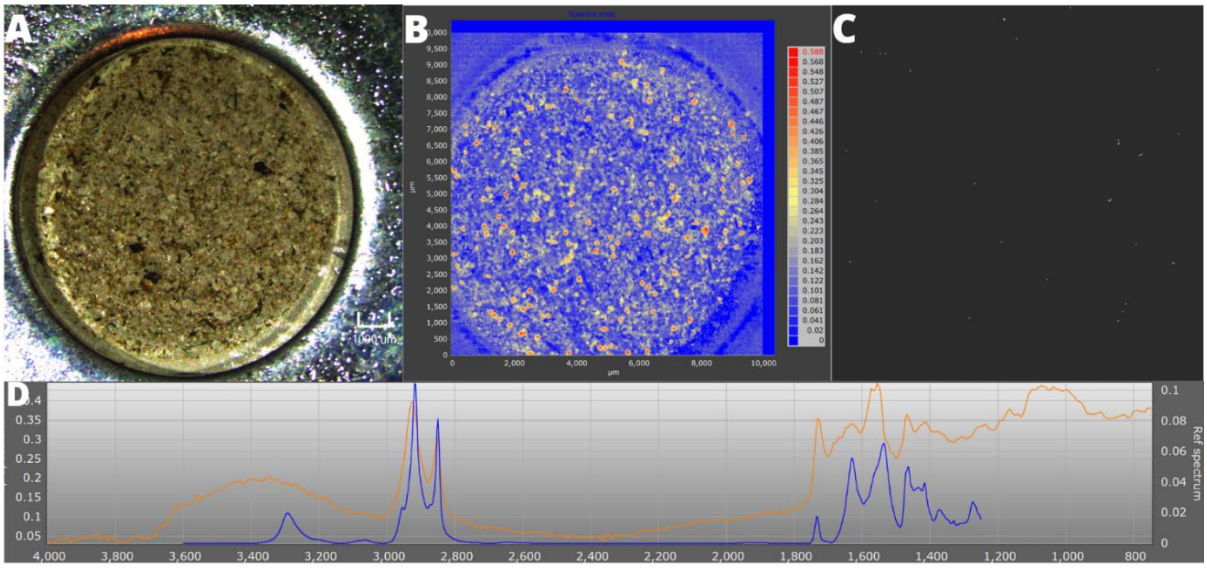


Figure 32. Illustration of the workflow of the siMPle software for automatic identification. The sample is collected on a silver membrane filter (A), a heat map is generated by the software (B) and a final image generated after threshold value correction (C). transmittance spectra area produced showing the reference (blue) and sample (orange). In this example a polyamide fragments > 50 µm are identified.

6.2.3 Plankton net samples

Microplastics were identified at all 10 stations using a vertical plankton net. The mean number of particles per station ranged from 0.26 to 3.14 /m^3, with an overall average of 1.54 (**Error! Reference source not found.**). There wasn't a significant difference between the sites. About 70% of the station averages were above the LOD (0.97) in the procedural blanks, but none exceeded the LOQ (3.23). The majority of the particles were fibres, which dominated at all sites with the exception of Færder, in the outer Osloford (Figure 28). The polymer composition varied between stations, with polyester and polypropylene found in all but one station (Figure 28). These low levels of MPs are in agreement the limited data in the literature.

6.3 Air samples

6.3.1 Microplastic level in active air and precipitation samples.

No literature data are available for MP in atmospheric samples analysed with pyrGC/MS, hampering comparison with other sites. As an alternative, the evaluation of back trajectories of airmasses within the periods of air sampling allows for an estimation of the source regions of atmospheric MPs. Figure 33 shows back trajectories for Birkenes and Zeppelin for the months October, November and December in 2021.

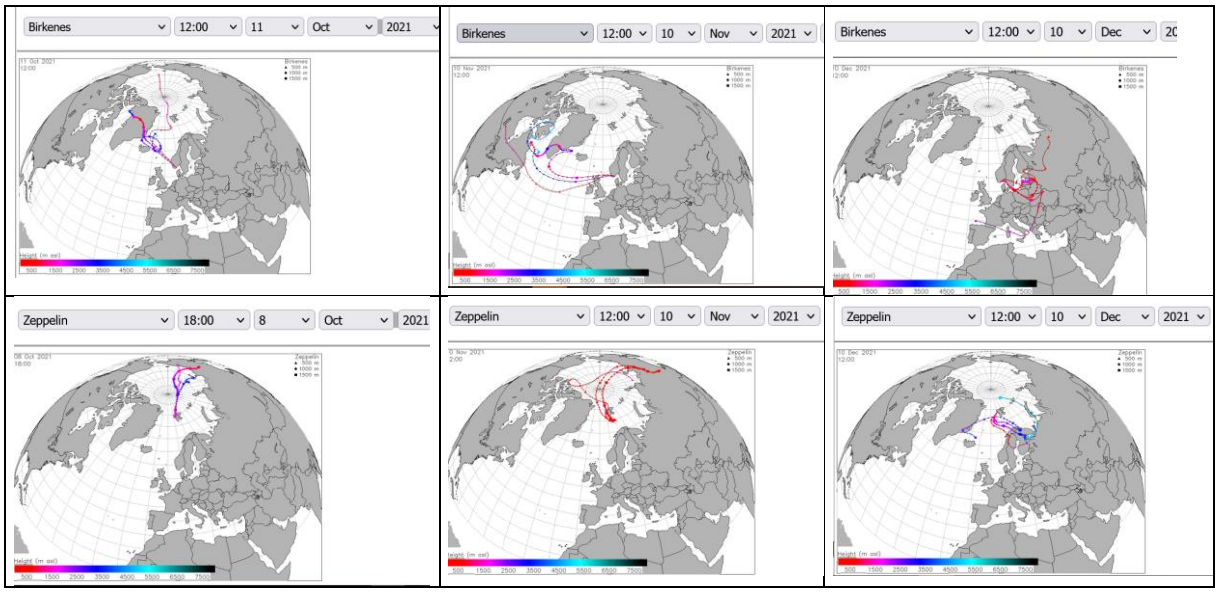


Figure 33. Back trajectories for Zeppelin and Birkenes, fall 2021.

As Figure 33 shows, were airmasses origin mostly from remote regions for both Birkenes and Zeppelin over the sampling period in October and November. In December however, airmasses from central Europe (Birkenes) and North Scandinavia reached the sampling stations.

However, during the days early in October, the airmasses reaching Zeppelin originated Central Europe as well, possibly explaining the higher MP concentrations found in October (Figure 34).

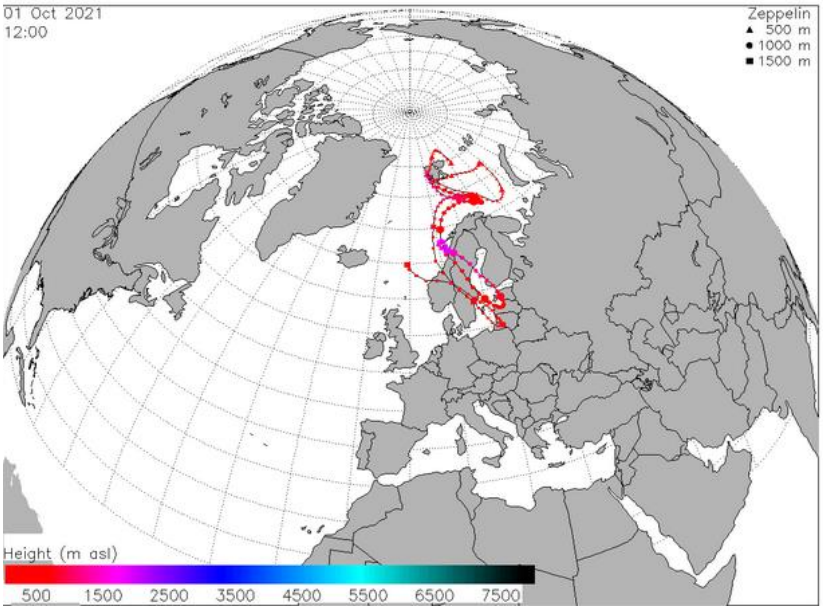


Figure 34. Back trajectories for Zeppelin the 1st of October.

Likewise, for Birkenes, episodes of airmasses transported passing over mainland Europe were observed, potentially causing elevated levels in the samples. To better determine episodes with elevated MP transport and improved source elucidation the temporal resolution would need to be improved. Shorter sampling times would be required, which again would impact the detection rate of MP in samples from remote regions due to the subsequent sampling of lower air volumes. Sampling from urban locations are recommended to evaluate local sources of MP to the air as well as human exposure.

In addition to the MP analysed in the samples UV compound were analysed in the samples. Of the five UV compounds analysed, UV-326 and UV-328 were the most dominant, and they were mainly found in the active air samples. The concentrations of UV substances found in this study are comparable to PFAS measured in air at the same stations in 2020. It is uncertain whether these substances originate from microplastics or whether they have been transported with other particles. Although MP has been observed in air and precipitation in the past, no suitable data are available in the literature for comparison, but a number of relevant research projects are under way, which will soon result in scientific publications. It is recommended to continue the sampling campaign to deepen our understanding of the scope and variations of microplastic transport, and associated chemicals, to the Arctic and other remote locations.

