TESTING A MONITORING STRATEGY FOR FLOATING MICROLITTER WITH MANTA-TRAWL SAMPLING IN DANISH COASTAL WATERS

Technical Report from DCE – Danish Centre for Environment and Energy No. 297 2023

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Abstract: The objective of the present project was to develop and test a coastal monitoring strategy for floating microlitter and microplastic (MP) in Danish marine surface waters using manta-trawl as sampling gear. 15 samples collected in transects along beach litter monitoring sites and analysed for MP > 300 µm. The median MP concentration was 0.057 particles m^{-3} and the maximum concentration was 0.213 particles m^{-3} indicating relatively low contamination levels of the seven investigated marine surface waters. This corresponded to a median value of 14630 MP per km^2 and a maximum value of 43639 MP per km^2. Other aspects considered include recommendation on sampling minimum of 100 m^3 sample volume, to analyse replicate samples and that sampling should be planned in spring/early summer.

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Contents

Preface **5**

Sammenfatning **6**

Summary **8**

1 Introduction **9**

2 Methods **11**
2.1 Sampling 11
2.2 Sample purification 13
2.3 Analysis 14
2.4 QA/QC 15

3 Results and discussion **16**
3.1 Background contamination 16
3.2 Concentration of MPs 17
3.3 Spectroscopic characterisation 20
3.4 Size and colour of MPs 21
3.5 Challenges 22

4 Recommendations **25**

5 Acknowledgments **27**

6 References **28**

7 Supplementary material **32**

Preface

This DCE report summarises the findings of a project testing a monitoring strategy for floating microlitter in coastal Danish surface waters requested by the Ministry of the Environment of Denmark. The report outlines a possible monitoring strategy for floating microplastics using a manta trawl for sample collection. Furthermore, it provides the first dataset generated according to the latest international harmonised guidelines (AMAP, 2021; HELCOM, 2022; Galgani et al., 2023) for microplastic monitoring in the marine environment.

Sammenfatning

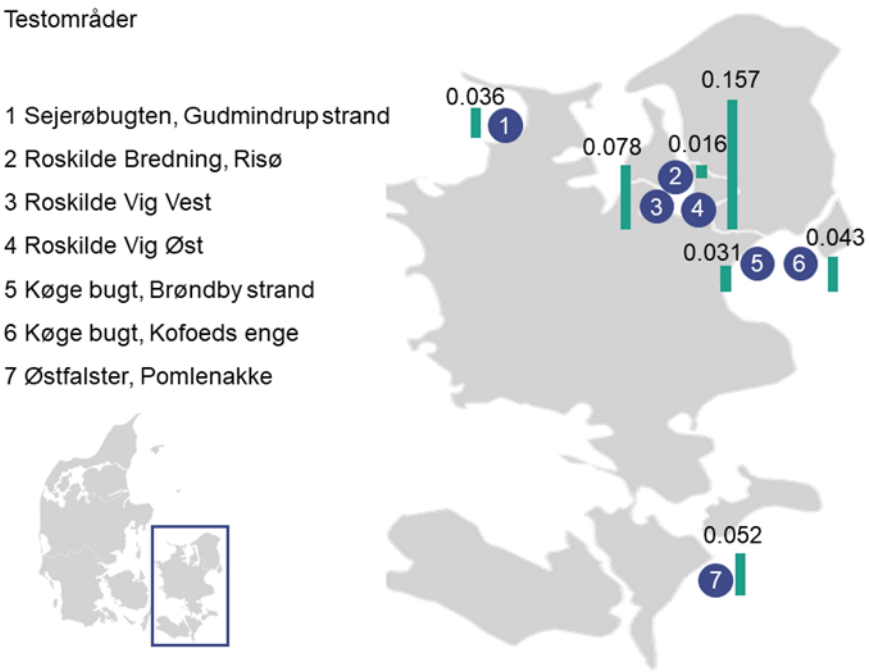
Formålet med EU's havstrategirammedirektiv (HSD) er at sikre en god miljøtilstand for havmiljøet i medlemslandene. Havmiljøets status skal således vurderes ved at etablere overvågningsprogrammer for at følge op på de skitserede mål, der er defineret på regionalt niveau. Deskriptor 10 i HSD inkluderer et kriterie D10C2 omhandlende mikroaffald med mikroplast (MP) som hovedkomponenten, dvs. fokus er på plastikpartikler og fibre < 5 mm, på grund af deres udbredte tilstedeværelse og potentielle miljøpåvirkninger. Som sådan skal sammensætningen, mængden og den rumlige fordeling af MP vurderes og overvåges i overfladelaget af vandsøjlen og havbundens sediment. Formålet med dette projekt er at udvikle en overvågningsstrategi for mikroplast i havoverfladevand for at overholde HSD. Projektet anvender de seneste internationale anbefalinger for rutinemæssig prøvetagning, analyse og datarapportering af mikroplast for at sikre datasammenlignelighed, hvilket er hjørnestenen i overvågningsprogrammer, der følger udviklingen over tid.

