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This report has been quality assured according to NIVA's quality system and has been approved by:

Vanja Alling
Project Manager/Lead Author

France Collard/Amy Lusher
Quality Assurer

Morten Jartun
Research Manager

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Author(s)
Vanja Alling, Espen Lund, Amy Lusher, Jemmima Knight, Sverre Hjelset, Cecilie Singdahl-Larsen, Elena Martinez-Frances, Elisabeth Rødland, Svetlana Pakhomova, Vilde Kloster Snekkevik, Chiara Consolaro, Bert van Bavel, Natascha Schmidt (NILU) and Dorte Herzke (NILU)

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Eivind Farmen

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The MIKRONOR monitoring program aims to establish baseline levels of microplastics in the Norwegian environment and to identify potential sources and sinks. This third MIKRONOR report focuses mainly on results from air samples, including data on tyre wear particles (TWP), as well as river and fjord surface water samples, and their correlation to rainfall and river discharge levels. Additionally, it presents data from sand samples taken from an OSPAR beach in the outer Oslofjord.
The results for 2023 provide evidence of the omnipresence of microplastics in the environment. However, levels were higher near cities and populated areas, with decreasing levels further from human activities. This trend was observed in both air and surface water samples. Sand samples from the OSPAR beach in the Oslofjord showed levels of microplastics comparable to, or slightly higher than studied beaches at Svalbard. Since no other beach studies have been conducted in the MIKRONOR program, it is difficult to determine typical microplastic levels on a beach in the outer Oslofjord. Determined levels of microplastics in the beach samples were comparable to levels in marine bottom sediment at remote areas along the coast and lower than levels in sediments from the Oslofjord.
Main conclusions of this report highlight the need for further research into the processes that control the levels and variations of microplastics and TWPs, such as weather conditions, river discharge, and air mass movement. Sampling of different matrices should, where possible, be conducted using similar strategies and equipment to improve the comparability of results. Additionally, the high spatial and temporal variability between samples must be considered to determine the appropriate number of analyses needed to obtain reliable results.

Keywords: Microplastic pollution, Environmental contaminants, monitoring, tyre wear particles
Emneord: Mikroplast, forurensning, overvåking, dekkpartikler

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Preface

The Norwegian Institute for Water Research (NIVA), acting on behalf of the Norwegian Environment Agency (NEA, Miljødirektoratet), organised the sampling and carried out subsequent quantitative and qualitative determination of microplastics in samples from the Norwegian environments for the third round/year of the national microplastic monitoring program "Microplastics in Norwegian coastal areas, rivers, lakes and air (MIKRONOR). Eivind Farmen coordinated the project at the NEA. The project was initiated in 2021, and Vanja Alling has been project manager at NIVA since May 2023. Before that, Bert van Bavel was project manager and he has also been responsible for the overall method development and quality assurance of NIVAs analytical work. The sampling was a collaborative effort, incorporating and coordinating collection of highly different sample materials from seven ongoing national monitoring programs run by the Agency. Sverre Hjelset and Cecilie Singdahl-Larsen managed the coordination of sampling equipment and logistics. Sample preparation and microplastic analyses was conducted by Sverre Hjelset, Cecilie Singdahl-Larsen, Chiara Consolaro, Svetlana Pakhomova, Elena Martinez-Frances, Madeline Jefroy and Vilde Kloster Snekkevik. Elisabeth Rødland analysed samples for the content of tyre wear particles with Pyrolysis-GCMS, while air sampling was coordinated and samples were analysed and reported by Dorte Herzke and Natascha Schmidt from the Climate and Environmental Research Institute NILU. The chemical analyses for the suspect screening were performed at NILU by Mikael Harju, Vladimir Nikiforov and Anders Røsrud Borgen. Data analyses was performed by Espen Lund, Vanja Alling, Natascha Schmidt, Amy Lusher and Jemmima Knight.

The scientific quality assurance was provided by Amy Lusher, France Collard and Morten Jartun. This report has been collaboratively written by Vanja Alling, Espen Lund, Amy Lusher, Elisabeth Rødland, Natascha Schmidt and Dorte Herzke.

Oslo, 22 October 2024

Vanja Alling

Project Manager

NIVA

Summary

This is the third report of MIKRONOR, Norway's national microplastics monitoring program. On behalf of the Norwegian Environment Agency, the Norwegian Institute for Water Research (NIVA), in collaboration with the climate and environmental research institute NILU, has administered the program since 2021, with funding secured until 2026. MIKRONOR aims to establish a baseline for future monitoring and time trends, identify high-impact areas and sources of microplastic contamination, and create a robust knowledge base for policymaking and public awareness. This report presents the 2023 samples in MIKRONOR.

Microplastics in air samples from Norwegian mainland and Svalbard

Understanding the sources, transport mechanisms, and impacts of airborne microplastics is crucial for assessing environmental and human health risks. Traffic emissions, industrial processes, and synthetic material use contribute to their release. Microplastics can travel long distances, reaching remote areas like the Arctic. Microplastics in deposition samples were measured at Birkenes station in the south of mainland Norway, and at Zeppelin station on High Arctic Svalbard. Active air samples were only analysed from Zeppelin. The microplastic deposition results, reflecting both wet and dry deposition over six 14-day periods, showed 4-6 times higher fluxes of microplastics in mainland (mean of 127 ± 146 SD µg/m^2/d) than in the samples from Svalbard (21 ± 29 SD µg/m^2/d). Birkenes exhibited an increasing trend from summer to November, while the results from Zeppelin showed no temporal trends, consistent with observations from the previous year. The highest values at Birkenes were associated with continental air masses coming from the east.

The polymer composition was dominated by Styrene-Butadiene Rubber (SBR), Polyvinylchloride (PVC) and Polyethylene terephthalate (PET) in both Birkenes and Zeppelin deposition samples. Styrene-Butadiene Rubber (SBR) data for atmospheric samples is included for the first time in this monitoring report as a marker for tyre wear particles (TWP). Previous monitoring campaigns, as reported in last year's MIKRONOR report, have shown the widespread presence of TWP in various parts of the Norwegian environment. The current campaign confirms that TWP are also present in the atmosphere. However, SBR was not detected in active air samples from Zeppelin, which samples suspended particles in air from the lowest layers of the atmosphere. Deposition samples, on the other hand, contain particles that can originate from the whole troposphere, as precipitation washes out particles from the entire air column. Therefore, these samples also represent air masses from higher atmospheric layers that have been transported from distant locations. The results thus indicate that the sources of SBR in the deposition samples were not local, but rather a result of long-range atmospheric transport.

Comparison between microplastic levels in river and fjord surface water in Oslo, and the relationship to weather and river discharge

Of the five rivers sampled for surface waters with manta nets for microplastics >200 µm, Alnaelva in Oslo had the highest mean levels, but with significant variations between sampling occasions (0.88 – 14 MP/m^3 with corresponding mass concentrations of 1.4 - 420 µg/m^3). Surface water samples from the inner Oslofjord, collected with a pump, showed higher levels of particles >200 µm (6.3 – 19 MP >200µm/m^3 and corresponding mass concentrations of 280-530 µg/m^3) than the Alnaelva, which discharges into the fjord, indicating that other sources are more important to the inner Oslofjord than Alnaelva. In the inner Oslofjord, also smaller particles than 200 µm were analysed, and the fraction 50-300 µm showed levels in the water based on the number of particles of 2-80 MP/m^3. In two out of three sampling occasions in 2023, the microplastics in the smallest fraction dominated the samples, based on the numbers, but the mass was dominated by the mass of the larger particles, as the small particles contribute considerably

less to the mass than larger particles. The levels of microplastic particles in the inner Oslofjord surface samples from 2022 and 2023 overlapped, with both the highest and lowest levels found in 2023. TWP were also measured in the fjord surface samples both years (for particles 50-300 µm). All three sampling occasions in 2023 exhibited significantly lower TWP concentrations (TWP measured in mg/m^3) than those in 2022.

In order to better understand the described variations in microplastic and TWP levels, the relationship between microplastic levels and river discharge patterns was assessed. However, no straightforward correlation was observed between these levels and the river discharge patterns. Extreme weather conditions in the Oslo region in August and September 2023, including multiple heavy rainfalls and floods, resulted in varied microplastic levels in the river and fjord samples. The fjord surface samples taken at the start of October likely represented integrated values from the heavy rainfalls in August and September, and showed high microplastic levels, but low TWP concentrations. In contrast, the river water samples from the end of a relatively dry October showed lower microplastic levels. The highest levels of microplastics in both the river and the fjord were found in the November samples, collected after significant rainfalls and subsequent high river run-off and other urban discharges to the fjord. TWP levels in the fjord were highest in November as well (TWP not measured in the river samples). We believe that the timing of the sampling is very sensitive when monitoring the effects of rainfall and floods on microplastic levels. Weather and run-off patterns could affect lighter microplastics different from heavier TWP particles, explaining the lack of TWP particles in the fjord in some samples where other microplastic levels were high.

Sea surface samples taken with the FerryBox system

Open sea and coastal waters were sampled using the FerryBox system, this year attached to the Hurtigruten ferries traveling from Bergen to Tromsø and from Tromsø to Svalbard. Compared to the river and fjord water samples, the samples taken along the Norwegian coast and between Tromsø and Svalbard exhibited lower levels of microplastics (number of MP/m^3). Generally, the levels ranged between 0.1-0.5 MP/m^3, which are also lower than those measured in the Oslofjord and Skagerrak with the Oslo-Kiel ferry in 2022.

Assessment of sand samples from a beach in the outer Oslofjord

The Norwegian OSPAR beach on Akerøya was sampled for microplastics in the sand for the first time in 2023. A total of 30 sand sediment samples were taken, divided into five transects, with top sediments collected from randomized squares along the transects. The average number of microplastics was calculated to be 0.095 MP/g d.w. (± 0.10 SD). This level of microplastics is lower than found in the Adventsfjord on Svalbard (0.7 MP/g at the remotest site and 2.2 MP/g at the site closest to Longyearbyen. It is however higher than found on a beach close to Barentsburg (also on Svalbard) where the level found was 0.01 MP/g dw. To us, the level found on the OSPAR beach in the Oslo fjord seems rather low in comparison to the Svalbard beach samples that might be expected to be lower due to the remote location of Svalbard. However, the methods used in this study, compared to the Svalbard studies are not directly comparable and results must be interpreted with caution. It will be interesting for future monitoring to investigate whether the repeated cleaning of this beach influences the low microplastic levels found in the sand as shown by other studies (e.g. Haave et al., 2023) Haave et. al.2023).

Suspect screening of organic compounds and metals on microplastic particles in marine sediment samples

Five filters containing microplastic particles from processed sediment samples were extracted for a suspect screening of chemicals used as additives in plastics, after microplastic particles had been

identified and quantified by FTIR and reported last year. Phthalates, organophosphorus flame retardants, novel brominated flame retardants, polybrominated diphenyl ethers, hydrogenated terphenyls, UV compounds and chlorinated paraffins were included in the screening. In general, phthalates were predominant, followed by organophosphorus flame retardants and chlorinated paraffins. Phthalates and organophosphorus flame retardants are common plastic additives, the former being e.g. used as plasticizers in PVC products. Phthalates were the major contributors in all samples, while organophosphorus flame retardants were only present at values > LOQ in two samples. UV compounds, chlorinated paraffins and hydrogenated terphenyls were present in most samples, but at low concentrations, while novel brominated flame retardants and polybrominated diphenyl ethers were not detected at all at levels > LOQ. The sample showing highest microplastic particle concentrations by count and mass, also corresponded to the sample showing highest chemical concentrations. Analyses of metals on similar filters with microplastic particles from sediments showed metal concentrations similar to those in the blanks. Small deviations from blank values probably mainly derived from metals associated with mineral particles on the filters.

Concerns about sampling design for plankton nets and blue mussel samples

The 2023 sampling campaign included a large number of plankton net water samples. However, substantial issues were encountered, including high contamination levels indicated by a high number of microplastics in the net blank samples. Additionally, the sampling design made the results difficult to interpret and use. We recommend discontinuing the use of vertical plankton nets for sampling due to the challenges in interpreting results from a 50-meter water column, which does not differentiate between particles floating on the surface and those in deeper layers.

Blue mussels were sampled at six stations, the same as those sampled in 2022. Similar to the 2022 samples, the number of microplastic particles was low, falling below the limit of detection (LOD) in all but one sample, which still remained below the limit of quantification (LOQ). This raises questions about the sampling methods for blue mussels, as we believe that small differences in sampling locations on a local scale can significantly affect the number of particles to which the mussels are exposed. Additionally, the optimal number of mussels to pool in one sample and the ideal size of the mussels are also in question. TWP concentrations were detectable in only one blue mussel station. The reason for this difference from last year's results is unclear, but small variations in exposure to TWP particles may play a significant role.

Sammendrag

Dette er den tredje rapporten fra MIKRONOR, Norges nasjonale overvåkingsprogram for mikroplast. På vegne av Miljødirektoratet har Norsk institutt for vannforskning (NIVA) i samarbeid med klima- og miljøforskningsinstituttet NILU administrert programmet siden 2021, med finansiering sikret frem til 2026. MIKRONOR har som mål å etablere et referansenivå for fremtidig overvåking og tidsserier, identifisere områder og kilder med høy påvirkning av mikroplastforurensning, og skape et robust kunnskapsgrunnlag for politikkutforming og offentligheten i allmennhet. Denne rapporten presenterer 2023-prøvene i MIKRONOR.

Mikroplast i luftprøver fra fastlands-Norge og Svalbard

Å forstå kildene, transportmekanismene og virkningene av luftbåren mikroplast er avgjørende for å vurdere miljø- og helserisiko. Trafikkutslipp, industrielle prosesser og bruk av syntetiske materialer bidrar til utslipp. Mikroplast kan forflytte seg over lange avstander og havne i avsidesliggende områder som Arktis. Mikroplast i nedbørsprøver ble målt ved Birkenes stasjon i Sør-Norge og ved Zeppelin stasjon på Svalbard. Aktive luftprøver ble kun analysert fra Zeppelin. Resultatene fra nedbørsanalysene, som reflekterer både våt og tørr deposisjon over seks 14-dagers perioder, viste 4-6 ganger høyere flukser av mikroplast på fastlandet (gjennomsnitt på 127 ± 146 SD µg/m^2/d) enn i prøvene fra Svalbard (21 ± 29 SD µg/m^2/d). Birkenes viste en økende trend fra sommer til november, mens resultatene fra Zeppelin ikke viste noen tidsmessige trender, i samsvar med observasjoner fra året før. De høyeste verdiene ved Birkenes var assosiert med kontinentale luftmasser som kom fra øst.

Polymerene styren-butadiengummi (SBR), polyvinylklorid (PVC) og polyetylen tereftalat (PET) dominerte polymersammensetningen i nedbørsprøvene fra både Birkenes og Zeppelin. Data for SBR for atmosfæriske prøver er inkludert for første gang i denne overvåkingsrapporten som en markør for dekkslitasjepartikler (TWP). Tidligere overvåking har vist en utbredt tilstedeværelse av TWP i ulike deler av det norske miljøet, som rapportert i fjorårets MIKRONOR-rapport (Alling et.al., 2023). Imidlertid ble SBR ikke påvist i aktive luftprøver fra Zeppelin, som samler partikler i luft fra de laveste lagene av atmosfæren. Nedbørsprøver, derimot, inneholder partikler som kan stamme fra hele troposfæren, ettersom nedbør vasker ut partikler fra hele luftkolonnen. Derfor representerer disse prøvene også luftmasser fra høyere atmosfæriske lag som har blitt transportert lange distanser. Resultatene indikerer dermed at kildene til SBR i nedbørsprøvene ikke var lokale, men heller et resultat av langtransport i høyere atmosfæriske lag.

Sammenligning mellom mikroplastnivåer i vann fra elv og fjord i Oslo, og forholdet til vær og vannføring i de lokale elvene

Av de fem elvene som ble prøvetatt for overflatevann med mantanett for mikroplast >200 µm, hadde Alnaelva i Oslo de høyeste gjennomsnittsverdiene, men med betydelige variasjoner mellom prøvetakingene (0,88 – 13 MP/m^3 med tilsvarende massekonsentrasjoner på 1,4 - 420 µg/m^3). Overflatevannprøver fra indre Oslofjord, samlet inn med en pumpe, viste høyere nivåer av partikler >200 µm (6,3 – 19 MP >200µm/m^3 og tilsvarende massekonsentrasjoner på 280-530 µg/m^3) enn Alnaelva, som renner ut i fjorden, noe som indikerer at andre kilder er viktigere for indre Oslofjord enn Alnaelva. I indre Oslofjord ble også mindre partikler enn 200 µm analysert, og fraksjonen 50-300 µm viste nivåer i vannet basert på antall partikler på 2-80 MP/m^3. I to av tre prøvetakinger i 2023 dominerte mikroplast i den minste fraksjonen prøvene, basert på antall MP/m^3, men massen ble dominert av de større fraksjonene, da små partikler bidrar betydelig mindre til masse enn større partikler. Nivåene av mikroplastpartikler i overflateprøver fra indre Oslofjord fra 2022 og 2023 overlappet, med både de høyeste og laveste nivåene funnet i 2023. TWP ble også målt i fjordoverflateprøver begge år (for partikler 50-300 µm). Alle tre prøvetakinger i 2023 viste betydelig lavere TWP-konsentrasjoner (TWP målt i mg/m^3) enn de i 2022.

For å bedre forstå de beskrevne variasjonene i mikroplast- og TWP-nivåer, ble forholdet mellom mikroplastnivåer og mønstre i elvevannføring (som en proxy for nedbør og variasjoner i avrenningsområdene) vurdert. Imidlertid ble det ikke observert noen enkel korrelasjon mellom mikroplastnivåene og vannføring i elvene. Ekstreme værforhold i Oslo-regionen i august og september 2023, inkludert flere kraftige regnskyll og flommer, resulterte i varierte mikroplastnivåer i elve- og fjordprøver. Fjordoverflateprøvene tatt i begynnelsen av oktober representerte sannsynligvis integrerte verdier fra ekstremnedbørsepisodene i august og september, og viste høye mikroplastnivåer, men lave TWP-konsentrasjoner. Derimot viste elvevannprøvene fra slutten av en relativt tørr oktober lavere mikroplastnivåer. De høyeste nivåene av mikroplast i både elven og fjorden ble funnet i novemberprøvene, samlet inn etter betydelige regnskyll og påfølgende høy vannføring i elvene og andre urbane vannutslipp til fjorden. TWP-nivåene i fjorden var også høyest i november (TWP ikke målt i elveprøvene). Vi tror at tidspunktet for prøvetaking er svært sensitivt når man overvåker effektene av regn og flom på mikroplastnivåer. Vær- og avrenningsmønstre kan påvirke lettere mikroplast annerledes enn tyngre TWP-partikler, noe som forklarer mangelen på TWP-partikler i fjorden i noen prøver der andre mikroplastnivåer var høye.

Vannprøver langs kysten og i åpent hav tatt med FerryBox-systemet

Åpent hav og kystvann ble prøvetatt ved hjelp av FerryBox-systemet, i år festet til Hurtigruten-fergene som reiser fra Bergen til Tromsø og fra Tromsø til Svalbard. Sammenlignet med elve- og fjordvannprøvene, viste prøvene tatt langs norskekysten og mellom Tromsø og Svalbard lavere nivåer av mikroplast (antall MP/m³). Generelt var nivåene mellom 0,1-0,5 MP/m³, som også er lavere enn de som ble målt i Oslofjorden og Skagerrak med Oslo-Kiel-fergen i 2022.

Vurdering av sandprøver fra en strand i ytre Oslofjord

Den norske OSPAR-stranden på Akerøya ble prøvetatt for mikroplast i sanden for første gang i 2023. Totalt ble 30 sandprøver tatt, fordelt på fem transekter, med toppsedimenter samlet fra tilfeldig valgte firkanter langs transektene. Gjennomsnittlig antall mikroplast ble beregnet til å være 0,095 MP/g tørrvekt (± 0,10 SD). Dette nivået av mikroplast er lavere enn funnet i Adventsfjorden på Svalbard (0,7 MP/g på det fjerneste stedet og 2,2 MP/g på stedet nærmest Longyearbyen). Det er imidlertid høyere enn funnet på en strand nær Barentsburg (også på Svalbard) hvor nivået var 0,01 MP/g tørrvekt. For oss virker nivået funnet på OSPAR-stranden i Oslofjorden ganske lavt sammenlignet med Svalbard-strandprøvene som kanskje forventes å være lavere på grunn av Svalbards avsides beliggenhet. Det vil være interessant for fremtidig overvåking å undersøke om den gjentatte ryddingen av OSPAR stranden på Akerøya påvirker mikroplastnivåene i sanden, som vist av andre studier (f.eks. Haave et. al. 2023).

Suspect screening av organiske forbindelser og metaller på mikroplastpartikler i marine sedimentprøver

Fem filtre som inneholdt mikroplastpartikler fra bearbeidede sedimentprøver ble ekstrahert for screening av kjemikalier brukt som tilsetningsstoffer i plast. Mikroplastpartiklene på filtrene ble identifisert og kvantifisert ved FTIR og rapportert i fjor, og de fem stasjonene som her ble analysert med screening av plastadditiver kom fra indre og ytre Oslofjord. Ftalater, organofosfor flammehemmere, nye bromerte flammehemmere, polybromerte difenyletere, hydrogenert terfenyl og klorerte parafiner ble inkludert i screeningen. Prøven som viste høyest nivåer av mikroplastpartikler etter antall og masse, tilsvarte også prøven som viste høyest kjemiske konsentrasjoner av additiver. Generelt var ftalater dominerende, etterfulgt av organofosforflammehemmere og klorparafiner, alle vanlige tilsetningsstoffer i plastproduksjon. Analyser av metaller på lignende filtre med mikroplastpartikler fra sedimenter viste metallkonsentrasjoner som lignet på de i blankprøvene. Små avvik fra blankverdiene stammer sannsynligvis hovedsakelig fra metaller assosiert med mineralpartikler på filtrene.

Problemer med prøvetakingsdesign for planktonhåv- og blåskjellprøver

Prøvetakingen i 2023 inkluderte et stort antall planktonhåvprøver av vann. Imidlertid ble det oppdaget betydelige problemer med prøvetakingen, inkludert høye kontaminasjonsnivåer indikert av et høyt antall mikroplast i håvblankprøvene. I tillegg gjorde prøvetakingsdesignet resultatene vanskelige å tolke og bruke. Vi anbefaler å avslutte prøvetaking med vertikale planktonhåvtrekk på grunn av utfordringene med å tolke resultater fra en 50-meters vannkolonne som ikke skiller mellom partikler som flyter på overflaten og de i dypere lag.

Blåskjell ble analysert i prøver fra seks stasjoner, de samme som ble prøvetatt i 2022. I likhet med prøvene fra 2022 var antallet mikroplastpartikler lavt, under deteksjonsgrensen (LOD) i alle unntatt én prøve, som fortsatt var under kvantifiseringsgrensen (LOQ). Dette reiser spørsmål om prøvetakingsmetodene for blåskjell, da vi tror at små forskjeller i prøvetakingssteder på lokal skala kan påvirke antallet partikler som blåskjellene blir utsatt for. I tillegg er det også spørsmål om det optimale antallet blåskjell å samle i én prøve og den ideelle størrelsen på blåskjellene. TWP-konsentrasjoner var påvisbare i prøver fra kun én blåskjellstasjon.

1 Introduction to the microplastic monitoring program MIKRONOR

The Norwegian Institute for Water Research (NIVA), on behalf of the Norwegian Environment Agency is responsible for the Norwegian national microplastic monitoring program. The climate and environmental research institute NILU serves as a subcontractor, handling the analyses of air samples and screening for organic compounds. The program, titled "Microplastics in Norwegian Coastal Areas, Rivers, Lakes, and Air" (MIKRONOR), began in 2021. It organizes the sampling of various environmental matrices from other ongoing national monitoring programs and is scheduled to run until 2026 (Alling et al., 2023; van Bavel et al., 2022). This is the third report in this program.

MIKRONOR aims to establish a baseline for future microplastics monitoring programs and to investigate potential high-impact areas and sources to microplastic contamination in the environment. The ultimate, long-term goal is to create a robust knowledge base on microplastics pollution for policymaking and to ensure the public is well-informed about the state of the environment.

As microplastics are ubiquitous in the environment, MIKRONOR has investigated several matrices to establish baseline levels and to start to acquire the data for future studies of trends of microplastics in the Norwegian environment. The samples have been analysed at NIVA, with the exception for the air samples and the suspect screening of plastic additives on particles found in sediments, that have been analysed at NILU.

Within MIKRONOR, we distinguish between the terms *microplastics* (MP) and *tyre wear particles* (TWP, particles resulting from tear and wear of vehicles tyres on the roads and the use of tyre granulates in e.g. football fields) for practical reasons, since the methods needed for the two fractions are different and we cannot merge the results. The definition of microplastics (MP) is in accordance with EU Directive 2019/904: Synthetic material (primarily oil-based polymers) identified in the environment. In this year's report the analyses referred to are for the size range 50 µm to 5 mm, except for air samples, where the mass weight is measured down to 5 µm in the deposition samples and the active air samples. We have measured the mass concentration for TWP, and for other microplastics, we have measured both the numbers and calculated the mass concentrations, with some exceptions (see **Table 1**). The lower size cut-off of 50 µm, is in accordance with the equipment and instrumentation limitations employed in the program. The samples analysed at NIVA were fractionated by particle size, using different identification methods for particles smaller or larger than 300 µm. Microplastic particles have been characterised and identified using Fourier Transform Infrared (FTIR) spectroscopy, identifying the categories and polymer types defined by AMAP (2021). Additionally, the mass of TWP, as well as mass of particles in air samples, have been determined by Pyrolysis Gas Chromatography/Mass Spectrometry (Pyrolysis GCMS). The mass of microplastic particles analysed with FTIR have been calculated based on the volume and density of the polymer types of each particle. A summary of the samples analysed, methods and size fractions analysed is presented in **Table 1**. All methods are described in detail in Alling et al., 2023, or in the appendices of this report.

This year's report is focusing on samples taken in the rivers and surface waters, air samples including for the first-time analyses of tyre wear particles (TWP), analyses of samples from an OSPAR beach, and the results from suspect screening of plastic additives and metals on plastic particles found in five sediment samples.

2 Overview of sample types and analyses

Table 1. The 2023 sample types in four environments with sampling methods, number of samples and field blank samples (net blanks + atmospheric blanks), size fractions and methods for lab analyses, including both Fourier-Transform Infrared Spectroscopy (FTIR), pyrolysis GCMS (Pyr-GCMS) and suspect screening.

Environment	Sample Type	Sampling Method	Number of samples	Number of field blanks	Size fractions analysed, lower limit	FTIR for MP analysis	Pyr-GCMS for TWP	Suspect screening
Coastal	Water, FerryBox	FerryBox system collecting seawater	22	3	100 µm	✓		
	Water, pump	High volume pump of surface ocean water	9	3	50 µm	✓	✓	
					300 µm	✓		
	Water, vertical plankton	Vertical plankton net haul	63	17 net + 60 atm	200 µm	✓		
	Beach sediment	Collection of sand from transects on an Ospar beach	30	3	50 µm	✓	*✓	
					300 µm	✓		
	Blue mussel	Collection of live mussels	18	0	50 µm	✓	✓	
					300 µm	✓		
	Marine sediment	Sediment grab	5	15 atm	50 µm	**✓	**✓	✓
Lake	Water, vertical plankton	Vertical plankton net haul	32	11 net + 30 atm	200 µm	✓		
River	Water, manta trawl	Trawl of river surface water using manta net	30	10 net + 30 atm	200 µm	✓		
Air	Active air samples	Full-metal filter holder	6	3	5 µm		*✓	
	Deposition	Full-metal bulk precipitation sampler	12	6	5 µm	***✓	*✓	
Total number of samples			**227**	**191**				

* Pyr-GCMS for air samples conducted for 9 polymers and for beach samples for 12 polymers, TWP not included.
** Results for FTIR and pyr-GCMS reported last year in Alling et al. 2023.
*** Performed with RAMAN (see appendix 5.3.2 and 5.4).

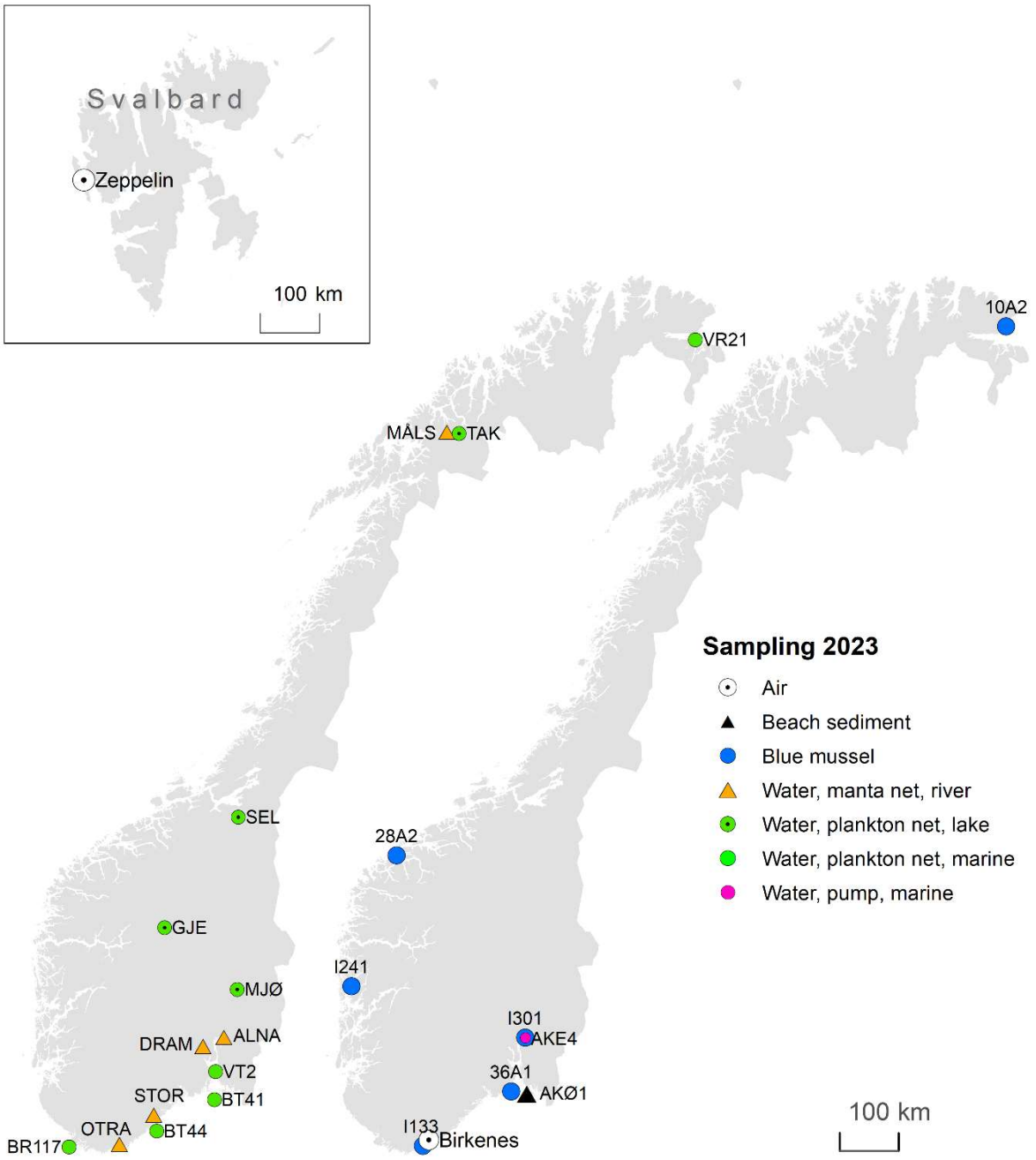

Figure 1. Stations for the analysis of microplastics in air, beach sediment, blue mussel and water in 2023. Stations names in Table 2. See Figure 2 and Table 3 for the FerryBox sampling.

Table 2. Codes and names of sampling stations for analysis of microplastics in 2023.