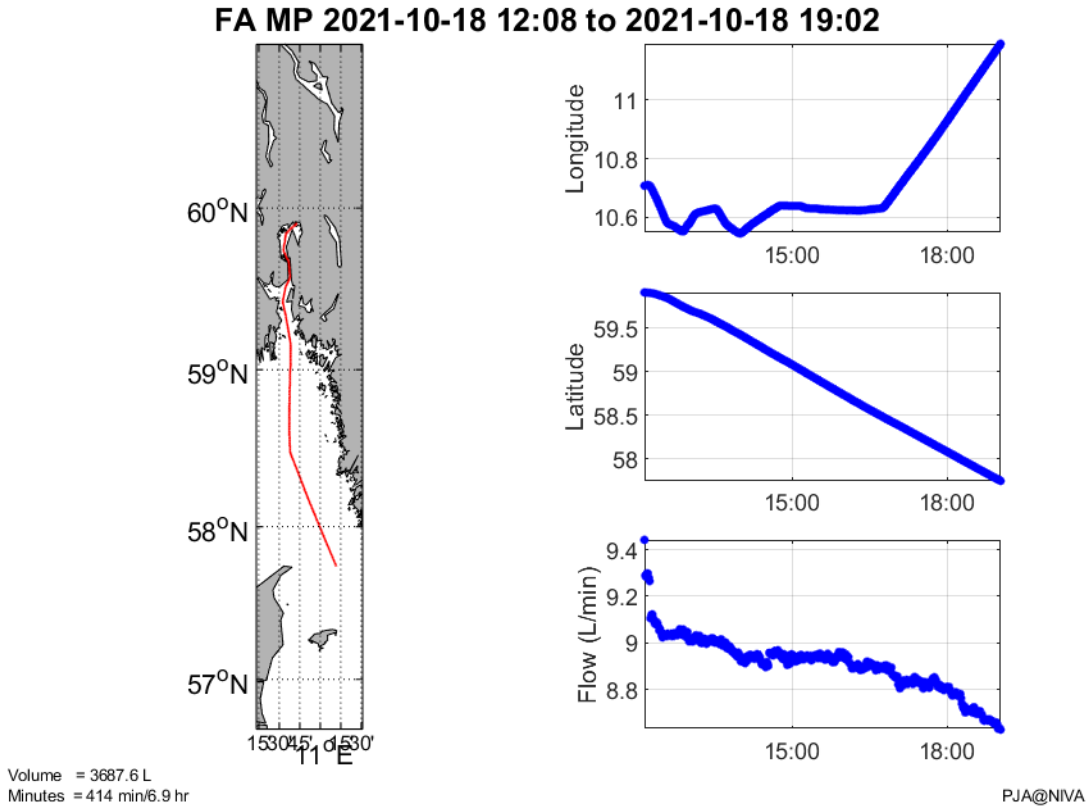
7 Appendix

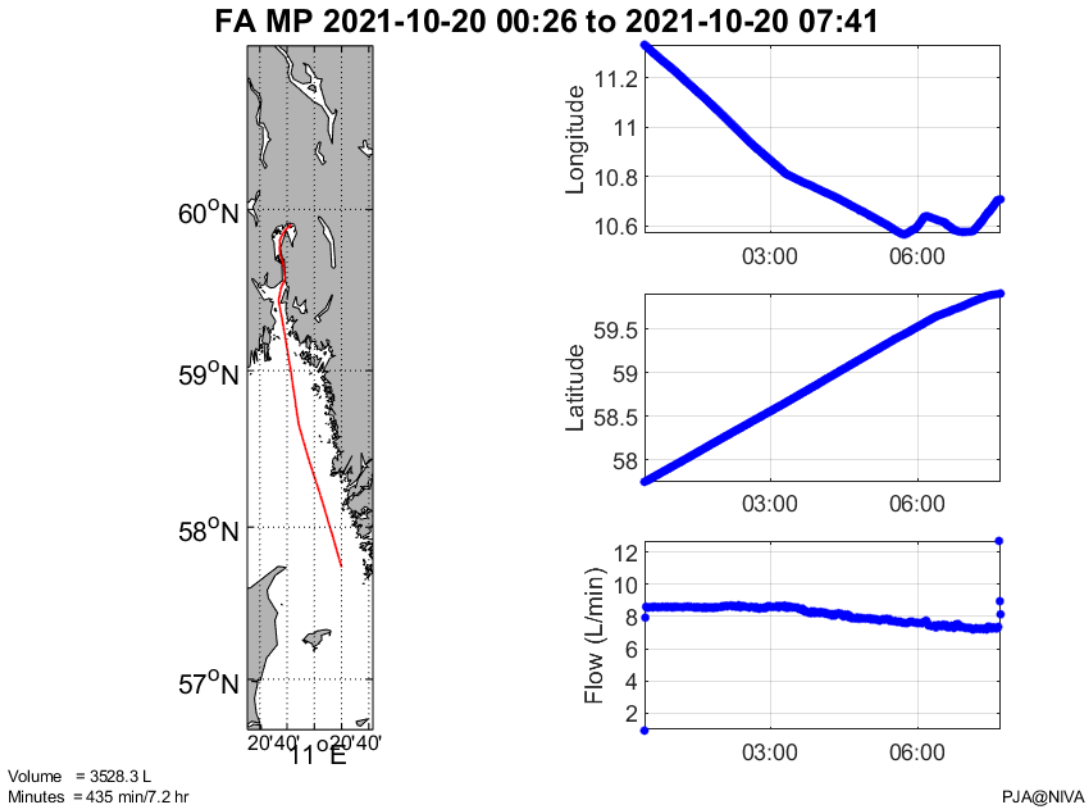
7.1 Results appendix

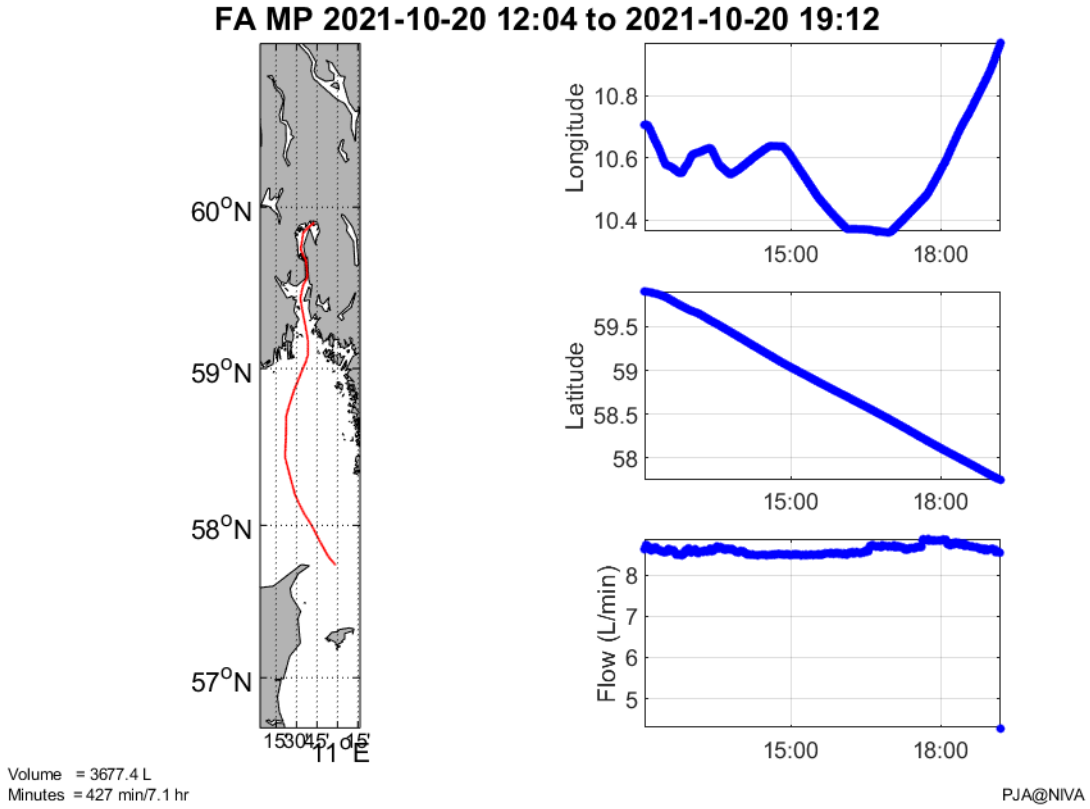
7.1.1 Water samples

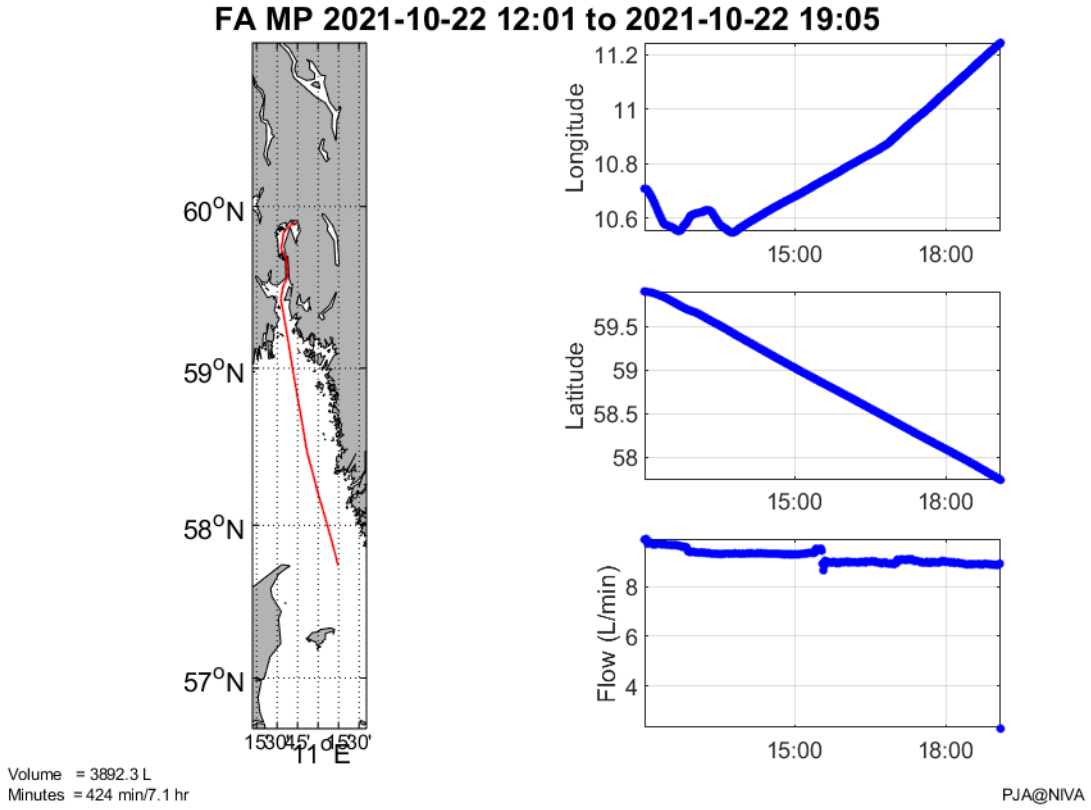
Link to excel or NIVAs database

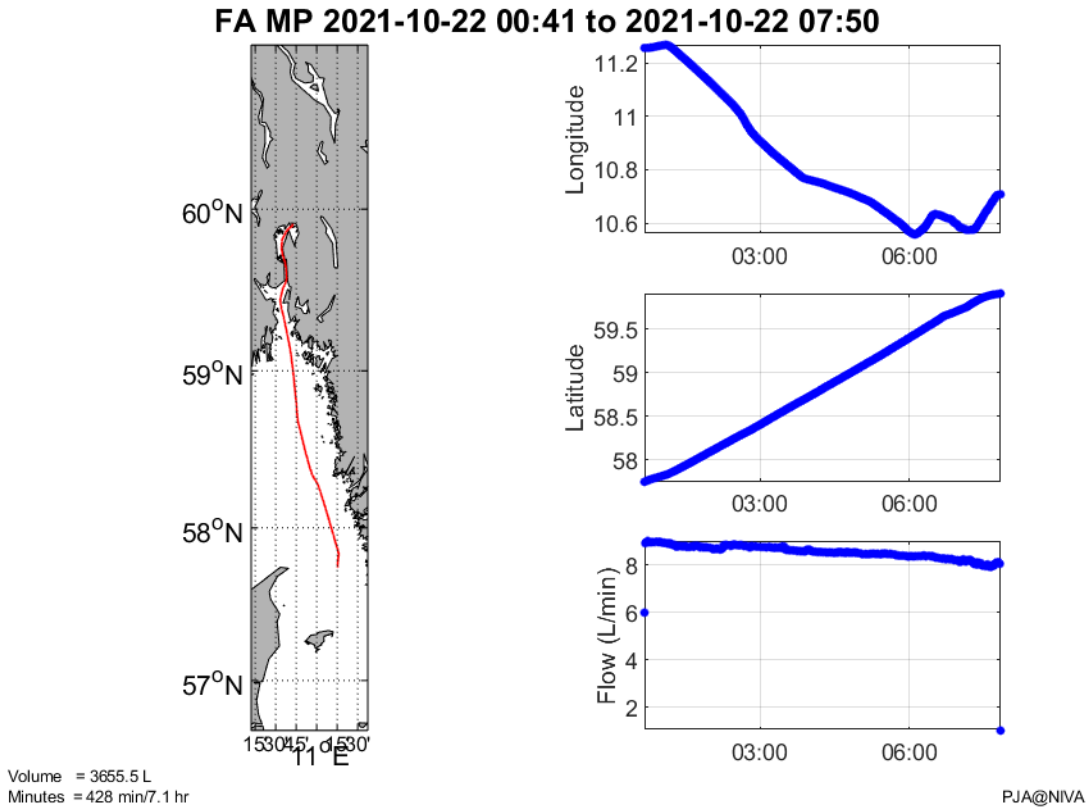
7.1.1.1 Ferrybox

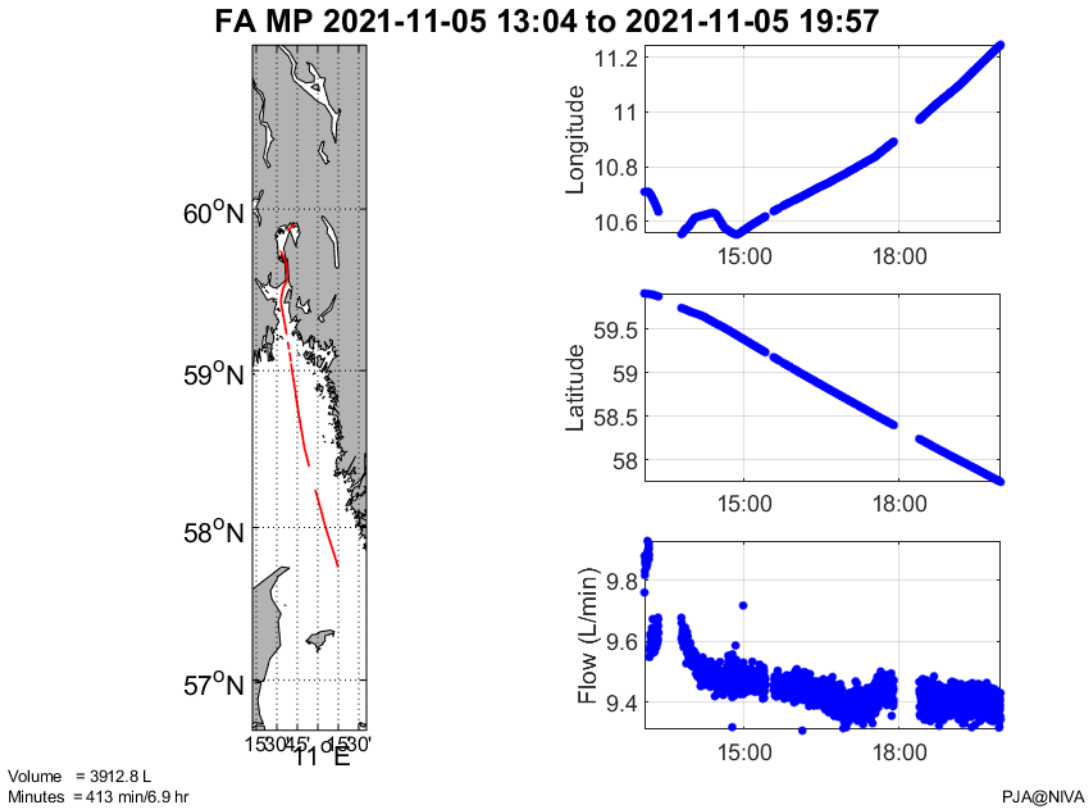


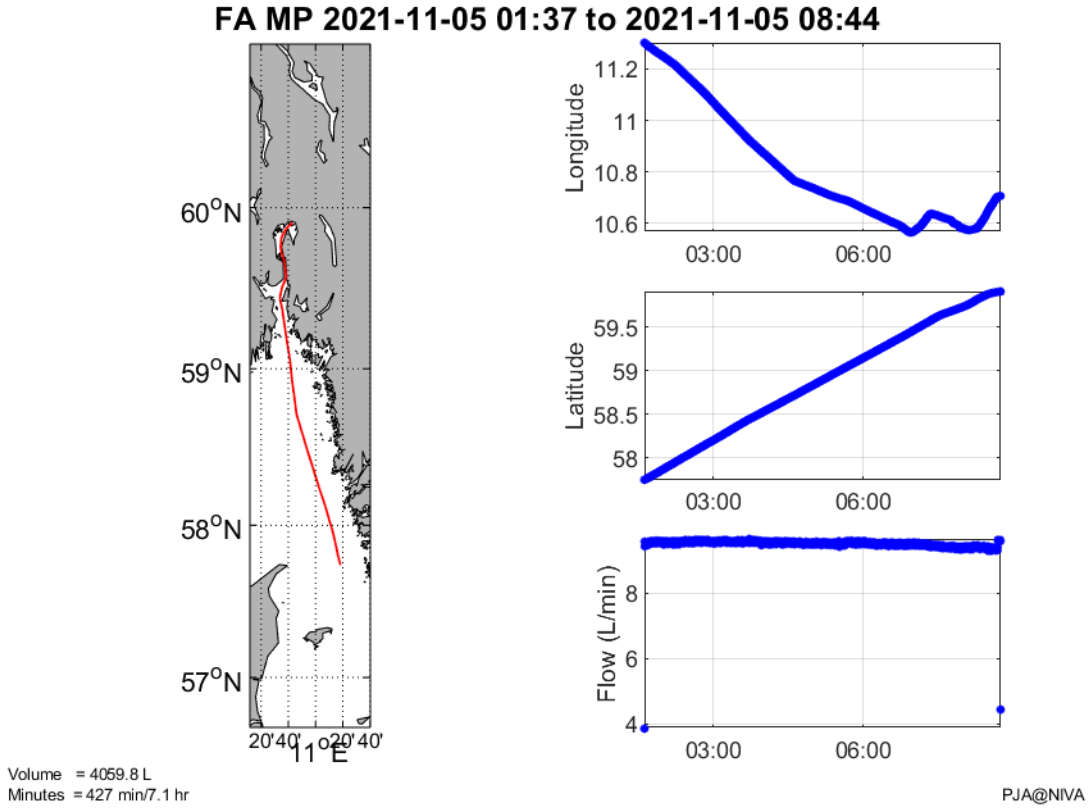

FA MP 2021-10-20 00:26 to 2021-10-20 07:41
60°N
59°N
58°N
57°N
20'40'
11°E
20'40'
Longitude
11.2
11
10.8
10.6
03:00
06:00
Latitude
59.5
59
58.5
58
03:00
06:00
Flow (L/min)
12
10
8
6
4
2
03:00
06:00
Volume = 3528.3 L
Minutes = 435 min/7.2 hr
PJA@NIVA