I dette projekt blev flydende mikroplastik med partikelstørrelser > 300 µm indsamlet fra overfladelaget på syv kystnære stationer i de indre danske farvande ved hjælp af et mantatrawl. Prøverne blev efterbehandlet i laboratoriet og derpå sigtet til forskellige størrelsesfraktioner. Analysen af partikler bestående af mikroaffald blev baseret på en visuel vurdering foretaget ved brug af stereomikroskopi, hvor de blev kvantificeret opdelt i typekategorier for fragmenter, film, fibre og kugler bestående af plast. Som validering af den visuelle karakterisering blev efterfølgende foretaget polymerbestemmelse på udvalgte MP-lignende partikler ved brug af spektroskopiske analyser.

Undersøgelsens resultater viste forholdsvist lave forureningsniveauer i de syv undersøgte kystnære områder med en medianværdi for MP-koncentrationen på 0,057 partikler per m^3 og med en maksimumsværdi på 0,213 partikler per m^3, når koncentrationen baseres på prøvetagningsvolumet. Dette svarer til medianværdi på 14630 partikler per km^2 og med en maksimumværdi på 43639 partikler per km^2, hvis koncentrationen angives per overfladeareal (baseret på længden af prøvetagningstransekt). De højeste koncentrationer blev fundet i inderfjorden Roskilde Vig. Dette niveau er sammenligneligt med andre publicerede undersøgelser fra Østersøregionen. Den spektroskopiske identifikation afslørede, at hovedparten af det analyserede MP bestod af plast-polymererne polyethylen og polypropylen.

De forholdsvist lave MP koncentrationer understøtter, at prøvetagningen skal omfatte et minimum på 100 m^3 prøvevolumen for at sikre den statistiske robusthed af de genererede data, hvilket er i overensstemmelse med anbefalinger i internationale moniteringsprotokoller. Ved at analysere replikater indsamlet ved hver prøveudtagningsstation kan variabiliteten reduceres mellem prøverne. Endelig bør prøveudtagningen planlægges i foråret for at undgå store mængder biomasse i havoverfladen, der kan forstyrre prøveudtagning og analyse.

Kort over indsamlingsområder med angivelse af de målte koncentrationer af mikroplastik-partikler (antal per m^3) i vandets overfladelag indsamlet med mantatrawl i syv kystnære områder, se også Figur 8 i kapitel 3.



Summary

The aim of the EU Marine Strategy Framework Directive (MSFD) is to ensure good environmental status of the marine environment in member states. Thus, the status of the marine environment must be assessed by establishing monitoring programs to follow up on the outlined targets defined at the regional level.

Descriptor 10 of the MSFD includes microlitter with microplastics (MPs) as the main component in criteria D10C2, i.e. focus is on plastic particles and fibres < 5mm, owing to their widespread presence and potential environmental impact. As such, the composition, amount and spatial distribution of floating MPs must be assessed and monitored in the surface layer of the water column and seabed sediment.

The objective of the present project was to develop and test a coastal monitoring strategy for MPs in Danish marine surface waters to comply with the MSFD. The project applies the latest international recommendations for routine sampling, analysis and data reporting of MPs to ensure data comparability, which is the cornerstone of monitoring programs to discover trends over time.

As such, microlitter > 300 µm was collected from marine surface waters at seven stations around Zealand, Denmark, using a manta trawl. The collected microlitter particles were sieved into size fractions and assessed visually to hand-pick MP-like particles and fibres. Spectroscopic characterisation of a subset of selected MP-like particles and fibres followed the visual assessment for validation.

The median MP concentration was 0.057 particles m^{-3} and the maximum concentration was 0.213 particles m^{-3} (based on the sampled volume), indicating relatively low contamination levels of the seven investigated marine surface waters. This corresponded to a median value of 14630 MP per km^2 and a maximum value of 43639 MP per km^2 if the concentrations instead are indicated per trawled area (based on transect length). The highest concentrations were measured in the inner fjord Roskilde Vig.

This level is comparable with findings in other published studies from the Baltic Sea. The spectroscopic identification revealed that most of the analysed MPs were made of polyethylene and polypropylene.

The study's key findings include low MP concentrations in coastal marine surface waters, which entails a minimum of 100 m^3 sample volume to ensure the statistical robustness of the generated data, as also recommended in the international monitoring protocols. Furthermore, analysing replicate samples collected at each sampling station can reduce inter-sample variability stemming from the heterogeneous distribution of MPs. Finally, the sampling should be planned in spring/early summer to avoid large amounts of biomass in the sea surface layer, which may interfere with sampling and analysis.