Code	Name	Code	Name	Code	Name
OTRA	Otra	VR21	VR21 Bugøynes	I301	Akershuskaia
STOR	Storelva	MJØ	Mjøsa	36A1	Tjøme
DRAM	Drammenselva	GJE	Gjende	I133	Kristiansand havn
ALNA	Alnaelva	SEL	Selbusjøen	I241	Bergen havn
MÅLS	Målselva	TAK	Takvatnet	28A2	Ålesund havn
BR117	BR117 Lista	ZD1-6	Zeppelin, Deposition	10A2	Skallneset
BT44	BT44 Arendal	ZA1-6	Zeppelin, Active air	AKE4	Akershuskaia
BT41	BT41 Ytre Oslofjord	BD1-6	Birkenes, Deposition	AKØ1	Akerøy
VT2	VT2 Ytre Oslofjord				

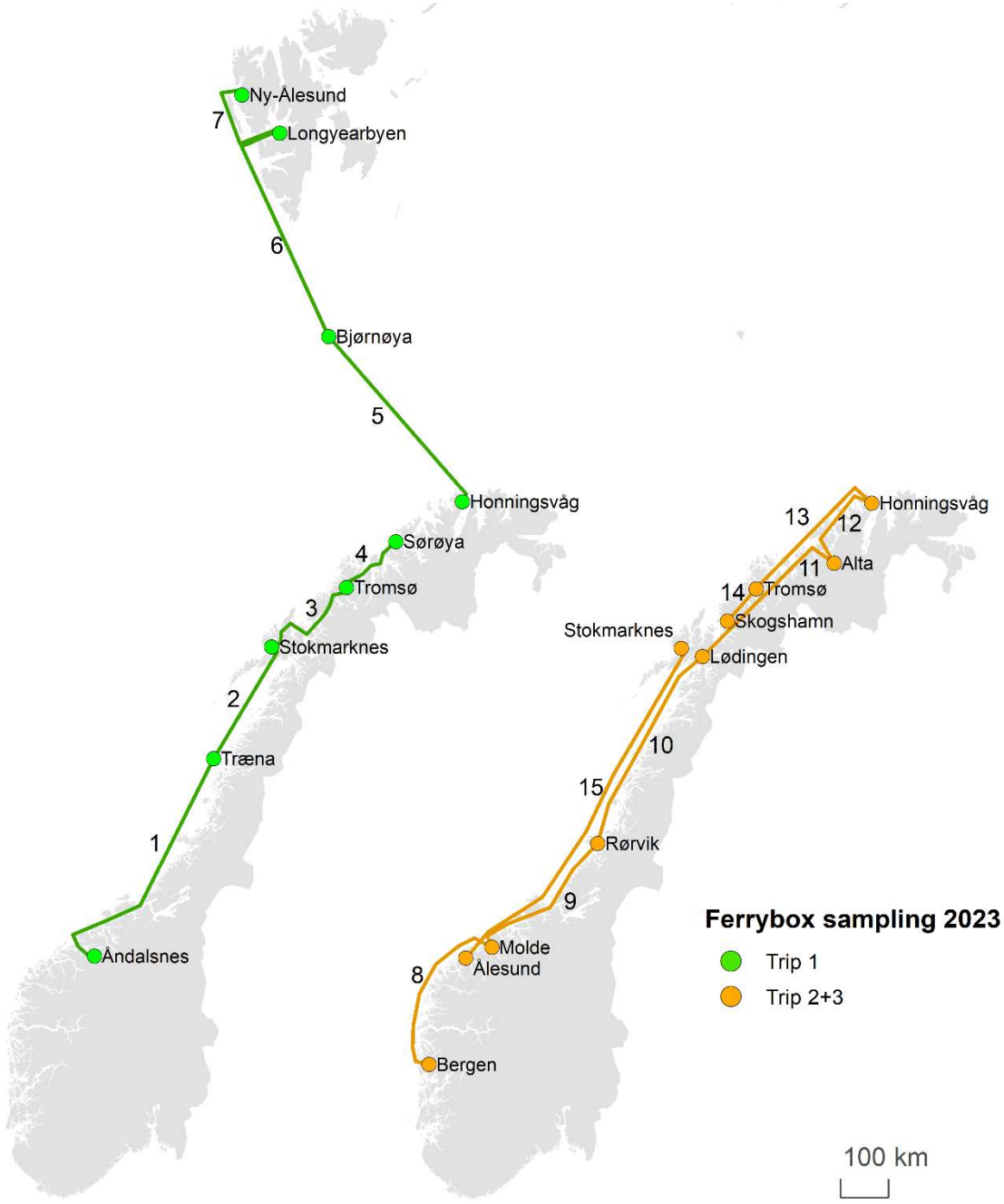

Figure 2. Transects for the analysis of microplastics in FerryBox samples in 2023. Transect names in Table 3. Transect lines are drawn schematic, not showing the exact route of the ship.

Table 3. Codes and transect names of FerryBox sampling for analysis of microplastics in 2023.

Nr.	Trip	Transect	Nr.	Trip	Transect
1	1	Åndalsnes-Træna	**8**	2+3	Bergen-Molde
2	1	Træna–Stokmarknes	**9**	2+3	Molde–Rørvik
3	1	Stokmarknes–Tromsø	**10**	2+3	Rørvik–Lødingen
4	1	Tromsø–Sørøya	**11**	2+3	Lødingen–Alta
5	1	Honningsvåg–Bjørnøya	**12**	2+3	Alta–Honningsvåg
6	1	Bjørnøya–Longyearbyen	**13**	2+3	Honningsvåg–Tromsø
7	1	Longyearbyen–Ny-Ålesund	**14**	2+3	Tromsø–Skogshamn
			15	3	Stokmarknes–Ålesund

3 Key findings

3.1 Microplastics and UV compounds in air and deposition samples

The results for microplastic deposition reflect a combination of both wet and dry deposition collected over six 14-day periods from August until November 2023. Maximum microplastic fluxes of 391 µg/m²/d and 76 µg/m²/d were observed in Birkenes and Zeppelin, while mean fluxes reached 127 µg/m²/d (± 146 µg/m²/d SD) and 21 µg/m²/d (± 29 µg/m²/d SD), respectively **(Figure 3**). While in Zeppelin station no temporal trend is apparent, microplastic fluxes seem to increase in Birkenes station from summer to end of November towards the end of the sampling campaign. This is in accordance with the observations from the previous sampling year (see Alling et al., 2023 report M-2624). No correlation is evident between the amount of precipitation during the sampling campaigns and the microplastic deposition fluxes (**Figure 4)**.

The polymer composition was dominated by SBR, PVC and PET (table with abbreviations for polymers in air, see **Table 18** in appendix 5.3.2.). SBR data for atmospheric samples is included for the first time in this monitoring report, as a marker compound for tyre wear particles. Previous monitoring campaigns have, however, shown the omnipresence of SBR in other compartments of the Norwegian environment, such as marine and freshwater sediments, blue mussels and urban run-off (see Alling et al., 2023 report M-2624). Our results now indicate that atmospheric samples are no exception for the widespread occurrence of SBR in the environment. It should be noted, however, that SBR was not detected at levels > LOQ in active air samples from Zeppelin (**Figure 5**). This might suggest that its presence in deposition samples from this station originated from long-range atmospheric transport in higher altitudes rather than local sources. As Py-GC/MS does not distinguish between particle sizes, relatively high fluxes of a given polymer (such as SBR in ZD2 & ZD5) might also originate from only few bigger particles with a high mass.

UV compounds were present in deposition samples from Birkenes and Zeppelin at a mean concentration of 1.51 and 2.28 ng/m²/d, respectively. The most abundant UV compounds were hereby UV-329 and UV-326, followed by UV-328, whereas UV-320 and UV-327 were either not detected or detected at low concentrations only (≤ 0.1 ng/m²/d).

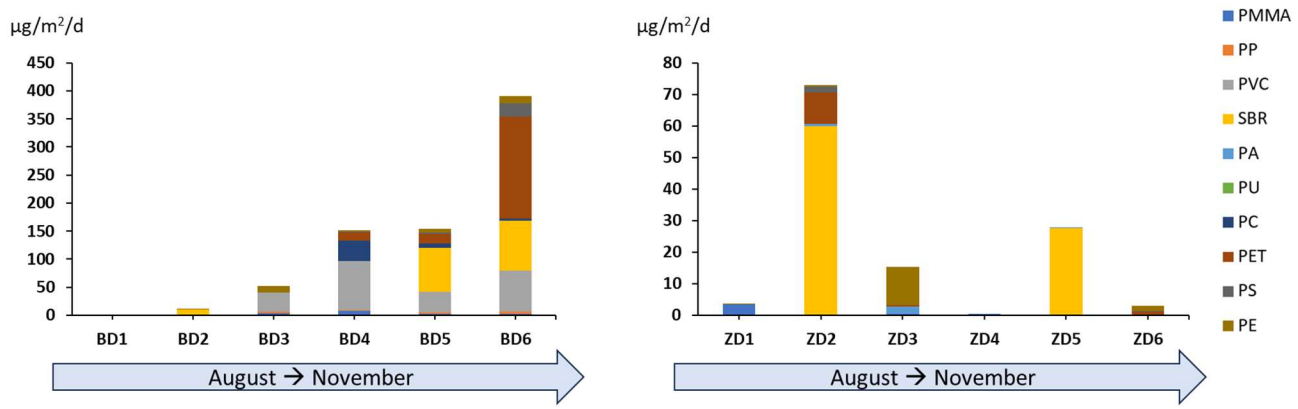

Figure 3. MP fluxes and polymer types observed in deposition samples from Birkenes (left, BD) and Zeppelin (right, ZD) stations.

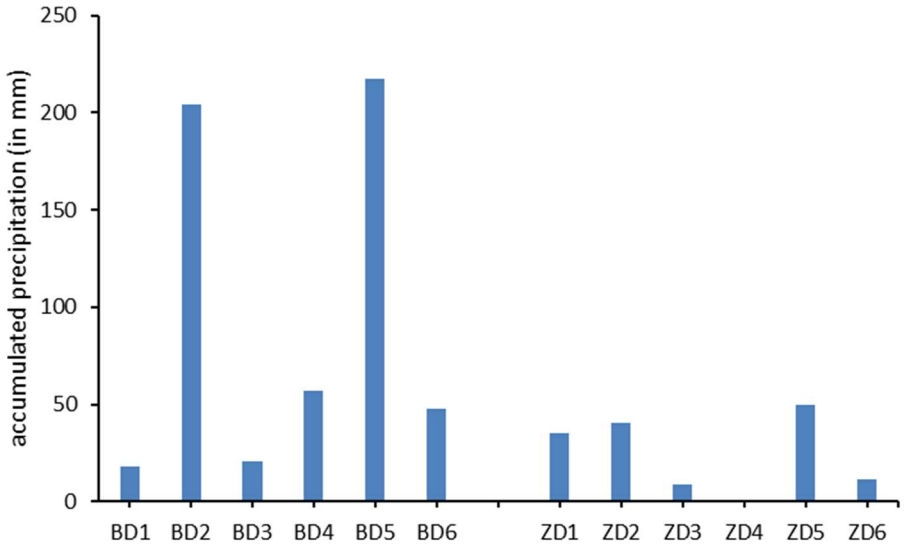

Figure 4. Accumulated precipitation amount (in mm) for each sampling campaign at Birkenes (B1-B6) and Zeppelin (Z1-Z6) stations. Data obtained from the Norwegian Meteorological Institute.

Active air samples from Zeppelin exhibited microplastic concentrations ranging from <LOQ to 3.7 ng/m^3 (mean 1.2 ng/m^3 ± 1.5 ng/m^3 SD) (**Figure 5**). These values are comparable with those reported for active air samples from a rural fjord in Sweden (~0.25 to ~2 ng/m^3), while the authors reported considerable higher values for an urbanized fjord (max. 49 ng/m^3). These air samples were dominated by PET, PMMA and PC (Goßmann et al., 2023)

PMMA, PVC and PET were major contributors to the polymer composition of the active air samples from Zeppelin station. Differences in the polymeric composition from deposition and active air samples from the same station can be explained by the different fractions that are being sampled: especially wet deposition can remove particles from the whole troposphere, while active sampling only collects suspended particles in the proximity of the sampling device. Deposition hereby also collects bigger particles, with snow being more effective in removing larger aerosol particles than rain, while suspended particles are generally small-sized (Van Leuven et al., 2023). Concentrations of UV compounds were generally low in the air samples, with an average of 0.001 ng/m^3. Here, UV-328 and UV-326 were predominant, whereas UV-329, UV-327 and UV-320 were not detected at levels > LOQ (**Figure 6**).

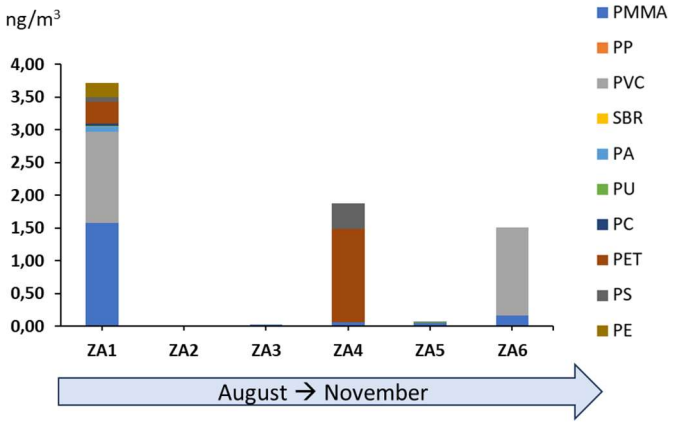

Figure 5. Microplastic concentration and polymer types observed in active air samples from Zeppelin station. ZA = Zeppelin active air samples.

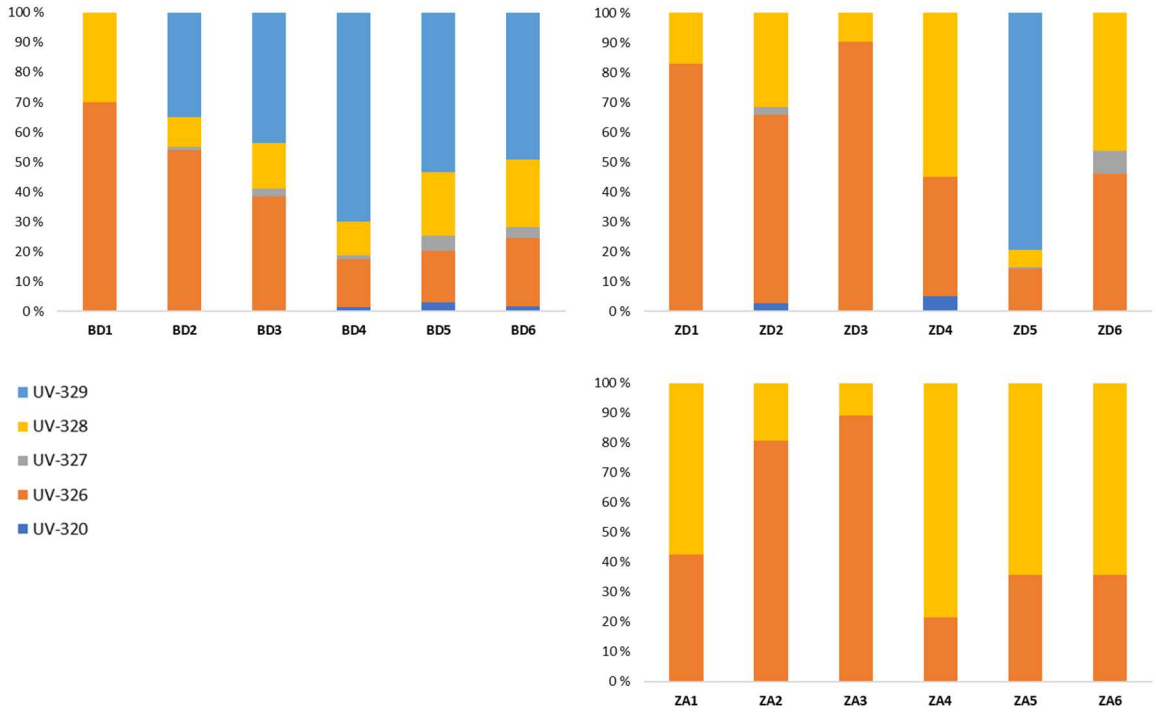

Figure 6. Relative abundance of UV compounds in deposition samples from Birkenes (BD, upper left) and Zeppelin (ZD, upper right) and air samples from Zeppelin (ZA, lower right).

Potential sources of airborne microplastics

As for other sample types, understanding microplastic sources in atmospheric samples remains challenging given the interconnectivity of environmental compartments, the ubiquity of microplastics and the multitude of potential sources, which further differ depending on the individual polymer types. A tool that can be employed to investigate potential sources of microplastics in atmospheric samples is air mass backwards trajectories, which indicate from which direction the sampled air masses originated from. As seen in **Figure 7**, for Birkenes station it seems like deposition samples with lower microplastic fluxes (BD1-3) were mainly influenced by air masses coming from the open sea (western/southwestern direction), whereas samples with higher microplastic loads (BD4-6) were mainly influenced by continental air masses coming from an eastern direction.

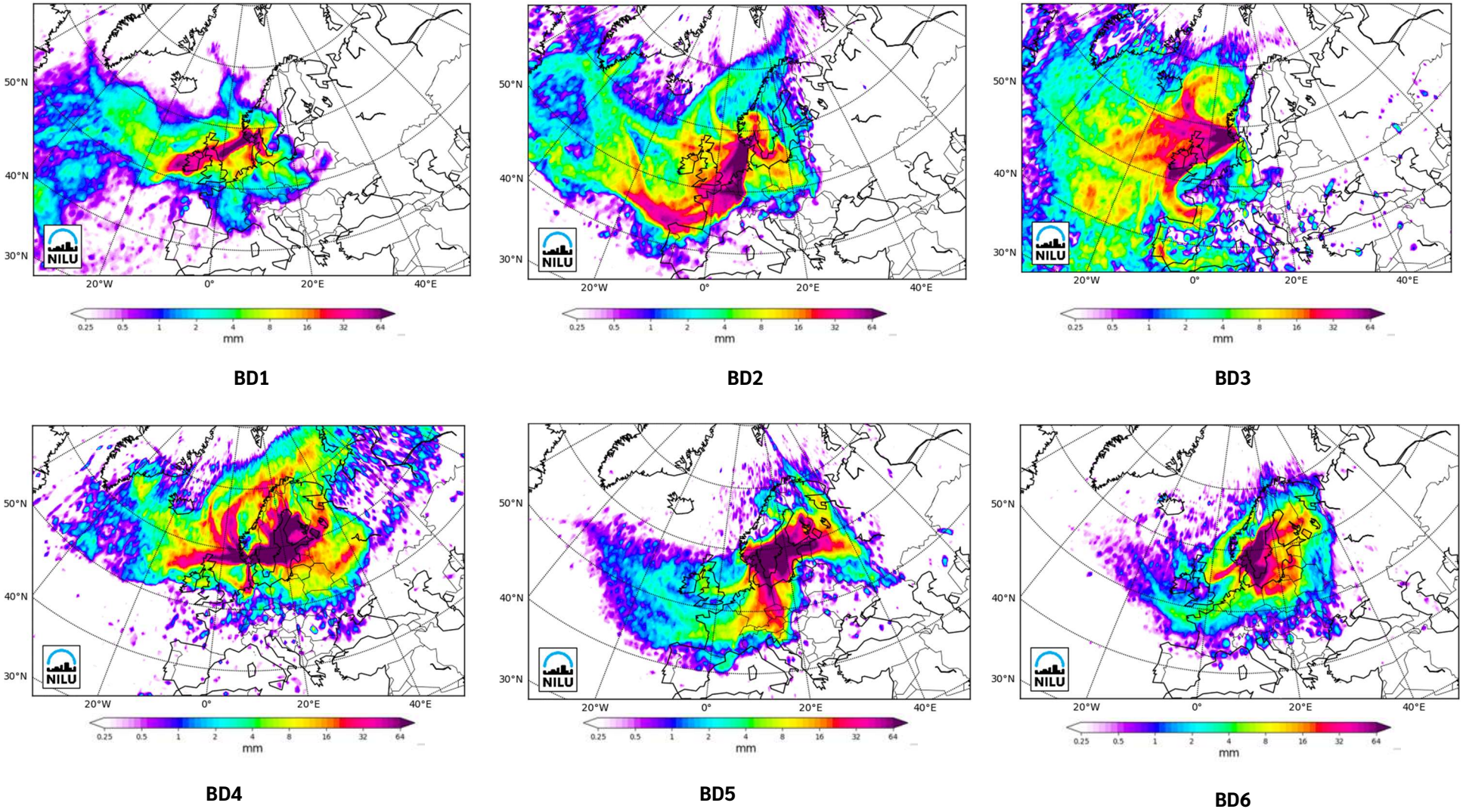

Figure 7. FLEXPART air mass backwards trajectories obtained for deposition samples from Birkenes station.

Another potential source for airborne microplastics can be local emissions, e.g. from industrial activities such as polymer production plants or recycling facilities. In the case of the Birkenes Observatory for example, a PVC production plant is situated approximately 100 km northeast of the monitoring station. While this could potentially be a local source for airborne PVC particles, it is difficult to pinpoint detected microplastic concentrations to such suspected emission points without taking dedicated samples along a spatial gradient for confirmation combined with the evaluation of airmass movements during the sampling period.

It should further be noted that the chemical marker used for the quantification of PVC using Pyrolysis-GC/MS, naphthalene, can also originate from other sources than PVC particles, specifically from soot produced from tyre treads and combustion engines (Goßmann et al., 2021; Goßmann, et al., 2023). Whilst a more specific marker for PVC quantification is currently missing, these results generally need to be considered with care.

The main source for SBR in environmental samples is vehicle tyres, which form tyre wear particles (TWP) or tyre and road wear particles (TRWP) through abrasion (Mattsson et al., 2023). Another SBR source can be sport fields with artificial turf, which use crumb rubber granulate made of end-of-life tyres as an infill. Specifically urban locations generally exhibit high SBR contents in atmospheric microplastic samples due to heavy traffic loads. However, the presence of SBR in two deposition samples from Zeppelin station indicate that, even remote locations with little to no traffic are not exempt from this pollution.

In 2023, the number of particles in the deposition samples from Birkenes and Zeppelin were measured with Raman measurements for the first time in MIKRONOR. However, as the number of detected particles (>20 µm) per sample was low and did not correspond to concentrations measured by py-GC/MS, Raman measurements are not recommended for further analyses of air samples in MIKRONOR, until a lower size detection limit for particles can be achieved. Data and discussion are included in appendix 5.4.1.

3.2 River water samples

River water samples were taken with a manta trawl with a mesh size of 200 µm in five rivers: Alnaelva in the city center of Oslo, Drammenselva in the center of Drammen city, Storelva and Otra in Agder county, and Målselva in Troms County (**Figure 1**). Sampling was more intensive in Alnaelva, with six sampling occasions in 2023, while the remaining rivers were sampled once. Each sampling event consisted of one net blank sample, three atmospheric blank samples and three samples.

The results from the net blanks were compared to mean levels of microplastics per station to ensure that contamination from the net itself was not a major contributor to the results (**Figure 8)**. The net blanks for Alnaelva and Drammenselva were mainly statistically significantly lower (t-test results in appendix 5.4.2) in microplastic levels than the mean values for the respective samples. Exceptions were Alnaelva in November, with high variability in the samples, and December, with low values in the samples. For the rivers Storelva, Otra and Målselva the net blank value was not statistically different from the mean value of the samples, however lower (Målselva net blank = 0 plastic particles). For more statistics, see appendix 5.4.2, **Table 27**. The procedure for sampling ensures that the net blanks were taken first, leading to less contamination in the samples than in the net blanks. Therefore, these estimates represent worst case scenarios estimates.

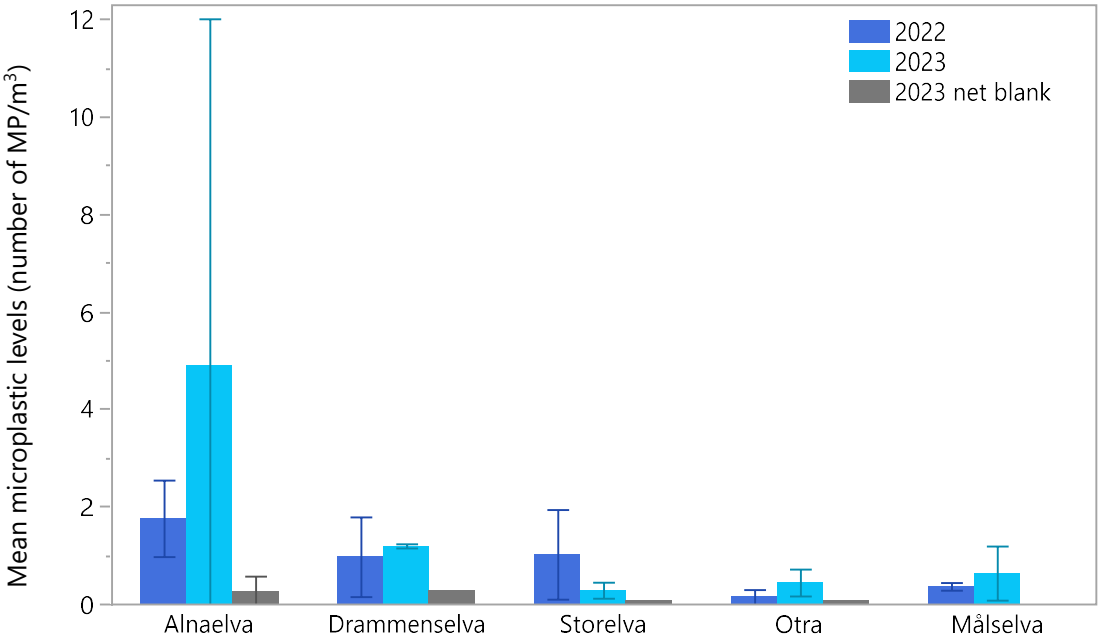

Figure 8. Mean microplastic levels (MP/m^3) in manta net water samples and net blanks per station in 2022 and 2023. Error bars are presented as ±SD. Number of 2023 samples = 3 per station except Alnaelva n = 18. Number of 2022 samples = 3 per station except Alnaelva n = 9. All 2023 values are above LOQ. Net blank value Målselva = 0.

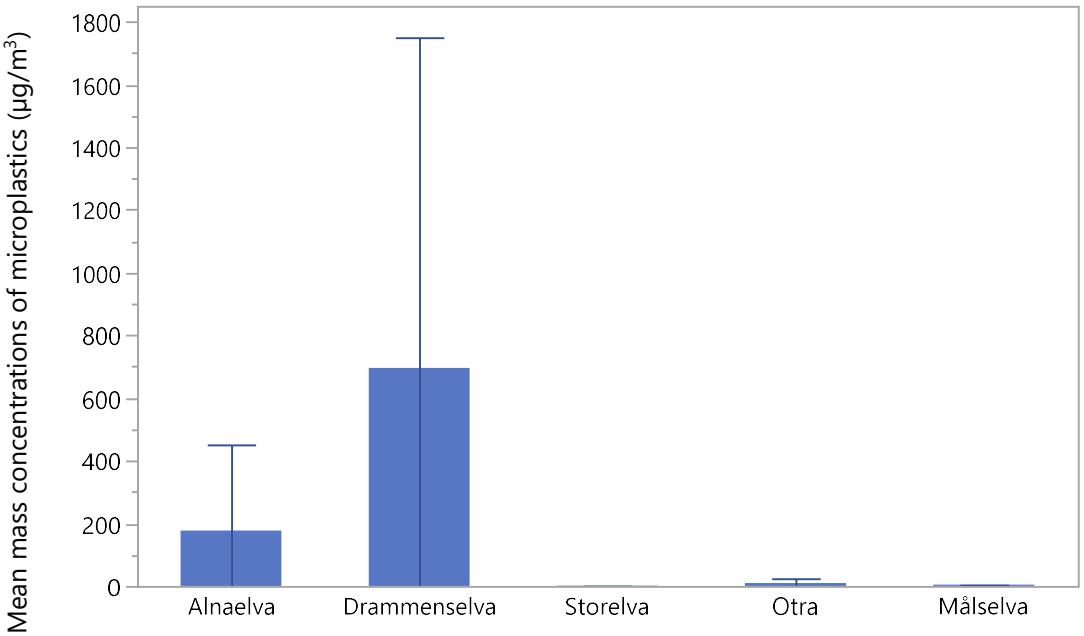

Figure 9. Mean mass concentration of microplastics per river station in 2023 (µg/m^3). Error bars are presented as ±SD. Storelva = 0.67 µg/m^3. Number of 2023 samples = 3 per station except Alnaelva n = 18.

Alnaelva exhibited the highest levels of microplastic particles (as number of microplastics per m^3) among the five rivers (mean concenteration 4.9 MP/m^3 (**Figure 8**), but with significant variations between samples (0.88 – 13.3 MP/m^3, **Figure 10**), which will be discussed in detail below. Other rivers were sampled only once in 2023, raising the question of whether the differences in mean levels between the rivers are due to actual variations in microplastic levels, contamination loads or arbitrary differences related to the timing of sampling. The study indicated that Drammenselva had the second-highest level of microplastic particles, based on 2022 and 2023 year's samples, with three other rivers showing lower levels. The mean mass concentrations (µg/m^3) of microplastics in the river samples were highest in Drammenselva, followed by Alnaelva. The three other rivers had low mass concentrations (**Figure 9**). Microplastic particles collected by Manta trawls have a minimum size of 200 µm, and the distribution of particles larger than 200 µm significantly affects the mass of the particles. For example, a few particles over 1 mm can determine the mass for the entire sample. Therefore, the mass concentrations do not reflect the number of particles in the samples well for the river samples.

To initially assess the temporal variations of microplastic loads (count and mass) in rivers, Alnaelva was monitored on six occasions in 2023 (**Figure 10**). The aim was to collect samples representing dry, wet, and extreme events. However, there are technical limitations on maximum water flow when using manta nets. For instance, the storm "Hans," which hit the Oslo region on August 7– 9th, 2023, along with subsequent heavy rainfall at the end of August 2023, caused significant damage and extremely high flow in Alnaelva, hindering the sampling of the initial floodwater.

The results are not straightforward to interpret. One notable instance was the sampling conducted in November, which exhibited the highest levels, with a mean level of 13.3 MP/m^3 ±16.8 SD. However, the three samples from that occasion exhibited substantial differences in microplastic levels. One of the three samples exhibited a level of microplastics of 32.7 MP/m^3, while the other two displayed levels of 4.4 and 2.9 MP/m^3, respectively (see **Figure 33** for the raw data as MP/sample). The sample with the highest levels of microplastics, contained over 200 particles of polyethylene foam. Rather than representing contamination or a factor that should be excluded from the datasets, this observation aligns with the prevailing understanding of microplastic presence in urban rivers, particularly the heterogenous microplastic levels that can be anticipated in rivers situated in proximity to urban areas (e.g. Hitchcock, 2020; Mani et al., 2015).

This raises the question of the optimal methodology for addressing the inherent heterogeneity of the collected samples. In light of the lack of knowledge regarding the representativeness of the samples to the true annual mean level at the sampling location and in the river generally, we have decided to include the "outlier" from the Alnaelva in our analysis. To obtain reliable estimates of annual mean values from the rivers, it is necessary to implement a significantly higher sampling frequency, given that the variance between samples is as high as was shown in the samples from Alnaelva. Furthermore, the data must be closely coupled to the discharge values in order to weigh levels to discharge, with the ultimate objective being the monitoring of the mean and variation of microplastic levels, as well as yearly discharge of MP from the respective rivers. The sampling events in Alnaelva 2023 are compared with water discharge of two of the Oslo rivers (discharge values from NVE, https://sildre.nve.no) in **Figure 17**, and further discussed in corresponding chapter (3.4).

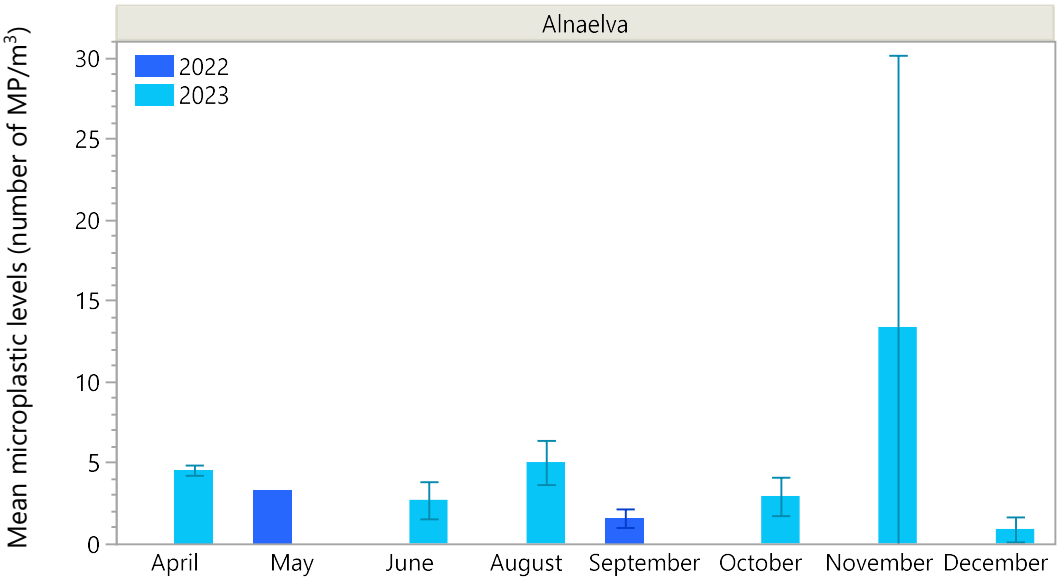

Figure 10. Mean microplastic levels (MP/m^3) in Alnaelva manta net water samples per sampling occasion in 2022 and 2023. Error bars are presented as ±SD. Number of samples = 3 per sampling except May 2022 (n = 1) and September 2022 (n = 8). All 2023 values are above LOQ.