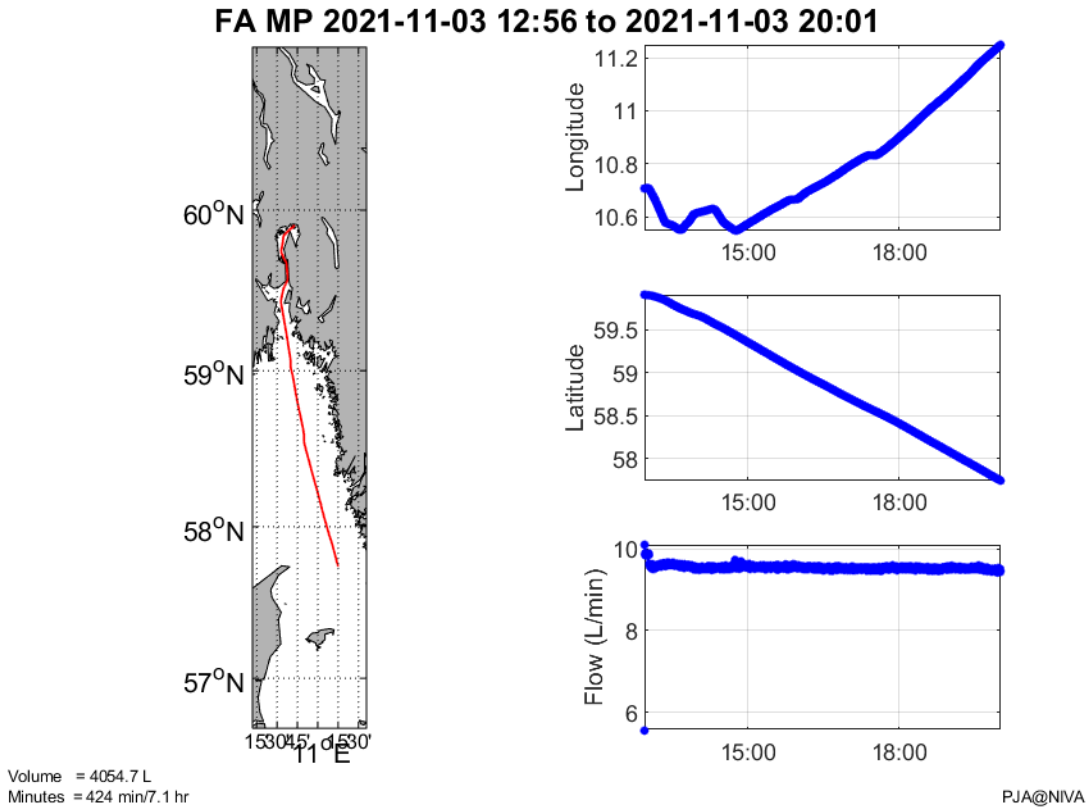

FA MP 2021-10-20 12:04 to 2021-10-20 19:12
60°N
59°N
58°N
57°N
15'30'45'
11°E
Longitude
10.8
10.6
10.4
15:00
18:00
Latitude
59.5
59
58.5
58
15:00
18:00
Flow (L/min)
8
7
6
5
15:00
18:00
Volume = 3677.4 L
Minutes = 427 min/7.1 hr
PJA@NIVA

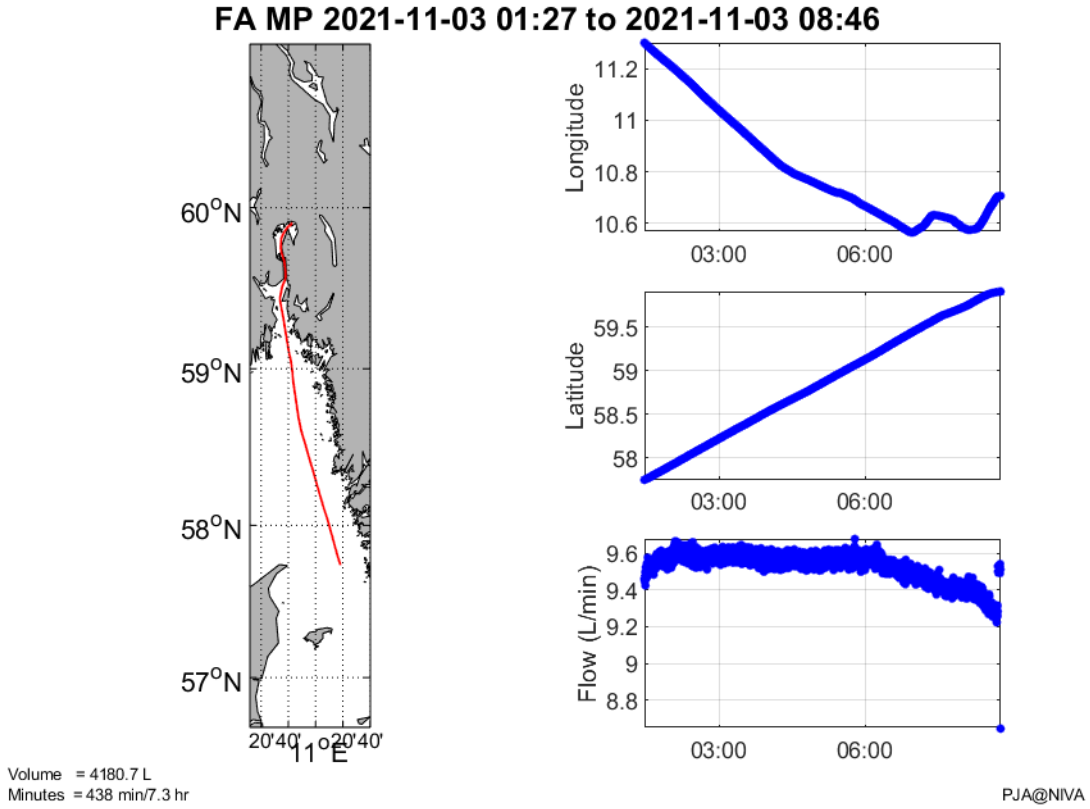

FA MP 2021-10-22 12:01 to 2021-10-22 19:05
60°N
59°N
58°N
57°N
15 30 45' 0 15 30'
11 E
Longitude
11.2
11
10.8
10.6
15:00
18:00
Latitude
59.5
59
58.5
58
15:00
18:00
Flow (L/min)
8
6
4
15:00
18:00
Volume = 3892.3 L
Minutes = 424 min/7.1 hr
PJA@NIVA

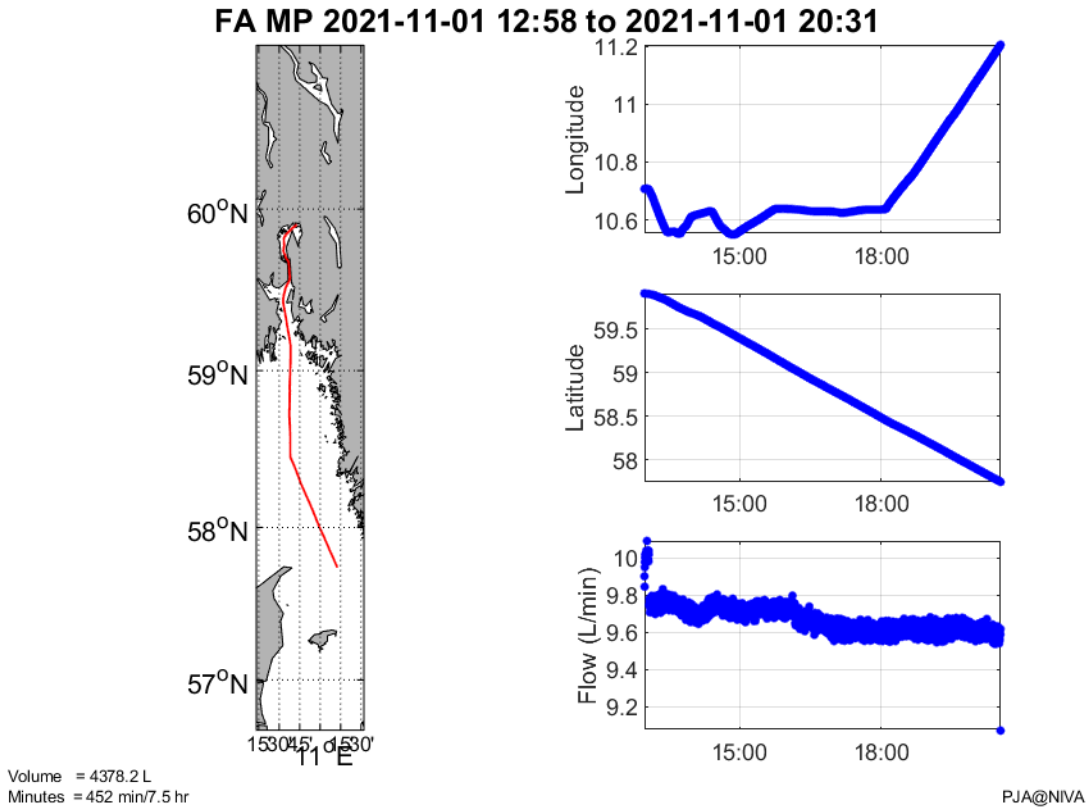

FA MP 2021-10-22 00:41 to 2021-10-22 07:50
60°N
59°N
58°N
57°N
15 30 45' 0 15 30'
11 E
Longitude
11.2
11
10.8
10.6
03:00
06:00
Latitude
59.5
59
58.5
58
03:00
06:00
Flow (L/min)
8
6
4
2
03:00
06:00
Volume = 3655.5 L
Minutes = 428 min/7.1 hr
PJA@NIVA

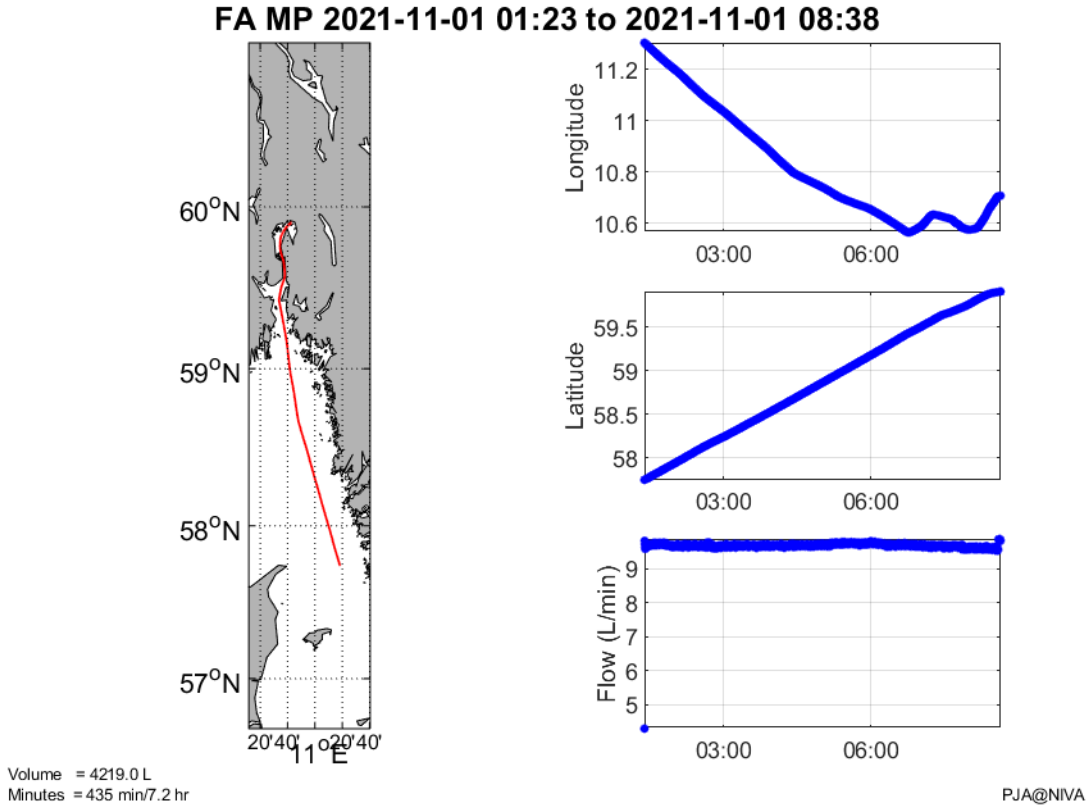

FA MP 2021-11-05 13:04 to 2021-11-05 19:57
60°N
59°N
58°N
57°N
15'30'45'
11°E
Longitude
11.2
11
10.8
10.6
15:00
18:00
Latitude
59.5
59
58.5
58
Flow (L/min)
9.8
9.6
9.4
Volume = 3912.8 L
Minutes = 413 min/6.9 hr
PJA@NIVA