1 Introduction

The continuous influx of plastic litter and the material's longevity have led to its accumulation in the environment (Barnes et al., 2009; Cole et al., 2011; Jambeck et al., 2015). These released plastic litter items are exposed to physical and chemical breakdown processes that generate small-sized plastic fragments, known as microplastic (MP) particles (< 5 mm) (Andrady, 2011; Browne et al., 2011; Cole et al., 2011). Abiotic factors, e.g. wind and currents, contribute to the global distribution of plastic litter, resulting in their presence even in remote locations (Waller et al., 2017). Recognising the widespread occurrence of MPs and related potentially harmful impacts, such as ingestion by a range of organisms, leaching of plastic additives and transport of associated chemicals and microbes, has raised concerns (Teuten et al., 2009; Thompson et al., 2009).

Consequently, microlitter, including MPs, has been incorporated in the EU Marine Strategy Framework Directive (MSFD) under descriptor 10, which aims to ensure the good environmental status of the marine environment in EU member states (European Parliament Council, 2008; Galgani et al., 2010, EU, 2022). To implement appropriate management measures to achieve such a goal, the microlitter composition, amount and spatial distribution must be assessed and monitored in the surface layer of the water column and seabed sediment (European Commission, 2017).

The Baltic Sea has a significant socioeconomic value to the 85 million inhabitants in its drainage area (HELCOM, 2018). The good environmental status of the Baltic Sea is vital for its ecosystem and economic wealth as well, but it is threatened by substantial anthropogenic pressure. The Baltic Sea is particularly vulnerable to pollution due to the slow water exchange with the North Sea. Marine litter is one of the seven identified pressures on the habitats in the Baltic Sea, of which 70% is plastic (HELCOM, 2018). Therefore, the spatial and temporal distribution of marine litter, including MPs, in the Baltic Sea needs to be better understood. To that end, studies applying harmonised sampling and analytical protocols to assess MP occurrence are required (Aigars et al., 2021).

Figure 1 illustrates the measured MP concentrations in various parts of the Baltic Sea from manta trawl surveys based on Aigars et al. (2021), Gewert et al. (2017), Karlsson et al. (2020), Mishra et al. (2022), Ory et al. (2020), Schönlau et al. (2020), Setälä et al. (2016) and Tamminga et al. (2018). Despite methodological differences, the results of the reviewed studies indicate a concentration difference between open sea and areas close to high anthropogenic activities.