Levels of microplastics in rivers collected with a floating manta net (200 µm mesh size) are known to vary widely between rivers reported worldwide. Our results of 1-5 MP/m^3, are comparable to data from, for example, the Mississippi River in the USA (1.94–17.93 MP/m^3) and the Danube River in Austria (0.32 MP/m^3), while much higher levels have been measured, for example, in a river in Los Angeles, USA and Yangtze River, China (Kumar et al., 2021).

Polymer distribution in river samples (>200 µm)

The distribution of polymer categories in the five monitored rivers is shown in **Figure 11**, and the corresponding total of distribution of polymer categories of microplastic particles in all manta net water samples is presented in **Figure 12**. Polyethylene was the predominant polymer identified in river samples (65 % of all particles found in river samples), especially within the microplastic particles of the Alnaelva and Målselva rivers. Polyester appeared as the second most prevalent polymer (15 %), whereas cellulose acetate was primarily found in Storelva. These results are not surprising since polyethylene is the most manufactured plastic polymer globally and is used in various plastic products, whilst polyester and cellulose acetate are commonly utilized in textiles, with cellulose acetate also being a component in cigarette filters. As shown in **Figure 12**, the levels of microplastics in the samples were considerably higher than in the net blanks. The most common polymer type in the samples -polyethylene, was not present in the net blanks.

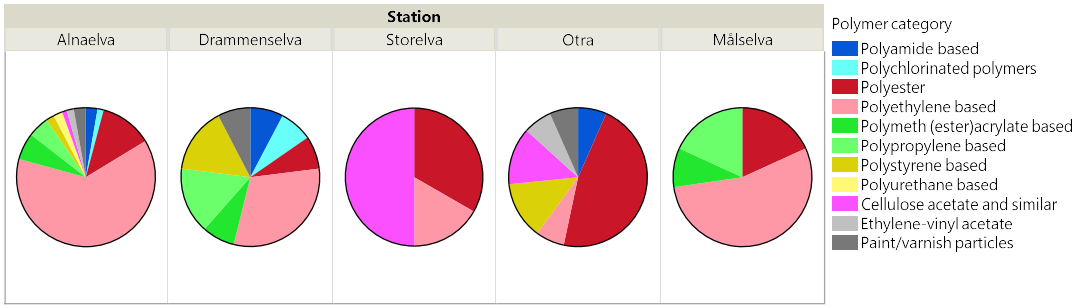

Figure 11. Distribution of polymer categories of microplastic particles in manta net water samples per river in 2023.

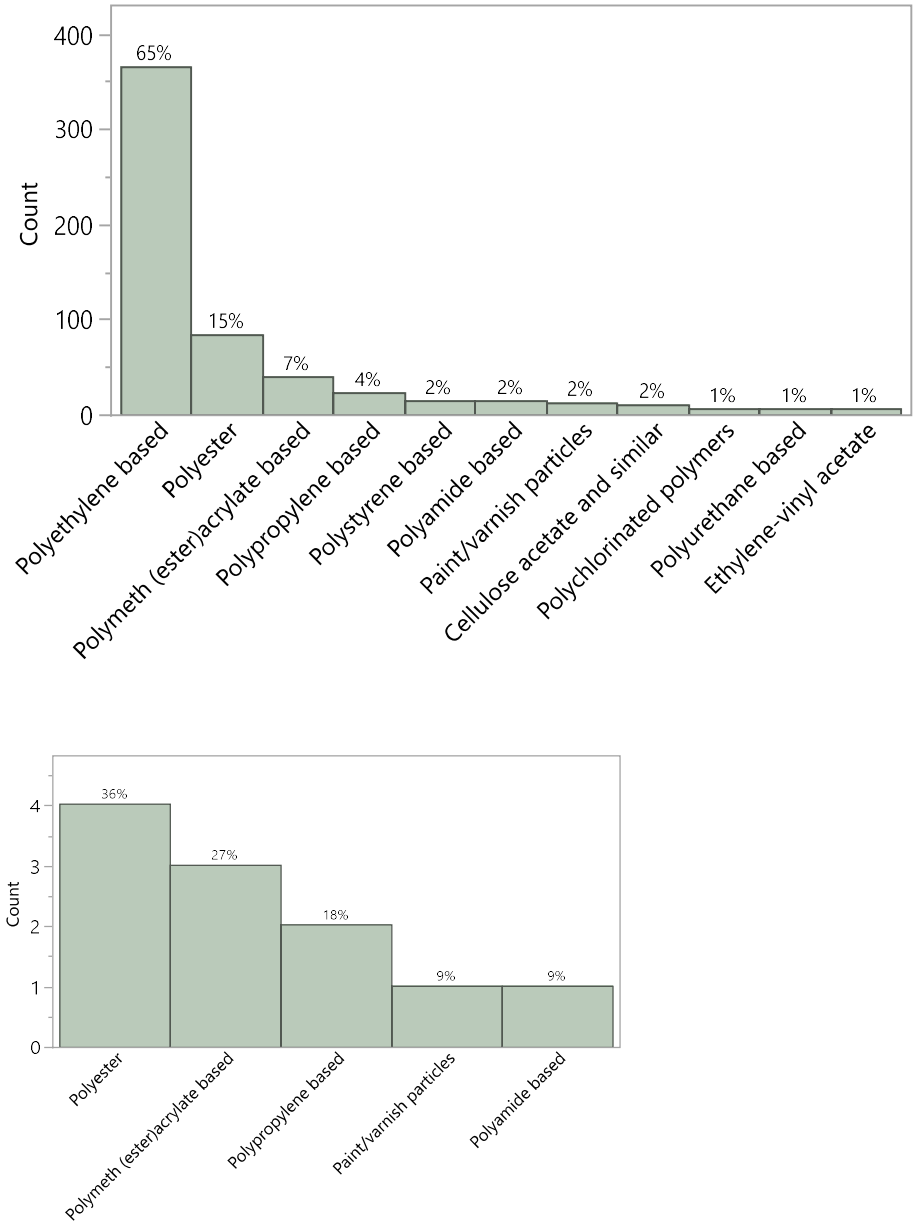

Figure 12. Upper: distribution of polymer categories of microplastic particles in all manta net water samples in 2023. Lower: distribution of polymer categories of microplastic particles found in net blanks in 2023

In the Alnaelva samples, polyethylene represented nearly 70% of all identified polymers (**Figure 13**). One of the November samples exhibited a high number of polyethylene microplastic particles. However, polyethylene was the predominant polymer in all Alnaelva samples, with the exception of the samples collected in August. The August sampling event occurred two weeks following the "Hans" flood in the Oslo region in August 2023. The distinct composition of the August sample (**Figure 13**) could be attributed to altered runoff patterns in the Alnaelva catchment area after the storm event “Hans” and following rainfalls.

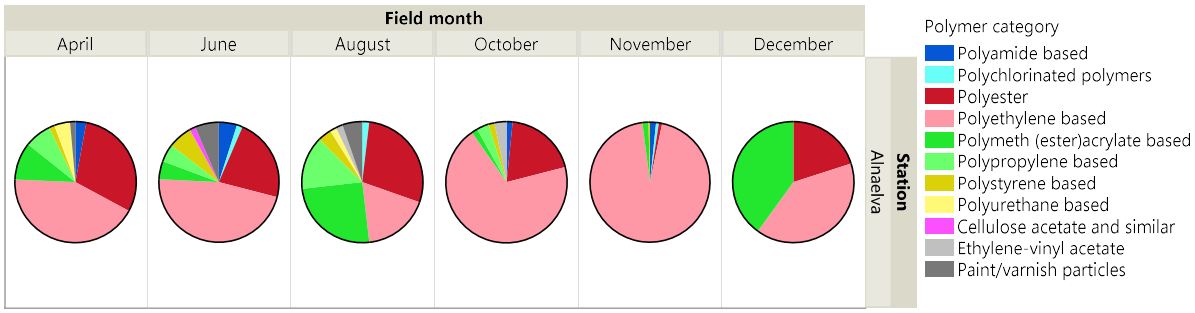

Figure 13. Distribution of polymer categories of microplastic particles in Alnaelva manta net water samples per sampling (month) in 2023.

Other studies have shown that extreme events and heavy rainfall can cause altered and higher microplastic discharges in urban rivers (Hitchcock 2020). Total organic carbon (TOC) concentrations in rivers are known to increase during spring floods and correlate with water discharge (De Wit et al., 2016; Vogt & Muniz, 1997). It would be interesting to look for similar correlations between microplastics (numbers and mass), TOC (particulate -POC and/or dissolved -DOC) and water discharge values in the rivers. The representativeness of a few microplastic samples could perhaps be better understood if they were paired with both discharge and TOC values for the same site and time. In MIKRONOR, TOC was not measured and water discharge data for the Alnaelva from NVE were incomplete for 2023. A table with the microplastic levels measured in MIKRONOR and the closest TOC concentration measurements is presented in appendix 5.4.2, **Table 26**. However, as neither the timing for the discharge values nor the TOC concentrations correspond directly to our sampling occasions, it is not possible to conclude a covariation.

3.3 Surface water samples of inner Oslofjord

The surface water of the inner Oslo fjord was sampled on three occasions in 2023, using a closed system pump that filtered 1 m³ of water through a 50 µm mesh. Samples were collected in June, October, and November (in triplicates). These results were compared to samples taken at the same location on three occasions in 2022 (**Figure 14**). The levels of microplastic particles from the two years overlapped, with both the highest and lowest levels found in 2023. Tyre wear particle (TWP) concentrations were also measured in the same samples both years (for particles 50-300 µm; see method description in Alling et al., 2023). All three sampling occasions in 2023 exhibited significantly lower TWP concentrations than those in 2022 (**Figure 14**).

The reasons for this discrepancy are unknown, but chance plays a significant role in the distribution of relatively heavy TWP in surface waters. TWP has a wide density range (1.2-2.1 g/cm^3, (Son & Choi, 2022; Wagner et al., 2022; Zhong et al., 2024), depending on the mixture between tyre tread, road surface minerals and other traffic-related components. Initially, these particles do not float, but if a recent discharge event is captured, particles may be present; however, over time, TWP particles will settle. Other microplastics may not sink or may sink more slowly than TWP, making the sampling occasion less sensitive to the timing of rainfall or high freshwater discharges. Additionally, rainfall intensity likely influences TWP distribution. As one of the main storage areas of TWP is the road surface and side bank areas of the road, prolonged heavy rainfall could contribute to flushing TWPs away from these areas. Subsequent rainwater may therefore have significantly lower levels of TWP, as well as the increased water flow to the fjord may cause some dilution to the measured concentrations compared to sampling during periods of less heavy rainfalls. This will be discussed in more detail in chapter 3.4, which addresses water discharges to the fjord.

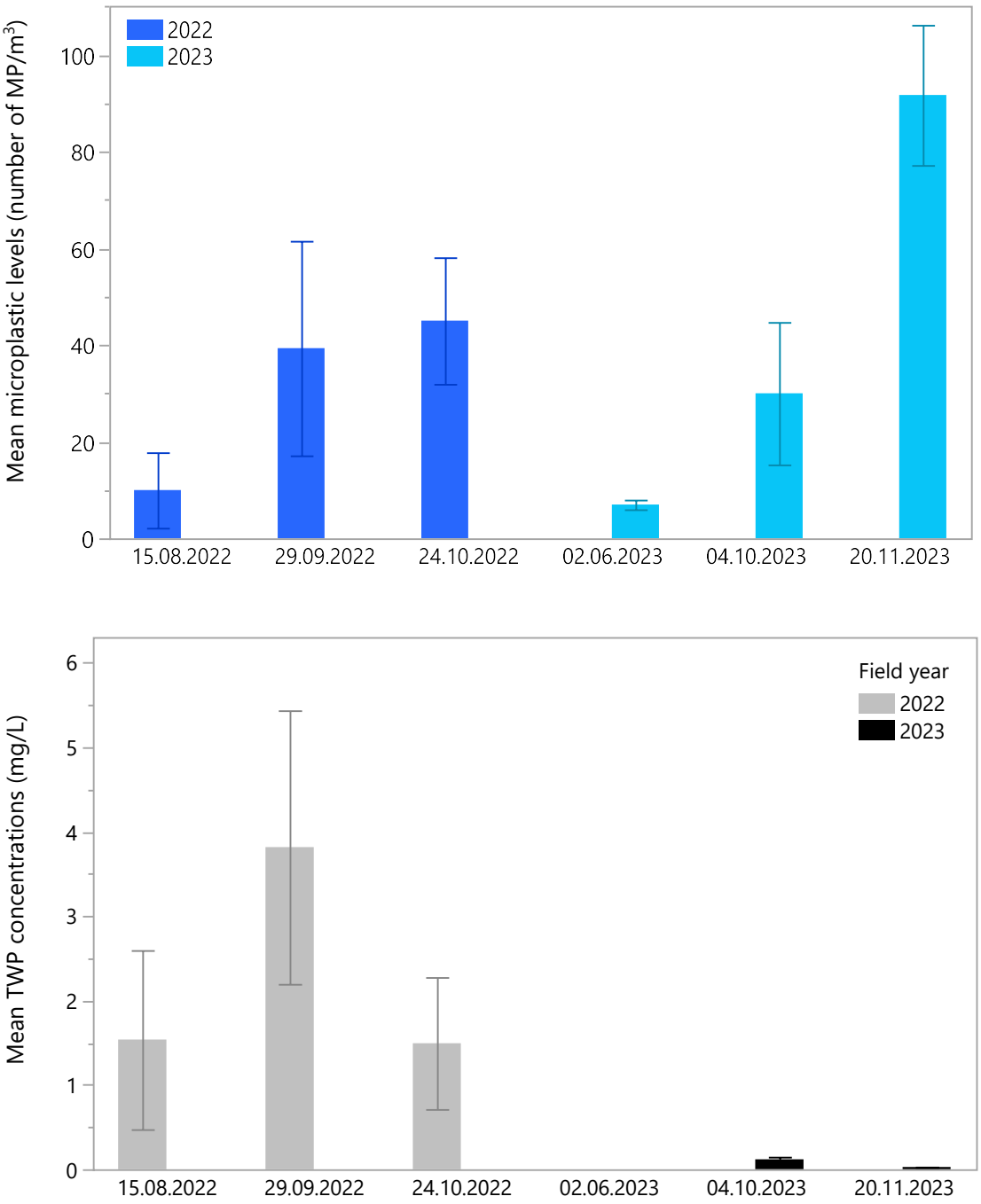

Figure 14. Upper: Mean microplastic levels (MP/m^3, 50 µm-5 mm); **lower**: mean predicted tyre wear particles (TWP mg/L, 50-300 µm), in water pump samples at Akershuskaia in 2022 and 2023. Error bars represent ±SD. All values shown were above the LOQ. In June 2023, TWP analysis results were "not detected" for all three samples. Number of samples per sampling occasion = 3.

In **Figure 15**, the levels of microplastic particles (MP/m³) and their mass (µg/m³) from the three sampling occasions are shown, categorized into three size classes: 50-300 µm, 300 µm-1 mm, and 1-5 mm. The number of small particles (50-300 µm) varied significantly between the sampling occasions, with the highest levels found in November.

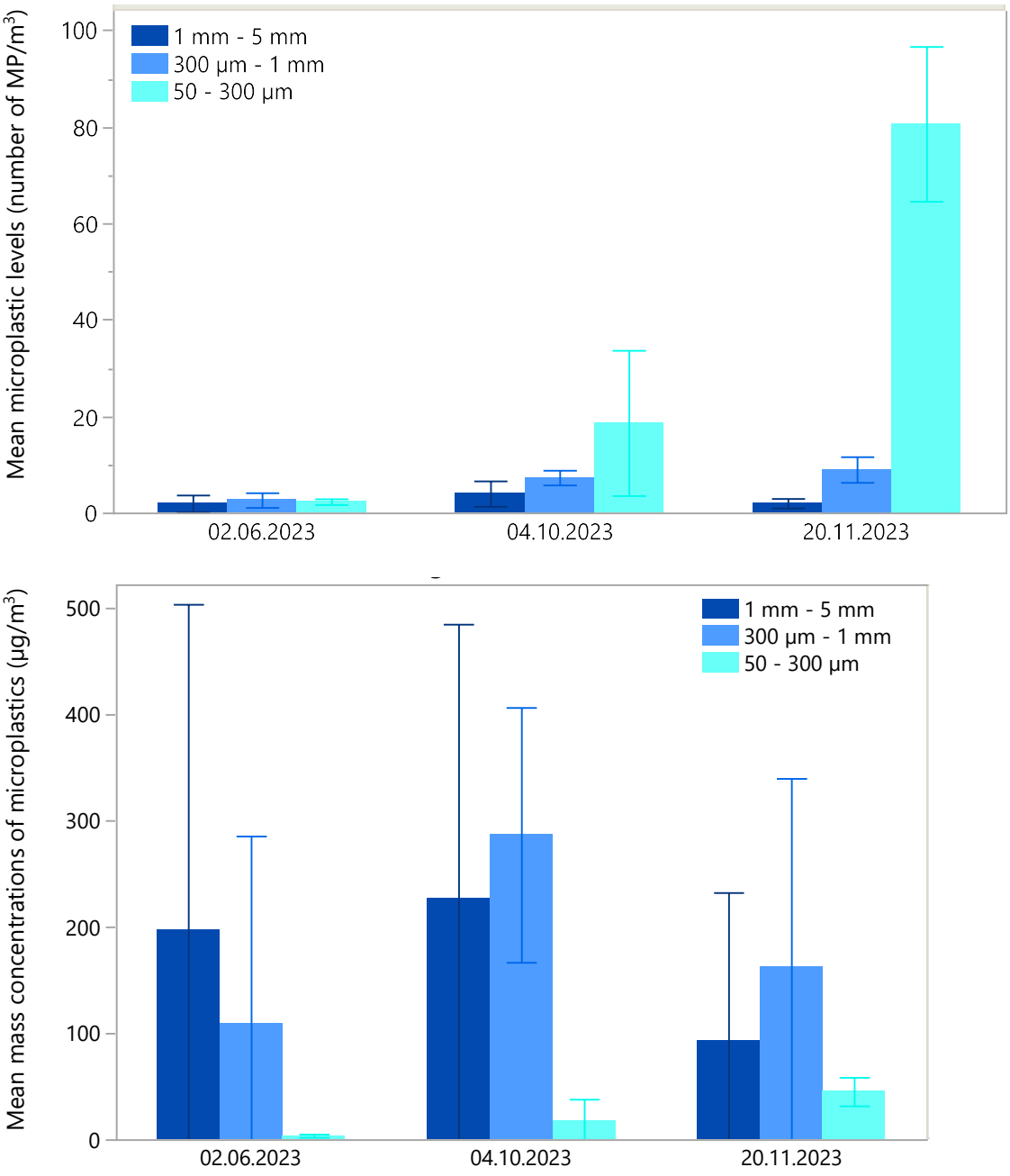

Figure 15. Upper: Mean microplastic levels (MP/m³) and lower: mean weight (µg/m³), per size class in water pump samples at station Akershuskaia in 2023. Error bars = ±SD. Number of samples per sample occasion = 3.

The mass concentration of particles exceeding 300 µm was found to constitute the majority of the microplastic mass in the surface waters samples of inner Oslofjord, even though the smaller particles dominated the second and third sample occasion by numbers of particles.

Polymer distribution in surface water samples from inner Oslofjord

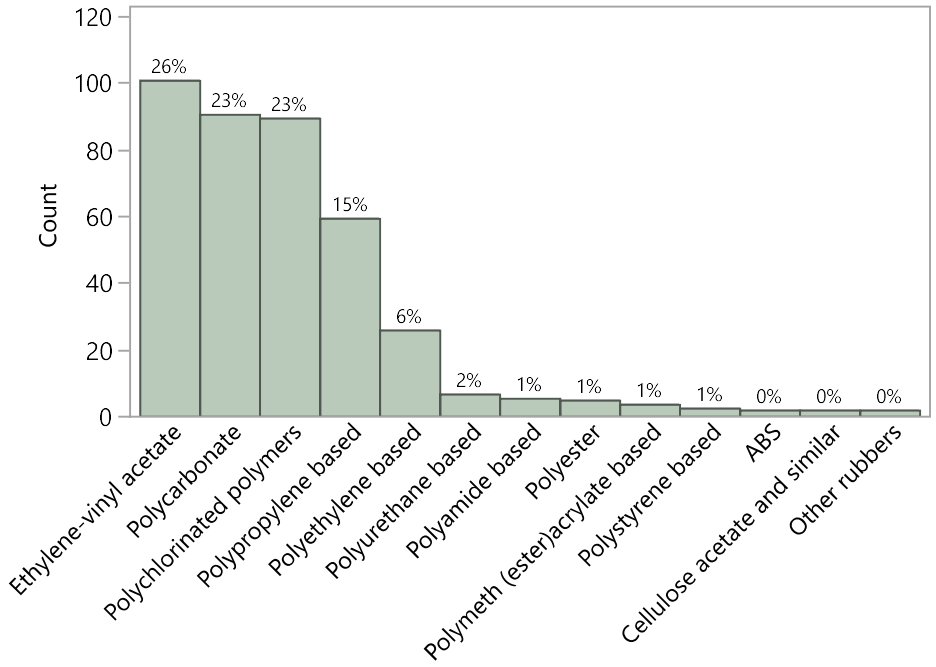

Figure 16. Distribution of polymer categories of microplastic particles in water pump samples at Akershuskaia, Inner Oslofjord, in 2023.

Ethylene-vinyl acetate, polycarbonate, and polychlorinated polymers dominated the surface water samples from the inner Oslofjord (**Figure 16**). These polymer categories are different from the samples from the Alnaelva, which were dominated by polyethylene, indicating that the Alnaelva might not be a main source of microplastics to the inner Oslofjord waters. However, all three polymer categories are widely used, making it difficult to pinpoint their specific sources.

3.4 Comparison of river discharge levels and microplastic levels in river and surface samples from the inner Oslofjord

The sampling campaign in 2023 aimed to achieve two main objectives:

1. Conduct river sampling and surface water sampling from the inner Oslofjord close in time, preferably sampling the river first followed by the fjord.
2. Capture both dry and wet conditions.

In the **Figure 17**, microplastic levels (MP/m^3) in Alnaelva manta samples (>200 µm) are compared with corresponding microplastic levels (presenting only number of particles >200 µm) in the inner Oslofjord surface samples at Akerhuskaia. This comparison is presented alongside water discharge data from two Oslo rivers, Alnaelva and Akerselva, to examine possible impacts of heavy rainfall and variable discharge levels on the microplastics results in 2023. It is important to note that Akerselva is a regulated river. Although it potentially represents a significant source of microplastic particles to inner Oslofjord, its discharge pattern does not necessarily show the peak from the first flush of water occurring during heavy rains, which affects not only the Alnaelva, but also all urban stormwater discharges into the Oslofjord.

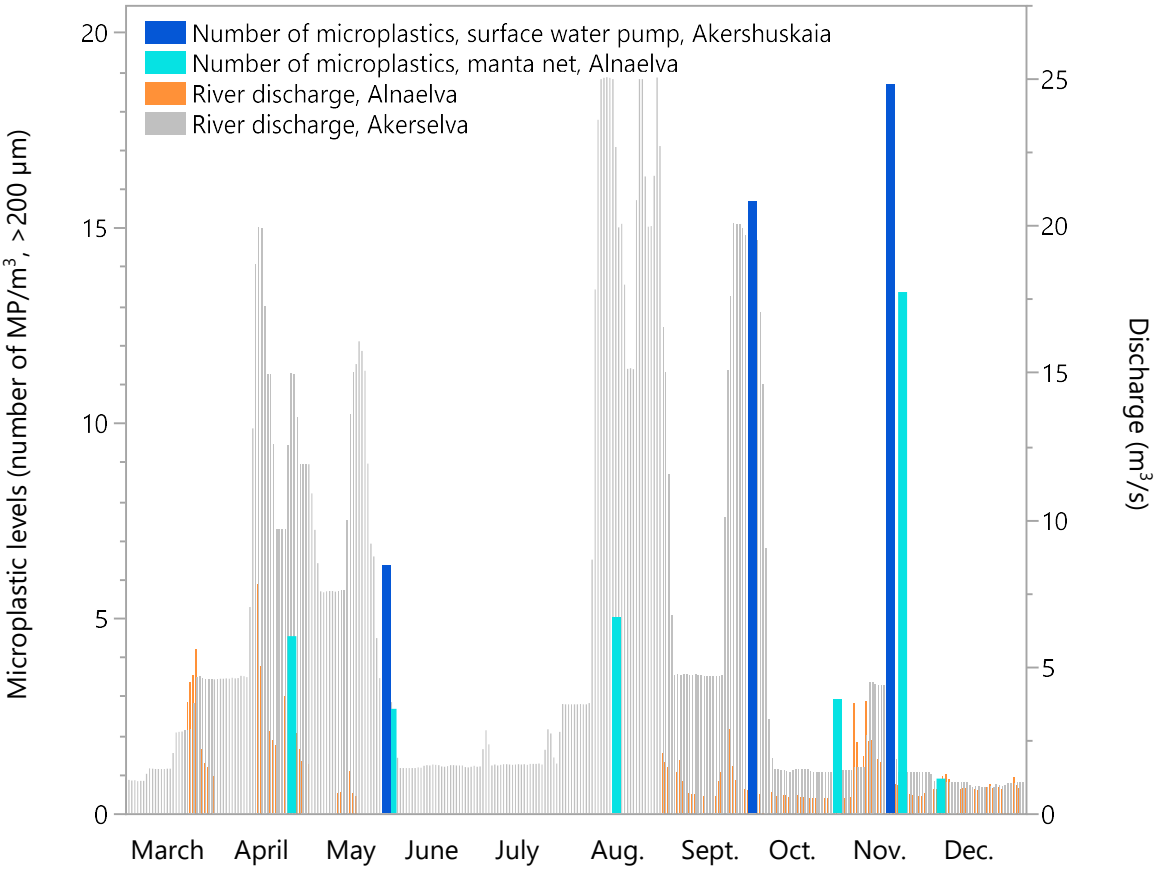

Figure 17. The 2023 microplastics results (MP >200 µm) for the manta nets in the Alnaelva and the inner Oslofjord surface water pump at Akershuskaia, combined with water discharge in two Oslo rivers. Number of microplastic samples per sample occasion = 3. Due to missing discharge values for Alnaelva during certain periods of 2023, we included discharge data from the larger, regulated Akerselva to illustrate the general discharge pattern in the Oslo area during 2023. Source: NVE: Kart | Sildre (nve.no)

In general, the levels of microplastic particles were higher in the fjord than in Alnaelva, suggesting that this river is not a major source of microplastic particles to the fjord; otherwise, a dilution of the levels would have been expected. It should be noted that the sampling was conducted with two different samplers -Manta net in the river and water pump in the fjord. We have extracted the number of particles > 200 µm found in the fjord samples, to make the results comparable. However, some caution should be applied when drawing detailed quantitative conclusions, due to the differences in the sampling devices. The August samples from the river were collected after storm “Hans” (an extreme weather event) but before the second August storm, which had an equal or greater impact on discharge levels in the Oslo region. Due to subsequent extreme weather conditions in August and September, sampling of the Oslofjord could not be conducted until early October, following additional floods at the end of September. The levels found in the fjord at this sampling occasion may represent an integrated value of microplastic levels, resulting from the multiple heavy rainfalls during August and September. The river sample from October on the other hand, was taken at the end of a relatively dry October, reflecting lower levels of microplastic levels. The highest levels of microplastic particles for both Alnaelva and the fjord were found in the November samples, which were taken directly after significant rainfalls at the end of October. However, it should be noted that the mean value of the three river samples represents two samples with relatively low levels and one extreme value (see Chapter 3.2.1 "River water samples" for a discussion on this particular sample).

TWP concentrations (see **Figure 14**) in 2023 were highest in the October samples from the fjord. This might indicate that the sampling occurred shortly after the last rainfall, allowing the heavy TWP particles to remain in the surface waters. In contrast, during the June and November sampling occasions, the time between the last heavy rainfall and the sampling was likely too long to capture the TWP that had been discharged into the fjord. The timing between rainfall/flood events and sampling occasions could explain the significant differences in TWP concentrations observed between 2022 and 2023. However, the relationship between rainfalls, river discharge, and TWP particles for the 2022 sampling campaign is not known.

3.5 Coastal and open sea water samples taken with the FerryBox system

Microplastics were sampled at three cruises with Hurtigruten ferries in 2023 with a filter system with a 100 µm mesh size, at a depth of approximately 4-5 m. First cruise between Åndalsnes and Ny-Ålesund (September 11.-17.), second cruise between Bergen and Skogshamn (October 21.-27.) and third cruise between Bergen and Ålesund (December 8. -15.). The FerryBox system enables large volume low cost microplastic sampler consisting of a filter holder allowing large sampling volumes (up to 10 000 L) to enable sampling down to background levels.

During the initial cruise, microplastic levels ranged from 0.05 MP/m^3 to 0.8 MP/m^3 (**Figure 18**), however, several results are below LOD and most of the results are below LOQ, and caution is advised when interpreting both the patterns and precise levels. The open waters between mainland Norway and Svalbard recorded the lowest levels. Only a few of the samples collected across three cruises showed elevated microplastic levels, indicating that there is little microplastic over 100 µm in these marine areas. Nonetheless, these levels were significantly lower than those found in the inner Oslofjord for particles sized between 100 µm and 5 mm **(Figure 15 and Figure 42**). The sample collected along the transect between Tromsø and Sørøya showed the highest levels, also marking the peak level among all FerryBox samples from the 2023 sampling.

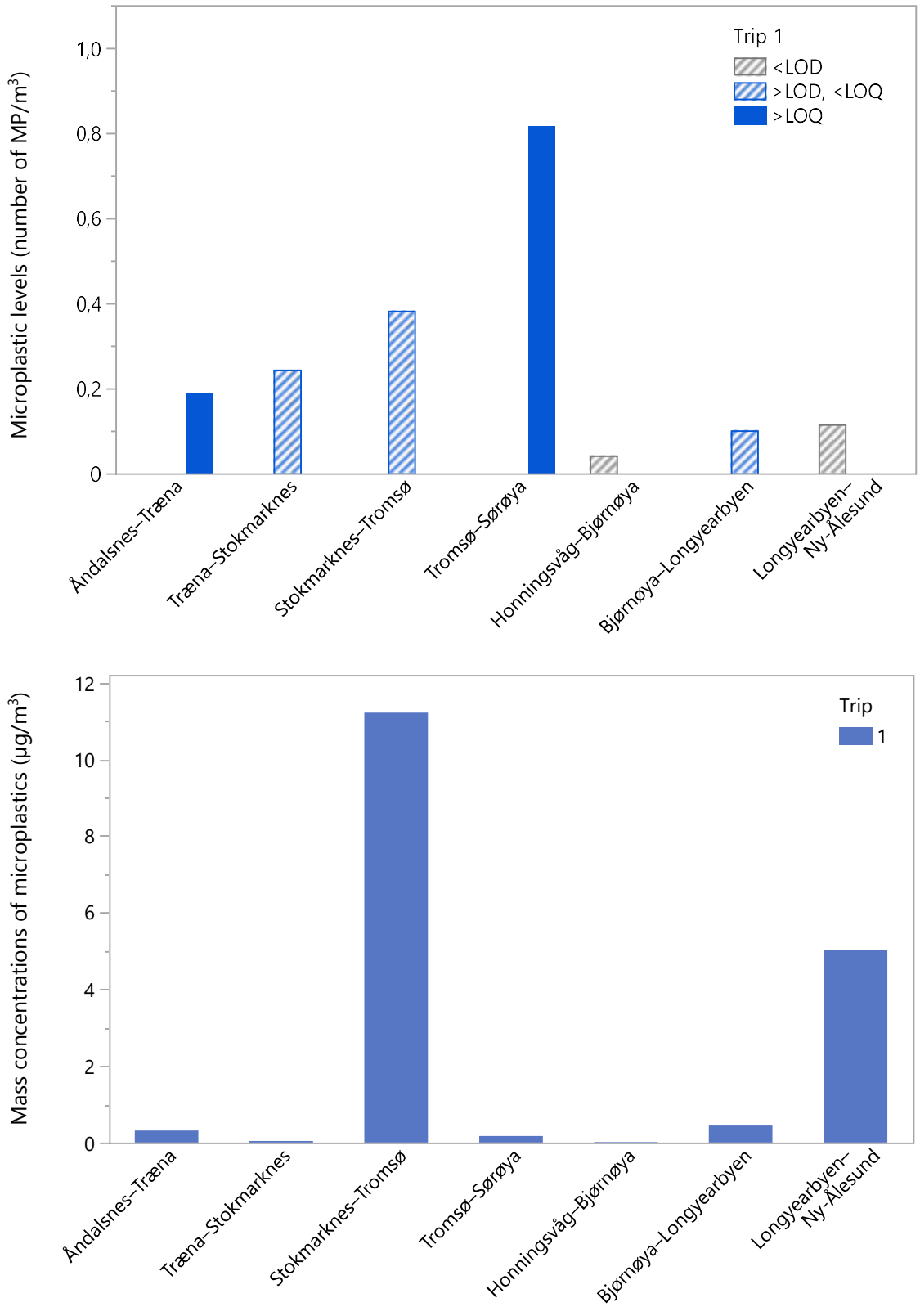

Figure 18. Upper: Microplastic levels (MP/m^3) in FerryBox water samples per transect on trip 1 in 2023, particle size >100 µm and one sample per transect. All values except Åndalsnes-Træna and Tromsø-Sørøya are below LOQ. Lower: Weight of microplastics (µg/m3) in FerryBox water samples per transect on trip 1 in 2023.