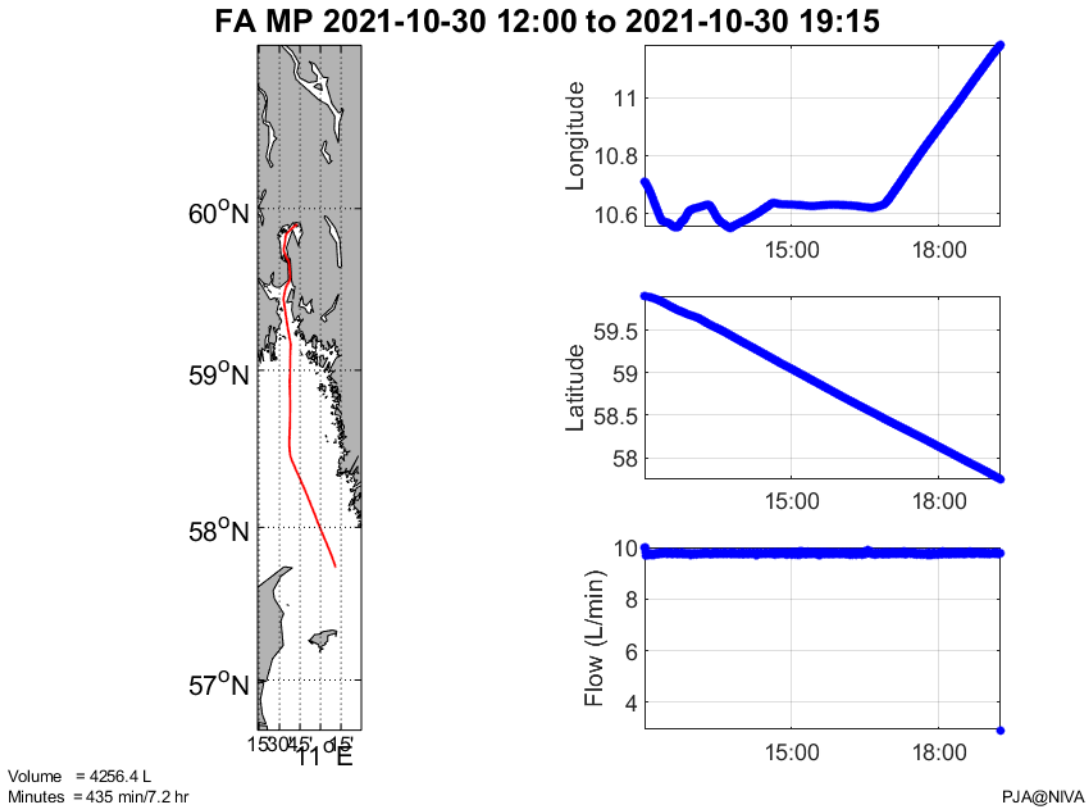

FA MP 2021-11-05 01:37 to 2021-11-05 08:44
60°N
59°N
58°N
57°N
20'40'
11°E
20'40'
Longitude
11.2
11
10.8
10.6
03:00
06:00
Latitude
59.5
59
58.5
58
Flow (L/min)
8
6
4
Volume = 4059.8 L
Minutes = 427 min/7.1 hr
PJA@NIVA

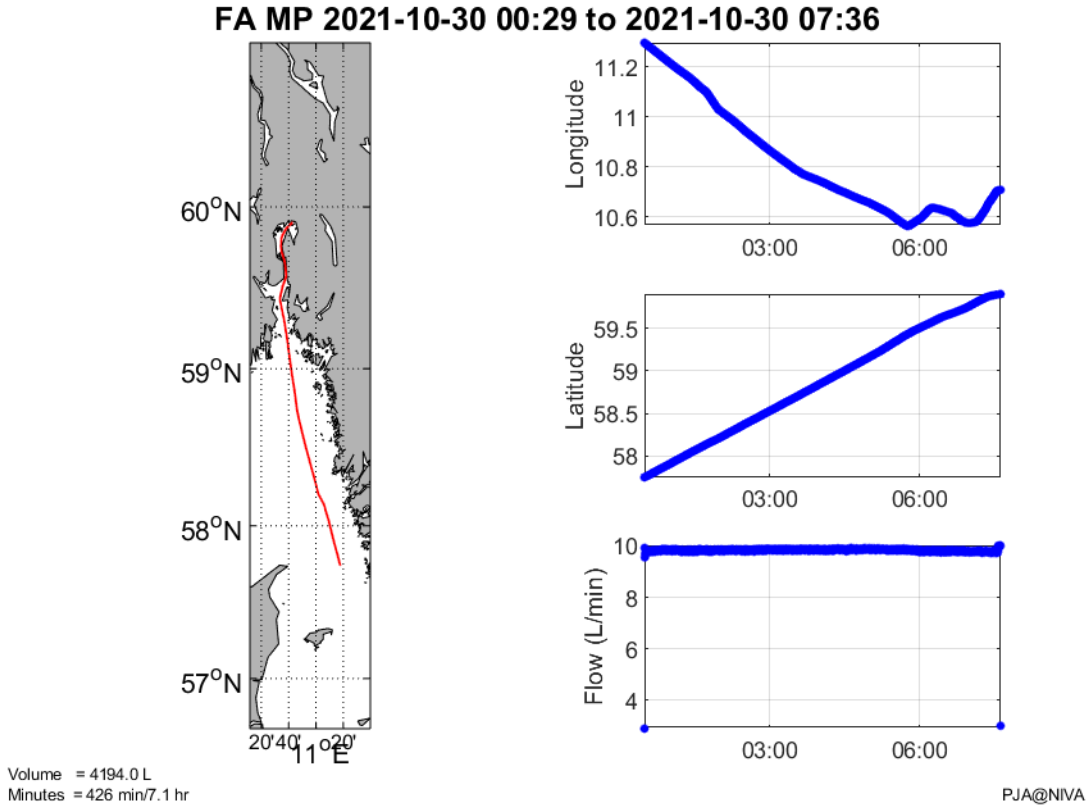

FA MP 2021-11-03 12:56 to 2021-11-03 20:01
60°N
59°N
58°N
57°N
15'30'45'
11°E
Longitude
Latitude
Flow (L/min)
15:00
18:00
Volume = 4054.7 L
Minutes = 424 min/7.1 hr
PJA@NIVA

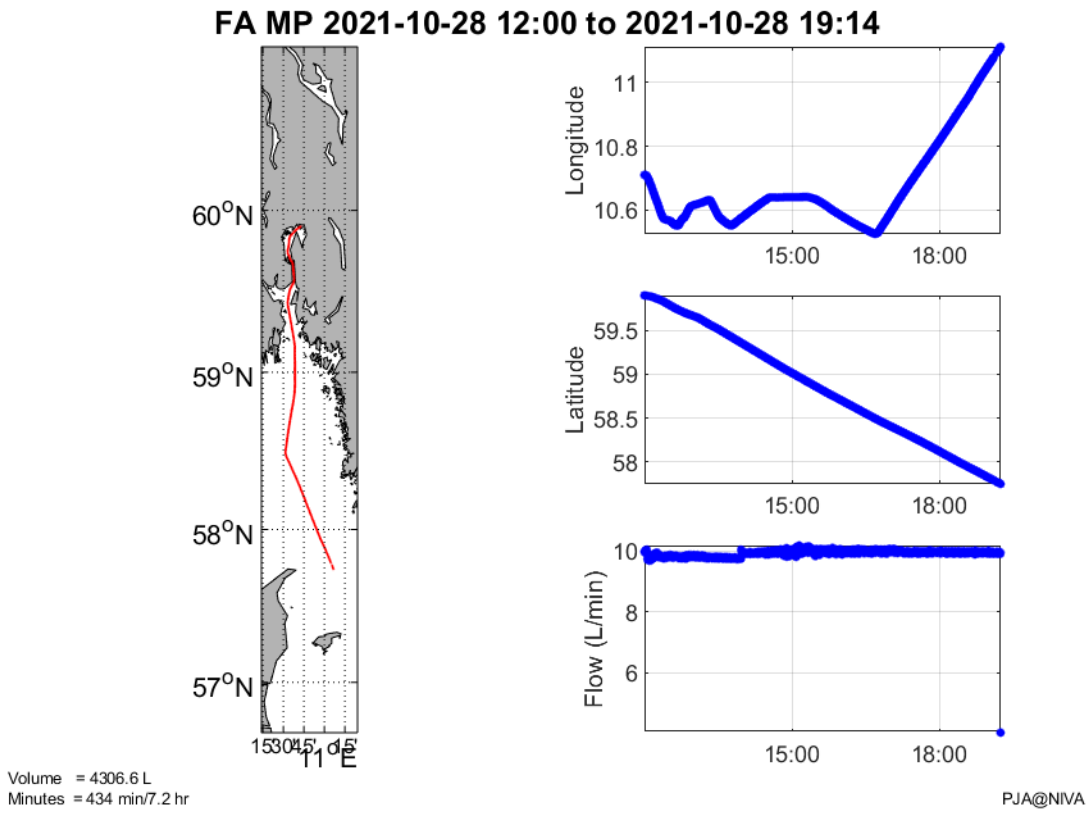

FA MP 2021-11-03 01:27 to 2021-11-03 08:46
60°N
59°N
58°N
57°N
20'40'
11°E
Longitude
Latitude
Flow (L/min)
03:00
06:00
Volume = 4180.7 L
Minutes = 438 min/7.3 hr
PJA@NIVA

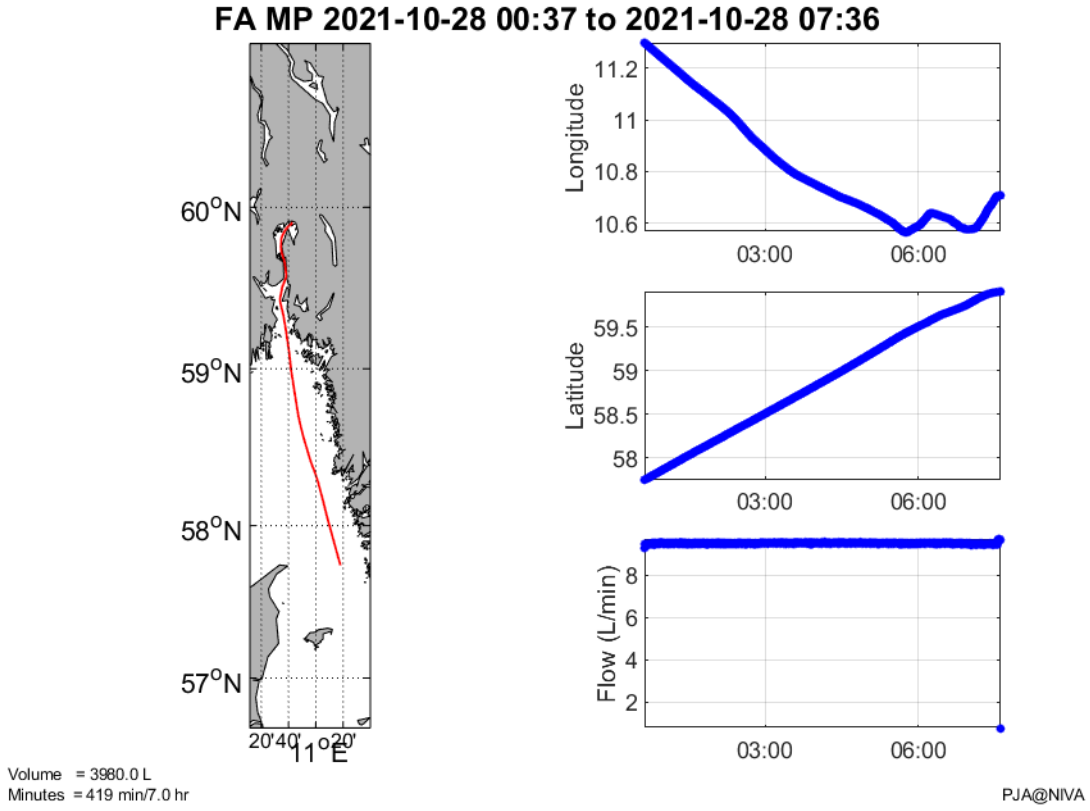

FA MP 2021-11-01 12:58 to 2021-11-01 20:31
60°N
59°N
58°N
57°N
15'30'45'
11°E
Longitude
Latitude
Flow (L/min)
15:00
18:00
Volume = 4378.2 L
Minutes = 452 min/7.5 hr
PJA@NIVA

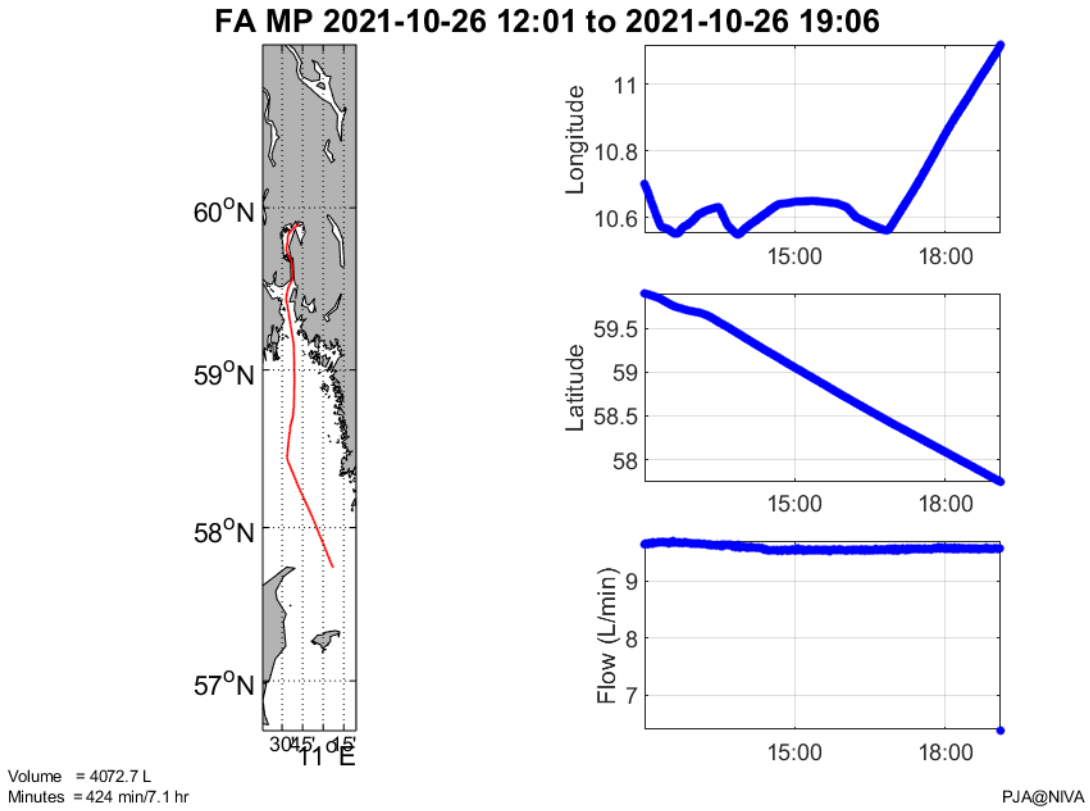

FA MP 2021-11-01 01:23 to 2021-11-01 08:38
60°N
59°N
58°N
57°N
20'40'
11°E
20'40'
Longitude
Latitude
Flow (L/min)
03:00
06:00
Volume = 4219.0 L
Minutes = 435 min/7.2 hr
PJA@NIVA