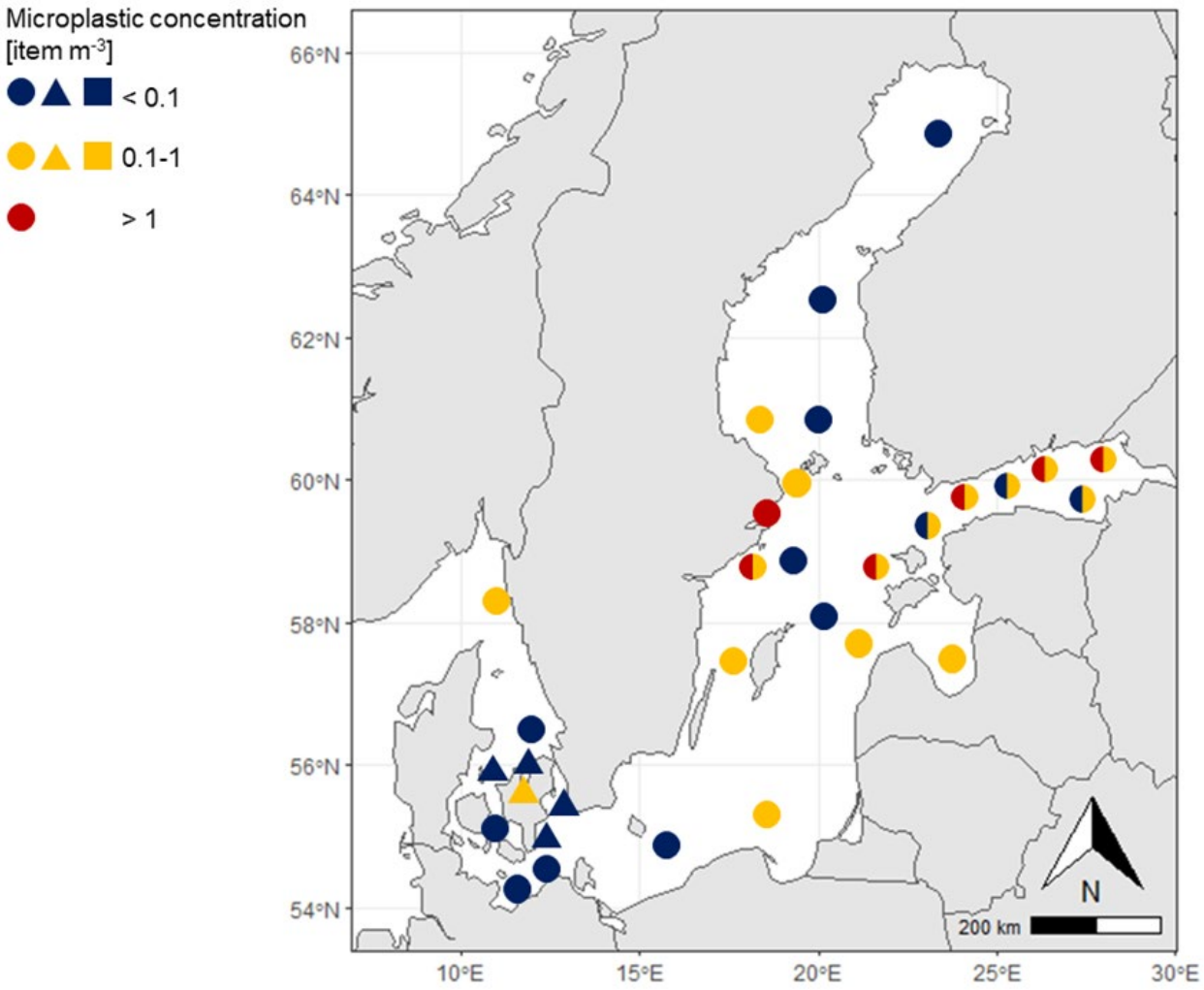


Figure 1. Microplastic concentrations in the Baltic Sea by manta trawl surveys in different scientific studies in 2015-2022 (reviewed). The red-yellow and blue-yellow points indicate that concentrations both below and above 1 and below and above 0.1 item m^{-3} were measured, respectively.

The present project aims to develop a strategy for sampling and analysing MPs in the surface layer of the water column in Danish marine waters to comply with the MSFD. The study uses manta trawl for collecting microlitter >300 µm following the latest international recommendations for harmonised sampling protocols for MP monitoring (AMAP, 2021; HELCOM, 2022; Galgani et al., 2023). Based on pilot sampling, the project proposes a sampling and analysis protocol or technical instructions considering recommendations for best practices by EU and HELCOM technical working groups on monitoring and assessments of marine litter. Although research has been conducted to assess MP pollution in Danish coastal waters, the project provides the first monitoring data set for microplastics in the surface layer of Danish marine waters in compliance with the new monitoring guidelines. The collected data also contribute to developing threshold values and indicators regionally and in the EU.

2 Methods

2.1 Sampling

2.1.1 Locations

The sampling was conducted over a two-week period, between the 1st and 5th of August 2022 and the 4th and 12th of October 2022. Replicate samples were collected in the vicinity of existing national monitoring sites for beach litter, namely Roskilde Bredning at Risø, Sejerøbugten at Gudmindrup strand, Køge Bugt at Kofoeds enge and Brøndby Strand and Østfalster at Pomlenakke (Figure 2). Furthermore, samples were taken at Roskilde Vig, far from the shores at the side exposed to (Roskilde East) and protected from the wind (Roskilde West), to assess the spatial variation of MPs. In addition, Roskilde Vig was revisited to evaluate the potential temporal variation of MPs (Figure 2). Two replicates were analysed from Roskilde Vig and Køge Bugt, while only one sample was analysed from each of the other sampling stations due to the limited time available for the analyses.