Samples from the second and third cruises showed low microplastic levels, ranging from 0 MP/m³ to 0.3 MP/m³ (**Figure 19**). All samples fell below the limit of quantification (LOQ), and some were also below the limit of detection (LOD). Consequently, these results should be interpreted with caution. The findings from all three cruises were lower than those found for the FerryBox samples in the outer Oslofjord, sampled with the Oslo-Kiel ferry in 2021 and 2022 and reported in (van Bavel, et al., 2022, and Alling et al., 2023), showing the presence of low microplastic levels in the >100 µm size fraction in the open waters off the Norwegian coast and in the marine waters between the mainland and Svalbard.

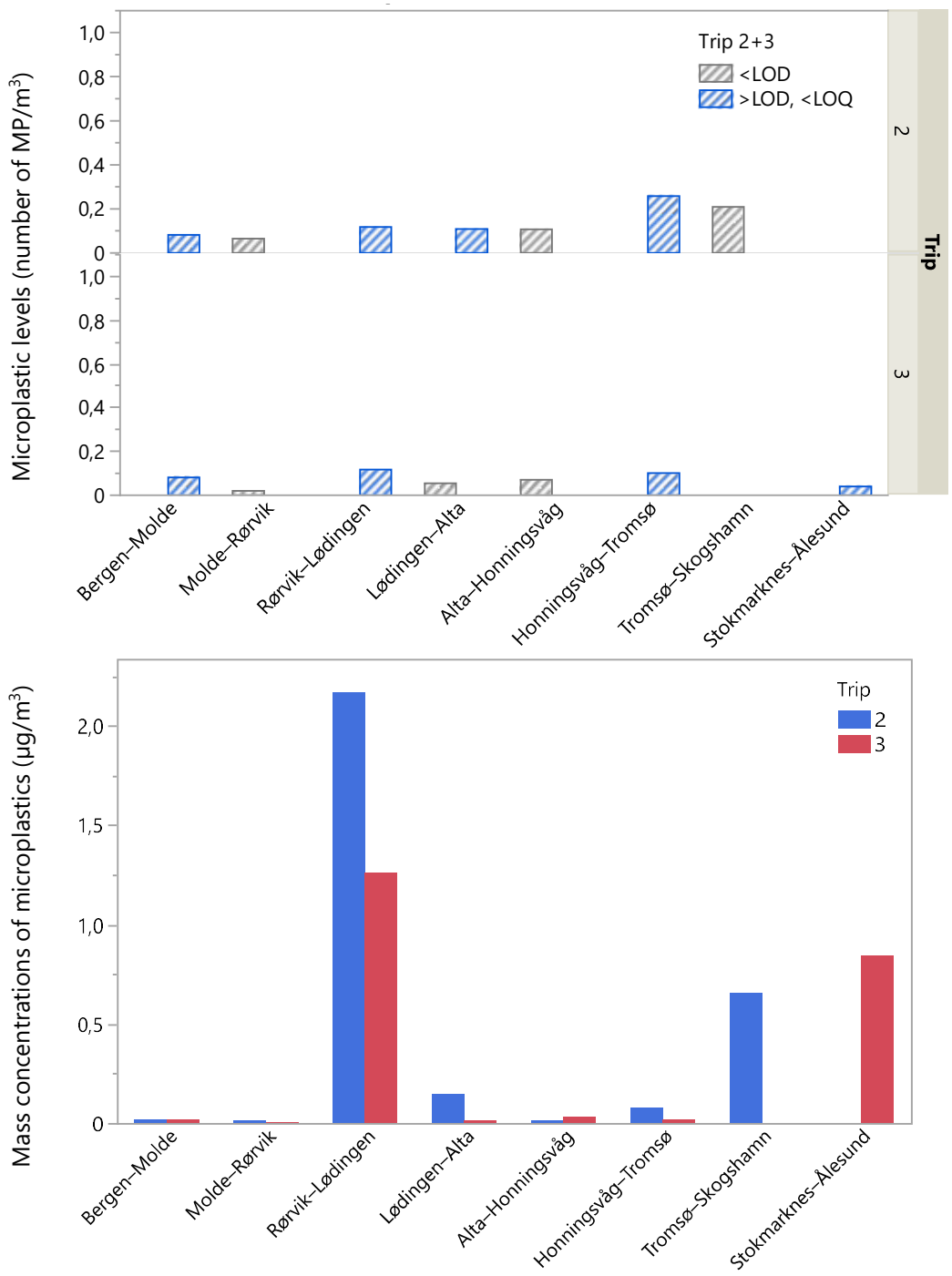

Figure 19. Upper: Microplastic levels (MP/m³). Lower: Mass concentrations of microplastics (µg/m³), in FerryBox water samples per transect on trip 2 and 3 in 2023, particle size >100 µm and one sample per transect per trip. Value trip 3, Tromsø-Skogshamn = 0. Stokmarknes-Ålesund not sampled on trip 2. All values are below LOQ.

3.6 Vertical plankton nets

Vertical plankton nets were deployed at 8 stations with between 3 and 36 samples per station in 2023 (**Figure 20**). Mean levels ranged from 0.08 MP/m^3 (± 0.08 SD) to 3.14 MP/m^3 (± 1.14 SD). There were larger variations of levels of microplastics per volume for the lakes compared to the coastal samples. Levels of microplastic particles were in general very low, and net blank levels werealmost in the same range as the samples, for all types of microplastics (different polymers and fibres as well as fragments). Net blanks were performed before sampling each station. Net blanks are supposed to represent background contamination at the sampling site but can be difficult to replicate sampling conditions and tend to produce elevated numbers of microplastics. This is especially the case when net rinsing must be performed in situ rather than using an external body of (pre-filtered) water. To reduce the influence of field contamination, all samples where the number of particles in blanks exceeded the number in the samples were excluded from further analysis.

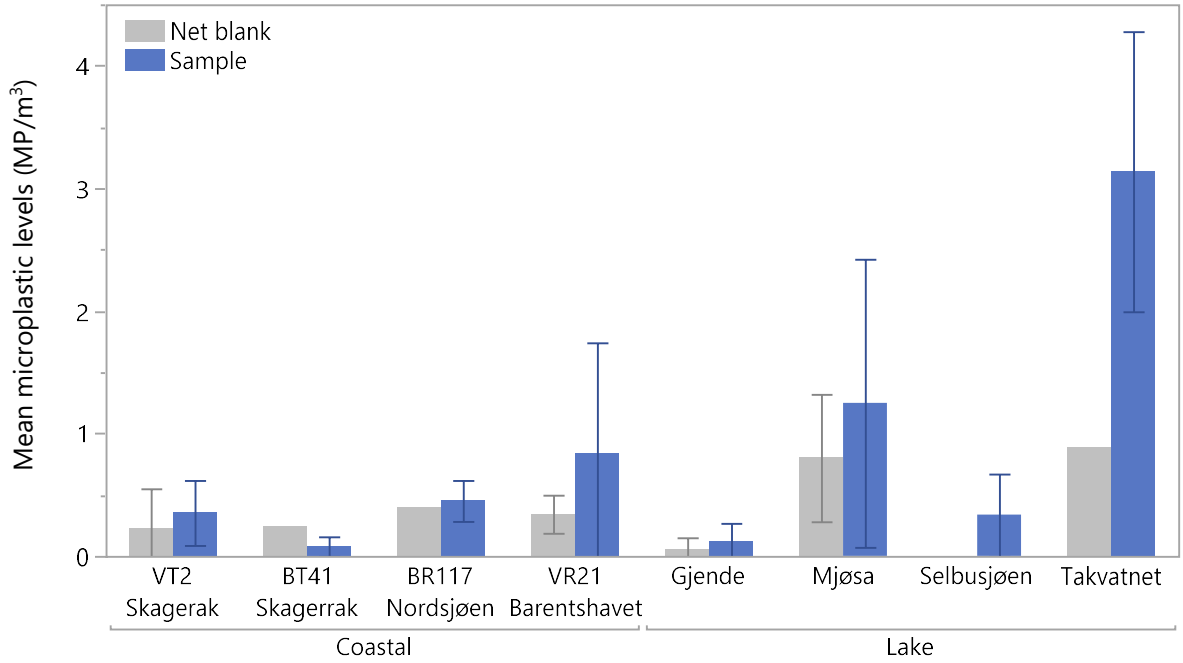

Figure 20. Mean microplastic levels (MP/m^3) in plankton net water samples per station in 2023. Error bars showing ±SD. Number of samples per station: BR117, BT41, Selbusjøen, Takvatnet = 3; VR21 = 36; VT2 = 21; Gjende = 9; Mjøsa = 17. Mean value of net blanks in grey bars. Standard deviation is given where number of net blanks per station is more than 1. Net blank value Selbusjøen = 0. All sample values above LOQ.

Sampling with vertical plankton nets assumes sampling starts at depth and transverses a predetermined distance (50 m) to the surface. The challenge with this approach is that microplastics generally float in the surface waters with some vertical fluxes occurring (Pakhomova et al.,2024, in press; Zhdanov et al., 2023). By sampling with a vertical plankton net, only a small proportion of the surface water is therefore sampled (with the diameter of the net mouth). Furthermore, the net starts sampling at deployment and will likely capture particulate matter during decent before hauling. Given that most of the water sampled are likely to have far fewer microplastics, there will be dilution of any observed microplastics from the surface waters. Therefore, producing values that underrepresent the actual level of microplastic

contamination in surface waters, without giving a representative value for deeper parts of the water column.

The use of vertical plankton nets for monitoring microplastics is not recommended for further monitoring. This is in accordance with international guidelines that point to manta nets, or other nets towed in the surface waters (with smaller mesh sizes). Other methods are available to monitoring surface waters, including the manta net, which has undergone significant sample design testing and now has international best practise (AMAP, 2021; Martin et al., 2022; Michida et al., 2023). High volume pumps or underway sampling devices are an alternative sampling approach which allows sampling of smaller microplastics at varied depths. However, each method has its strengths and weaknesses, see further information under FerryBox and Surface water pump sections.

Results for each sampling occasion, as well as mass concentrations, and polymer types in both samples and net blanks are shown in appendix 5.4.5.

3.7 Blue mussels

Blue mussels were collected from the same six stations in 2023 as in 2022, and the results are displayed in **Figure 21**. The levels of microplastics were below the Limit of Quantification (LOQ) for all samples, with only a few samples having values above the Limit of Detection (LOD). This was also the case for the 2022 samples, as reported in Alling et al., 2023. LOD and LOQ were determined as MP/sample, as described in appendix 5.1. QA/QC. The Kristiansand samples, where the blue mussels collected in 2023 were extremely small, displayed high estimated levels (expressed as MP/g dw). The few particles found in these samples (2-7 MP particles/sample), when normalized to the low sample weights, gave relatively high levels, but these results are still under the LOD. Consequently, these results should be interpreted with caution.

The TWP concentrations were only detectable in two of the three replicates from Kristiansand (**Figure 22**). The results are over LOQ for our method, but the actual concentration (in mg/g dw) should be interpreted with caution, as the samples from Kristiansand were very small (small total weight of the mussels), and small errors in the dry weight might cause large differences in calculated concentrations

The distribution of microplastic particle sizes is depicted in **Figure 23**. Across all 18 samples, the total count of particles was approximately 100. Over 90% of the particles detected fell into the smaller size fraction (under 300 µm).

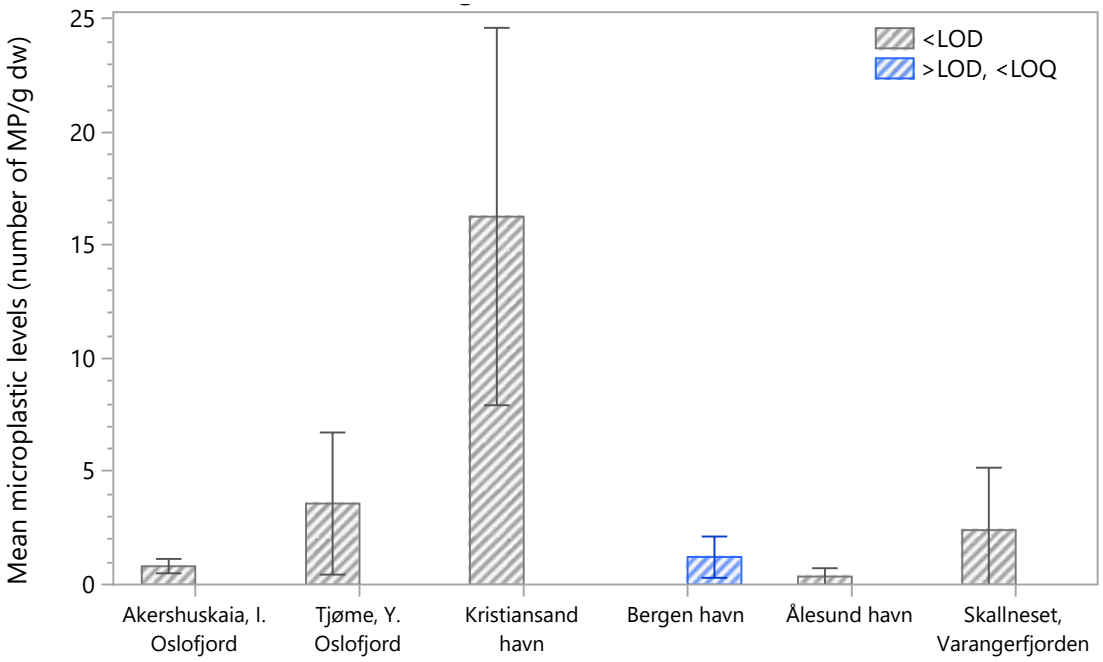

Figure 21. Mean microplastic levels (MP/g dw) in blue mussel stations in 2023. Error bars = SD. Number of samples = 3 per station.

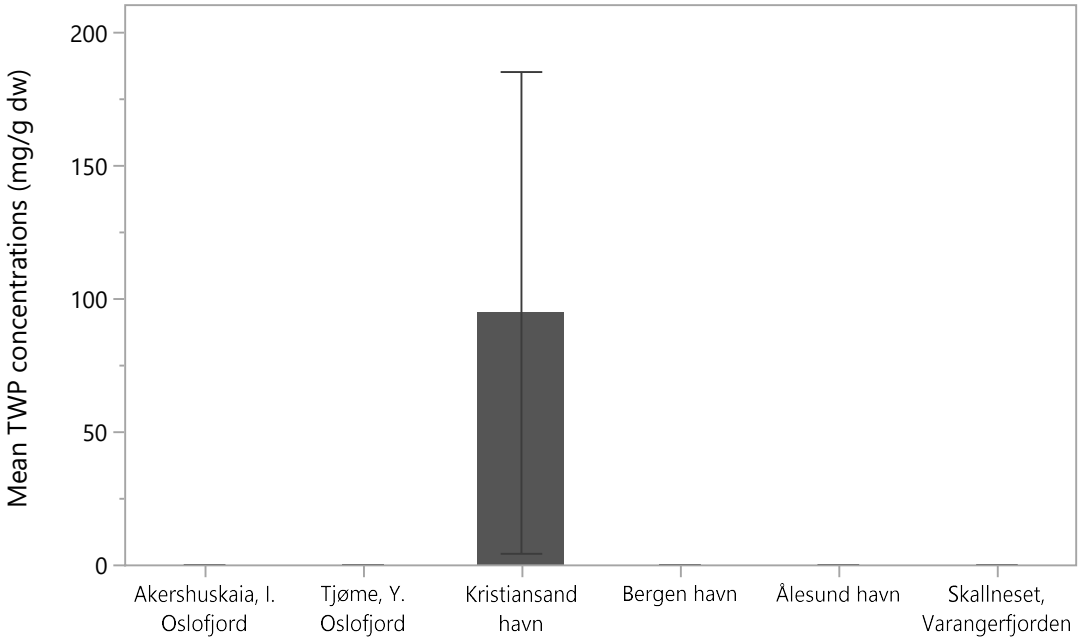

Figure 22. Mean concentration of tyre wear particles (TWP) in mg/g dry weight of blue mussel samples from six stations in 2023. Number of samples = 3 per station. For stations without value, analysis result was “not detected”.

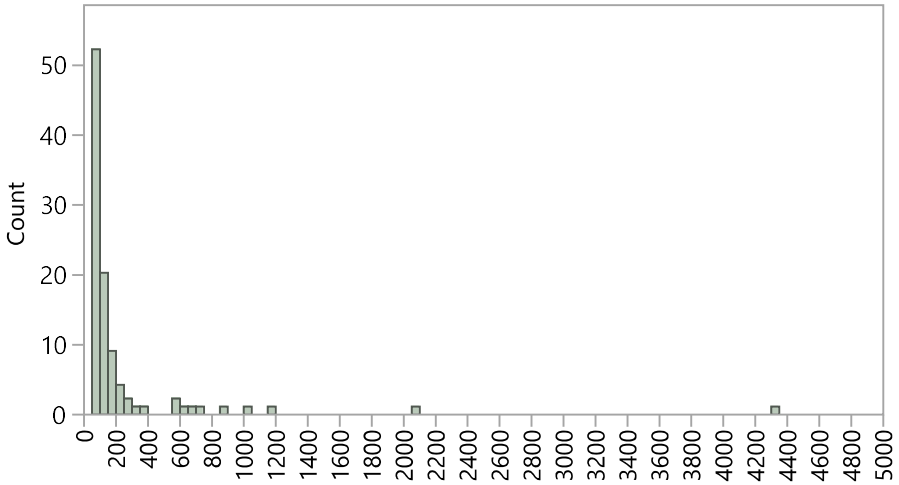

Figure 23. Distribution of microplastic particle sizes (µm) in all blue mussel samples in 2023.

The polymer compositions of the microplastic particles found in samples from each station are shown in **Figure 24**. The differences in the relative contribution of different polymers might simply reflect the low number of particles found in total. These results should be interpreted with great caution, as all blue mussel samples, except those from Bergen, had microplastic levels below the detection limit. In other words, we are uncertain whether these particles originated from real environmental exposure or from contamination during the sampling preparations.

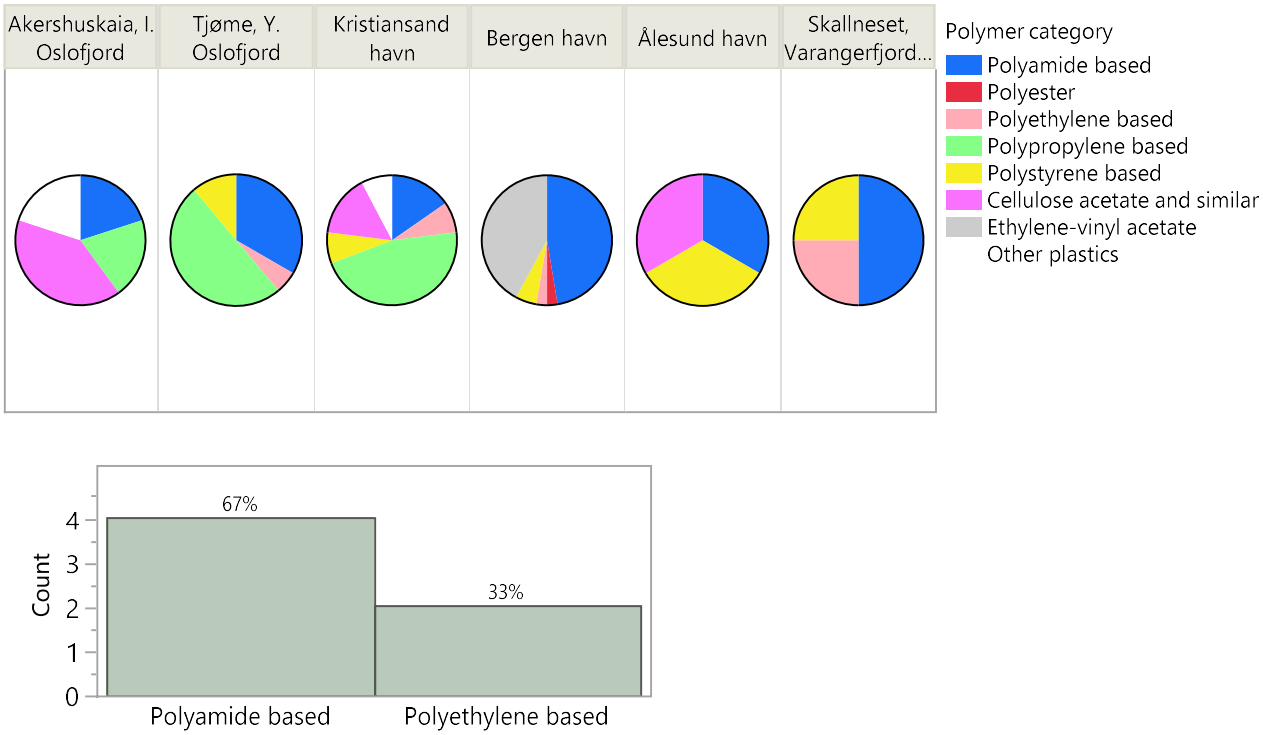

Figure 24. Upper: Distribution of polymer categories of microplastic particles per station in blue mussel in 2023. Lower: Number of microplastic particles and polymer types in the lab blanks for blue mussels.

The small number of larger particles in the dataset poses a statistical problem and makes it difficult to interpret differences between stations and years for this size class. On the other hand, the smaller fraction has a higher uncertainty related to the analytical method (for method validation see Alling et al., 2023).

We consider that the observed variations in the blue mussel datasets between years and stations could be attributed to random chance and the disparity in sampling locations at a very local level, such as the mussels' exposure to various types of microplastic particles, the depth at which they were collected, and their age.

Determining whether variations between stations and years reflect actual environmental changes or are merely the result of chance, or changes in method (mass/composite), is challenging. Notably, this year's samples from Akershuskaia showed low numbers of particles (<1 MP/g dw) and non detected TWP concentrations, despite having high concentrations of TWP, and higher microplastic levels in the previous year. In contrast, Kristiansand recorded the highest count of microplastic particles (16.3 ± 8.3 SD MP/g dw) and TWP concentrations (142 ± 54 SD mg/g dw) in 2023.

It may be beneficial to increase the number of samples collected at each station or to implement additional measures to achieve more consistent sampling across years. The decline of blue mussels along the Norwegian coast presents a challenge for the sampling program, as it becomes difficult to obtain a sufficient number of mussels, particularly those of the size required for microplastic analysis.

3.8 Beach sediment samples

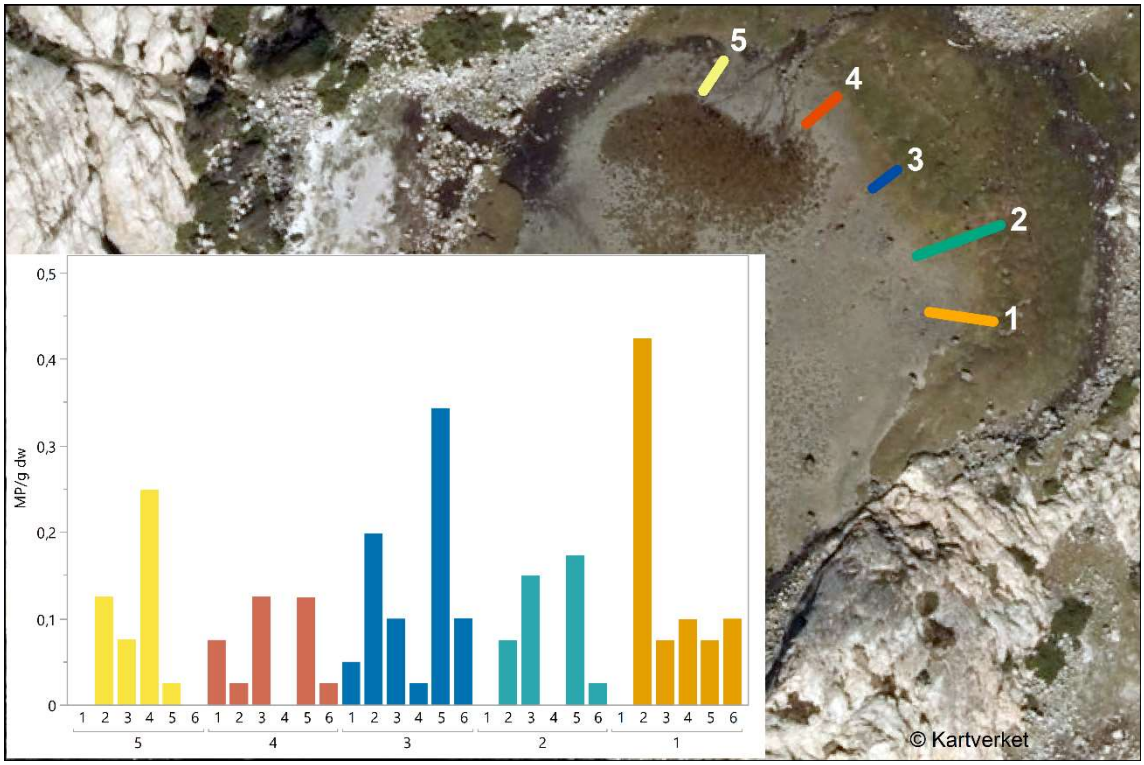

Figure 25. Microplastic levels (MP/g dw) in beach sediment samples per transect (5-1) at Akerøya in 2023. All values were below LOD except one, which was below LOQ.

Microplastics were assessed on the OSPAR beach on Akerøya in 2023. Samples were collected using a partially stratified and randomized sampling design to allow for investigation of the potential influence of position on the shoreline. Five transects were laid with equal spacing apart, from the last high tide mark to the water line (**Figure 25**). Six samples were collected per transect totaling 30 samples. The position of each sample was determined by random number generator, both for position on the transect and position within the quadrat. See appendix 5.2 for full field protocol, especially randomized sampling design (**Figure 36**).

Each transect was tested for normality. No significant differences were found within any transect ($P > 0.05$). Transects (T1-T5) were then compared to one another (**Figure 26**). There was no significant difference between the mean ranks of any pair (Kruskal-Wallis, $H = 1.7228$, $P = 0.7866$). Note that the test power was low due to sample size (n=6/transect).

Based on this assessment, it was inferred that all samples should be considered representative of the whole beach and transects were summed together. The average number of microplastics per g (d.w.) was calculated as 0.095 MP/g dw (± 0.101 SD.) on Akerøya beach in 2023. This could be compared to a beach study from four beaches in Adventfjorden and Isfjorden with levels of 0-3 MP/g dw (Lloyd-Jones et al., 2023). Note that the authors noted high variation at all sites but there may have been patterns linked to proximity to human activities. Such an assessment is not possible with the current data given that we performed high intensity sampling on a single beach. When comparing our data to previous works (table

4), at first glance, all studies were within the same range as reported as the present investigation. However, methods had similar but not directly comparable steps (some level of digestion and/or density separation with particle confirmation using FTIR) and therefore the data comparison should be used with caution.

Microplastics were found in 24 out of 30 samples from Akerøya, ranging between 0-17 particles per sample (LOD = 15). Smaller microplastics (50-300 µm) dominated the confirmed plastics, followed by those within the 1-5 mm (18.3 %) and 300 µm-1 mm (13.9 %) size classes (**Figure 27**). Particles were categorized as fragments (80.9%) and fibres (19.1%).

A total of 115 microplastics were identified across all samples. The FTIR analysis indicated that the most common polymers found were polypropylene (PP, 30.4%), polyethylene (PE, 25.2%) and polystyrene (18.3%) (**Figure 28** and **Figure 56** in appendix). In the lab blanks, the particles found were dominated by polyethylene and polyamide, indicating that particles found in the samples were not solely originating from contamination, but the results should be interpreted with caution (see **Figure 30**).

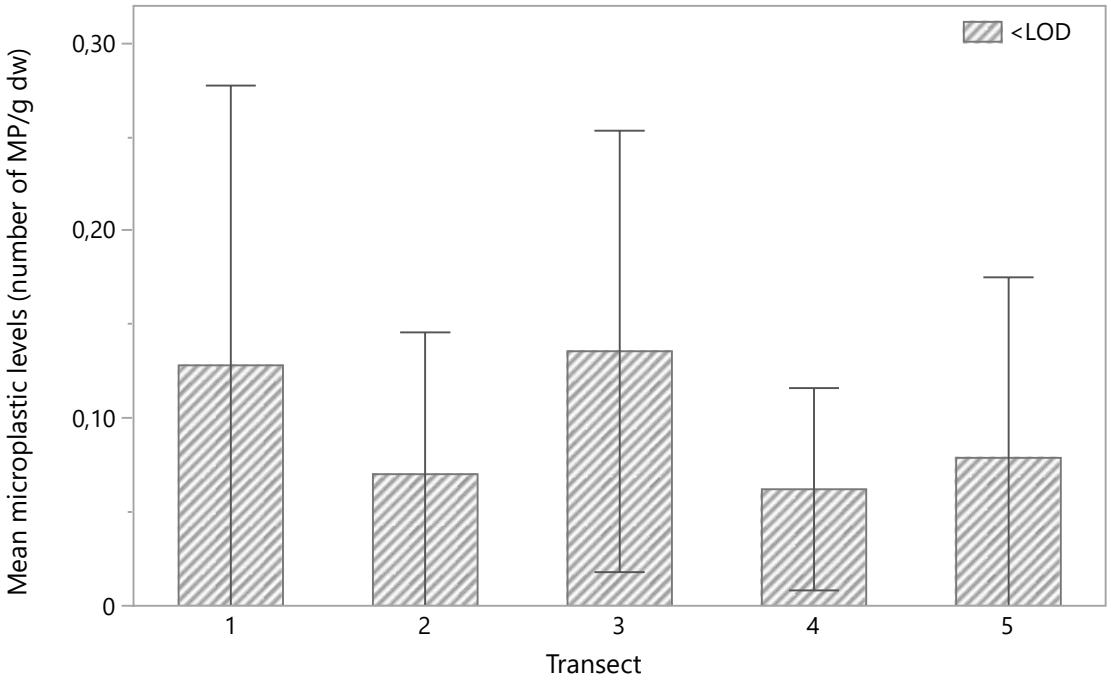

Figure 26. Mean microplastic level (MP/g dw) per transect of beach sediment samples at Akerøya 2023. Error bars = SD.