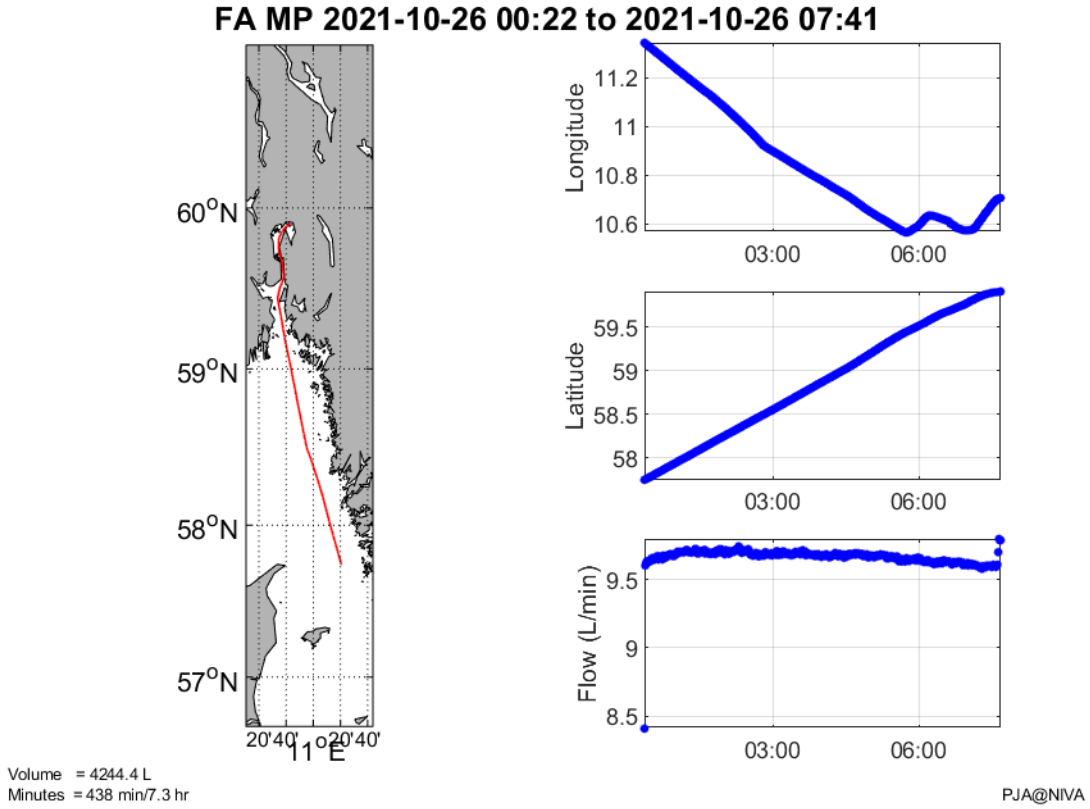

FA MP 2021-10-30 12:00 to 2021-10-30 19:15
60°N
59°N
58°N
57°N
15'
30'
45'
0'
15'
11°E
Longitude
11
10.8
10.6
15:00
18:00
Latitude
59.5
59
58.5
58
15:00
18:00
Flow (L/min)
10
8
6
4
15:00
18:00
Volume = 4256.4 L
Minutes = 435 min/7.2 hr
PJA@NIVA

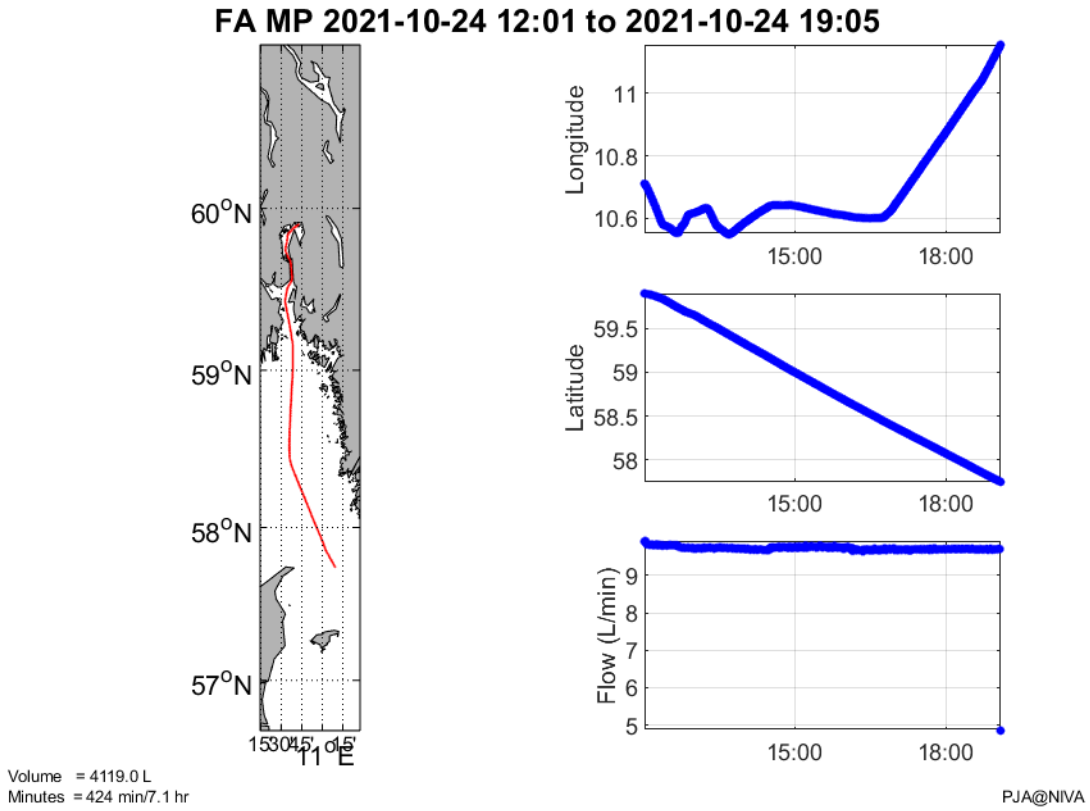

FA MP 2021-10-30 00:29 to 2021-10-30 07:36
60°N
59°N
58°N
57°N
20'
40'
20'
11°E
Longitude
11.2
11
10.8
10.6
03:00
06:00
Latitude
59.5
59
58.5
58
03:00
06:00
Flow (L/min)
10
8
6
4
03:00
06:00
Volume = 4194.0 L
Minutes = 426 min/7.1 hr
PJA@NIVA

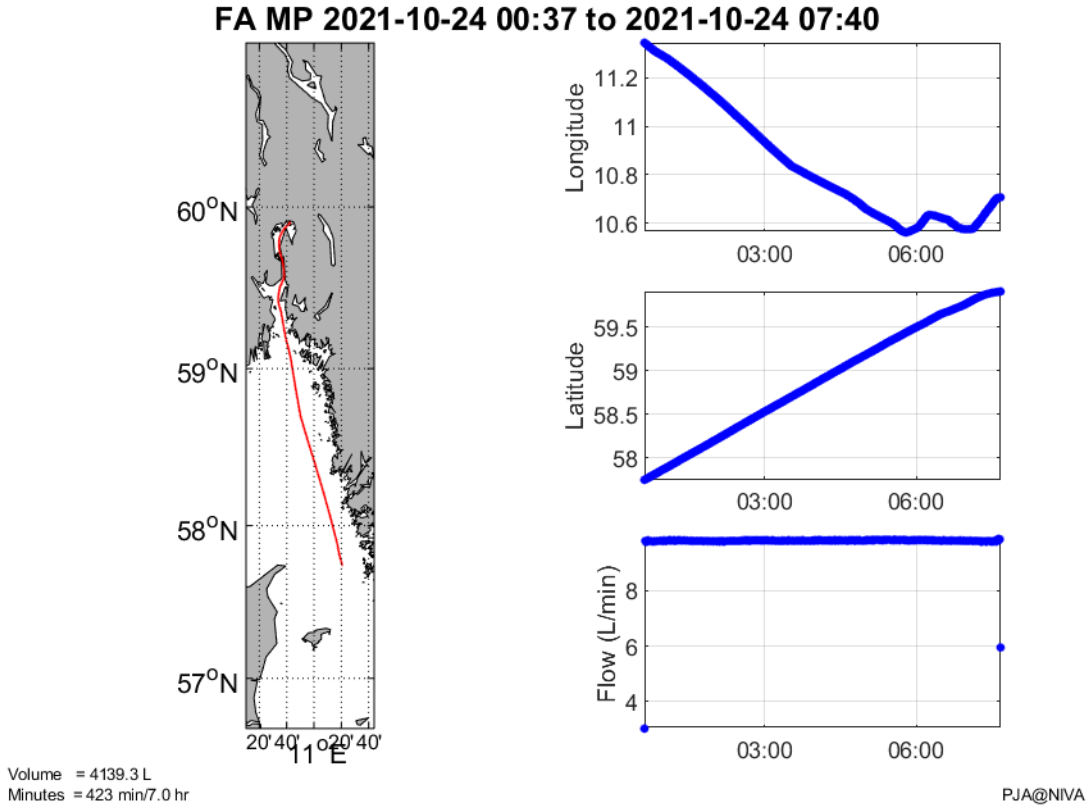

FA MP 2021-10-28 12:00 to 2021-10-28 19:14
60°N
59°N
58°N
57°N
15'
30'
45'
0'
15'
11°E
Longitude
11
10.8
10.6
15:00
18:00
Latitude
59.5
59
58.5
58
15:00
18:00
Flow (L/min)
10
8
6
15:00
18:00
Volume = 4306.6 L
Minutes = 434 min/7.2 hr
PJA@NIVA

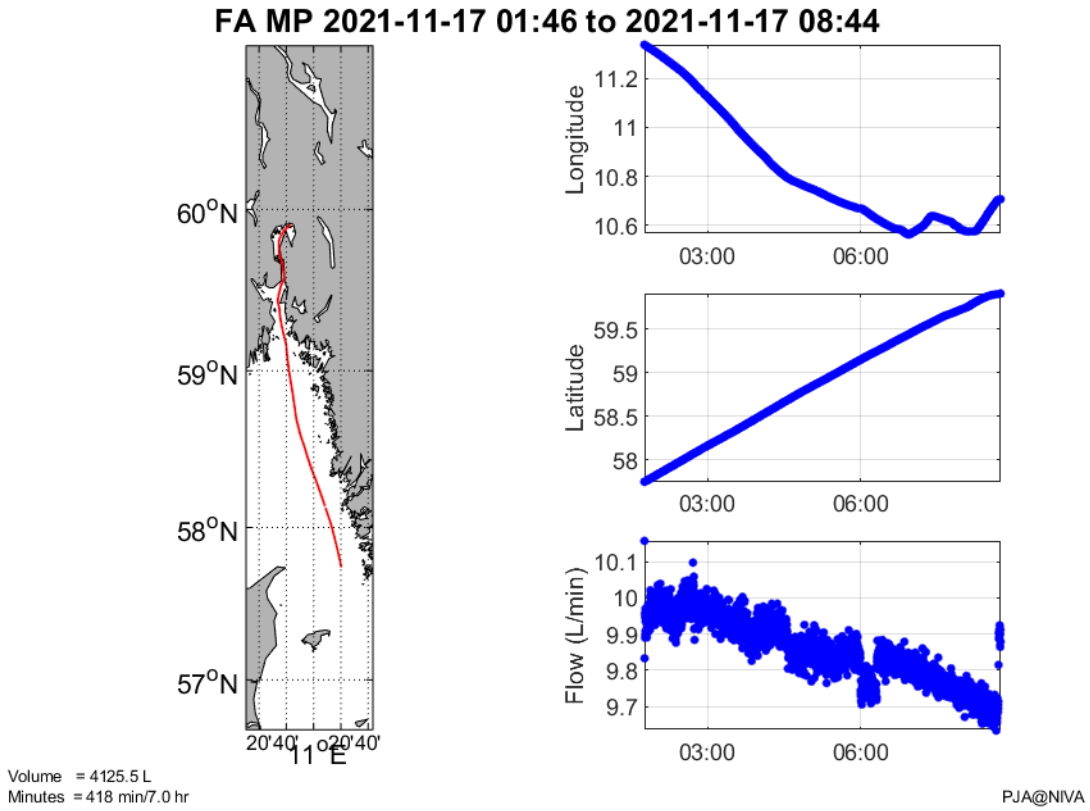

FA MP 2021-10-28 00:37 to 2021-10-28 07:36
60°N
59°N
58°N
57°N
20'
40'
20'
11°E
Longitude
11.2
11
10.8
10.6
03:00
06:00
Latitude
59.5
59
58.5
58
03:00
06:00
Flow (L/min)
8
6
4
2
03:00
06:00
Volume = 3980.0 L
Minutes = 419 min/7.0 hr
PJA@NIVA