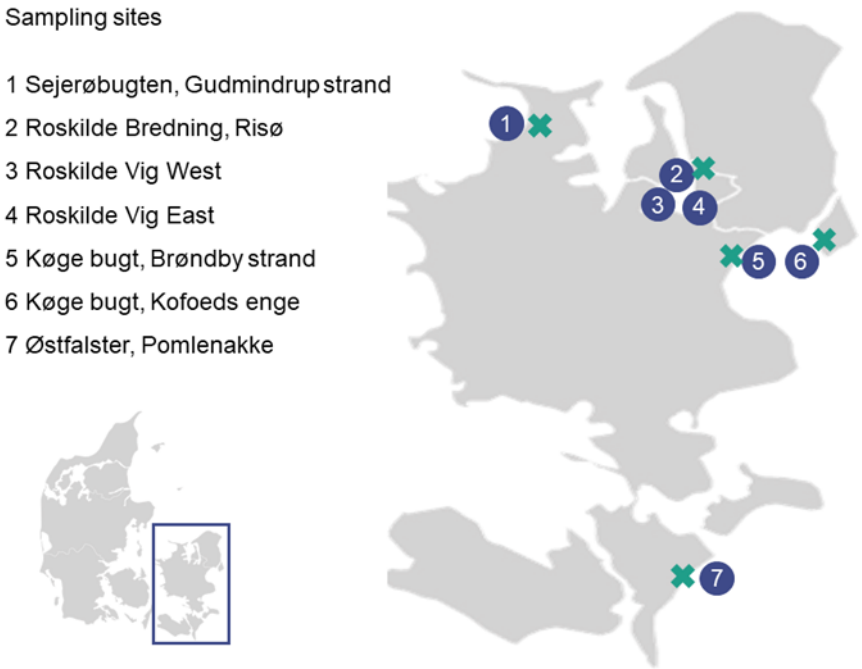


Figure 2. Map of test sites for manta trawl sampling (**1-7**). Replicate samples were collected at each site, though replicates only from Roskilde Vig and Køge Bight were evaluated for assessing the spatial variability within two subareas of the same coastal water body. The existing national monitoring beaches for beach litter in the Eastern part of Denmark (see Feld et al., 2023) are annotated (**X**). The map was accessed from https://freevectormaps.com/denmark/DK-EPS-01-0002?ref=atr.

2.1.2 Sampling technique

Microlitter from the water surface was collected with manta trawl. The device comprises a floating metal bridle with an aperture of 70 x 30 cm (width x height), to which a 2 m long net of 300 µm mesh size is attached. During sampling, a stainless-steel sample cylinder (cod-end) is connected to the net. It has five windows covered by a steel net; the mesh size equals the main net. In addition, the cod-end is equipped with a buoyancy that keeps it afloat. The sampling gear was produced by KC Denmark (product ID: 23.500).

The manta trawl was mounted to the vessel's side with a boom to avoid contaminating the sample with particles potentially flaking off the boat (Figure

3). The manta trawl was submerged to ensure 20 cm immersion depth of the aperture. The net was towed alongside the vessel with a speed of 3 knots for at least one nautical mile to ensure a minimum of 100 m^3 of sampled water. Environmental parameters, e.g. water temperature, wind speed and current direction, were recorded and found in the supplementary material (Table S1, Table S2).

Figure 3. Sampling microplastic with a 70 cm wide manta trawl alongside a small vessel in Danish coastal waters in 2022.

Replicate samples were collected at each site. At the end of the sampling transect, the manta net was lifted from the water and flushed with seawater from the outside to remove and gather the attached solids in the cod-end. The net was thoroughly inspected to ensure that all microlitter particles were removed to minimise potential particle loss and carry-over to the next sample. Afterwards, the cod-end was removed and placed into a glass jar (Figure 4). In case the collected solids filled up the cod-end completely and the lower part of the net, they were removed into 5 L pre-rinsed polyethylene buckets.

The manta trawl was equipped with a digital flow meter (Model 23.90, KC Denmark). The sampled volume was calculated using the following equation defined by the manufacturer:

Volume = No. of revolutions x 0.3 x opening area of the net

The opening area was calculated by multiplying the width of the net (70 cm) by the immersion depth (20 cm). The sampled volumes were also calculated by multiplying the immersion depth with the towed distance (transect length) based on GPS coordinates for start and end positions for comparison. MP concentrations were calculated based on the volume determined from the flowmeter, except for Østfalster, Pomlenakke T1, T2 and Roskilde East II T2 (Table S3). In these cases, the GPS-based volumes were used due to technical difficulties, e.g. entanglement of the flowmeter propeller.

In addition to sample volume, also sampled area of surface water (in m^2) were determined as based on transect length multiplied with the width of 0.70 cm of the manta trawl.

The sampled volumes and areas for each sites can be found in Table S2 and S3 in the Supplementary material.