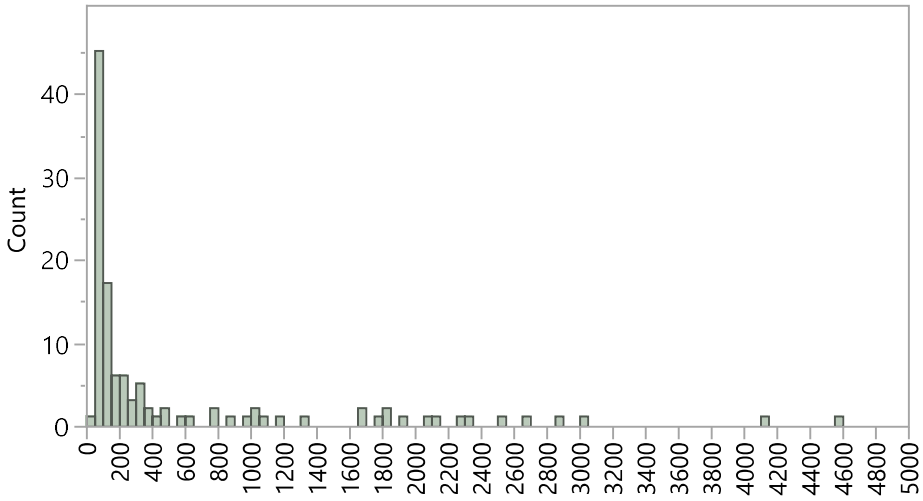

Figure 27. Count of microplastic particles per size class (µm) in beach sediment samples at Akerøya in 2023. Note that the method has a lower size limit at 50 µm.

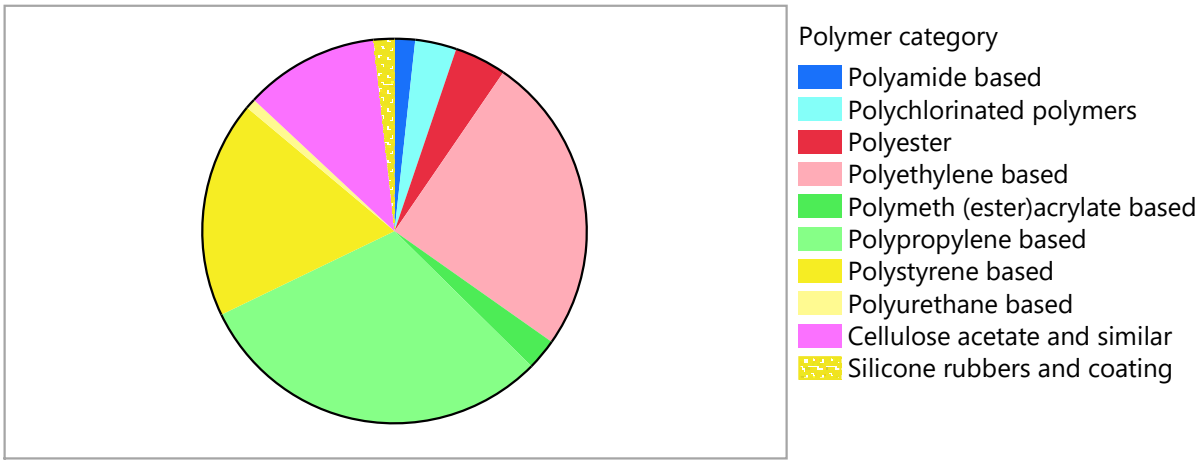

Figure 28. Distribution of microplastic particles in polymer categories in beach samples at Akerøya 2023

A variety of different methods have been used to assess microplastics on beaches. One of the most common methods has been to use a similar approach to the OSPAR protocols for macrolitter surveys, whereby 100m of beach is assessed along the most recent high tide line. Such a survey on sandy beaches is not easy to perform in Norway given that most beaches do not conform to the OSPAR guidelines (length and composition). Similarly, the number of samples to collect for a representative assessment of a beach is still under assessment. Therefore, using knowledge from previous work we develop a stratified sampling approach to capture the likely distribution on a beach in Norway.

We performed a mini-review of recent literature (n=43, 2011-2024) identifying that few used similar or comparable approaches (survey design, sampling processing, data analysis, **Table 4**). Similarly, when we designed the beach survey we based our protocols of COBSEA protocols due to the lack of literature. Out of the 43 investigated papers, 74% used quadrats, 84% focused on sandy beaches, 40 % used transects for sample collection, only 42% had a lower limit of <100 µm. Density separation was employed in all 43 studies, 65% used NaCl, 26% using ZnCl and only 4% using NaI. Often less dense salts are used because beached microplastics are likely low-density plastics having been washed ashore. 7 out of 43 of the studies used more than 1 density solution.

Digestion was performed in 15 out of 43 papers (35%), this likely links to sand being the predominant substrate, void of the needs for removal of organic litter.

FTIR dominates the identification of plastic polymers (84%), although different approaches to data compilation were encountered, including the proportion of samples confirmed as plastic, the grouping of the polymers and the library match. Older studies (ca. 2019) did not use FTIR analysis or had limited procedural controls, yet included particles less the 100 µm in their reported microplastics. This review highlighted that care must be taken when comparing studies due to the diversity in methodological approaches used by research groups, especially studies from the earlier days of microplastics research since it can be the case that some employed methods are no longer recommended approaches. **Conclusion: no studies used similar methods throughout analysis procedure (unless from the same research group).**

Table 4. Mini-review of recent literature on beach sediment sampling approaches.

	Survey design	Sample processing	Data analysis	Average (min-max) MP / g d.w.
This study *Norway*	*Mud-sand,* *1 beach/5 transect /6 samples (n=30)* *Depth: 2 cm*	*Density: NaI* *Digestion: KOH* *Procedural controls: Yes*	*FTIR – 100%* *MP: 5 mm – 20 µm*	*0.095* *(0-0.42)*
Anderson and Turner, 2023 England	Sand, 1 beach/ 5 transect/ 4 samples (n=20) Depth: 2 cm	Density: $ZnCl_2$ Digestion: n.a. Procedural controls: Yes	FTIR -20% subsample (65% match) MP: 5 mm – 20 µm	n.r. (0.04-0.56)
(Gül, 2023) Turkey	Sand, 9 beach/ 3 transect/ 5 samples / 2 sampling events (n=270) Depth: 5 cm	Density: NaCl Digestion: H_2O_2 Procedural controls: Yes	FTIR - subsample (n.r. % match) MP: 5 mm – 50 µm	n.r (0.007-0.09)
Lloyd-Jones et al., 2023 Adventfjord, Svalbard	Sand-gravel, 4 beach/ 10 samples (n=40) Depth: surface	Digestion: H_2O_2, HCl Density: Sodium polytungstate Procedural controls: Yes	FTIR – subsample. (70 % match) MP: 2 mm -	(0.0-3.0)
(Carlsson et al., 2021) Dicksonfjorden, Svalbard	Sand-gravel, 1 beach (n=6, 200g) Depth: 2 cm	Density: NaCl Digestion: n.a. Procedural controls: Yes	FTIR - subsample (60 % match) MP: 5 mm – 100 µm	0.01 (0.002-0.026)
(Godoy et al., 2020) Spain	Sand, 3 beach/ 4 transect/ 11 samples (n=112) Depth: 1 cm	Density: NaCl Digestion: n.a. Procedural controls: No	FTIR - subsample (n.r. % match) MP: 5 mm – 50 µm	n.r (0.003-0.054)
(Constant et al., 2019) Gulf of Lion	Sand, 3 beach/ 3 transect/ 4 samples (n=24) Depth: 1 cm	Density: NaCl Digestion: n.a. Procedural controls: Yes	FTIR - subsample (70 % match) MP: 5 mm – 50 µm	n.r (0.012-0.80)
Granberg et al., 2019 Barentsburg, Svalbard	Beach sediment, 1 beach/ 1 replicate: no details.	Density: NaCl Digestion: n.a. Procedural controls: No	"AMPs" – anthropgenic microparitcles – no FTIR MP: - 20 µm	11 AMPs / kg
(Piperagkas et al., 2019) Crete	Sand, 3 beach/ 4 transect/ 5 samples / 2 events (n=120) Depth: 3 cm	Density: NaCl Digestion: n.a. Procedural controls: No	FTIR - subsample (75 % match) MP: 5 mm – 42 µm	n.r (0.005-0.085)
(Tiwari et al., 2019) India	Sand, 3 beach/ 1 transect/ 10 samples / 2 events (n=30) Depth: 4 cm	Density: NaCl Digestion: n.a. Procedural controls: No	FTIR – 50% (n.r. % match) MP: 5 mm – 36 µm	n.r (0.045-0.22)

3.9 Suspect screening marine sediments

3.9.1. Occurrence of additives in sediment samples

Five filters containing microplastic particles from processed sediment samples were extracted for a suspect screening of chemicals used as additives in plastics, after microplastic particles had been identified and quantified by FTIR (and reported last year in Alling et al., 2023). The samples chosen are from the inner Oslofjord, both from Akershuskaia and from outside the outlet of Bekkelaget wastewater treatment plant, and from the outer Oslofjord (station BT41, see map in **Figure 1**). We screened for additive groups of phthalates, organophosphorus flame retardants, novel brominated flame retardants, polybrominated diphenyl ethers, hydrogenated terphenyls and chlorinated paraffins. In general, phthalates were predominant, followed by organophosphorus flame retardants and chlorinated paraffins. All results reported were over LOD. The organophosphorus flame retardant results should however be treated with caution, as the blank values, and so the LOQ was in the same range as the sample values **(Table 11).** Phthalates are commonly used plastic additives, which can readily leach out and have been detected in a multitude of environmental compartments (Andvik et al., 2024; Collard et al., 2024; Schmidt et al., 2021). The sample showing highest microplastic particle by count and mass (SED.BEK2; 1.4 µg/g dw) also correspond to the sample showing highest chemical concentrations (total sum 2638 ng/sample). For the three samples showing similar microplastic concentrations (SED.AKE1, SED.AKE2 & SED.BEK1) some variability in additive concentrations can be observed. This is a common observation, since additives are not equally distributed within all microplastics, but can rather be found in individual microplastics depending on their original use. Also, e.g. recycled plastic materials can contain higher amounts of phthalates than items made of “virgin” plastic (Pivnenko et al., 2016) and certain polymer types, such as PVC, contain higher levels of plasticizers than others.

The low amount of microplastic particles detected in sample SED.BT41.1 (11 MP particles or 0.03 µg/g dw) is reflected by the low amount of detected chemicals in this sample (**Figure 29**). Novel brominated flame retardants and polybrominated diphenyl ethers were not detected in any sample at levels > LOD. All results are reported in **Tables 20-25** in appendix 5.4.

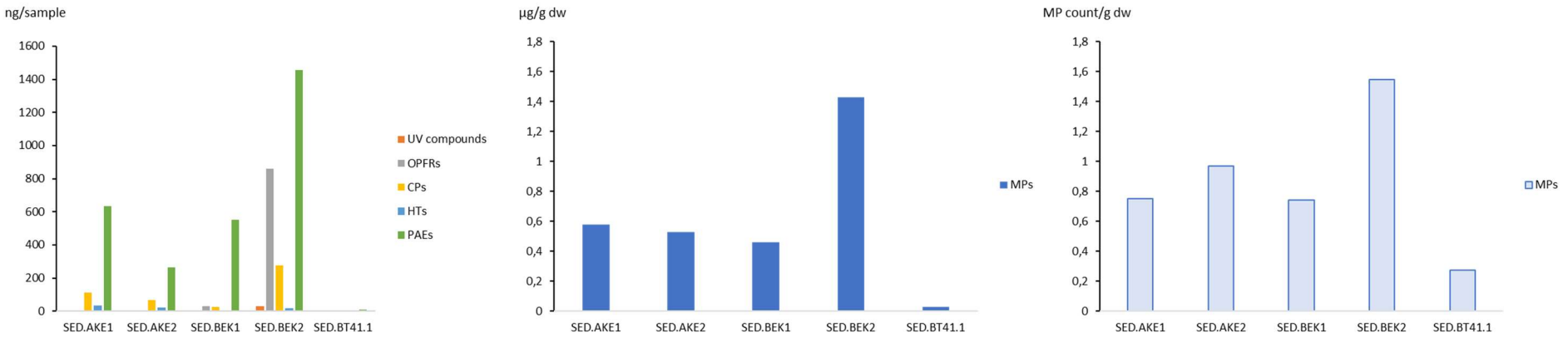

Figure 29. (Left): Sum (in ng/sample) of UV compounds, organophosphorus flame retardants (OPFRs), chlorinated paraffins (CPs), hydrogenated terphenyls (HTs) and phthalates (PAEs) detected in processed sediment samples. Note that LOQ for OPFRs was 800 ng/sample, based on high blank values. **(Middle):** Total mass of MP particles (µg/g dw) and **(right)**: number of particles (MP/g dw) detected in the same samples. All the sediment samples had an approximate dry weight of 40 g before processing.

Since small remains of organic matter remain on the silver filters used for FTIR measurements after processing, it cannot be excluded that these remains might have an influence on the results of the suspect screening. The presence of a relatively high amount of microplastic particles in the samples suggests however, that most extracted chemicals originate from the microplastic particles rather than the sediment remains themselves. It should further be noted that the sample preparation process (sediment digestion and filtration) could have led to a loss of compounds e.g. through degradation or transformation of the chemicals.

3.9.2. Metals

It is established that a number of metals are employed as additives in the manufacture of plastic products. For this year's report, five filters containing plastic particles (50-300 µm, number of microplastic and mass for TWP for those samples of sediments were reported in 2023) were analysed for the presence of metals. The quantities of metals in each sample were normalised to the weight of sediments from which the microplastic particles were extracted. It was assumed that the blanks represented an equal quantity of sediment. However, to interpret the relevance of metals associated with plastic particles, it is crucial to ascertain the concentrations of metals associated with the raw sediments.

Table 5. Concentrations of metals on the plastic particles, compared to blanks and raw sediments.

Averages for 5 filter samles (µg/g dw)	Cr	Mn	Cu	Zn	As	Cd	Pb
Blanks	0,0022	0,0004	0,0005	0,0068	0,0000	0,0000	0,0006
Filters samples	0,0020	0,0064	0,0048	0,0250	0,0001	0,0002	0,0038
sediments	42	626	72	160	20	0	77

As illustrated in **Table 5**, the concentrations of metals on the filters with microplastic particles were found to be within the same range or slightly higher than those observed in the blanks, while the metals present in the raw sediments exhibited a concentration that was 100,000 times higher. Given that the filters with plastic particles also contain small amounts of sediments, it is reasonable to assume that some of the metals found in the filter samples with the plastic particles primarily originated from residual sediments on the filters.

If we assume that the metals found on the filters derived from the plastic particles, the metals associated with sediments at those stations were in concentrations that were four orders of magnitude higher. We can therefore conclude that the microplastic particles present in sediments at these stations does not impose an additional environmental risk of heavy metal contamination, when compared to heavy metals that occur naturally or are of anthropogenic origin and are directly associated with sediments.

In light of the findings from the comparison of means for concentrations in blanks, particles on filters and raw sediments, and in consideration of the conclusion that the metals on the microplastic particles could not be distinguished from those associated with raw sediments, no further interpretations of the metal concentrations on microplastic particles were conducted.

3.10 Reflections on monitoring program approach and data quality

Recommendations for monitoring microplastics in atmospheric samples

Currently no standardized approach for sample collection, treatment and analysis is available for the monitoring of microplastics in atmospheric samples. In the absence of such protocols, we want to highlight following important aspects for future monitoring campaigns:

- Allow flexibility in protocols to account for climatic conditions and the accessibility and equipment of monitoring stations.
- Ensure the inclusion of a sufficient number of field blanks when collecting atmospheric samples for microplastic determination.
- Preferably collect both active air samples and deposition samples in parallel for comprehensive data. Prioritize deposition samples when needed.
- Recognize the difficulty in detecting and identifying small airborne microplastic particles. We recommend using Pyrolysis-GC/MS for its advantages, including no lower size limit for detection and effective identification and quantification of SBR, especially in urban deposition samples.
- Be aware of the limitations of vibrational spectroscopy techniques like Raman or FTIR for detecting smaller particles.

Recommendations for monitoring microplastics in surface waters

- Rivers and coastal surface waters should continue to be monitored. Preferably with similar (or comparable) sampling equipment/methods/size fractions in both rivers and coastal waters.
- Water samples should be linked to precipitation and water run-off to understand the processes that control the transport of microplastic from land to sea. Monitoring extreme events is challenging; it is difficult to plan logistically, some sampling equipment is not designed to sample at very high flows, and taking enough samples to get representative results of a flood event requires large budgets. Efforts to collect representative baseline data for future modelling of such events should therefore be prioritised.

Other recommendations for monitoring of microplastics

- Sampling with vertical plankton nets should not be continued due to problems with the interpretation of the results found in a 50 m water column, without separating particles floating in the surface from the deeper layers.
- There is a need for a thorough discussion about the blue mussel samples. Are they being collected from the right locations, both on a very local scale and on a larger scale? How can we obtain microplastic values that are above the LOD/LOQ? Introducing larger batches of mussels to analyze more material per sample may include more microplastic particles, but it will also increase unknown factors, such as variations between individual mussels. Additionally, processing more mussels in a single sample will increase the time the samples are exposed to air in the lab, leading to more contamination and a higher LOD.

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5 Appendix

5.1 QA/QC

This chapter includes a description of quality assurance and quality control (QA/QC) applied throughout the project. Two groups of blanks are included in this chapter: field blanks and laboratory blanks. This chapter also contains information about how we have calculated LOD and LOQ, and the results from new recovery tests.

5.1.1. Field blanks

Atmospheric blanks

Atmospheric blanks were used during field sampling to account for any microplastic contamination that may have occurred during the sampling process due to deposits from the surrounding air. The air at the sampling site could have been contaminated with particles from the clothing and skin of the sampler, as well as from other sources (boats, equipment onboard etc.) at the sampling site.

Atmospheric blanks were taken together with the following sample types:

- Manta nets
- Plankton nets
- Beach samples
- FerryBox samples[1]

Net blanks

To mitigate contamination arising from the nets used for sampling (plankton nets, newton nets and manta trawls), a net blank was conducted following net cleaning. This net blank was taken by attaching a freshly cleaned cod-end (the cup collecting the sample at the end of the net) and flushing the net multiple times (a minimum of four) from the outside with a seawater hose to transfer its content into the cod-end. Subsequently, the material from the cod-end was moved to a sample glass using RO-water.

During the laboratory analyses, the net blanks were analysed before the samples to get an indication of potential net-related contamination. In cases where a net blank contained more than 50 fibres, based on experience with MIKRONOR net samples, we know that this is a clear sign of contamination, and the number of fibres in the sample will not be of any scientific value. The fibre counts for all samples connected to that net blank were recorded but not included into further analysis. However, any fragments present in the sample were still counted and analysed. When a net blank contained less than 50 fibres, a comprehensive count and analysis of all fibres and fragments were conducted.

The next stage in quality control involved comparing the fibre count (and any other microplastics if necessary) in the net blank with the count in the environmental samples. Following international recommendations, if the net blanks displayed a higher or equivalent fibre count compared to the environmental samples, fibres in the environmental samples were not reported and considered contamination from the net (Montoto-Martínez et al., 2022; Ryan et al., 2020). It is worth noting that most of the plankton net samples collected in 2022 had a higher fibre count in the net blanks than in the environmental samples. Consequently, all fibres in plankton nets, as well as Neuston nets from Svalbard were excluded from the reporting of the 2022 sampling. This action was taken to ensure an accurate

[1] *Filter blanks: Air was pumped through the FerryBox system, simulating contamination risk during actual sampling.*

representation of the quantity of fibres present in the environment, thus avoiding both underestimation and overestimation.

5.1.2. Laboratory (Lab) procedural blanks

Laboratory (lab) procedural blanks monitor potential contamination that may occur during processing and analysing the samples in the laboratory. Particles in the lab blanks might come from airborne contamination (such as ventilation and clothes), equipment and chemicals used to process the samples. In all our methods, each batch of samples was accompanied by ca. three lab blanks, consisting of 200 ml RO water that were treated in the same way as the environmental samples[2]. One batch is defined as samples that are processed on the same day(s). The number of environmental samples analysed within a single batch differ between sample types as the methods for sample processing differ in complexity and time used. Number of samples in one batch may also differ within each sample type.

Table 6. Number of lab-blanks per sample type.

Sample type	Number of lab-blanks
Water, FerryBox	9
Water, pump	3
Water, vertical plankton nets	9
Water, manta trawl	6
Blue mussel	3
Beach sediment	6

5.1.3. Summary of sample analysis quality control using blank analyses

1. **The field blanks** were analysed as part of QA/QC to check that the sampling situation had not caused any significant contamination of the samples. Procedure:
    a. The number of particles and the particle/polymer type in the field blank were compared to those in the environmental samples taken in parallel. If the number of particles in the field blank for a station were higher or equal to the number of particles in the samples, the sample must be regarded as contaminated and not to be further analysed.
        i. If the number of fibres in the field blank were higher or equal to the numbers of fibres in the sample, fibres were excluded from further analyses. Fibres are a well-known contamination problem in most net samples, where international recommendations are to exclude fibres when analysing net samples (OSPAR protocol or Guidelines for MSFD, 2023).
        ii. If there were microplastic particles present in both field blanks and samples that were matching in all characteristics: shape, approximate size, colour and polymer type, these particles could be excluded from the samples[3].
        iii. If potential sources to contamination of samples were identified, such as textiles, ropes etc, those were analysed and compared with particles in the samples and blanks. If there was a match, the similar particles in the samples were excluded[4].
2. **The laboratory blanks** (three per batch of samples processed) were analysed and used to:
    a. QA/QC to check that the treatment used in the laboratory had not caused any unusually high contamination of the samples.

[2] *In a few batches, a lab blank has been lost in the procedure.*

[3] *This was never the situation in the MIKRONOR samples analysed in 2023. It did occur in one FerryBox sample analysed in 2022 (see MIKRONOR report, 2022)*

[4] *Not the case in any MIKRONOR samples so far*

b. Calculate LOD/LOQ for sample type as described in next chapter (as number of microplastic particles in the analysed sample, not normalised against volume or weight).

3. The number of microplastics particles in each analysis were compared to LOD/LOQ established for each sample type (MP/sample **Figures 30-35** in this appendix).

Table 7. The mean MP per sample type and respective lab-blanks, LOD and LOQ for each sample type.

Matrix	Sample type	Mean MP/sample	Mean MP/lab- blank	LOD	LOQ
Sediment	Beach	3.8	3.8	14.8	40.4
Biota	Blue mussel	5.5	2.0	12.4	36.6
Water	Water, FerryBox	5.1	0.8	3.7	10.5
	Water, pump	42.9	0.7	2.4	6.4
	Water, manta trawl	18.7	0.0	0.0	0.0
	Water, vertical plankton nets	6.7	0.0	0.0	0.0

The difference in the number of particles in lab blanks between sample types mainly reflects the time and complexity of processing different types of samples (**Table 7**). The blue mussel and beach samples were exposed to possible contamination for a longer time in the lab, as they required more cleaning and processing steps compared to many of the water samples, such as the pump and plankton net samples. The FerryBox samples represent an intermediate situation in terms of time and steps involved in the preparation of the samples. This situation is well-known, as described by Noonan et al. (2023).

5.1.4. Calculation of LOD/LOQ from lab blanks

The lab blanks in MIKRONOR were used to calculate the LOD and LOQ for the different sample types, as follows:

- LOD: the mean number of microplastics in the lab blanks for that sample type + 3 x SD
- LOQ: the mean number of microplastics in the lab blanks for that sample type + 10 x SD

Blue mussels and beach samples were found to have number of particles below/in the same range as LOD and/or LOQ. The lab blanks for the water samples had very low numbers of microplastics (0 in almost all samples), resulting in low LOD/LOQ. The results for all environmental sample types are plotted and shown together with the calculated LOD and LOQ (as dotted lines) in **Figures 30-35**.

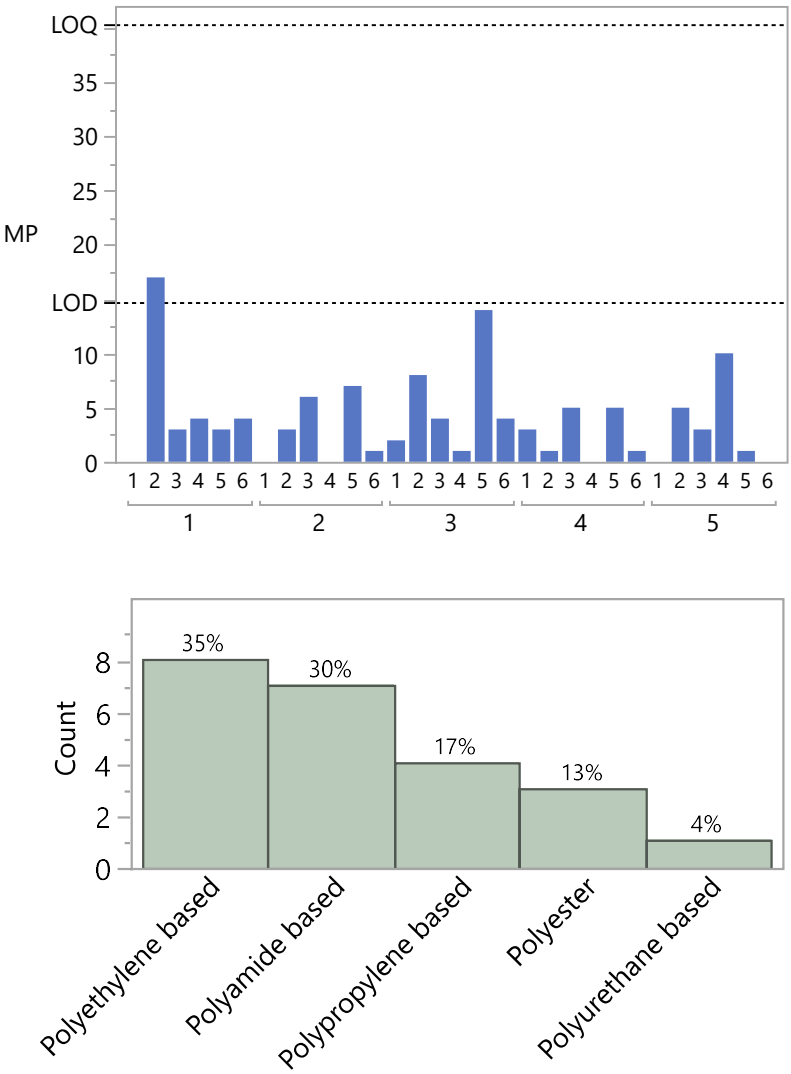

Figure 30. Beach samples 2023. Upper: number of microplastic per sample per transect with LOD and LOQ indicated by dotted lines. Lower: total number and polymer types for particles found in lab blanks corresponding to the beach samples.

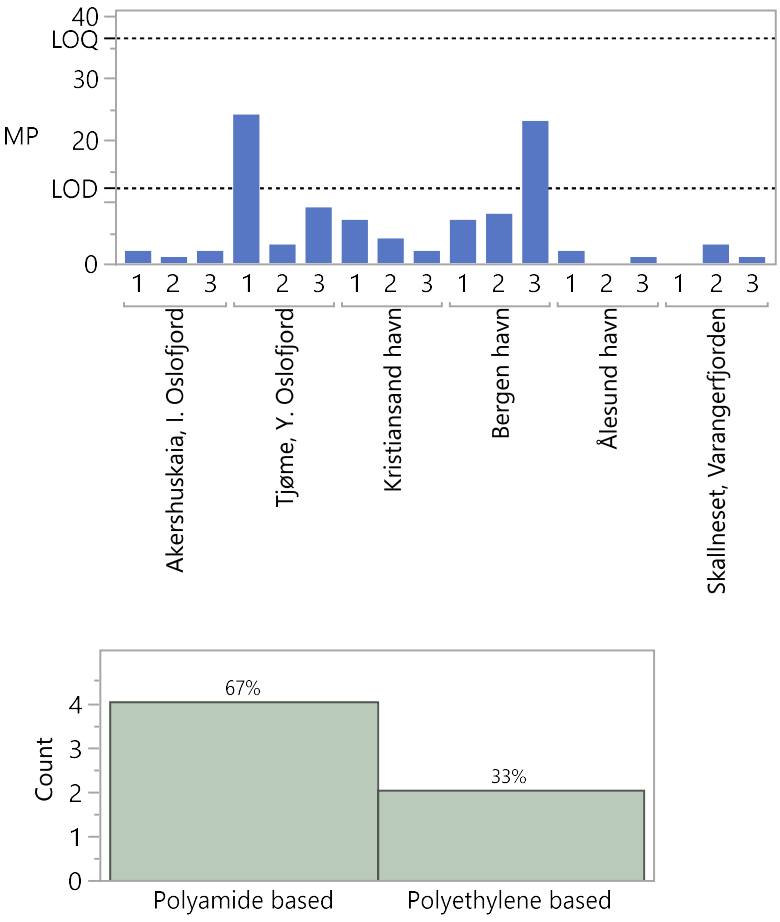

Figure 31. Blue mussel samples 2023. Upper: number of microplastic per sample per station with LOD and LOQ indicated by dotted lines. Lower: total number and polymer types for particles found in lab blanks corresponding to the blue mussel samples.

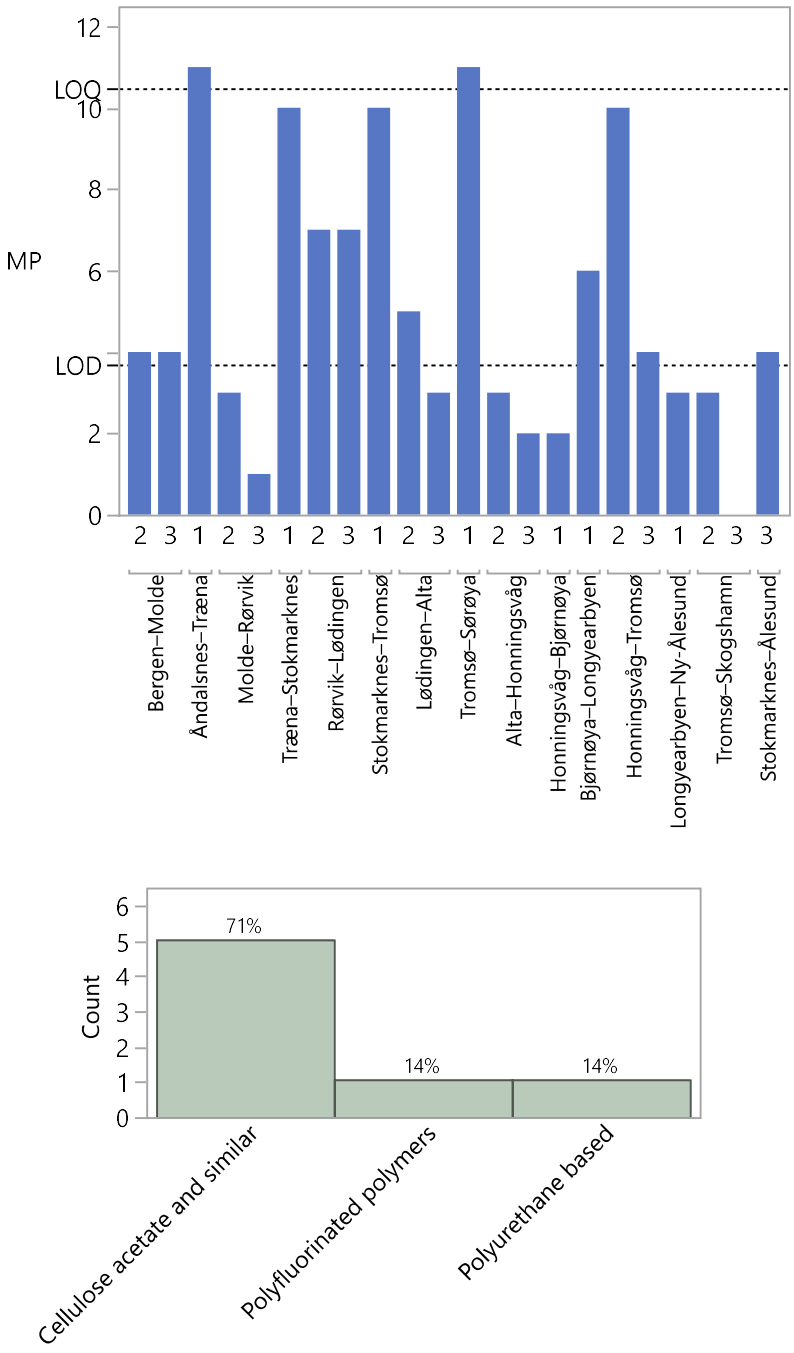

Figure 32. FerryBox samples 2023. Upper: number of microplastic per sample (trip) with LOD and LOQ indicated by dotted lines. Lower: total number and polymer types for particles found in lab blanks corresponding to the FerryBox samples.