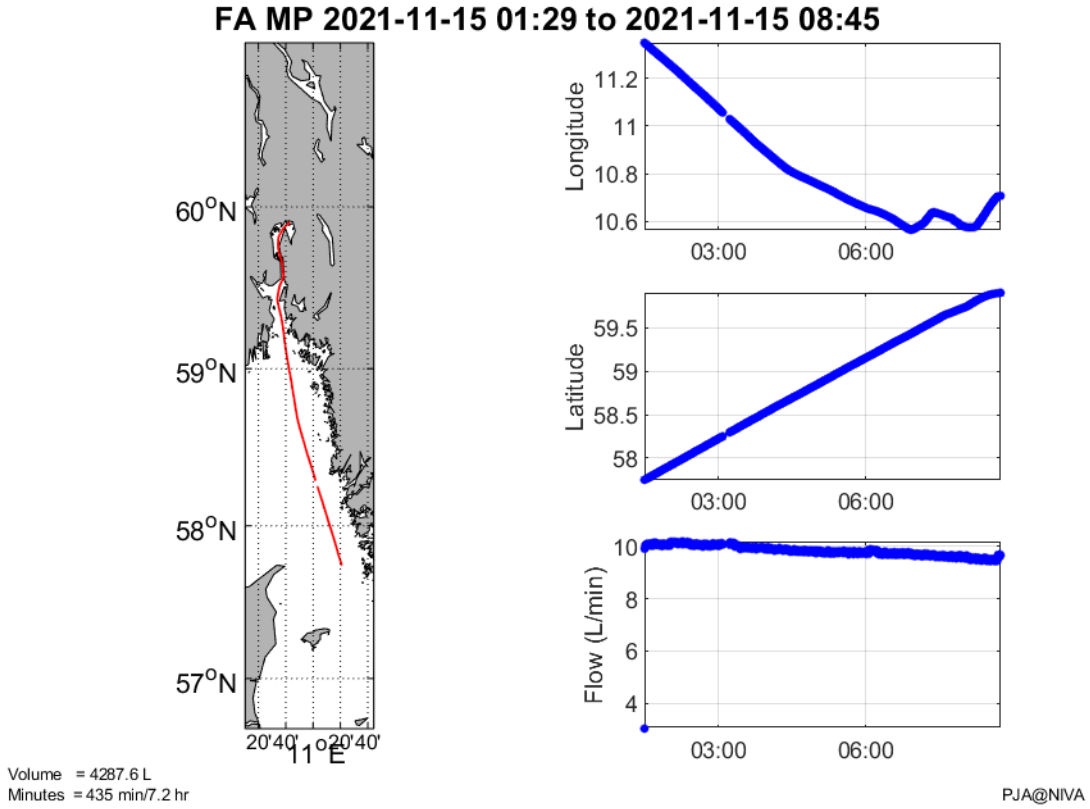

FA MP 2021-10-26 12:01 to 2021-10-26 19:06
60°N
59°N
58°N
57°N
30'
45'
0'
15°E
Longitude
11
10.8
10.6
15:00
18:00
Latitude
59.5
59
58.5
58
15:00
18:00
Flow (L/min)
9
8
7
15:00
18:00
Volume = 4072.7 L
Minutes = 424 min/7.1 hr
PJA@NIVA

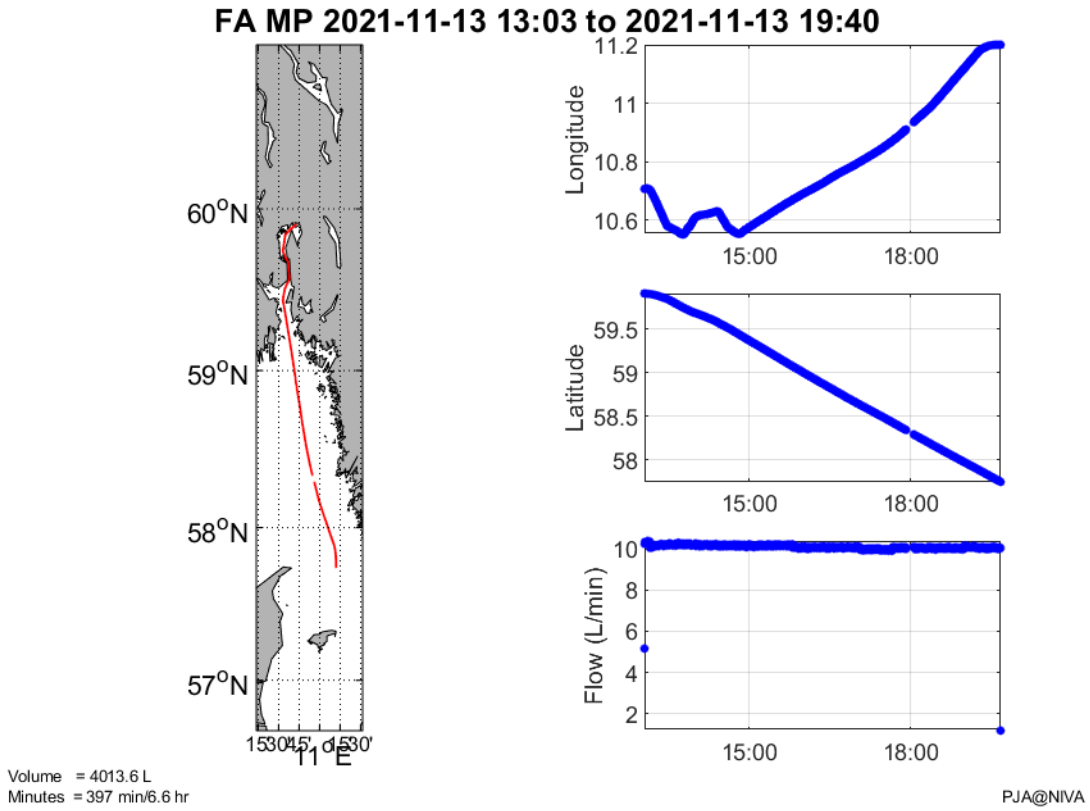

FA MP 2021-10-26 00:22 to 2021-10-26 07:41
60°N
59°N
58°N
57°N
20'40'
20'40'
11°E
Longitude
11.2
11
10.8
10.6
03:00
06:00
Latitude
59.5
59
58.5
58
03:00
06:00
Flow (L/min)
9.5
9
8.5
03:00
06:00
Volume = 4244.4 L
Minutes = 438 min/7.3 hr
PJA@NIVA

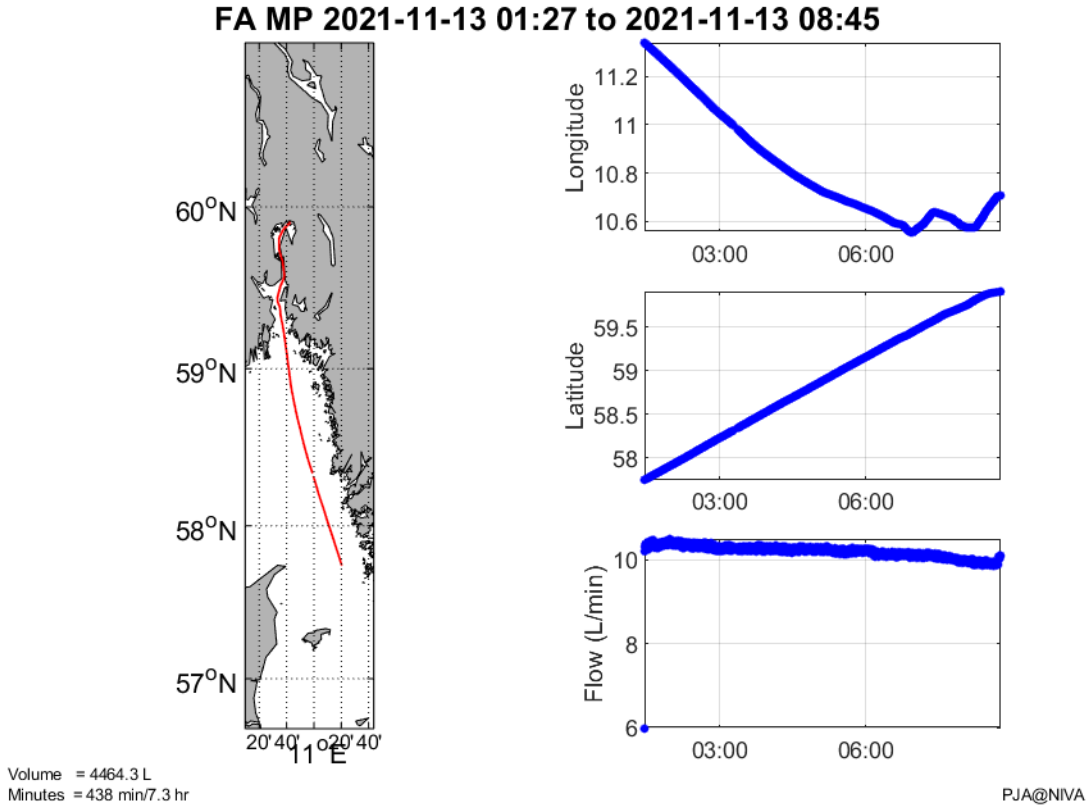

FA MP 2021-10-24 12:01 to 2021-10-24 19:05
60°N
59°N
58°N
57°N
15'
30'
45'
0
15'
11° E
Longitude
11
10.8
10.6
15:00
18:00
Latitude
59.5
59
58.5
58
15:00
18:00
Flow (L/min)
9
8
7
6
5
15:00
18:00
Volume = 4119.0 L
Minutes = 424 min/7.1 hr
PJA@NIVA

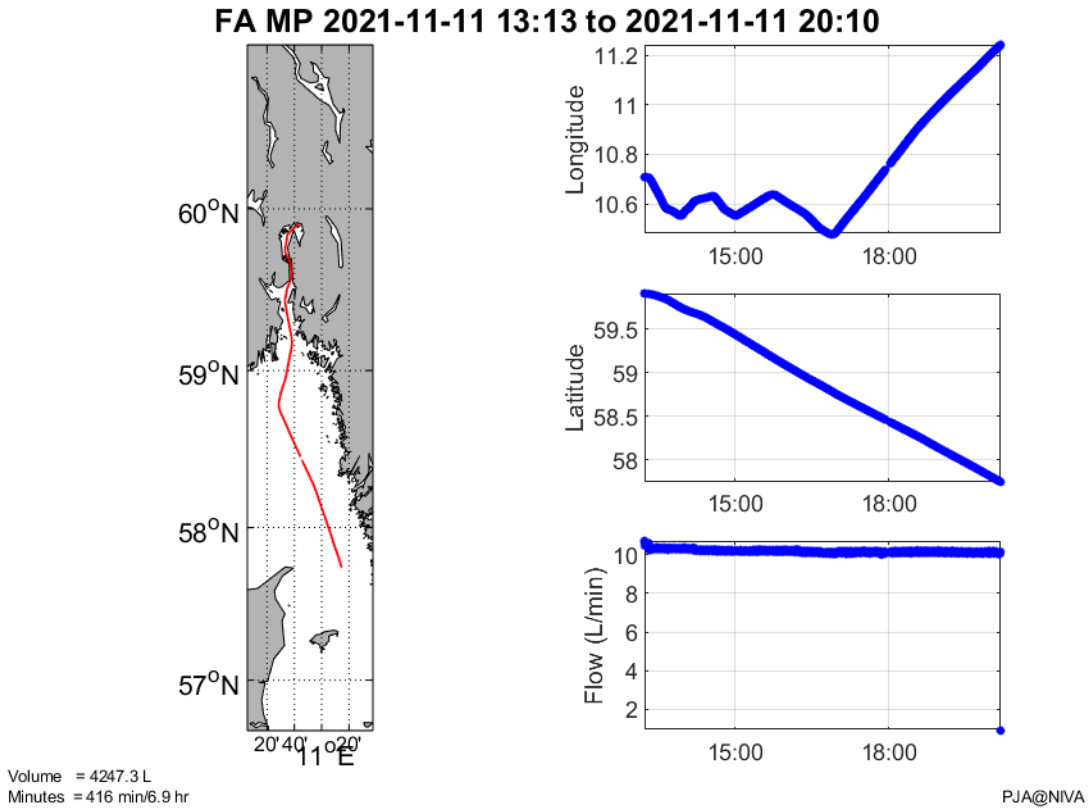

FA MP 2021-10-24 00:37 to 2021-10-24 07:40
60°N
59°N
58°N
57°N
20'
40'
11° E
20'
40'
Longitude
11.2
11
10.8
10.6
03:00
06:00
Latitude
59.5
59
58.5
58
03:00
06:00
Flow (L/min)
8
6
4
03:00
06:00
Volume = 4139.3 L
Minutes = 423 min/7.0 hr
PJA@NIVA

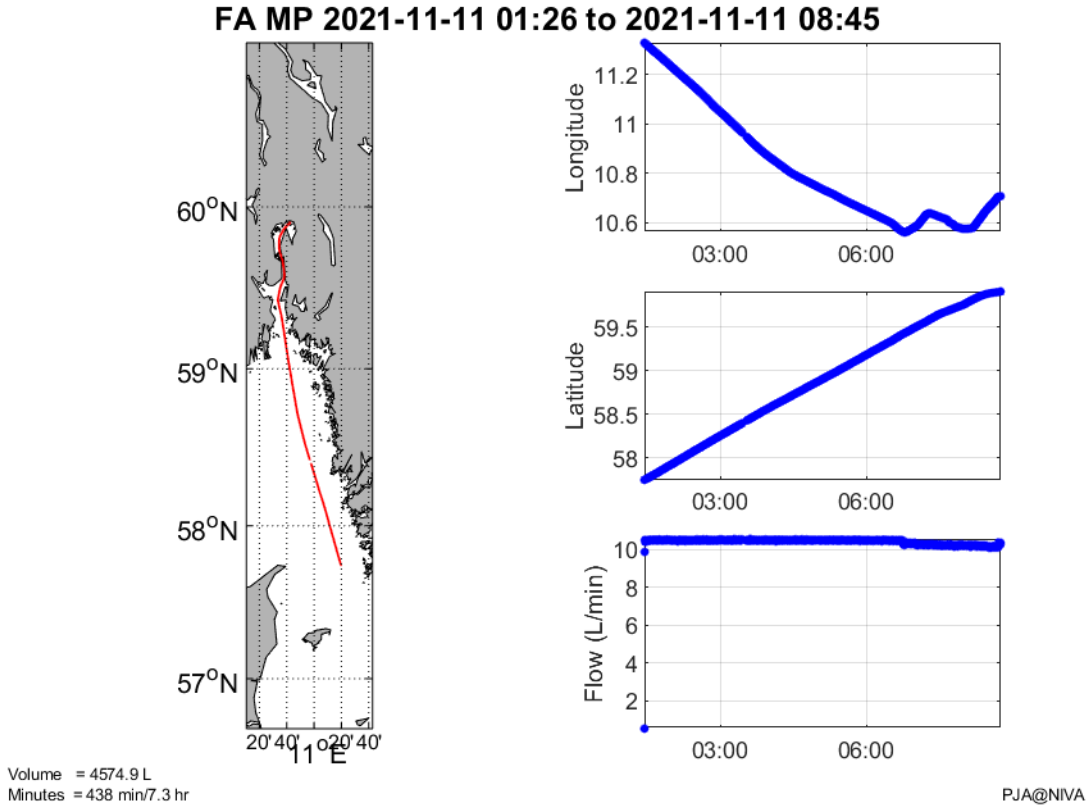

FA MP 2021-11-17 01:46 to 2021-11-17 08:44
60°N
59°N
58°N
57°N
20'40'
11°E
20'40'
Longitude
11.2
11
10.8
10.6
03:00
06:00
Latitude
59.5
59
58.5
58
03:00
06:00
Flow (L/min)
10.1
10
9.9
9.8
9.7
03:00
06:00
Volume = 4125.5 L
Minutes = 418 min/7.0 hr
PJA@NIVA