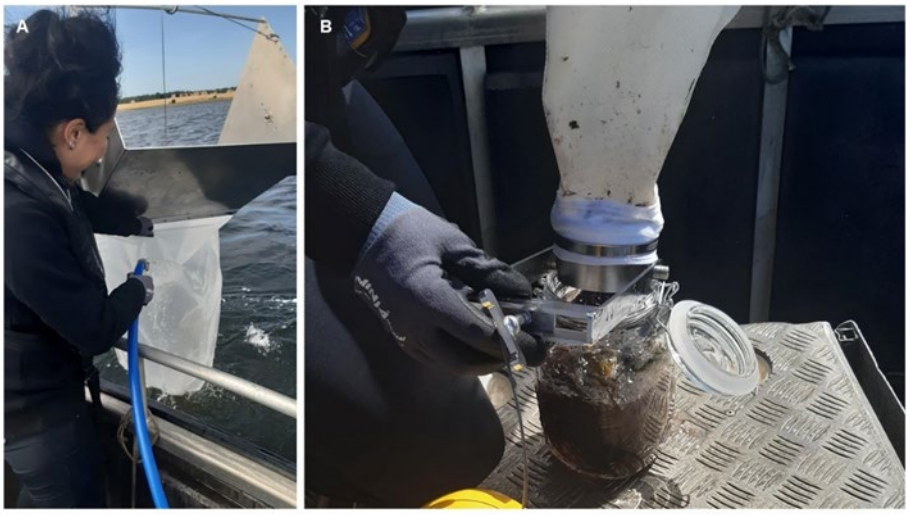


Figure 4. Sampling microlitter in marine surface waters. The net is flushed from the outside to gather solids in the sample cylinder (A), and the collected solids are placed in a glass jar (B).

2.2 Sample purification

Figure 5 illustrates the main steps of the sample purification procedure. First, the content of the cod-end was transferred onto a stack of 5 mm and 100 µm sieves in the laboratory. Next, it was thoroughly flushed with demineralised water filtered through a stainless-steel filter of 10 µm mesh size. The solids collected on the 5 mm sieve were inspected, and plastic-like pieces were placed into a Petri dish for further analysis. At the same time, organic material, such as eelgrass and insects, was discarded. Finally, the content of the 100 µm sieve was scraped and flushed into a glass jar, where KOH and NaOCl solutions were added to achieve a final concentration of approximately 5-10% of both chemicals. The sample was agitated for two hours and was incubated with the digesting agents for 48 hours. Afterwards, the sample was filtered through a 100 µm mesh-size zooplankton net. The net was rinsed with filtered demineralised water and placed into the Petri dish for storage and analysis.

The purification procedure slightly differed for Roskilde East II T1 and Østfalster, Pomlenakke T1, as the vast amount of organic matter caught during sampling hindered filtering the samples through the 100 µm sieve. Therefore, the samples were pre-digested with approximately 10% KOH for 48 hours. Subsequently, the Østfalster, Pomlenakke T1 sample could be filtered directly on a 100 µm zooplankton mesh. However, the pre-digested Roskilde East II T1 sample was filtered through a 5 mm and 100 µm sieve, and the solids on the 100 µm sieve were digested again with the mixture of KOH and NaOCl. The rest of the preparation steps were identical to the other samples.

Figure 5. Digesting organic matter. The sample was rinsed through a 5 mm sieve (A). The collected liquid was filtered through a 100 µm sieve (B). The collected solids were digested (C,D).

2.3 Analysis

The extracted particles were visually inspected using a Nikon SMZ18 stereo microscope in bright field mode. The potential MP particles were selected, and their shape, colour, length and width were recorded. The length was defined as the longest dimension of the particle, and the width as the longest dimension perpendicular to the length.

The chemical composition of a subset of particles from the laboratory and field blanks and trawl samples (n=65) was analysed with FTIR-ATR (Fourier Transform Infrared-Attenuated Total Reflectance) technique according to Feld et al. (2022) to increase the certainty of visual identification. An Agilent Cary 650 ATR accessory with a diamond internal reflection element was used for the spectroscopic characterisation of particles. Sixteen background and 32 sample scans were collected in the range of 4000-650 cm^{-1} with a spectral resolution of 4 cm^{-1}. The collected spectra were pre-processed and assigned to known reference spectra using the Essential FTIR v3.50.2013 (Operant LLC.) software toolbox. The pre-processing steps included smoothing using the Savitsky-Golay algorithm, fitting a second-order polynomial with a smoothing window size of 13 cm^{-1} and automatic baseline correction applying quadratic function fit. Finally, the spectra offset was set to zero. The reference library comprises more than 200 spectra of weathered and non-weathered plastic materials and natural matter compiled at Aarhus University (Feld et al., 2022). The library search was run in correlation mode, excluding the spectral range between 2400 and 1900 cm^{-1}. The Hit Quality Index (HQI) was derived from the Pearson correlation coefficient and matches above 0.8 HQI scores were accepted. The spectra assignment with 0.6-0.8 HQI was validated with expert judgement.

Statistical analyses and data visualisation were carried out in RStudio 4.1.3 (R Core Team 2022) using basic R functions and the packages ggpubr (v.0.4.0; Kassambra, 2020), sf (Pebesma, 2018), rnaturalearth (v.0.10; South, 2017) and ggspatial (v.1.16; Dunnington, 2022). The normal distribution of the data deriving from the visual identification was tested with the Shapiro-Wilk normality test, while the F-test was used to test for homogeneity of variance.