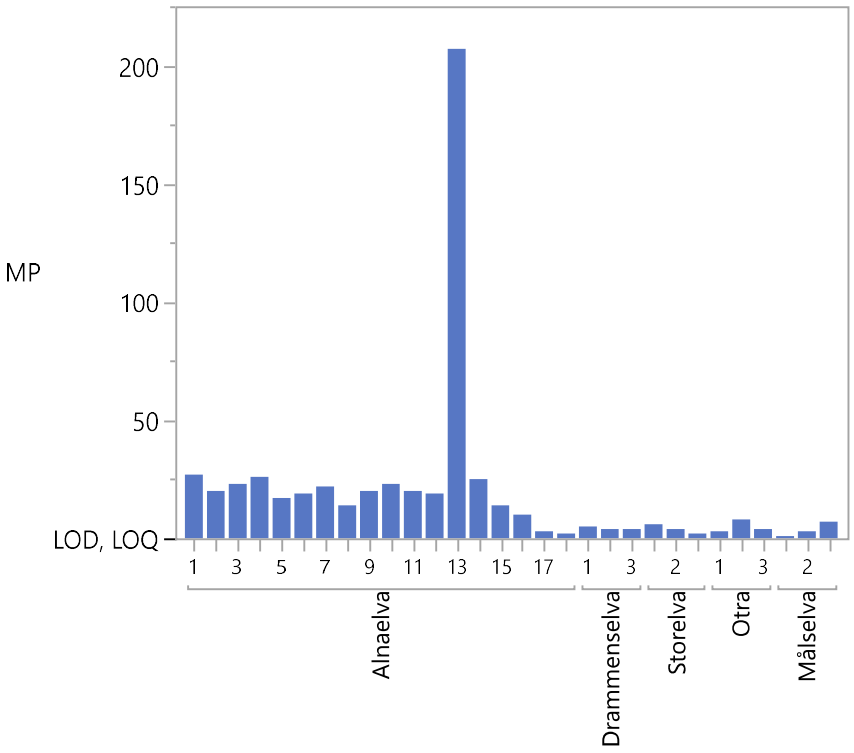

Figure 33. Manta net 2023: Number of microplastic particles per sample per station with LOD and LOQ indicated at value = 0. No plastics were found in the lab blanks for the Manta net samples.

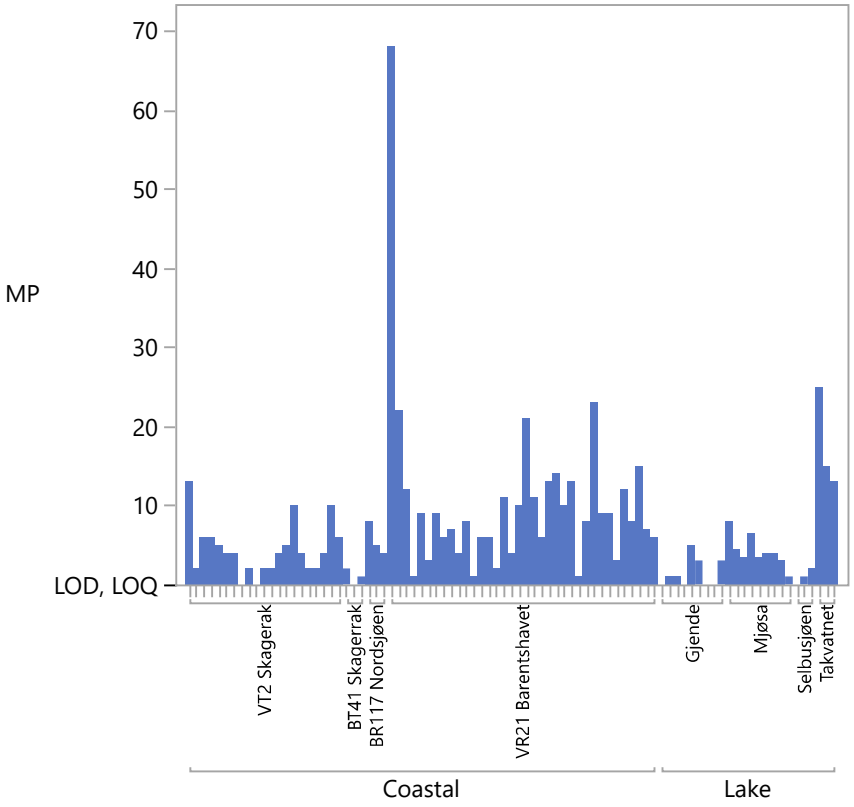

Figure 34. Plankton net 2023: Number of microplastic particles per sample per station with LOD and LOQ indicated at value = 0. No plastics were found in the lab blanks for Plankton net samples.

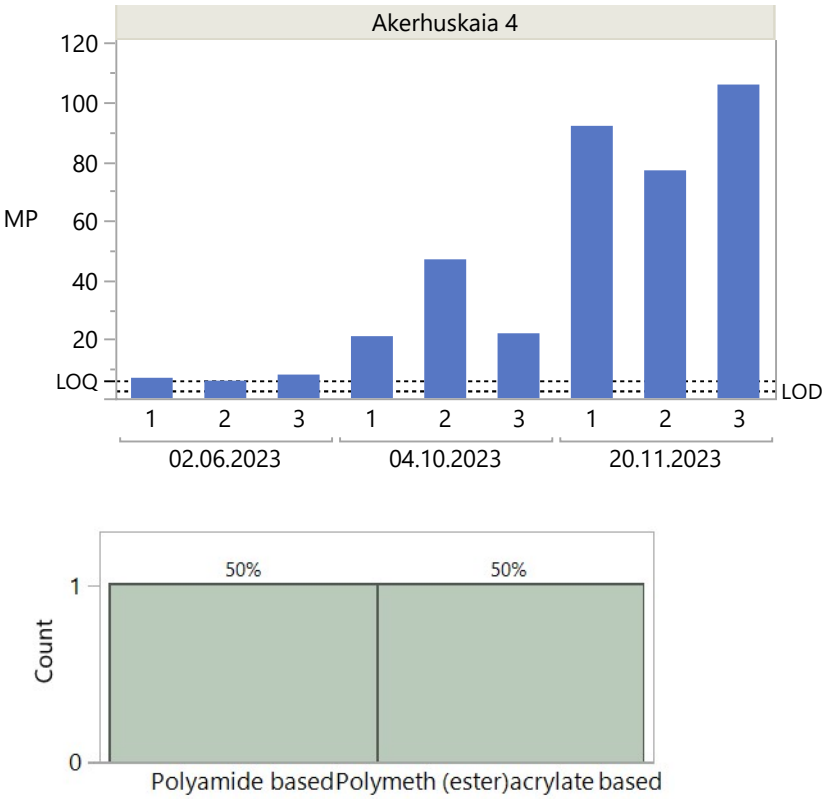

Figure 35. Water pump samples 2023. Upper: number of microplastic particles per sample per sampling date with LOD and LOQ indicated by dotted lines. Lower: total number and polymer types for particles found in lab blanks corresponding to the water pump samples.

5.1.5. About blank corrections for microplastic analyses (count and FTIR)

Within microplastics research, there has been an ongoing discussion whether to blank correct microplastic samples or not. As pointed out by Hermsen et al., 2018, who assessed potential airborne contamination in the laboratory; *blank correcting by particle count can often lead to an incorrect final sample number*. This was after determining that no particles were of a similar appearance to particles in environmental samples in that study.

Munno et al., (2023), however, recommended a complex correction by specific characteristics using combined methods. While this is more precise, and the total corrected value subtracts the lowest number of particles, it is time consuming and uncertain if it is applicable to a lab where lots of samples are handled in a large monitoring program.

Our approach has been to align microplastic monitoring with procedures that are common among other environmental monitoring analyses, to establish LOD and LOQ for methods and matrices, and to adjust number of replicates and amount of sample material to the established LOD/LOQ. This is also in line with the latest updates of international guidelines, e.g., EU Marine Strategy Framework Directive (MSFD)

In samples from areas without known nearby sources, the analyses generally revealed low levels of microplastics, often below the detection limits. However, in samples from highly impacted areas, the levels

were higher and above the detection limits (see figures above). For some sample types, it was challenging to obtain values above the LOD and LOQ. When necessary, we have tried to modify our methodological approach. Last year, we increased the number of individuals in the blue mussel samples to raise the number of microplastic particles in each processed sample. Both this year and last year, the blue mussels provided to MIKRONOR were much smaller than in previous years. Several stations did not have enough blue mussels to provide 30 individuals to MIKRONOR, and in several stations, the blue mussels were smaller than MIKRONOR's specifications. The blue mussel samples did not increase in size, and we encountered the same situation this year as in 2023, resulting in blue mussel microplastic counts, below LOD in most samples.

In two cases, our standard procedures include subtractions of microplastic particles:

- If the contamination source was known, and particles with certainty came from that source, we have been subtracting those particles from the sample. However, this was not the case in this year's analyses.
- Fibres are a known problem in all net samples. If the number of fibres in the field blank were higher or equal to the numbers of fibres in the sample, fibres were excluded from further analyses. This year, we had rather high numbers of microplastic in general (not only fibres) in the fiels blanks for the plankon nets and 15 samples had to be excluded from reporting/further analyses. For the Manta net samples, we did not experience such high levels of contamination in the net blanks, including fibres. Our procedures are in line with international recommendations (Guidelines for MSFD, 2023, Michida et al., 2019).

5.1.6. QA/QC for air samples

Procedural and field blanks were in most cases showing similar contributions by contamination, and LODs were calculated by using field blank data, since they incorporate both the contribution in the field and the procedure used in the laboratory (**Table 8**).

Table 8. LODs and LOQs for the determination of various polymer types in the air samples.

		Unit	PMMA	PP	PVC	SBR	PA	PU	PC	PET	PS	PE
Zeppelin deposition	LOD	µg/m²/d	0.84	15	16	0.01	0.12	0.28	0.13	0.99	0.20	0.01
	LOQ		1.14	20	22	0.01	0.16	0.37	0.18	1.35	0.26	0.01
Zeppelin active air	LOD	ng/m³	0.06	0.24	2.20	0.01	0.01	0.04	0.01	0.37	0.08	0.01
	LOQ		0.07	0.32	2.76	0.01	0.01	0.05	0.01	0.51	0.11	0.01
Birkenes deposition	LOD	µg/m²/d	0.18	1.07	6.30	3.19	0.03	0.16	0.01	0.24	0.05	0.01

Table 9. Mean recovery rates (in %) and standard deviation of deuterated recovery standards of UV compounds.

	Unit	d4-UV-320	d4-UV-326	d4-UV-327	d4-UV-328
Mean Recovery	%	80	72	68	79
SD	%	20	34	26	26

Table 10. LOD and LOQ values (in ng/sample) of UV compounds in ethanol extracts.

		UV-320	UV-326	UV-327	UV-328	UV-329
Zeppelin deposition	LOD	0.02	0.62	0.42	0.26	0.59
	LOQ	0.06	1.29	1.12	0.51	1.61
Zeppelin active air	LOD	0.02	0.51	0.03	0.11	0.10
	LOQ	0.06	1.41	0.06	0.25	0.30
Birkenes deposition	LOD	0.02	0.47	0.06	0.09	0.10
	LOQ	0.06	1.15	0.14	0.17	0.23

5.1.7. QA/QC for suspect screening

LOD for the suspect screening was based on the instrumental detection limit. The LOQ was calculated as *mean in the blanks + 3 x SD*. LOQs for OPFRs and PAEs were elevated due to high concentrations in blanks, while HT's CP's, UVs nBFRs and PBDEs were not detected in the blanks. In general, the LOD/LOQ calculation is not straightforward for the suspect screening, as the suspect screening is a semi-quantitative approach, and results should not be interpreted quantitative.

Table 11. LOD and LOQ values (ng/sample) of compound groups measured in the Suspect Screening. LOQs for OPFRs and PAEs are elevated due to high concentrations in blanks.

	HTs	CPs	OPFRs	UVs	nBFRs	PBDEs	PAEs
LOD	0.25	1.0	0.1	0.01	1	1	0.01
LOQ	0.78	3.0	800	0.03	3	3	68

5.2 Beach sampling protocol

In 2023, Miljødirektoratet initiated a sampling campaign for one of the Norwegian OSPAR beaches under MIKRONOR. The assignment included the development of a sampling collection protocol. This chapter describes the developed protocol, including its background, references to other international protocols, strategy for randomized sampling, and datasheet templates for environmental description for beach sampling.

5.2.1. Introduction

Coastal environments are profoundly impacted by plastic debris, primarily stemming from human activities, particularly tourism and industrial practices. This plastic debris extends to beach and marine sediments, encompassing a wide range of plastic sizes, from large pieces (macroplastics) to smaller, fragmented plastics (<5 mm, microplastics). The longevity of plastic presence in these coastal settings relies on various factors, including plastic characteristics, beach morphology, wind patterns, water circulation and wave conditions (Zhang et al., 2023).Microplastics have received increased attention in beach surveys due to their higher susceptibility to mechanical and, to some extent, UV degradation when situated in sand as opposed to water. The increased exposure accelerates plastic fragmentation, resulting in an increased quantity of smaller microplastics. This is a matter of concern as research has demonstrated that toxicity increases as microplastic size decreases (Gao et al., 2022; Soursou et al., 2023). Numerous methods have been developed to assess the prevalence of microplastics on beaches. However, it is important to note that different environmental setting present unique challenges. For example, a method designed for sandy Australian beaches may not be suitable for rocky Arctic shores. Consequently, the development of methodologies tailored to the specific conditions of each beach environment is essential.

5.2.2. Objectives

This protocol outlines the methodology for collecting shoreline sediment samples to assess the prevalence of microplastics on beaches. It is designed to be applicable for sampling microplastic particles within two size ranges (50-300 µm and 300 µm – 5 mm) with densities below 1.2 g cm-3, within the top 1 cm layer of beach sediment. The systematic approach for sampling beach sediment is based on provided protocols by COBSEA & CSIRO (2022), using a quadrat when sampling along predetermined transects. The survey design is constructed to ensure unbiased assessments of the target beach, irrespective of its size or composition.

5.2.3. Equipment

Table 12. Equipment needed for collecting beach samples to analyse for microplastics.

Equipment	Amount	Volume	Comment
Logbook/data sheets and pencil	1 per quadrat	-	This could be using the same data log that COBSEA use
GPS and camera for sampling locations			Installed on phone / use COBSEA tool
Measuring tape (50m)	1		
Glass jars / metal cans	1 per quadrat	(at least 1 L capacity)	
Square frame quadrat divided into 4 sections (50x50 cm)	1		The frame van be made of wood or metal
Metal shovel/spoon	1		
Metal sorting tray	1 per sample		Used for 1-5 mm fraction
Paper tape/adhesive			For sample labelling

5.2.4. Contamination Control

Microplastics are omnipresent, found in various environments, including both indoor and outdoor air. Therefore, during field sampling, the inclusion of atmospheric blanks is crucial to account for potential contamination originating from sources like atmospheric deposition, clothing materials and equipment usage. Furthermore, during the sampling process, it is important to avoid wearing synthetic clothing known to shed fibres easily. It is also essential to avoid the use of plastic equipment when collecting samples, and to minimise exposure to air after collection to mitigate contamination.

5.2.5. Methods

Establishing the transects:

- To ensure a representative assessment of the microplastics content on the chosen beach, a randomised sampling approach should be employed. This process begins by evenly distributing a predetermined number of transects along the entire length of the beach. To obtain the most accurate estimations, it is recommended that there is a **minimum of five transects**. For longer beach in width, increasing the number of transects is recommended to get the most accurate assessment of the beach.
- Next, **each transect should be subdivided into ten segments**. The number of samples collected on the beach will dictate how many are taken from each transect. For example, if 30 samples are to be collected and five transects are laid out, each transect should have six samples collected (**Figure 36.A**).
- To determine the sampling area along each transect, **randomly select wished number of samples per transect, out of the ten segments within the transect**. There must be a minimum of three collected samples per transect.

Sampling on each transect:

1. Place a 50 x 50 cm quadrat on the predetermined sampling segment of the transect (**Figure 36.B**)
2. Divide the quadrat into four sections, as illustrated in **Figure 36**. Use a random number generator to identify the section from which the sample should be taken.

   Note that if one or more of the four sections are unsuitable for sampling (e.g. covered with vegetation, a large rock, or overlapping with previously sampled area) choose randomly among the sections that are suitable.
3. In the selected section, collect the top centimetres of sand using a metal spoon or shovel, ensuring that only the top cm is sampled. Remove any large stones or rocks and avoid sampling anoxic sand/sediments, which are identifiable by their black colour and unpleasant smell.

   Note that if the purpose of the study is to investigate other sizes of litter, ensure that the procedure for macro/mesolitter is followed. If macro/meso debris is not being collected for other purposes, it must be removed prior to sampling.
4. When collecting the sample, kneel in front of the sampling area and face the wind to minimise contamination.
5. Put out and open an atmospheric blank for contamination control.

   Note that preferably, an atmospheric blank should be taken for each sample, but at a minimum, three atmospheric blanks should be analysed for the entire beach.
6. Store each sample in a pre-cleaned metal or glass container with a lid, and label it with the site, transect and replicate number.
7. Samples can be stored at room temperature until analysis unless they have a high organic content.
8. Complete the datasheets for both general beach observations and descriptions of each transects.
9. Repeat the sampling procedure for all transects.

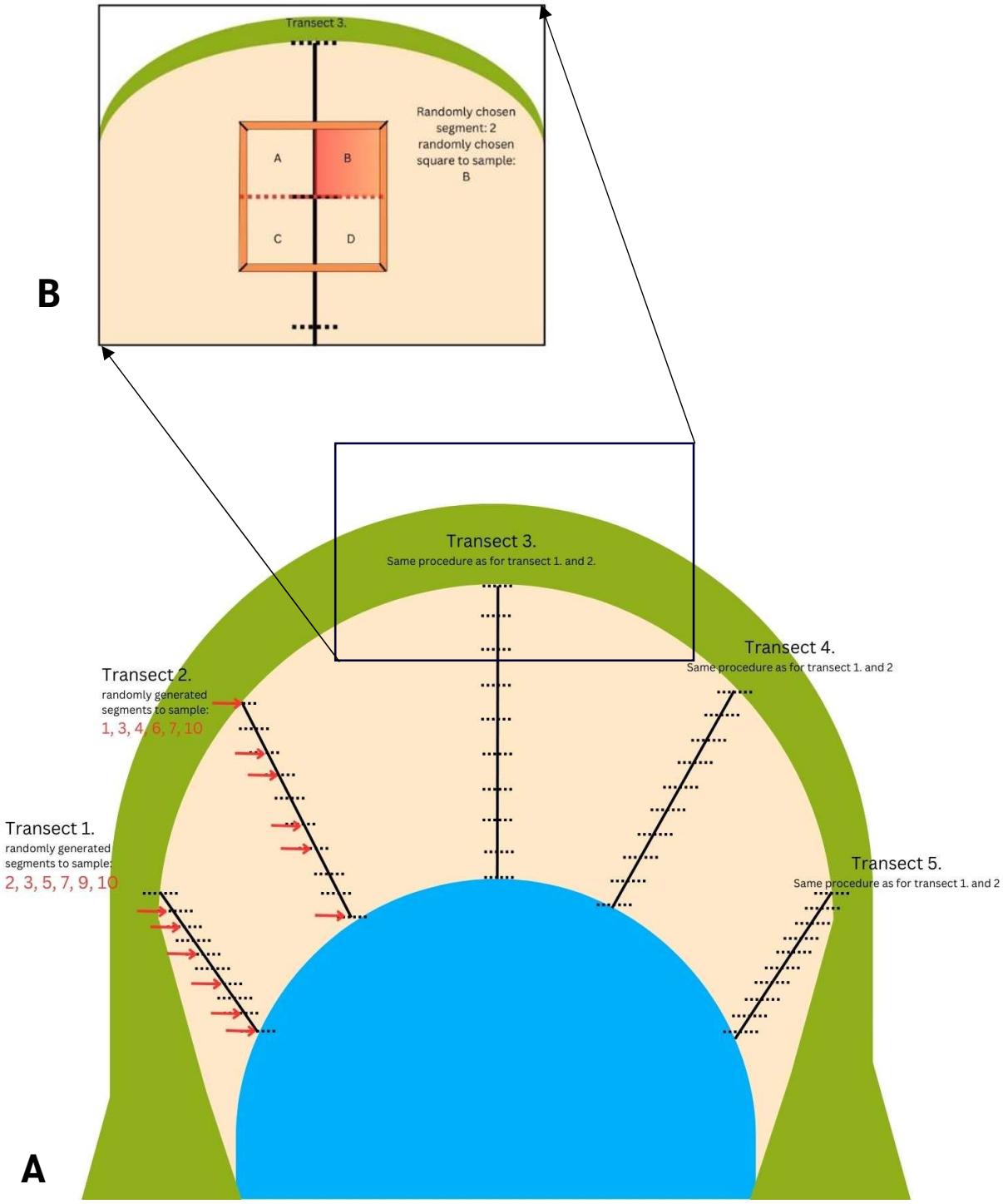

Figure 36. Shows the randomly selected segments for sample within each transects along the entire beach's length (A) and provides guidance on the sampling procedure within each quadrat to sample within each quadrat (B).

Table 13. Datasheets for environmental description for beach sampling:

Date:	Location:	Surveyors:
Width of beach:	Site ID:	
Transect number: of	Transect length (m):	Transect width (m):
Subsampled? Y N	Subsample measurement:	
Subsample/quadrat position is determined by dividing the dividing the width of the beach (from back shore to water line) by 10. Random number generator between 1-10 to find the centre point of the quadrat. i.,e 20m beach, random number generator 4= quadrat at 4m from the back of the beach, random number generator 8 = 16 m from back of beach.		

Transect start:	Latitude:…… Longitude:…… Start time(00:00)…… Photo #/tag name:……	Transect end:	Latitude:…… Longitude:…… Start time(00:00)…… Photo #/tag name:……
Distance to dominant debris line (m):			*Distance from water edge to major debris line (in metres) at time of survey. If no obvious debris line use NA.*
Beach gradient:	A B C D E		*Difference in elevation from start to end of transect.* *A = < 1m (less than hip height)* *B = 1-2 m (hip to head height)* *C = 2-4 m (1-2 body length)* *D=4-8 m (2-4 body lengths)* *E = >8 m (more than 4 body lengths)*
Substrate type:	Mud Sand Boulders Pebble/Gravel Rock slab		*Major substrate type*
Substrate colour:	White/cream Yellow Orange Brown Black Grey Red Green		*Predominant colour of substrate (not vegetation)*
Backshore type:	Cliff Seawall Urban building Forest/tree (>3 m) Shrub (<3 m) Dune Gress – tussock Grass – pasture		
Aspect	N NE E SE S SW W NW		*Direction when you are facing the water*
Evidence of dumping	None Construction Household Other (specify)		
Evidence of recent activities in transect area:	None Clean-up or removal of rubbish Apparent spilled trash or rubbish storm or flood high winds public event mowing		
Shore exposure or shape:	Cove/bay Straight Headland		

Table 14. Datasheets for beach sampling:

Quadrat number:____of___	Transect ID:	Transect width (m):
Transect section: /10	Quadrat section: A B C D	

Quadrat	Latitude:..... Longitude:..... Start time(00:00)..... Photo #/tag name:.....	
Distance to dominant debris line (m):		*Distance from water edge to major debris line (in metres) at time of survey. If no obvious debris line use NA.*
Substrate type:	Mud Sand Pebble/Gravel Boulders Rock slab	*Major substrate type*
Substrate colour:	White/cream Yellow Orange Brown Black Grey Red Green	*Predominant colour of substrate (not vegetation)*
Aspect	N NE E SE S SW W NW	*Direction when you are facing the water*
Evidence of macro		

Quadrat number:____of___	Transect ID:	Transect width (m):
Transect section: /10	Quadrat section: A B C D	

Quadrat	Latitude:..... Longitude:..... Start time(00:00)..... Photo #/tag name:.....	
Distance to dominant debris line (m):		*Distance from water edge to major debris line (in metres) at time of survey. If no obvious debris line use NA.*
Substrate type:	Mud Sand Pebble/Gravel Boulders Rock slab	*Major substrate type*
Substrate colour:	White/cream Yellow Orange Brown Black Grey Red Green	*Predominant colour of substrate (not vegetation)*
Aspect	N NE E SE S SW W NW	*Direction when you are facing the water*
Evidence of macro		

Quadrat number:____of___	Transect ID:	Transect width (m):
Transect section: /10	Quadrat section: A B C D	

Quadrat	Latitude:…….. Longitude:…….. Start time(00:00)…….. Photo #/tag name:……..	
Distance to dominant debris line (m):		*Distance from water edge to major debris line (in metres) at time of survey. If no obvious debris line use NA.*
Substrate type:	Mud Sand Pebble/Gravel Boulders Rock slab	*Major substrate type*
Substrate colour:	White/cream Yellow Orange Brown Black Grey Red Green	*Predominant colour of substrate (not vegetation)*
Aspect	N NE E SE S SW W NW	*Direction when you are facing the water*
Evidence of macro		

Quadrat number:____of___	Transect ID:	Transect width (m):
Transect section: /10	Quadrat section: A B C D	

Quadrat	Latitude:…….. Longitude:…….. Start time(00:00)…….. Photo #/tag name:……..	
Distance to dominant debris line (m):		*Distance from water edge to major debris line (in metres) at time of survey. If no obvious debris line use NA.*
Substrate type:	Mud Sand Pebble/Gravel Boulders Rock slab	*Major substrate type*
Substrate colour:	White/cream Yellow Orange Brown Black Grey Red Green	*Predominant colour of substrate (not vegetation)*
Aspect	N NE E SE S SW W NW	*Direction when you are facing the water*
Evidence of macro		

Quadrat number:____of___	Transect ID:	Transect width (m):
Transect section: /10	Quadrat section: A B C D	

Quadrat	Latitude:…….. Longitude:…….. Start time(00:00)…….. Photo #/tag name:……..	
Distance to dominant debris line (m):		*Distance from water edge to major debris line (in metres) at time of survey. If no obvious debris line use NA.*
Substrate type:	Mud Sand Pebble/Gravel Boulders Rock slab	*Major substrate type*
Substrate colour:	White/cream Yellow Orange Brown Black Grey Red Green	*Predominant colour of substrate (not vegetation)*
Aspect	N NE E SE S SW W NW	*Direction when you are facing the water*
Evidence of macro		

Quadrat number:____of___	Transect ID:	Transect width (m):
Transect section: /10	Quadrat section: A B C D	

Quadrat	Latitude:…….. Longitude:…….. Start time(00:00)…….. Photo #/tag name:……..	
Distance to dominant debris line (m):		*Distance from water edge to major debris line (in metres) at time of survey. If no obvious debris line use NA.*
Substrate type:	Mud Sand Pebble/Gravel Boulders Rock slab	*Major substrate type*
Substrate colour:	White/cream Yellow Orange Brown Black Grey Red Green	*Predominant colour of substrate (not vegetation)*
Aspect	N NE E SE S SW W NW	*Direction when you are facing the water*
Evidence of macro		

5.3 Methods for MIKRONOR 2023 sampling and analyses

This is the third annual report for MIKRONOR. Most sampling procedures and analytical methods are thoroughly described in van Bavel et al., 2022, and Alling et al., 2023. **Table 15** provides an overview of sample collection, laboratory treatments and analytical methods for each sample type. The methods and sampling procedures or field data that are new for this report are provided in chapter 5.3.1 and 5.3.2.

Table 15. Overview of sampling and methods, and references to description of these for each sample type

Environment	Sample type	Methods
Air	Deposition	Sample collection, laboratory treatment and analytical methods, see Alling et al., 2023. Sampling periods for each station and sample type in Table 16. Raman measurements are described under 6.2.2.
	Active air samples	
River	Water, manta trawl	Sample collection, laboratory treatment and analytical methods, see Alling et al., 2023.
Lake	Water, vertical plankton nets	Sample collection, laboratory treatment and analytical methods, see Alling et al., 2023.
Coastal	Water, FerryBox	Sample collection, laboratory treatment and analytical methods, see Alling et al., 2023. For description of some minor changes in sample equipment and this year's sampling volumes per transect, see chapter 5.3.1.
	Water, pump	Sample collection, laboratory treatment and analytical methods, see Alling et al., 2023. For TWP analytical methods, the procedures specifical to this year's report is presented in chapter 5.3.2.
	Water. Vertical plankton nets	
	Water, Blue Mussel	
	Sediment, Beach samples	Sampling collection, see Chapter 5.2. Laboratory treatment and analytical methods, same as for sediments, see Alling et al., 2023
	Sediment, suspect screening	Sampling and analyses of MPs and TWP see methods and results in Alling et al. 2023. Laboratory treatment and analytical methods for suspect screening, see chapter 5.3.2

5.3.1. Sampling

Air samples

Table 16. Sample ID, Station, Sample type (deposition or active air samples) and sampling period for 2023 for the air samples

Sample ID	Station	Sample Type	Sampling period
ZD1	Zeppelin	Deposition	25.08.2023 - 08.09.2023
ZD2	Zeppelin	Deposition	08.09.2023 - 22.09.2023
ZD3	Zeppelin	Deposition	22.09.2023 - 04.10.2023
ZD4	Zeppelin	Deposition	04.10.2023 - 18.10.2023
ZD5	Zeppelin	Deposition	18.10.2023 - 01.11.2023
ZD6	Zeppelin	Deposition	01.11.2023 - 15.11.2023
ZA1	Zeppelin	Air sample	25.08.2023 - 08.09.2023
ZA2	Zeppelin	Air sample	08.09.2023 - 22.09.2023
ZA3	Zeppelin	Air sample	22.09.2023 - 04.10.2023
ZA4	Zeppelin	Air sample	04.10.2023 - 18.10.2023
ZA5	Zeppelin	Air sample	18.10.2023 - 01.11.2023
ZA6	Zeppelin	Air sample	01.11.2023 - 15.11.2023
BD1	Birkenes	Deposition	30.08.2023 - 13.09.2023
BD2	Birkenes	Deposition	13.09.2023 - 27.09.2023
BD3	Birkenes	Deposition	27.09.2023 - 11.10.2023
BD4	Birkenes	Deposition	11.10.2023 - 25.10.2023
BD5	Birkenes	Deposition	25.10.2023 - 08.11.2023
BD6	Birkenes	Deposition	08.11.2023 - 22.11.2023

In this report, monitoring stations for active air and deposition (dry and wet) sampling were strategically placed to document the long-range transport of microplastics and minimize local influences. Two observatories were chosen to represent different regions of Norway and areas that receive air from diverse global source regions: Birkenes (58°23'17.9"N 8°15'08.1"E), situated in southern Norway, and Zeppelin (78°54'23.9"N 11°53'20.8"E), located on Svalbard in the Arctic Ocean (**Figure 1**). For additional details about the sampling sites, visit: https://nilu.com/facility/nilus-observatories-and-monitoring-stations/.

Collection of air and deposition samples for microplastic analysis was conducted over a 14-day period each, by applying the methods described in Alling et al., 2023.

Active Air Samples:

- Full-metal filter holders equipped with 5 µm steel filters were attached to an active air sampler (approx. flow rate of 3 m³/hour) to collect total suspended particles (TSP).
- Field blanks were obtained by attaching a filter holder to the sampler's second inlet without active air flow.

- After collection, filter holders were sealed with metal caps and wrapped in aluminium foil for transport to the laboratory.

Deposition Samples (Dry and Wet):

- Full metal bulk precipitation samplers (Innovation Nilu's Atmospheric Microplastic Collector) were employed.
- After collection, samples were transferred to 2-L glass bottles and covered with aluminium foil to prevent contact with the cap.
- The metal sampler was rinsed twice, and the rinse water was added to the sample.

Field blanks were obtained by rinsing the sampler once more with approximately 500 mL of water and transferring it to a separate glass bottle.

FerryBox samples

1. FerryBox system was equipped with a new type of filters, so called Socklets. The sampler unit consists of a closed housing easy to exchange without contact with the surroundings, avoiding sample contamination. The low-cost filters allow taking several samples during a sampling campaign which are shipped back to the laboratory where they are analyzed under controlled conditions. (Sensors/Samplers - Nautilos (nautilos-h2020.eu) here a mesh size of 100 µm was used.

2. Sampling at 6 stations failed to report volumes, or pump system turned off during sampling. NIVA has analysed the samples, but they are not reported, as the results could not be normalized for volumes to obtain levels (number of MPs per cubic meter).

Table 17 Trip, date of sampling, start and end location and volume per sample for FerryBox transects in 2023.