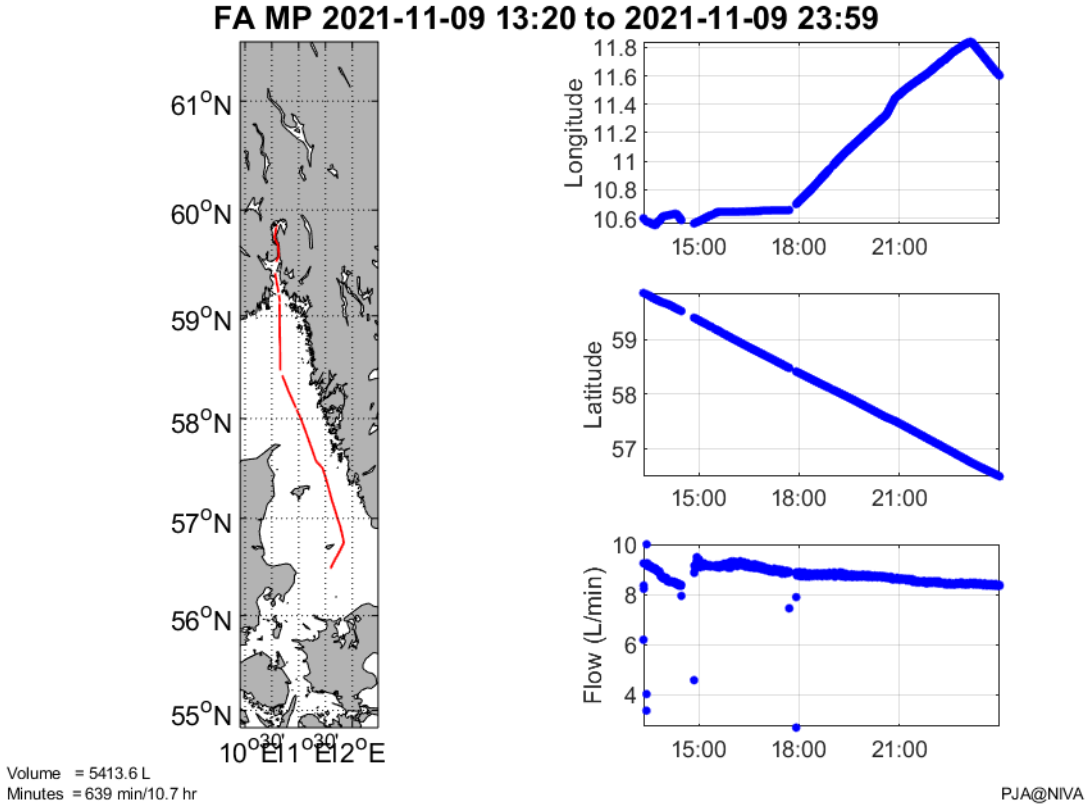

FA MP 2021-11-15 01:29 to 2021-11-15 08:45
60°N
59°N
58°N
57°N
20'40'
11°E
20'40'
Longitude
11.2
11
10.8
10.6
03:00
06:00
Latitude
59.5
59
58.5
58
03:00
06:00
Flow (L/min)
10
8
6
4
03:00
06:00
Volume = 4287.6 L
Minutes = 435 min/7.2 hr
PJA@NIVA

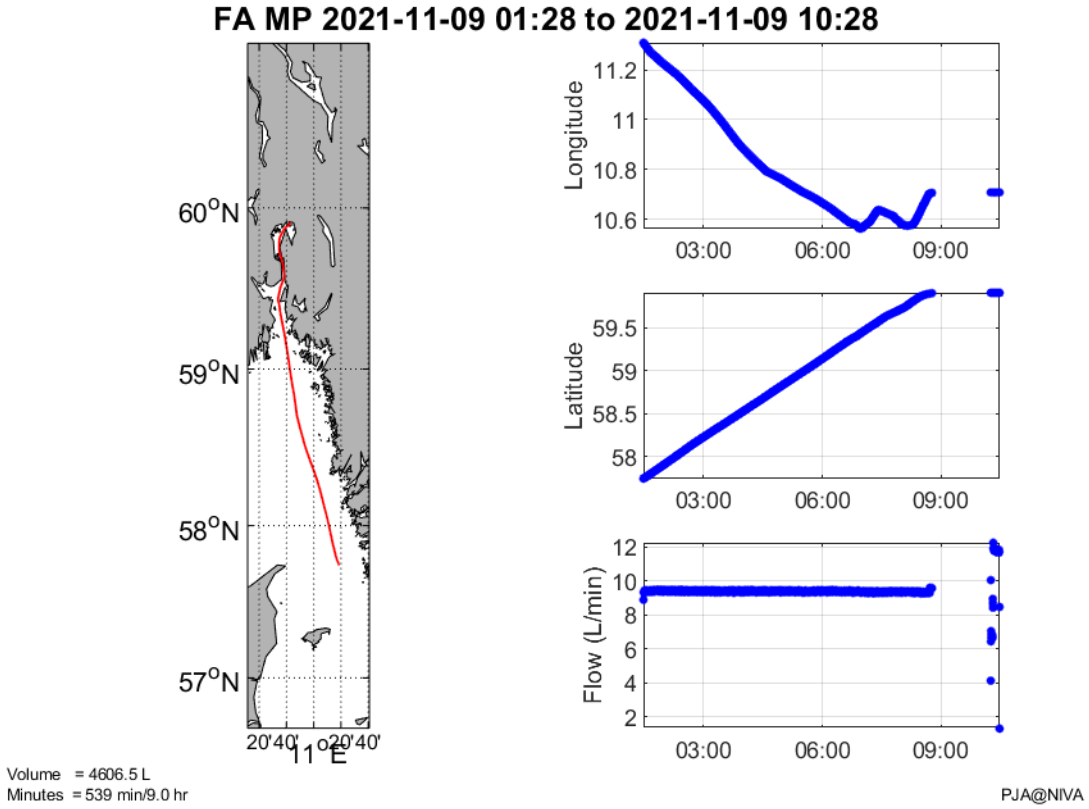

FA MP 2021-11-13 13:03 to 2021-11-13 19:40
60°N
59°N
58°N
57°N
15'
30'
45'
11°E
Longitude
Latitude
Flow (L/min)
15:00
18:00
Volume = 4013.6 L
Minutes = 397 min/6.6 hr
PJA@NIVA

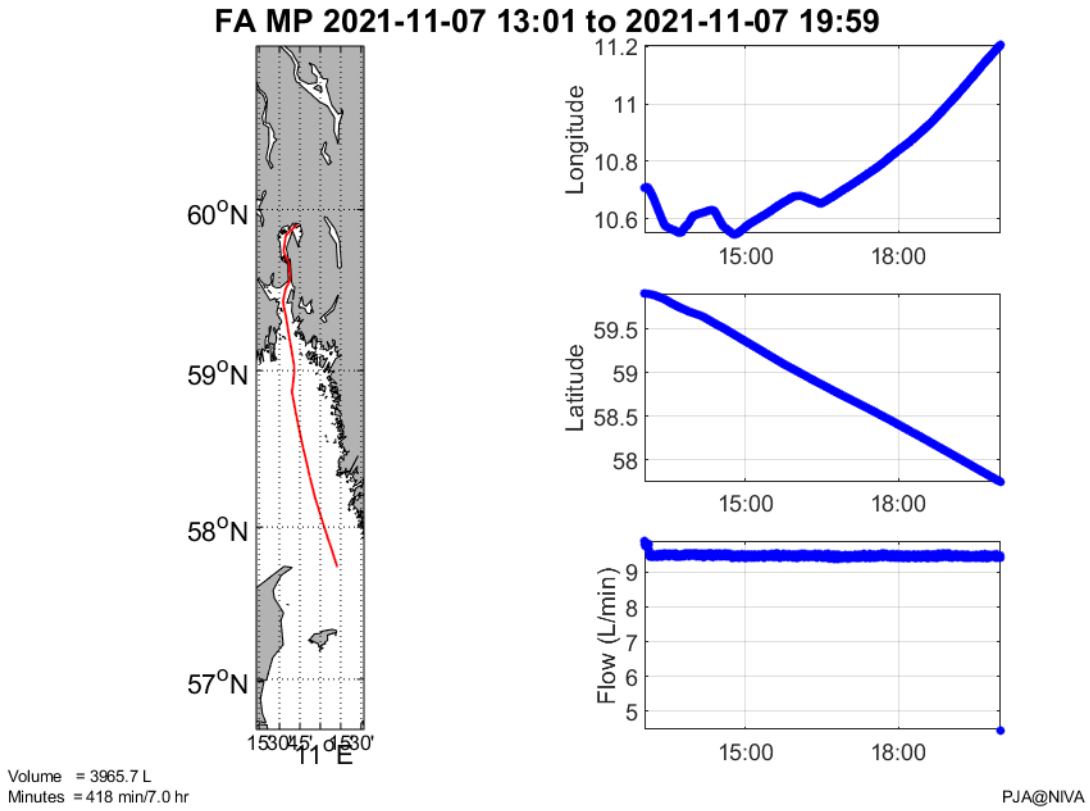

FA MP 2021-11-13 01:27 to 2021-11-13 08:45
60°N
59°N
58°N
57°N
20'
40'
11°E
Longitude
Latitude
Flow (L/min)
03:00
06:00
Volume = 4464.3 L
Minutes = 438 min/7.3 hr
PJA@NIVA

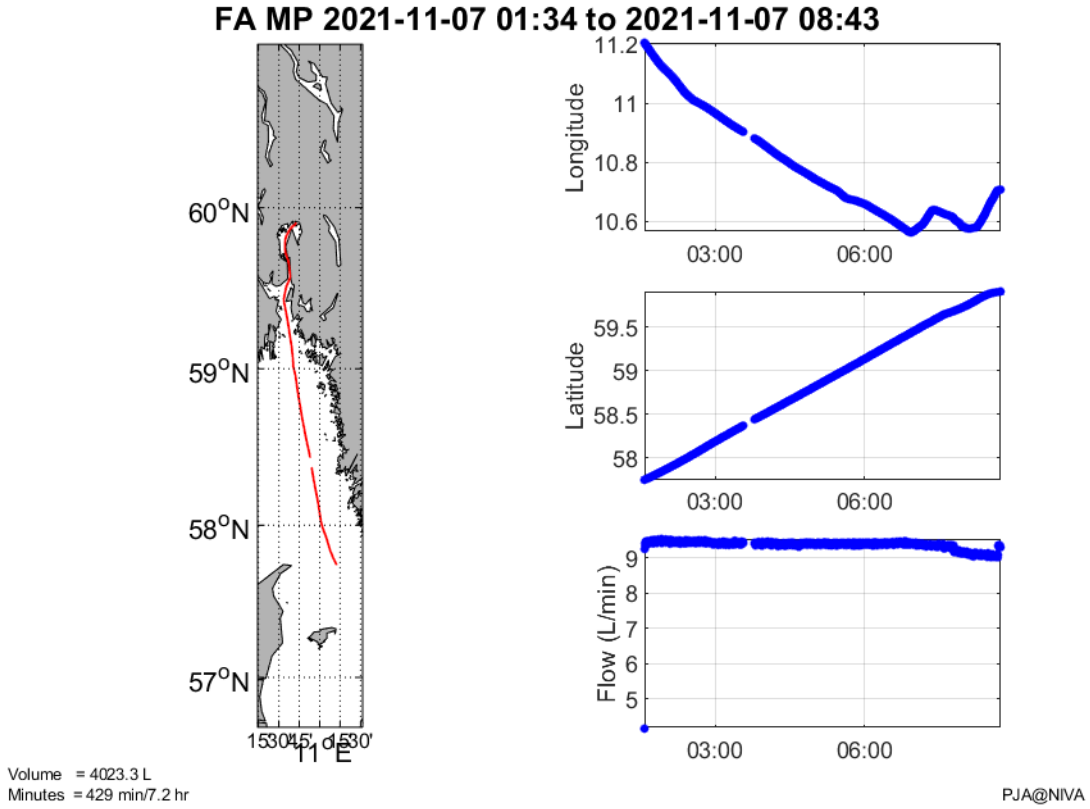

FA MP 2021-11-11 13:13 to 2021-11-11 20:10
60°N
59°N
58°N
57°N
20'
40'
11°E
20'
Longitude
11.2
11
10.8
10.6
15:00
18:00
Latitude
59.5
59
58.5
58
15:00
18:00
Flow (L/min)
10
8
6
4
2
15:00
18:00
Volume = 4247.3 L
Minutes = 416 min/6.9 hr
PJA@NIVA


FA MP 2021-11-11 01:26 to 2021-11-11 08:45
60°N
59°N
58°N
57°N
20'
40'
11°E
20'
40'
Longitude
11.2
11
10.8
10.6
03:00
06:00
Latitude
59.5
59
58.5
58
03:00
06:00
Flow (L/min)
10
8
6
4
2
03:00
06:00
Volume = 4574.9 L
Minutes = 438 min/7.3 hr
PJA@NIVA


FA MP 2021-11-09 13:20 to 2021-11-09 23:59
61°N
60°N
59°N
58°N
57°N
56°N
55°N
10°30'E
11°E
11°30'E
12°E
Longitude
Latitude
Flow (L/min)
15:00
18:00
21:00
Volume = 5413.6 L
Minutes = 639 min/10.7 hr
PJA@NIVA