2.4 QA/QC

Tools and equipment made of glass and metal were used instead of plastic whenever possible in the field and in the laboratory to reduce potential contamination sources. Furthermore, field blanks were collected to assess airborne contamination during sampling. 1 L demineralised water filtered through 10 µm mesh was added into pre-rinsed 5 L white polyethylene buckets at each sampling site. The bucket was kept open when the net and the cod end were not submerged in water. Otherwise, the bucket was kept closed. After sampling, the water from the bucket was filtered through a muffled stainless-steel filter with a mesh size of 100 µm. The collected particles were analysed in the same manner as the samples.

Furthermore, an environmental blank in the laboratory was collected along with sample preparation and microscope analysis. 50 mL filtered demineralised water was added to a small glass container, which was kept open when the sample was exposed to open air. Otherwise, it was closed with a glass lid. The water from the container was filtered and analysed in the same manner as the field blanks. Furthermore, three procedural blanks were prepared in the laboratory and were treated identically to the samples.

Recovery tests for the sample purification procedure were not performed. However, previous recovery tests applying a similar digestion method of sediment, which is a more complex matrix than surface water, showed total extraction of 99 % of 500-600 µm beads and 91 % of 125-150 µm beads. A similar recovery rate can also be expected from the manta trawl samples.

3 Results and discussion

3.1 Background contamination

3.1.1 Field blanks

MPs were visually identified in two of the six collected field blank samples (Table 1). One piece of black film was found in the field blank from Brøndby Strand, while one yellow fibre was deposited in the blank during the first sampling occasion at the Roskilde fjord. Overall, background contamination deriving from airborne MPs during sampling was negligible.

Table 1. The results of the visual analysis of microlitter particles in the collected field blank samples.

Sample	Shape	Colour	Length [µm]	Width [µm]	Remarks
Køge Bugt, Brøndby str.	Film	Black/grey	1000	1000	
Sejerøbugten, Gudmindrup					No MP identified visually.
Roskilde vig East & West	Fibre	yellow	10000		
Køge Bugt, Kofoeds enge					No MP identified visually.
Roskilde vig West II					No MP identified visually.
Roskilde vig East II					No MP identified visually.
Østfalster, Pomlenakke					No MP identified visually.

3.1.2 Laboratory blanks

The laboratory blanks showed negligible airborne contamination and MPs deriving from the applied tools and reagents (Table 2). The samples mainly contained MP-like fibres and one fragment.

Table 2. Visually identified microplastics in the laboratory blank samples.

Sample	Shape	Colour	Length [µm]
Air blank	Fibre	Transparent/No colour	354
Procedural blank 1	Fibre	Transparent/No colour	537
	Fibre	Transparent/No colour	437
Procedural blank 2	Fragment	Black/grey	1821
	Fibre	Transparent/No colour	1932
Procedural blank 3	Fibre	Transparent/No colour	916
	Fibre	Transparent/No colour	855

3.1.3 Limit of detection (LOD)

The limit of detection (LOD) can be calculated from the visually identified MPs in the field blank samples as the sum of the mean concentration and three times the standard deviation (HELCOM 2022, Galagani et al., 2023). In the present study, the average value of the 5 field blanks is 0.29 and the LOD is 1.64 MP per sample, corresponding to 0.016 MP per 100 m^3. The HELCOM

(2022) guideline argues against subtracting blank values from the sample values and instead report both of them separately.

3.2 Concentration of MPs

Fifteen samples were analysed from the 24 collected trawl samples, and the data for particle concentrations by size classes and in total are reported in the unit of MP per m^3 and per km^2 in Table S4 and S5, respectively. The preferred data described and assessed further in this report are based on Table S4.

The total number of visually identified MPs in the analysed samples is 170, of which 87 are fibres and 83 particles. Figure 6 shows examples of visually identified MPs. Most particles are characterised as film and fragments, while only a few beads were found (Figure 7). Foams and industrial pellets were not found in the analysed samples. Since both field and laboratory blanks indicate minor contamination, it is safe to assume that the identified MPs derive from the samples.