Trip	Date	Start	Stop	Volume (L)
1	11.09.2023	Åndalsnes	Træna	58 104
1	12.09.2023	Træna	Stokmarknes	41 086
1	13.09.2023	Stokmarknes	Tromsø	26 165
1	14.09.2023	Tromsø	Sørøya	13 472
1	15.09.2023	Honningsvåg	Bjørnøya	47 830
1	16.09.2023	Bjørnøya	Longyearbyen	59 692
1	17.09.2023	Longyearbyen	Ny-Ålesund	26 154
2	21.10.2023	Bergen	Molde	49 070
2	22.10.2023	Molde	Rørvik	46 503
2	23.10.2023	Rørvik	Lødingen	59 695

2	24.10.2023	Lødingen	Alta	45 947
2	25.10.2023	Alta	Honningsvåg	27 816
2	26.10.2023	Honningsvåg	Tromsø	38 787
2	27.10.2023	Tromsø	Skogshamn	14 363
3	08.12.2023	Bergen	Molde	48 739
3	09.12.2023	Molde	Rørvik	49 338
3	10.12.2023	Rørvik	Lødingen	59 685
3	11.12.2023	Lødingen	Alta	54 969
3	12.12.2023	Alta	Honningsvåg	28 293
3	13.12.2023	Honningsvåg	Tromsø	39 293
3	14.12.2023	Tromsø	Skogshamn	12 129
3	17.12.2023	Stokmarknes	Ålesund	98 509

5.3.2. New or changed analytical methods

Measuring microplastics in air samples: pyrolysis-GC/MS

For full method description, see Alling et al., 2023

In this study, 10 polymer types were measured in atmospheric samples:

Table 18. Polymer types analysed in air samples with Pyr-GC/MS and abbreviations used in this report.

Polymer type	Abbreviation
Poly(methyl methacrylate)	PMMA
Polypropylene	PP
Polyvinylchloride	PVC
Polyamide/ Nylon	PA
Polyurethane	PU
Polystyrene	PS
Polyethylene	PE
Polyethylene terephthalate	PET
Polycarbonate	PC
Styrene-butadiene rubber	SBR

The Frontier Laboratories Microplastics Calibration Standard mixed with $CaCO_3$ was used for a one-point calibration. SBR was calibrated using an in-house standard consisting of a mix of tyre tread from 20 different tyres, mixed with sand (Foscari et al., 2023). To investigate potential sources, air mass backwards trajectories were simulated using the Flexpart model for atmospheric particle transport, allowing to track particles forward and backward in time, influenced by Eulerian wind fields generated by 3D meteorological models.

Measuring microplastic numbers in air samples by Raman

Aliquots (200 mL) from deposition samples were filtered onto aluminium oxide membrane filters (25 mm, 0.02 µm pore size, ANODISC, Whatman) and analysed using an InVia confocal Raman microscope (Renishaw). The Raman laser (785 nm) scanned three pre-defined fields (top, centre, bottom) on each filter, resulting in a total area of 27% of the filter being scanned. For particles suspected to be polymers, a full spectrum was obtained to confirm their64 identity. The spectra were obtained using the WiRE software (Renishaw) and further processed with MATLAB. Matches with an R index > 0.70 were considered

relevant. No particles identified as polymers were detected in field blanks. Results from Raman measurements are reported in the appendix 5.4.1.

Measuring tyre wear particles in environmental samples with pyrolysis GC/MS

Biota samples and high-volume water samples for TWP analysis were pretreated as described in Alling et al. 2023, results for FTIR analyses are presented in this report chapter 3.2.2 and 3.5, and filters (15 mm silver filters, 5µm pore size) were inserted in pyrolysis cups. Each cup were spiked with 25 µg/cup of internal standard (d6-Polybutadiene, Polymer Source Inc, Canada) and analyzed with a Multi-Shot Pyrolyzer (EGA/PY-3030D) equipped with an Auto-Shot Sampler (AS-1020E) (Frontier lab Ltd., Fukushima, Japan) coupled to gas chromatography mass spectrometer (GC/MS) (5977B MSD with 8860 GC, Agilent Technologies Inc., CA, USA). All samples were pyrolyzed at 700C and in 25:1 split, following the same methods described in Alling et al., 2023.

The calibration curve was established by adding 1, 2, 5, 10, 20, 40 SBR (SBR1500, Polymer Source Inc., Canada) per cup and 25µg d6-PB/cup for all levels. Seven different marker compounds for SBR and BR rubber were monitored: m/z 78 for benzene (B), m/z 118 for α-methylstyrene (MS), m/z 117 for ethylstyrene (ES), m/z 91 for butadiene trimer (Bt), m/z 54 for 4-Vinylcyclohexene (4-VCH), m/z 104 for styrene butadiene dimer (SB) and m/z 91 for styrene butadiene trimer (SBB). Quantification of SBR+BR was performed using the combined peak heights of the four markers B, MS, ES and Bt, normalized by the internal standard (d6-Pb) (calibration curve R2 = 0.996). The signal to noise ratio (S/N) is determined by the Agilent Masshunter software for each of the selected markers and then summarised to represent the sum of markers. The S/N level was plotted against the concentration level of SBR to determine the S/N vs concentration relationship following the method by Donovan (2016), using power of regression. The calculated LOD (3 x S/N) using the sum of markers were 0.23µg SBR and LOQ (10 x S/N) were 0.76 µg SBR.

The concentration of TWP were further calculated based on the SBR concentrations, following the method described in (Rødland et al., 2022), using measured SBR levels in Norwegian tyres (n=32) and Monte Carlo prediction modelling.

Suspect screening

Organic compounds

Five pre-conditioned sediment samples (number of microplastic particles reported in Alling et al., 2023 on silver filters were solvent-extracted and subjected to a suspect screening regarding additive chemicals, including UV compounds, phthalates, brominated flame retardants, organophosphorus flame retardants, chlorinated paraffins (short chain and medium chain chlorinated paraffins) and hydrogenated terphenyl. Additionally, 3 filter blanks and 1 glass vial blank were included. To each sample 1 mL of ethyl acetate and 20 µL of internal standard (D4-DEHP) was added. The samples were vortexed, extracted via ultrasonication for 30 minutes, placed on a horizontal shaker overnight, centrifuged and the extract was transferred into GC vials. The samples were then analysed with GC/MS in full scan mode.

Due to their presence in blanks, the results for organophosphorus flame retardants (OPFRs) and phthalates (PAEs) were blank-corrected by subtracting the average amount detected in three filter blanks plus two times the standard deviation. No positive controls or stability tests were performed.

The CP results were divided into congener groups. It is impossible to separate the individual congeners in a congener group (ex: $C_{14}Cl_7H_{23}$ is a general formula that accounts for hundreds of different congeners). Attached in 5.4.1 is therefore a table which also reports the congener groups for the MCCPs. The SCCP

levels were too low making sense of dividing into separate congener groups, and were therefore only reported as a sum.

Metals

The filters containing microplastics (and small particles of sediment) were digested in concentrated HNO3 solution and heated to 50 degrees Celsius. The identification and quantification of the different metals was carried out by means of ICP-MS.

5.4 Results

All results are presented at NIVAs interactive website superset, where data can be downloaded, and the results can be filtered and explored by the viewer. In this report we present a highlight of the most interesting findings.

In this chapter, we present results not presented in the key findings, including:

- The raw data results from the air samples and suspect screening of organic compounds
- Comparison between Raman analyses and Quantitative GCMS analyses for deposition samples
- Additional data from river water samples, surface water samples from inner Oslofjord, FerryBox samples, vertical plankton nets, blue mussels, and beach sediment samples

5.4.1. Data table and additional results from Air sampling

Table 19. Microplastic masses measured in deposition and air samples from Zeppelin and Birkenes station. Results are blank-corrected and (for deposition samples) volume- corrected to account for the sub-sample taken for the Raman analysis.

Unit	Sample ID	Station	Sample Type	sampling period	PMMA	PP	PVC	SBR	PA	PU	PC	PET	PS	PE	Sum MPs
µg/m²/d	ZD1	Zeppelin	Deposition	25/08-08/09/2023	<LOQ	<LOQ	<LOQ	<LOD	<LOQ	<LOQ	<LOD	<LOQ	<LOQ	0.26	**0.26**
	ZD2	Zeppelin	Deposition	08/09-22/09/2023	3.36	<LOQ	<LOQ	59.9	0.55	<LOQ	<LOD	10.1	1.82	0.43	**76.2**
	ZD3	Zeppelin	Deposition	22/09-04/10/2023	0.08	<LOQ	<LOQ	<LOD	2.31	0.03	<LOD	0.54	0.11	12.1	**15.1**
	ZD4	Zeppelin	Deposition	04/10-18/10/2023	0.34	<LOQ	<LOQ	<LOD	<LOQ	<LOQ	<LOD	<LOQ	<LOQ	<LOD	**0.34**
	ZD5	Zeppelin	Deposition	18/10-01/11/2023	0.42	<LOQ	<LOQ	27.6	0.12	<LOQ	<LOD	<LOQ	<LOQ	<LOD	**28.1**
	ZD6	Zeppelin	Deposition	01/11-15/11/2023	0.04	<LOQ	<LOQ	<LOD	<LOQ	<LOQ	<LOD	1.07	0.32	1.67	**3.11**
ng/m³	ZA1	Zeppelin	Air sample	25/08-08/09/2023	1.57	<LOQ	1.39	<LOD	0.08	0.01	0.04	0.33	0.07	0.21	**3.71**
	ZA2	Zeppelin	Air sample	08/09-22/09/2023	<LOQ	<LOQ	<LOQ	<LOQ	<LOD	<LOQ	<LOD	<LOQ	<LOQ	<LOD	**<LOQ**
	ZA3	Zeppelin	Air sample	22/09-04/10/2023	0.02	<LOQ	<LOQ	<LOD	<LOD	<LOQ	<LOD	<LOQ	<LOQ	<LOD	**0.02**
	ZA4	Zeppelin	Air sample	04/10-18/10/2023	0.06	<LOQ	<LOQ	<LOD	<LOD	<LOQ	<LOD	1.43	0.38	<LOD	**1.87**
	ZA5	Zeppelin	Air sample	18/10-01/11/2023	0.05	<LOQ	<LOQ	<LOD	<LOD	0.02	<LOD	<LOQ	<LOD	<LOD	**0.07**
	ZA6	Zeppelin	Air sample	01/11-15/11/2023	0.16	<LOQ	1.35	<LOD	<LOD	<LOQ	<LOD	<LOQ	<LOQ	<LOD	**1.51**
µg/m²/d	BD1	Birkenes	Deposition	30/08-13/09/2023	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOD	<LOQ	<LOQ	<LOD	**<LOQ**
	BD2	Birkenes	Deposition	13/09-27/09/2023	<LOQ	<LOQ	<LOQ	10.4	<LOQ	<LOQ	<LOD	0.43	<LOQ	0.83	**11.7**
	BD3	Birkenes	Deposition	27/09-11/10/2023	3.17	2.91	34.0	<LOQ	<LOQ	0.09	<LOD	<LOQ	<LOQ	11.5	**51.6**
	BD4	Birkenes	Deposition	11/10-25/10/2023	7.31	1.20	87.6	<LOQ	<LOQ	0.12	37.1	13.8	1.26	3.48	**152**
	BD5	Birkenes	Deposition	25/10-08/11/2023	2.93	1.94	36.3	79.2	<LOQ	0.08	7.31	17.6	2.53	6.61	**154**
	BD6	Birkenes	Deposition	08/11-22/11/2023	2.07	4.11	73.9	88.5	0.13	0.21	3.89	182	23.4	13.0	**391**

Comparing Pyrolysis-GC/MS with Raman measurements

Aliquots from the deposition samples were analysed with Raman to get particle count-based information for these samples in addition to the mass-based results obtained with the pyrolysis-GC/MS. As seen when comparing **Figures 3** and **37**, the results obtained with these two analytical techniques differ significantly. For example, the temporal trend observed in Birkenes using pyrolysis-GC/MS (i.e., higher fluxes towards the end of the year) is not reflected in the Raman results. Furthermore, more microplastic particles were detected in samples from Zeppelin compared to Birkenes, while the mass-based results show higher microplastic loads in Birkenes samples. This discrepancy might be due to several factors: firstly, the microplastic number and mass do not necessarily need to correlate, as the mass of each particle will be dependent on its size, density and degree of degradation. Furthermore, SBR particles cannot be reliably identified with Raman, but constitute an important part of the deposition samples by mass. The limitation for the detection of very small particles using Raman (here approximately 20 µm) further complicates the comparison of the results from both analytical techniques.

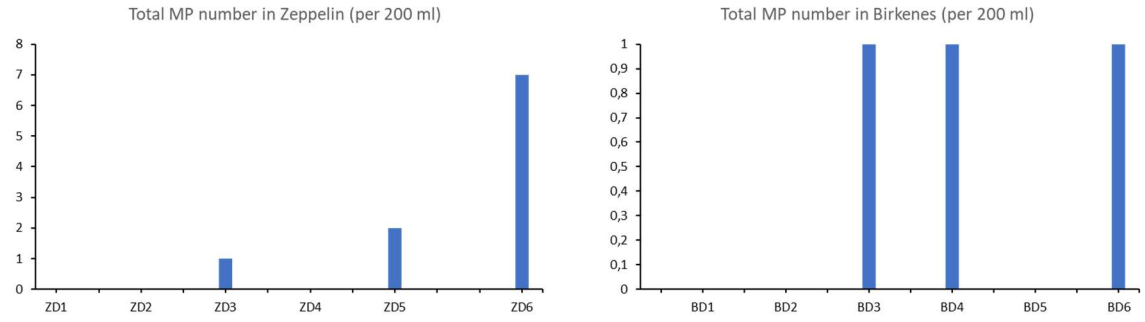

Figure 37: Total number of microplastics (per 200 mL aliquote) detected with Raman in deposition samples from Zeppelin (left) and Birkenes (right) stations.

Table 20. Organophosphorus Flame Retardant (OPFR) concentrations (ng/sample) measured in the Suspect Screening. Concentrations in the table are not blank-corrected.

	Sample ID	Mikronor name	2IPPDPP	4IPPDPP	B4IPPPP	EHDP	T2IPPP	T35DMPP	TBEP	TCEP	TCPP	TDCPP	TEHP	TEP	TMTP	TNBP	TOTP	TPHP	TPrP	TPTP	Sum OPFRs
Organophosphorus Flame Retardants																					
	Glass blank	Glass blank	< LOD	< LOD	< LOD	0.01	< LOD	< LOD	< LOD	< LOD	0.22	0.01	0.01	0.63	< LOD	0.10	< LOD	< LOD	< LOD	< LOD	0.98
	Blank 1	Blank 1	< LOD	4.55	< LOD	0.65	< LOD	< LOD	0.07	0.06	1.70	< LOD	< LOD	1.36	0.24	2.87	< LOD	486	< LOD	< LOD	498
	Blank 2	Blank 2	< LOD	3.33	< LOD	0.71	< LOD	< LOD	< LOD	0.06	1.81	< LOD	< LOD	1.36	0.26	3.36	< LOD	192	< LOD	< LOD	203
	Blank 3	Blank 3	< LOD	2.86	< LOD	1.97	< LOD	< LOD	< LOD	0.05	1.73	0.01	< LOD	2.45	< LOD	2.70	< LOD	173	< LOD	< LOD	185
	NR-2022-07576	SED.BT41.1	< LOD	3.40	< LOD	2.19	< LOD	< LOD	< LOD	< LOD	2.89	< LOD	0.08	1.15	< LOD	0.51	< LOD	60.7	< LOD	< LOD	71.0
	NR-2021-10717	SED.AKE2	0.55	< LOD	< LOD	12.2	< LOD	< LOD	< LOD	13.6	284	0.08	1.89	27.3	< LOD	1.17	< LOD	261	< LOD	< LOD	602
	NR-2021-10714	SED.AKE1	< LOD	< LOD	< LOD	11.4	< LOD	< LOD	< LOD	0.08	80.3	3.90	3.44	3.22	< LOD	1.13	< LOD	143	< LOD	< LOD	246
	NR-2021-10726	SED.BEK1	< LOD	2.88	< LOD	2.66	< LOD	< LOD	< LOD	57.4	420	0.80	0.96	74.3	< LOD	0.26	< LOD	117	< LOD	< LOD	676
	NR-2021-10729	SED.BEK2	10.2	< LOD	< LOD	4.34	< LOD	< LOD	21.3	119	974	0.08	10.1	106	< LOD	0.45	< LOD	263	< LOD	< LOD	1507

Table 21. UV compound concentrations (ng/sample) measured in the Suspect Screening. Concentrations in the table are not blank-corrected.

	Sample ID	Mikronor name	UV-320	UV-326	UV-327	UV-328	UV-329	Sum
UV compounds								
	Glass blank	Glass blank	n.d.	n.d.	n.d.	0.06	n.d.	**0.06**
	Blank 1	Blank 1	n.d.	n.d.	n.d.	n.d.	n.d.	**n.d.**
	Blank 2	Blank 2	n.d.	n.d.	n.d.	n.d.	n.d.	**n.d.**
	Blank 3	Blank 3	n.d.	n.d.	n.d.	n.d.	n.d.	**n.d.**
	NR-2022-07576	SED.BT41.1	n.d.	n.d.	n.d.	0.03	n.d.	**0.03**
	NR-2021-10717	SED.AKE2	0.48	0.44	0.65	3.73	0.02	**5.31**
	NR-2021-10714	SED.AKE1	0.37	2.31	0.99	2.31	0.09	**6.08**
	NR-2021-10726	SED.BEK1	0.14	0.05	0.33	2.66	0.02	**3.19**
	NR-2021-10729	SED.BEK2	1.01	3.49	3.88	20.0	1.14	**29.5**

Table 22. Chlorinated paraffin concentrations (ng/sample) measured in the Suspect Screening. Concentrations in the table are not blank-corrected.

	Sample ID	Mikronor name	SCCP	MCCP	Sum
Chlorinated paraffins					
	Glass blank	Glass blank	n.d.	n.d.	**n.d.**
	Blank 1	Blank 1	n.d.	n.d.	**n.d.**
	Blank 2	Blank 2	n.d.	n.d.	**n.d.**
	Blank 3	Blank 3	n.d.	n.d.	**n.d.**
	NR-2022-07576	SED.BT41.1	n.d.	n.d.	**n.d.**
	NR-2021-10717	SED.AKE2	5.64	61.3	**67**
	NR-2021-10714	SED.AKE1	8.09	103	**111**
	NR-2021-10726	SED.BEK1	0.21	25.5	**26**
	NR-2021-10729	SED.BEK2	9.60	265	**275**

Table 23. Medium-chain chlorinated paraffin (MCCP) concentrations (ng/sample) divided into congener groups, measured in the Suspect Screening. Concentrations in the table are not blank-corrected.

	Sample ID	Mikronor name	C14Cl4	C14Cl5	C14Cl6	C14Cl7	C14Cl8	C14Cl9	C14Cl10	C15Cl4	C15Cl5	C15Cl6	C15Cl7	C15Cl8
Chlorinated paraffins														
	Glass blank	Glass blank	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
	Blank 1	Blank 1	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
	Blank 2	Blank 2	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
	Blank 3	Blank 3	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
	NR-2022-07576	SED.BT41.1	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
	NR-2021-10717	SED.AKE2	n.d.	1.2	4.7	9.1	7.9	5.9	2.0	n.d.	<LOD	3.1	5.7	4.3
	NR-2021-10714	SED.AKE1	n.d.	3.0	11	13	8.2	3.9	<LOD	n.d.	1.7	7.1	11	7.0
	NR-2021-10726	SED.BEK1	n.d.	n.d.	2.4	4.6	2.5	<LOD	n.d.	n.d.	n.d.	2.3	3.9	2.0
	NR-2021-10729	SED.BEK2	n.d.	7.6	31	35	14	3.9	<LOD	n.d.	4.3	23	32	15

	Sample ID	Mikron or name	C15Cl9	C15Cl10	C16Cl4	C16Cl5	C16Cl6	C16Cl7	C16Cl8	C16Cl9	C16Cl10	C17Cl4	C17Cl5	C17Cl6	C17Cl7	C17Cl8	C17Cl9	C17Cl10
Chlorinated paraffins																		
	Glass blank	Glass blank	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
	Blank 1	Blank 1	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
	Blank 2	Blank 2	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
	Blank 3	Blank 3	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
	NR-2022-07576	SED.BT4 1.1	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
	NR-2021-10717	SED.AKE 2	2.9	<LOD	n.d.	n.d.	1.9	3.2	2.8	2.0	n.d.	n.d.	n.d.	<LOD	1.5	<LOD	n.d.	n.d.
	NR-2021-10714	SED.AKE 1	3.9	<LOD	n.d.	n.d.	4.7	6.9	5.2	3.1	<LOD	n.d.	n.d.	3.2	3.9	3.1	1.8	n.d.
	NR-2021-10726	SED.BEK 1	n.d.	n.d.	n.d.	<LOD	1.1	2.1	<LOD	n.d.	n.d.	<LOD	n.d.	<LOD	1.0	n.d.	n.d.	n.d.
	NR-2021-10729	SED.BEK 2	5.4	<LOD	n.d.	2.3	15	23	13	5.2	1.2	1.3	1.5	6.6	12	8.1	3.8	1.1

Table 24. Hydrogenated terphenyl concentrations (ng/sample) measured in the Suspect Screening. Concentrations in the table are not blank-corrected.

	Sample ID	Mikronor name	DDHT-1	DDHT-2	DDHT-3	DDHT-4	HHT-1	HHT-2	HHT-3	T-1	T-2	T-3	Sum
Hydrogenated terphenyls													
	Glass blank	Glass blank	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	**n.d.**
	Blank 1	Blank 1	n.d.	n.d.	n.d.	0.01	n.d.	0.03	n.d.	n.d.	0.04	n.d.	**0.08**
	Blank 2	Blank 2	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0.04	n.d.	**0.04**
	Blank 3	Blank 3	n.d.	n.d.	n.d.	0.01	0.02	0.06	0.03	n.d.	0.05	n.d.	**0.19**
	NR-2022-07576	SED.BT41.1	< 0.2	< 0.2	< 0.2	0.17	< 0.2	< 0.2	< 0.2	< 0.2	0.41	0.21	**0.80**
	NR-2021-10717	SED.AKE2	< 1	< 1	< 1	5.36	< 1	< 1	< 1	1.43	9.28	5.25	**21.3**
	NR-2021-10714	SED.AKE1	< 1	< 1	< 1	4.17	< 1	0.99	< 1	2.41	17.2	10.4	**35.1**
	NR-2021-10726	SED.BEK1	< 0.2	< 0.2	< 0.2	0.68	< 0.2	0.30	0.22	< 0.2	1.70	0.83	**3.73**
	NR-2021-10729	SED.BEK2	< 1	< 1	< 1	1.53	< 1	1.67	1.16	1.22	8.10	4.39	**18.1**

Table 25. Phthalate concentrations (ng/sample) measured in the Suspect Screening. Concentrations in the table are not blank-corrected.

	Sample ID	Mikronor name	DMP	DEP	DiBP	DnBP	BMEP	BMPP	BEEP	DPP	DHxP	BBP	DBOEP	DEHP/ DCHP	DOP	DINP	DNP	DIDP	Sum
Phthalates																			
	Glass blank	Glass blank	1.23	5.26	6.05	4.16	0.03	0.02	0.06	0.68	0.12	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0.02	**17.6**
	Blank 1	Blank 1	6.86	15.1	7.65	0.07	0.05	0.11	4.53	0.04	n.d.	n.d.	0.16	n.d.	n.d.	n.d.	n.d.	0.02	**34.6**
	Blank 2	Blank 2	7.3	16.5	7.41	0.05	0.10	0.03	0.06	0.69	0.03	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0.01	**32.1**
	Blank 3	Blank 3	9.45	22.2	7.97	0.06	0.09	0.21	5.96	0.16	n.d.	n.d.	0.12	n.d.	n.d.	n.d.	n.d.	0.02	**46.2**
	NR-2022-07576	SED.BT41.1	11.2	30.9	6.96	n.d.	0.03	0.07	11.9	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	**61.1**
	NR-2021-10717	SED.AKE2	n.d.	22.3	20.4	21.1	n.d.	14.3	8.21	229	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	**316**
	NR-2021-10714	SED.AKE1	27.2	41.6	33.0	18.4	n.d.	92.7	20.9	454	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	**688**
	NR-2021-10726	SED.BEK1	3.09	13.4	17.0	9.05	n.d.	0.03	n.d.	36.1	12.2	506	5.78	n.d.	n.d.	n.d.	n.d.	n.d.	**602**
	NR-2021-10729	SED.BEK2	n.d.	18.5	15.5	72.2	n.d.	n.d.	32.1	8.66	1347	n.d.	13.0	n.d.	n.d.	n.d.	n.d.	n.d.	**1507**

5.4.2. River sampling with manta trawl (>200 µm)

Table 26. Alnaelva mean microplastic concentrations and TOC concentrations in 2023.

MP sampling date	Mean concentration microplastic (MP/m^3)	TOC (mg/L)	TOC sampling date
28.04.2023	4.5	4,3	02.05.2023
01.06.2023	2.7	3,5	05.06.2023
16.08.2023	5.0	7	09.08.2023
30.10.2023	2.9	6,1	06.11.2023
21.11.2023	13.4		
04.12.2023	0.9	4,2	04.12.2023

Table 27. Manta water samples in rivers 2023: microplastic levels in field net blank samples and in samples, with test of sample means vs. net blank values.

River	Sampling occasion	Net blank MP/m^3	Sample mean MP/m^3	Net blank/ sample mean	t-test Prob>|t|
Alnaelva	1	0,00	4,54	0,00	**0,0004***
Alnaelva	2	0,00	2,67	0,00	**0,0176***
Alnaelva	3	0,75	5,01	0,15	**0,0111***
Alnaelva	4	0,12	2,91	0,04	**0,0245***
Alnaelva	5	0,18	13,35	0,01	0,0939
Alnaelva	6	0,53	0,88	0,60	0,5517
Drammenselva	1	0,28	1,19	0,23	**0,0004***
Målselva	1	0,00	0,63	0,00	0,1420
Otra	1	0,08	0,44	0,18	0,1321
Storelva	1	0,07	0,28	0,24	0,1417

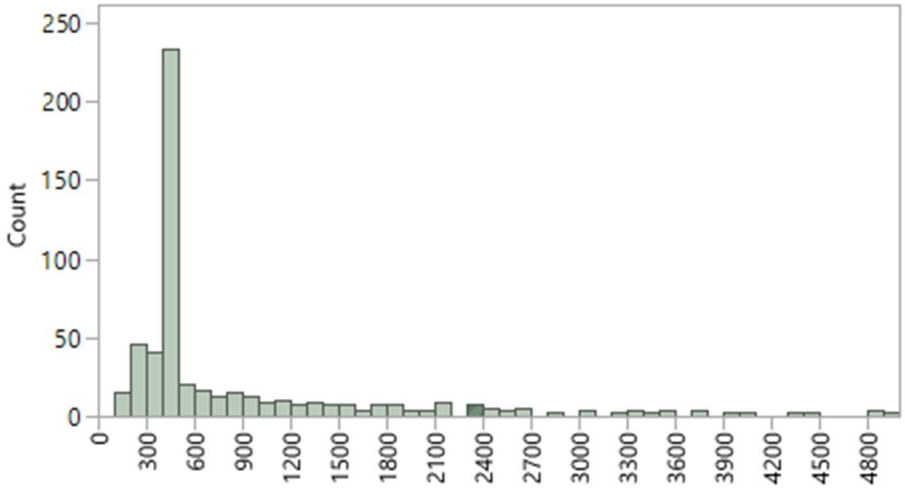

Figure 38. Distribution of microplastic particle sizes (µm) in manta net water samples in Alnaelva in 2023.

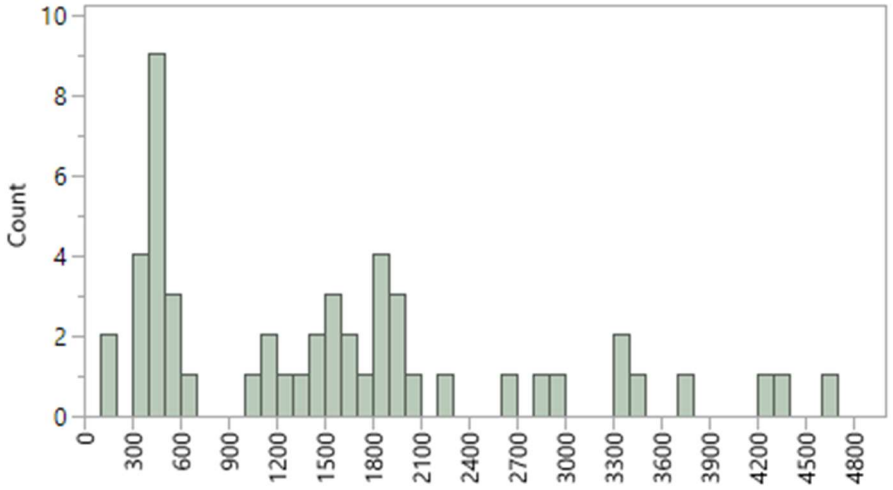

Figure 39. Distribution of microplastic particle sizes (µm) in manta net water samples in Drammenselva, Storelva, Otra and Målselva in 2023.

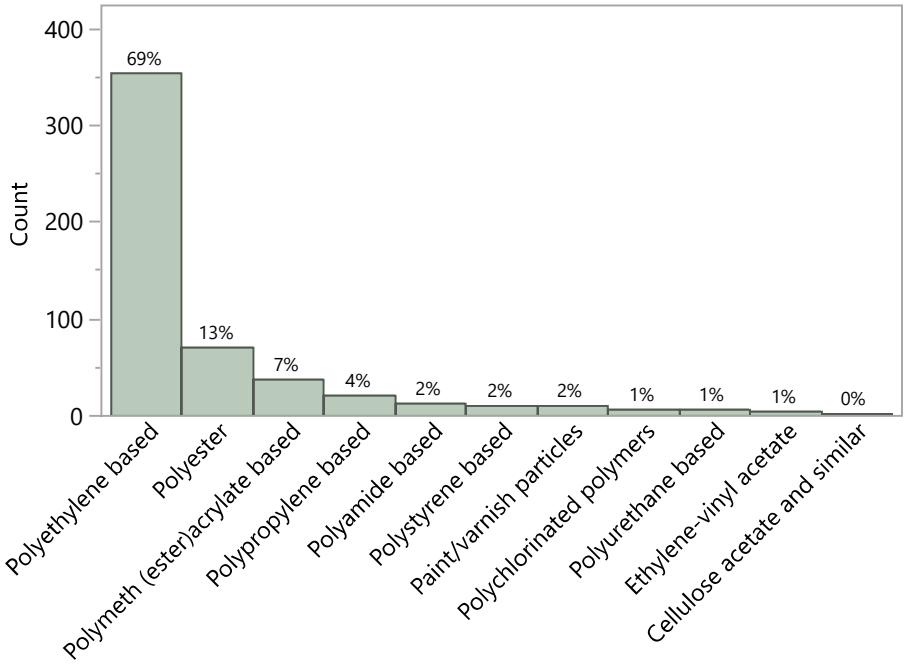

Figure 40. Distribution of polymer categories of microplastic particles in manta net water samples in Alnaelva in 2023.

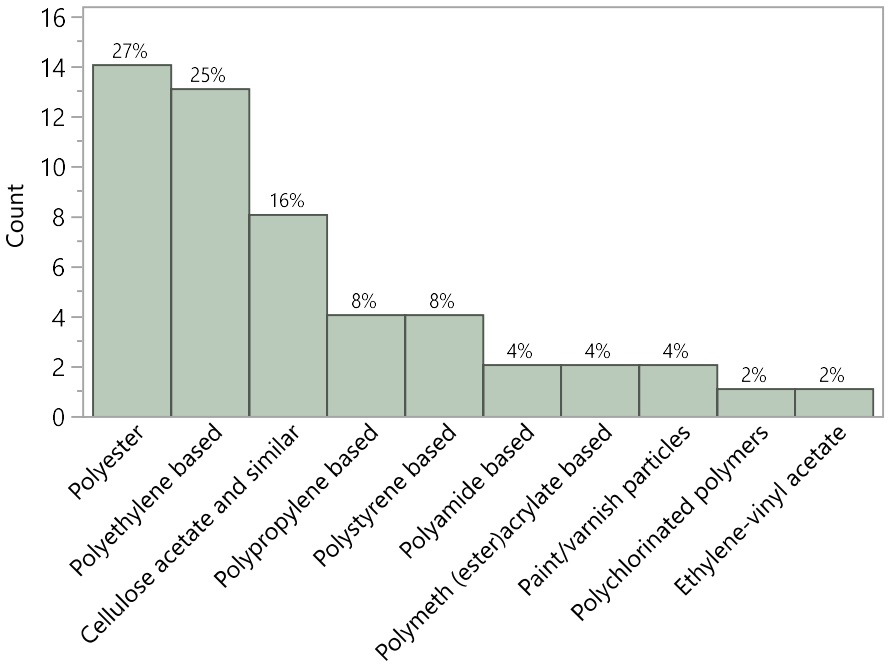

Figure 41. Distribution of polymer categories of microplastic particles in manta net water samples in Drammenselva, Storelva, Otra and Målselva in 2023.