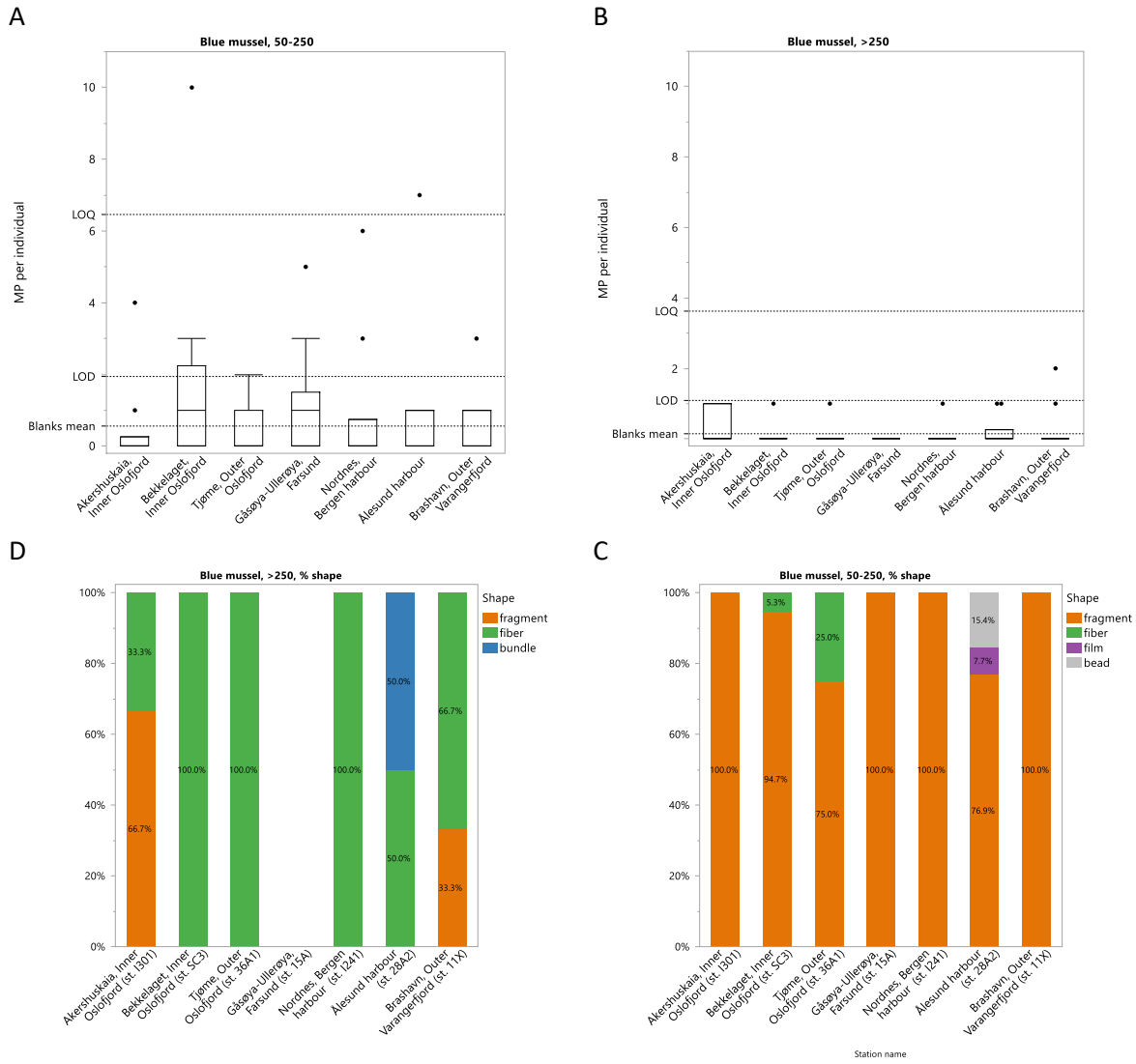

FA MP 2021-11-09 01:28 to 2021-11-09 10:28
60°N
59°N
58°N
57°N
20'40'
11°E
20'40'
Longitude
Latitude
Flow (L/min)
03:00
06:00
09:00
Volume = 4606.5 L
Minutes = 539 min/9.0 hr
PJA@NIVA


FA MP 2021-11-07 13:01 to 2021-11-07 19:59
60°N
59°N
58°N
57°N
15°30'
45'
11°E
30'
Longitude
11.2
11
10.8
10.6
15:00
18:00
Latitude
59.5
59
58.5
58
15:00
18:00
Flow (L/min)
9
8
7
6
5
15:00
18:00
Volume = 3965.7 L
Minutes = 418 min/7.0 hr
PJA@NIVA


FA MP 2021-11-07 01:34 to 2021-11-07 08:43
60°N
59°N
58°N
57°N
15°30'
45'
11°E
30'
Longitude
11.2
11
10.8
10.6
03:00
06:00
Latitude
59.5
59
58.5
58
03:00
06:00
Flow (L/min)
9
8
7
6
5
03:00
06:00
Volume = 4023.3 L
Minutes = 429 min/7.2 hr
PJA@NIVA

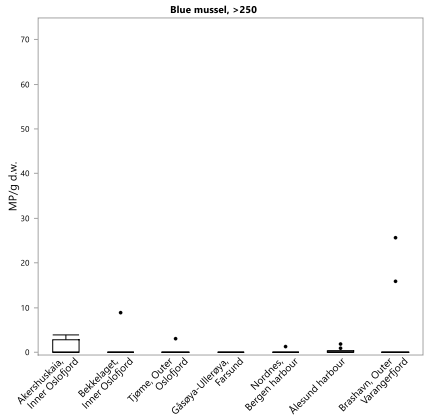
7.1.2Blue mussels

Link to database

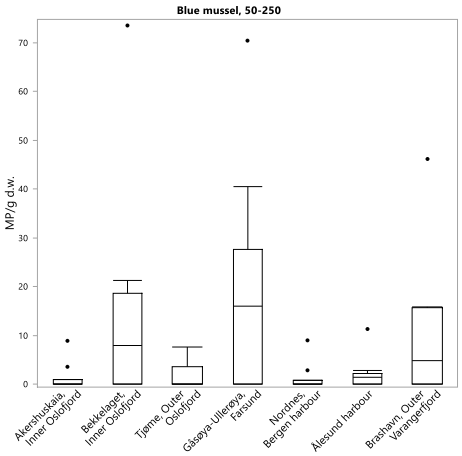


Number of microplastics identified in blue mussels from 7 sites on the Norwegian coast a MP/individual. (A) displays data for particles >250 µm, (B) displays data for particles 50-250 µm, (C) morphology of microplastics >250 µm and (D) morphology of microplastics 50-250 µm. Results of number of microplastics are displayed as medians with minimum and maximum. The lines represent the mean, LOD and LOQ of the blanks. Outliers are indicated as dots.

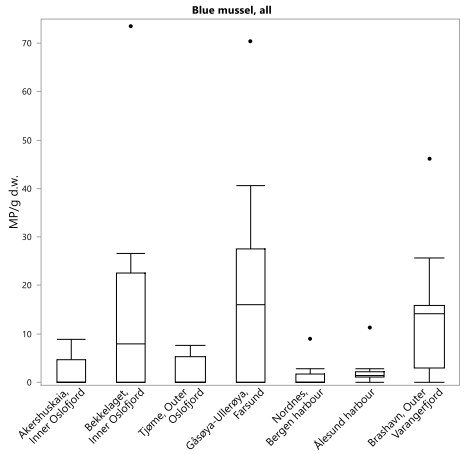
A



B

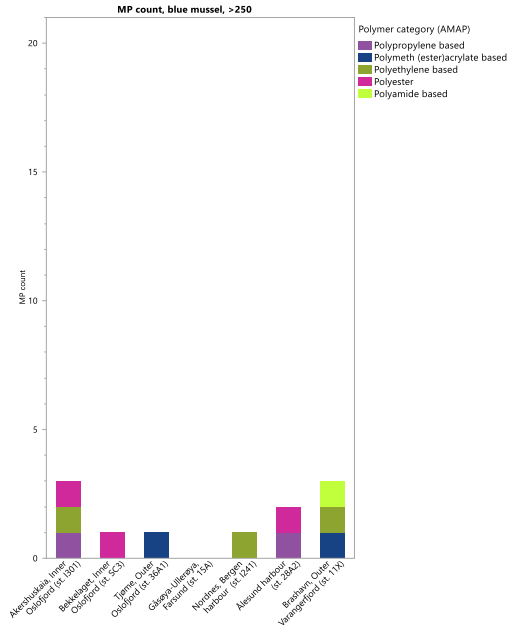


C

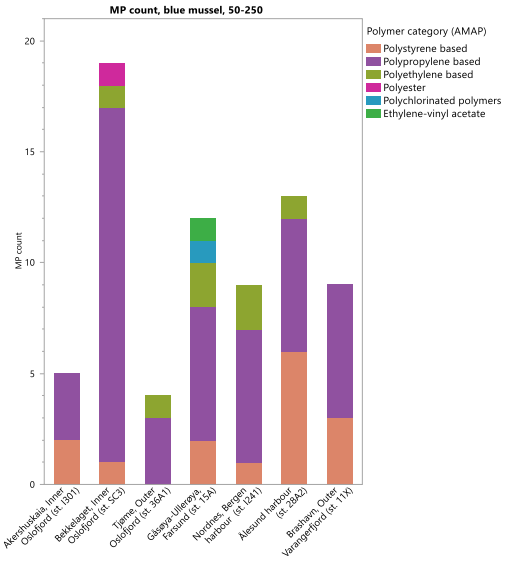


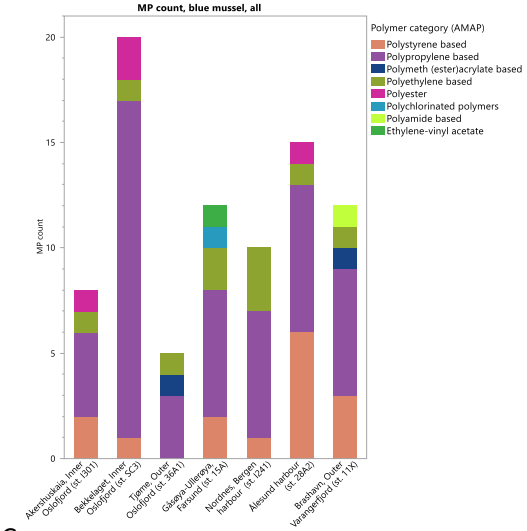
Number of microplastics identified in blue mussels from 7 sites on the Norwegian coast a MP/g d.w. (A) displays data for particles >250 µm, (B) displays data for particles 50-250 µm, and (C) displays data compiled for all size fractions. Results are displayed as medians with minimum and maximum. The lines represent the mean, LOD and LOQ of the blanks. Outliers are indicated as dots.

A



B





C

Polymer categories of microplastics identified in blue mussels from 7 sites on the Norwegian coast. Data displayed here includes (A) data for particles >250 µm, (B) data for particles 50-250 µm, and (C) data compiled for all size fractions.

7.2 Air samples

Link to database.

8 Appendix – Sample metadata

Link to excel sheet or "on demand" on NIVAs database.

Table 2: Sites sampled for microplastics in 2021 (blanks not included)

Sampling program	Station code	Station name	Number of samples	Longitude (DD)	Latitude (DD)
Havforsuringsprogrammet	FBOK	Oslo-Kiel	20		
ØKOKYST	BT40	Færder, Ytre Oslofjord	3	10.3715	59.0
	BT44	Arendal, Arendal-Tromøy	3	9.027614	58.403169
	BR108	Klokkavika	3	5.1787	60.2122
	BT132	Maurangsfjorden	3	6.168	60.1061
	BR12	Skinnbrokleia	2	5.761956	62.330674
	BR70	Herøyfjorden	3	5.535993	62.293487
	BR119	Ullsfjorden/Fugløyfjorden	3	19.7712833	69.7617667
	VR54	Straumsfjorden	3	18.338	69.502
	VR21	Bugøynes, Varangerfjorden	3	29.8804	69.9584
	BR43	Tanafjorden ytre del	3	28.638	70.8759
MILKYS	I301	Akershuskaia, Inner Oslofjord	10	10.73633333	59.90533333
	36A1	Tjøme, Outer Oslofjord	10	10.42522	59.07357
	15A	Gåsøya-Ullerøya, Farsund	10	6.886	58.05116667
	I241	Nordnes, Bergen harbour	10	5.30166667	60.40066667
	28A2	Ålesund harbour	10	6.131	62.465
	11X	Brashavn, Outer Varangerfjord	11	29.74416667	69.89866667
Screeningprogrammet	SC3	Bekkelaget, Inner Oslofjord	10	10.754876	59.874892
MIKRONOR	ALN2	Alnaelva, near Alnabru	3	10.84288	59.93055
	ALN1	Alnaelva, near Kværner	3	10.7915993	59.9046727
	FEM1	Femunden site 1	2	11.8284264	62.0949788
	FEM2	Femunden site 2	2	11.768043	62.1260343
	FEM3	Femundsite site 3	2	11.8103314	62.0754786
Milfersk and MIKRONOR	MJB1	Mjøsbru transekt, pkt. 1 (by bridge)	3	10.66873333	60.93498333
	MJB2	Mjøsbru transekt, pkt. 2	3	10.67258333	60.92843333
	MJB3	Mjøsbru transekt, pkt. 3	3	10.67306667	60.92656667
	MJH1	Hamar transekt pkt. 1 (by city)	3	11.06683333	60.7912
	MJH2	Hamar transekt pkt. 2	3	11.05931667	60.78358333
	MJH3	Hamar transekt pkt. 3	3	11.04911667	60.771
Urbanfjord and MIKRONOR	AKE1	Akershuskaia transekt, pkt. 1 (by dock)	3	10.74005	59.90203333
	AKE2	Akershuskaia transekt, pkt. 2	3	10.73278	59.90131333
	AKE3	Akershuskaia transekt, pkt. 3	3	10.72659	59.89976167
	BEK1	Bekkelaget transekt pkt. 1	3	10.75693333	59.88225
	BEK2	Bekkelaget transekt pkt. 2	3	10.7537	59.88003333
	BEK3	Bekkelaget transekt pkt. 3	3	10.75108333	59.87705
Monitoring programme for long-range transported atmospheric contaminants	NO0001R NO0002R	Birkenes	12	8.25	58.38
	NO0042G	Zeppelin	12	11.88	78.90

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