5.4.3. Surface water samples from inner Oslofjord (>50 µm)

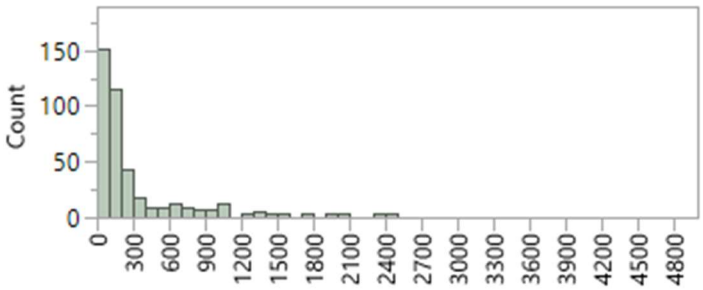

Figure 42. Distribution of microplastic particle sizes (µm) in water pump samples at Akershuskaia, Inner Oslofjord, at all three sample occasions in 2023.

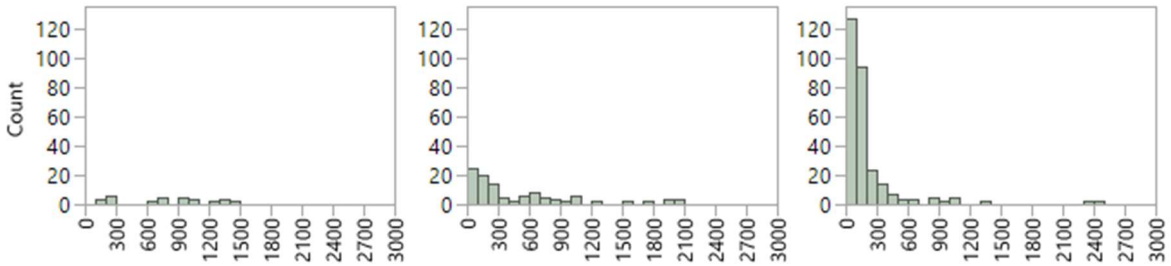

Figure 43. Distribution of microplastic particle sizes (µm) in water pump samples at Akershuskaia, Inner Oslofjord, at each of three sample occasions in 2023. Left: June, mid: October, right: November.

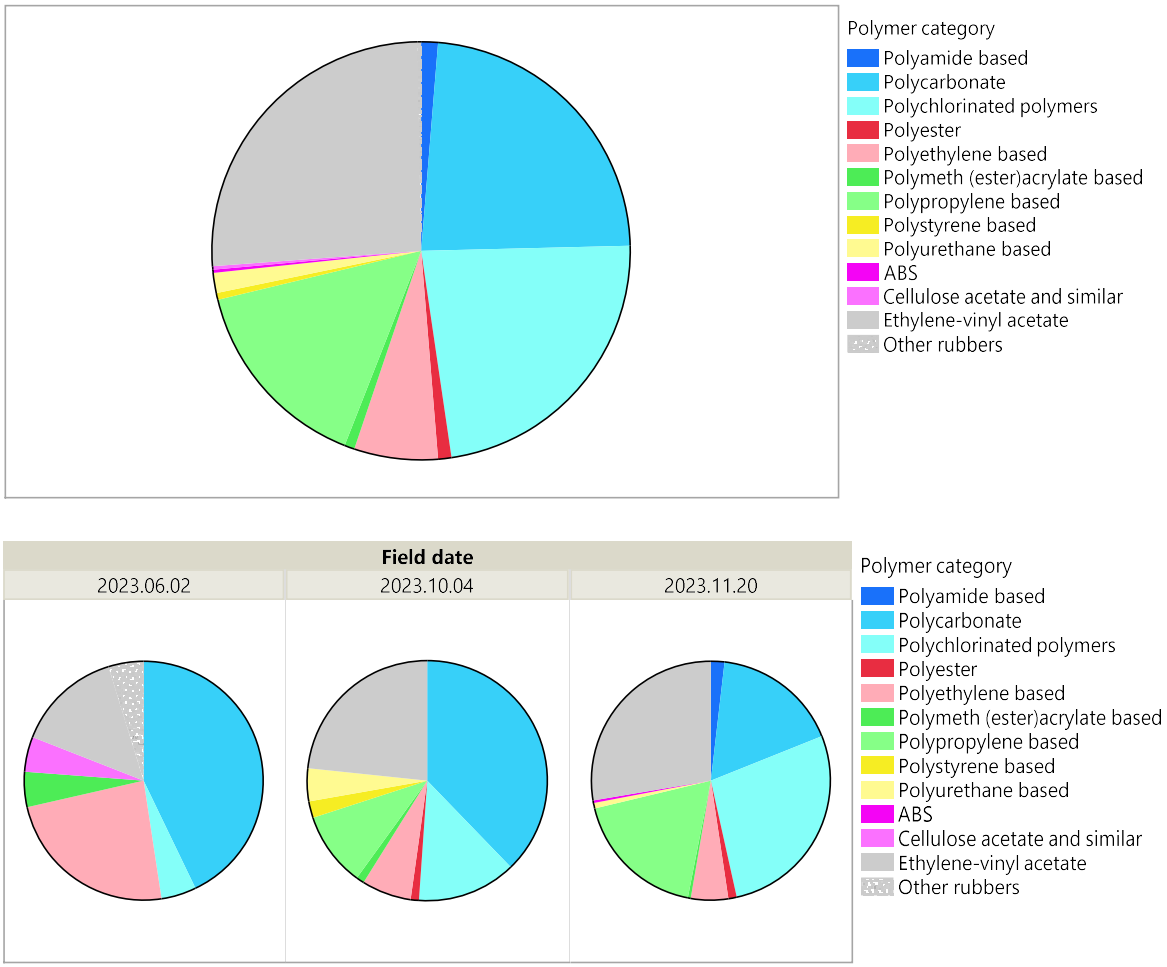

Figure 44. Distribution of polymer categories of microplastic particles in water pump samples at Akershuskaia, Inner Oslofjord, in 2023, presented as pie charts. Upper: all samples. Lower: per sample occasion.

5.4.4. FerryBox samples (>100 µm)

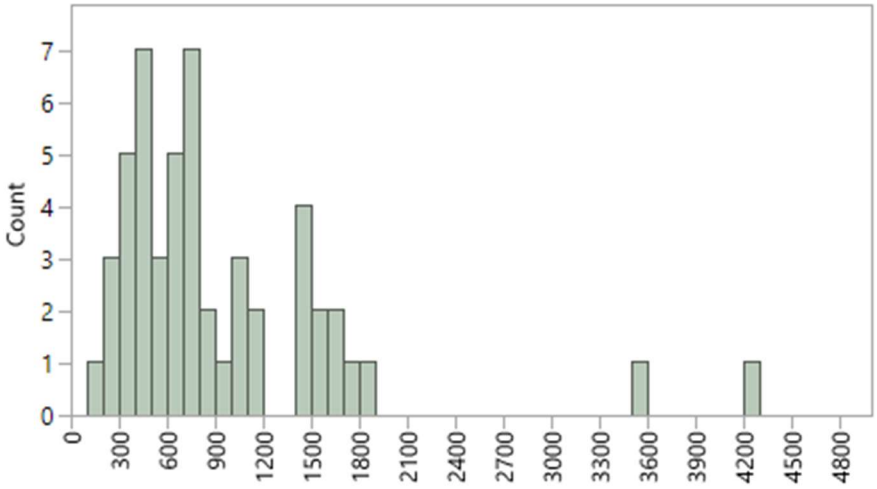

Figure 45. Distribution of microplastic particle sizes (µm) in water samples on FerryBox trip 1 in 2023.

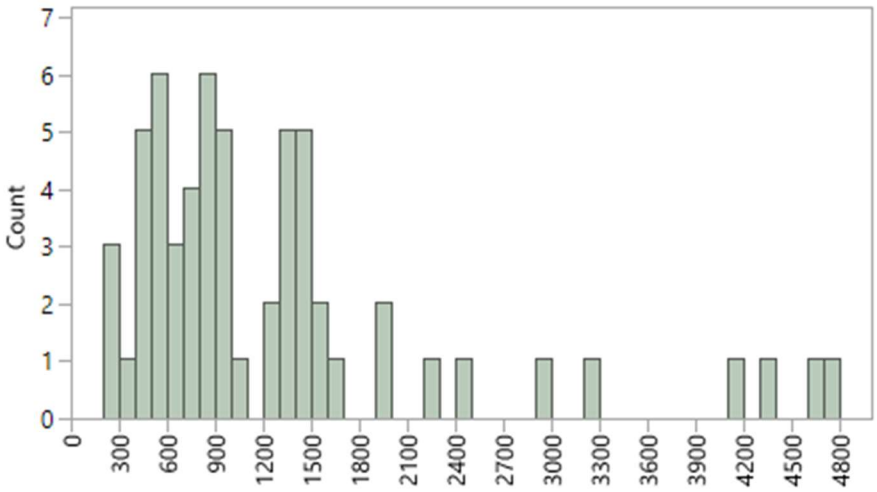

Figure 46. Distribution of microplastic particle sizes (µm) in water samples on FerryBox trip 2 and 3 in 2023.

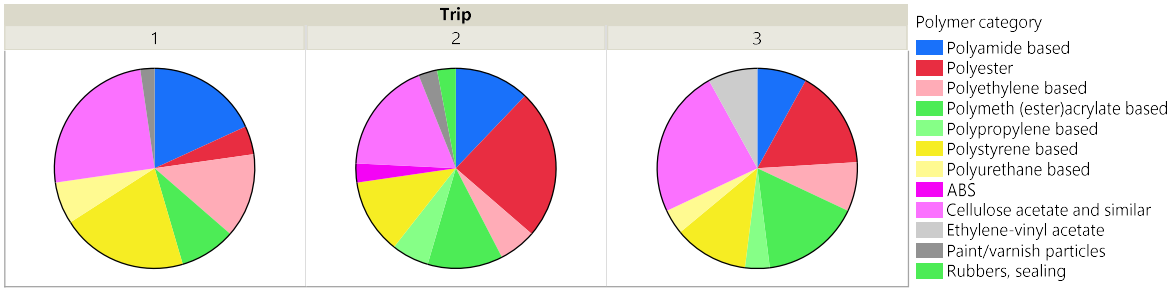

Figure 47. Pie charts of polymer categories of microplastic particles in water samples on FerryBox trip 1, 2 and 3 in 2023.

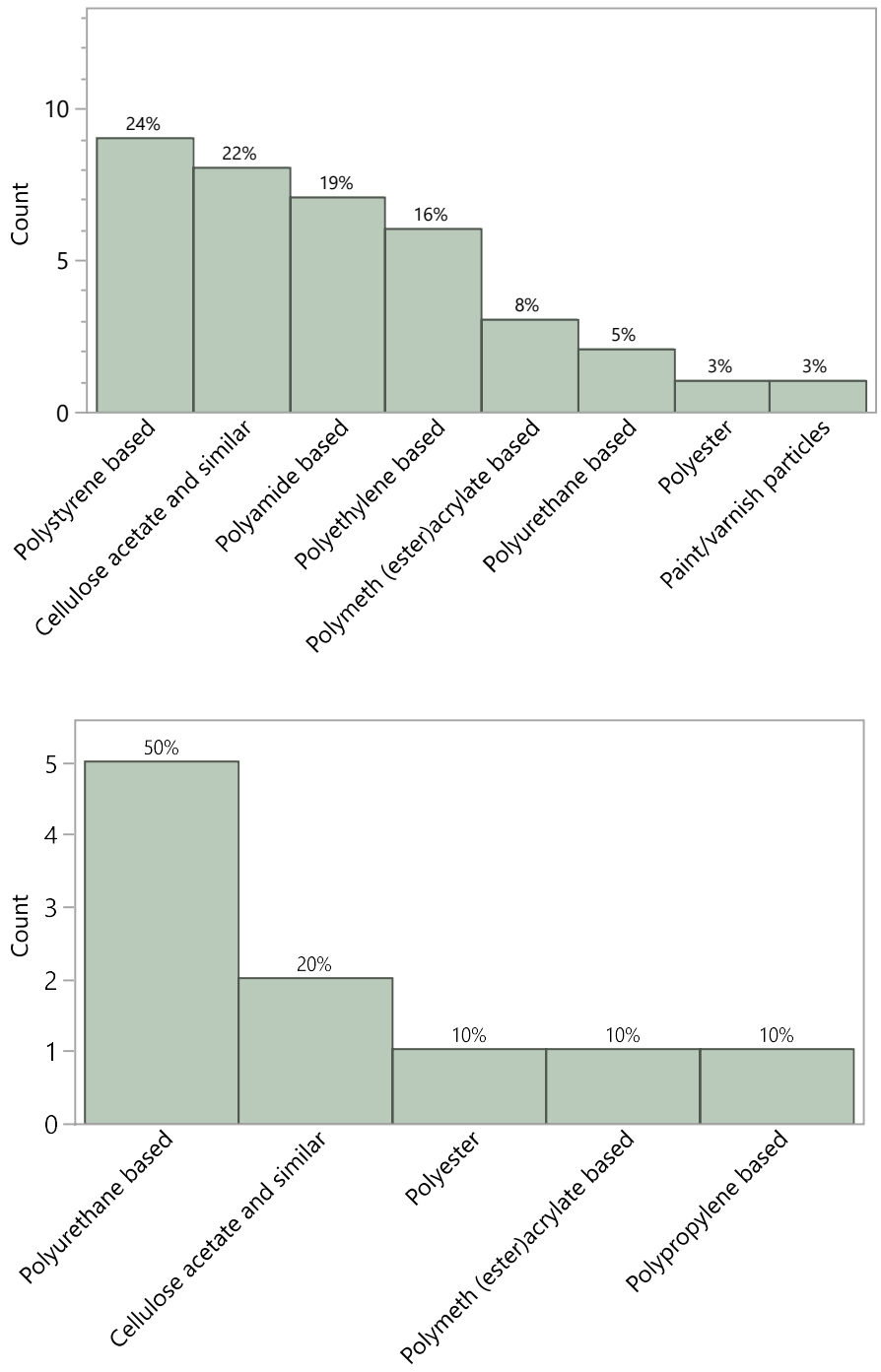

Figure 48. Upper: distribution of polymer categories of microplastic particles in water samples on FerryBox trip 1 in 2023. Lower: distribution of polymer categories of microplastic particles in the field blanks in 2023

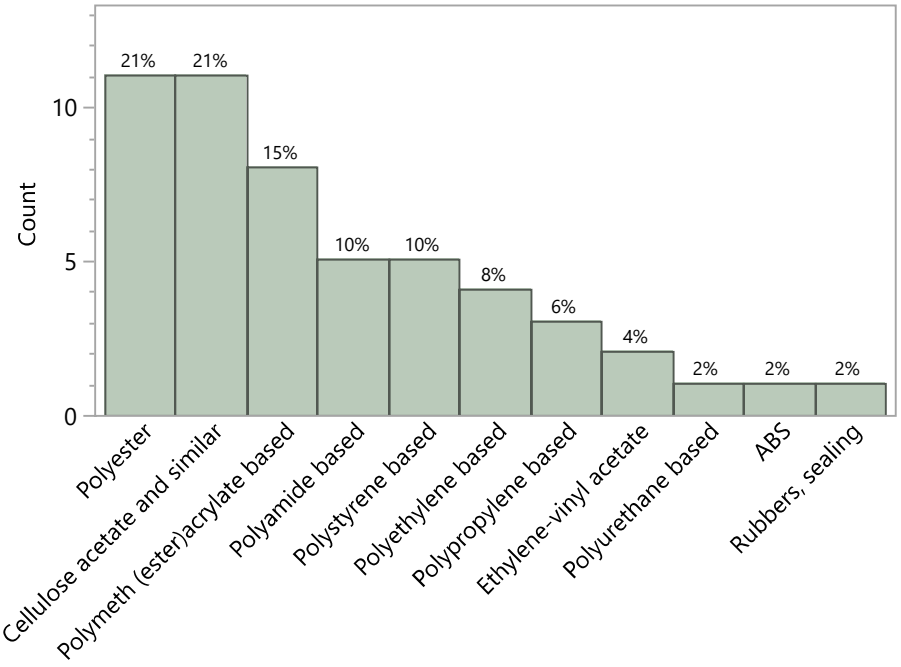

Figure 49. Distribution of polymer categories of microplastic particles in water samples on FerryBox trip 2 and 3 in 2023.

5.4.5. Vertical plankton nets

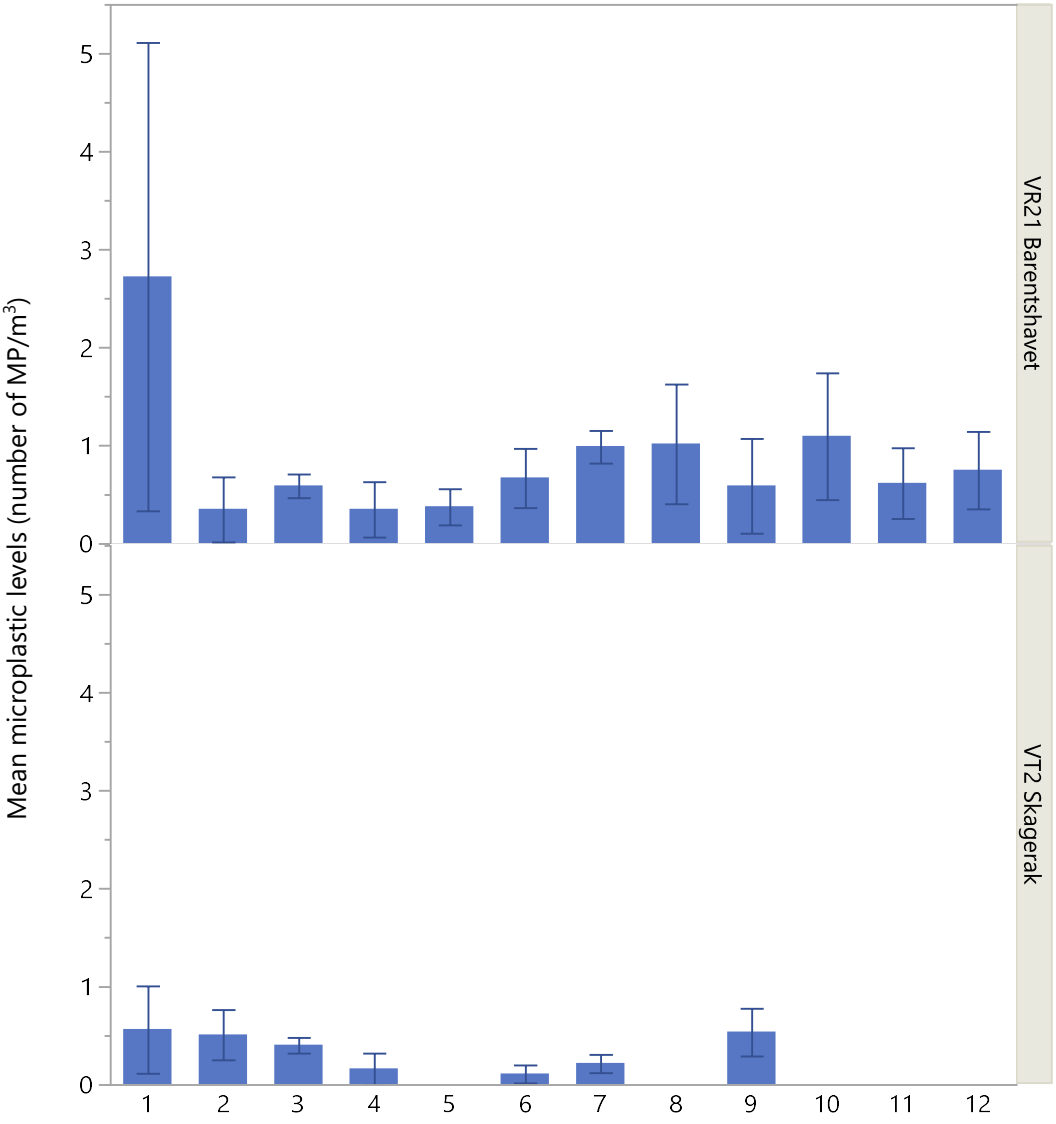

Figure 50. Mean microplastic levels (MP/m^3) in plankton net water samples at stations VR21 (top) and VT2 for each sampling occasion in 2023. Error bars showing ±SD. Number of samples per occasion = 3.

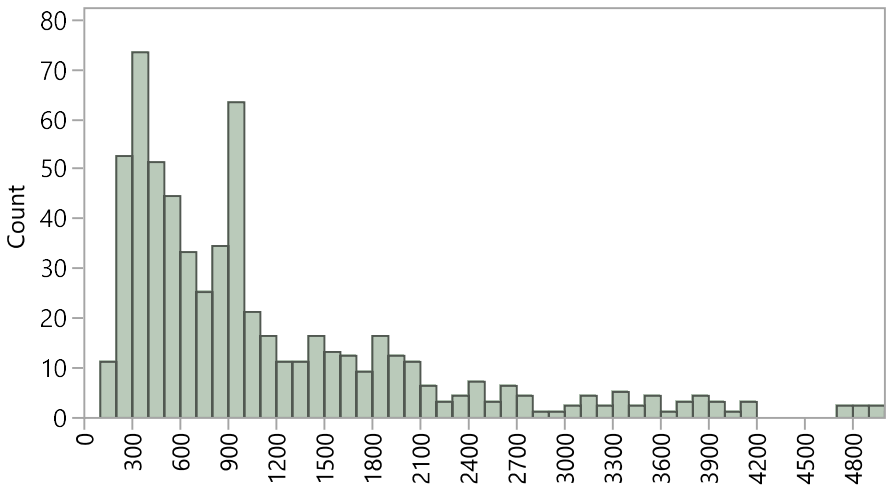

Figure 51. Distribution of microplastic particle sizes (µm) in plankton net water samples in 2023. Nets collects particles with an approximate lower size of 200 µm.

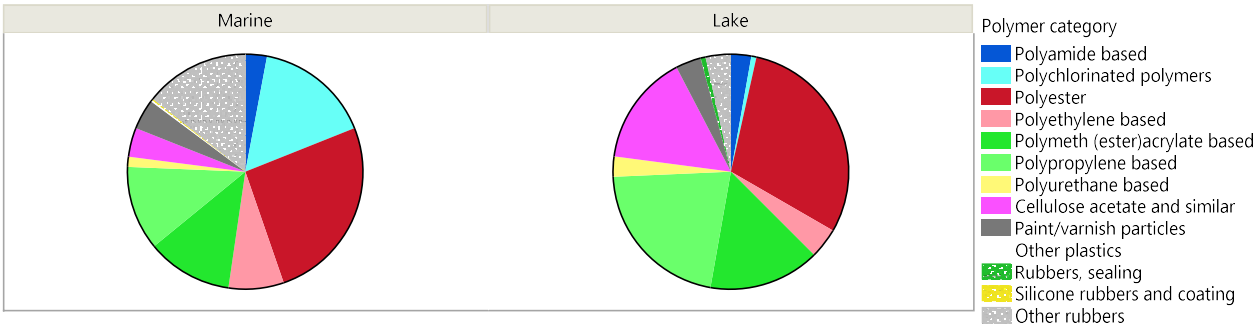

Figure 52. Distribution of polymer categories of microplastic particles in plankton net water samples in 2023.

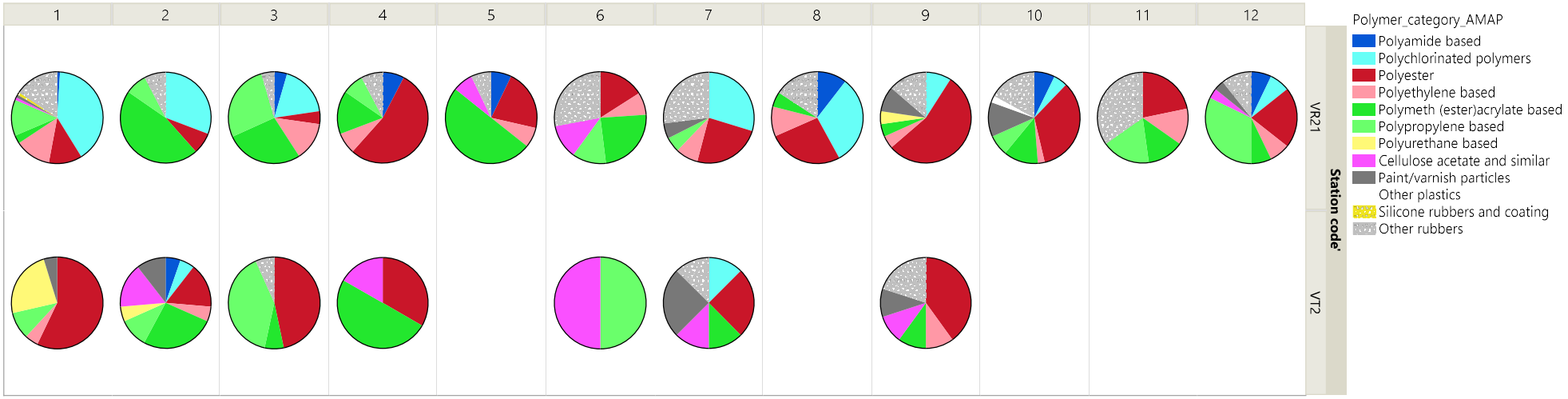

Figure 53. Distribution of polymer categories of microplastic particles in plankton net water samples at stations VR21 (top) and VT2 at each sampling occasion in 2023.

5.4.6. Blue mussels (>50 µm)

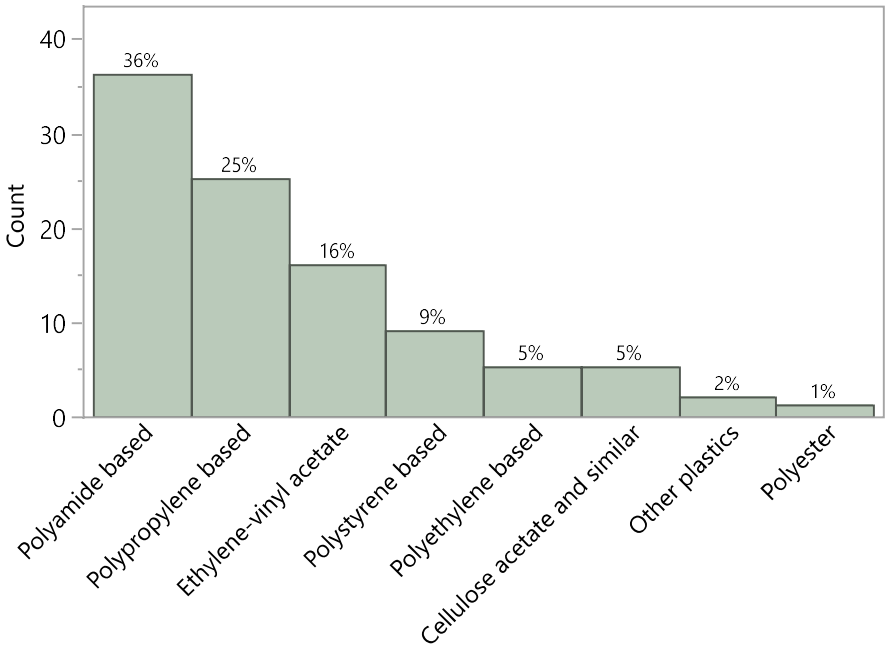

Figure 54. Distribution of polymer categories of microplastic particles in blue mussel in 2023.

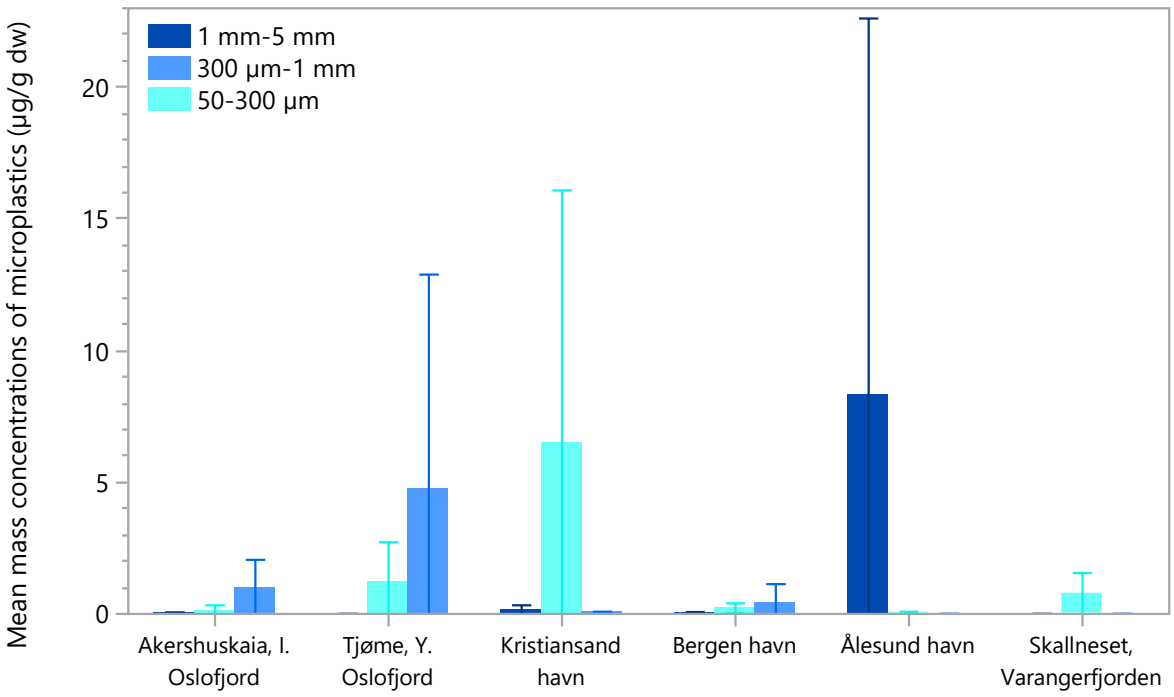

Figure 55. Mean mass (µg/g dw) per station in 2023 with three size classes side by side. Number of samples per station = 3. Error bars = ±SD

5.4.7. Beach sediment samples

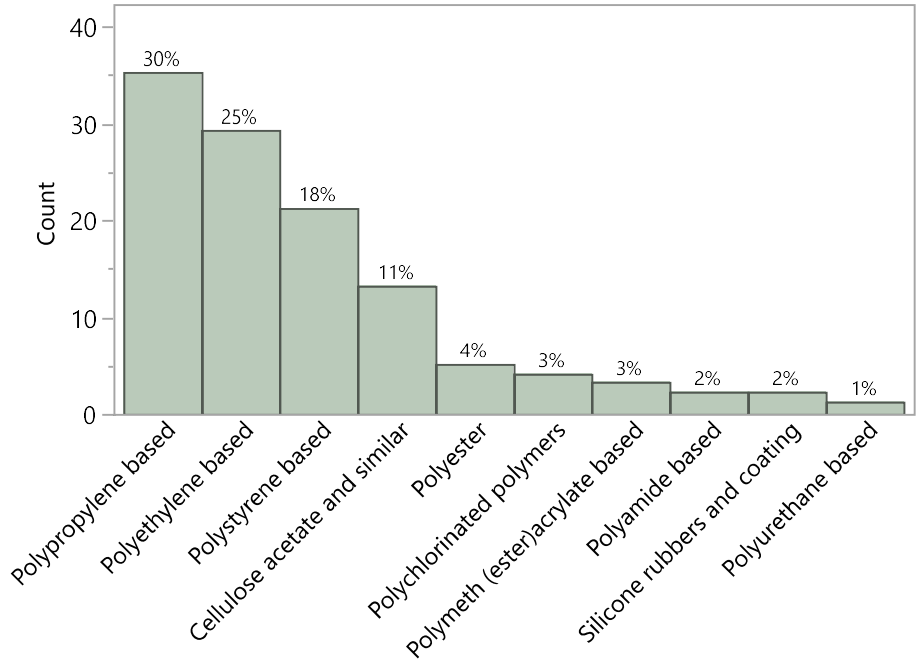

Figure 56. Distribution of MP in polymer categories in beach samples at Akerøya 2023.

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