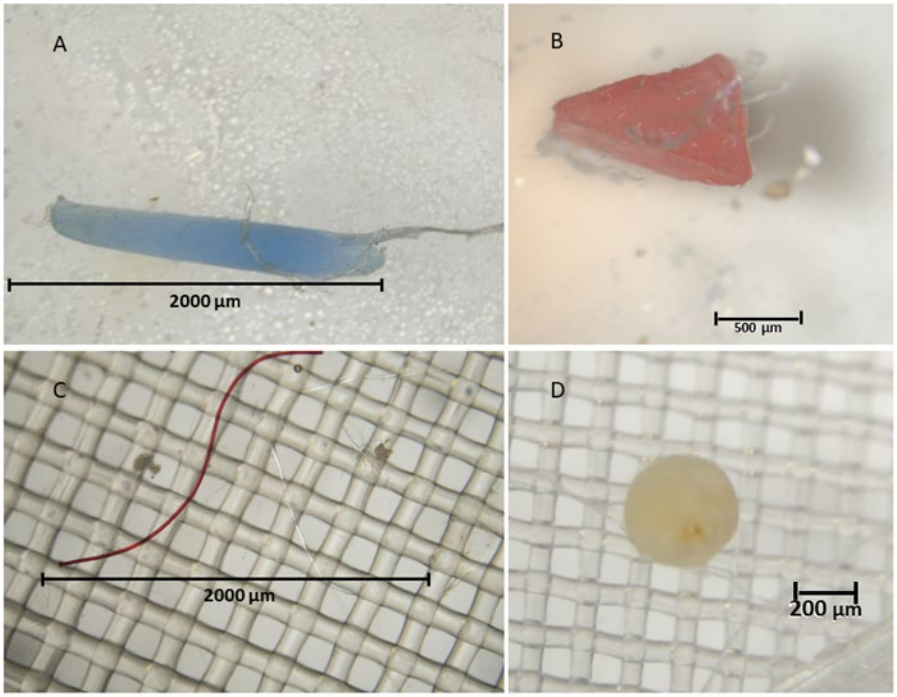
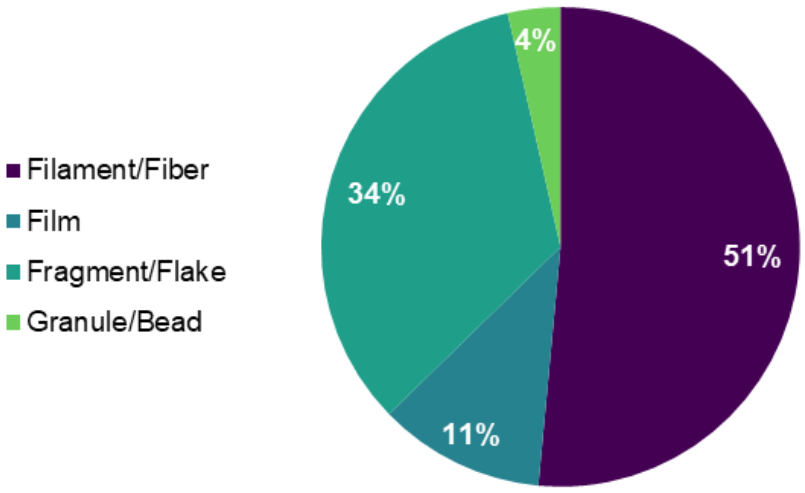


Figure 6. Examples of visually identified microplastics: film (A), fragment (B), fibre (C) and bead (D).

Figure 7. Distribution of microplastic shapes among the 170 visually identified particles and fibres. Foams and industrial pellets were not found in the analysed trawl samples.



The total MP concentration (including fibres and particles) in the analysed samples ranges between 0.006-0.213 item m^{-3}, and the median concentration is 0.057 item m^{-3} (Table 3 and Figure 8), when based on the sampled volumes This corresponded to a median value of 14630 MP per km^2 and a maximum value of 43639 MP per km^2 (Table S5) if the concentrations instead are indicated per trawled area (based on transect length). The highest concentrations were measured in the inner fjord Roskilde Vig.

Table 3. Levels of floating microplastic in measured at the coastal Danish stations in 2022, reported both per sample and per m^3.

Sample	No. of fibres	No. of particles	Total counts	Volume [m^3]	Concentration [MP m^{-3}]		
					Fibres	Particles	Total
Køge Bugt, Brøndby St. T1	9	2	11	193	0.047	0.010	0.057
Køge Bugt, Brøndby St. T2	0	1	1	173	0	0.006	0.006
Sejerøbugten, Gudmindrup	8	0	8	222	0.036	0	0.036
Køge Bugt, Kofoeds enge T1	1	1	2	183	0.005	0.005	0.011
Køge Bugt, Kofoeds enge T2	1	13	14	185	0.005	0.07	0.076
Østfalster, Pomlenakke	6	3	9	172	0.035	0.017	0.052
Roskilde Bredning, Risø	2	1	3	184	0.011	0.005	0.016
Roskilde Vig East I T1	5	3	8	184	0.027	0.016	0.043
Roskilde Vig East I T2	12	12	24	126	0.095	0.095	0.191
Roskilde Vig West I T3	9	6	15	162	0.056	0.037	0.093
Roskilde Vig West I T1	11	4	15	135	0.081	0.030	0.111
Roskilde Vig East II T1	7	20	27	149	0.047	0.134	0.181
Roskilde Vig East II T2	4	14	18	85	0.047	0.166	0.213
Roskilde Vig West II T1	8	3	11	140	0.057	0.021	0.078
Roskilde Vig West II T2	4	0	4	130	0.031	0	0.031

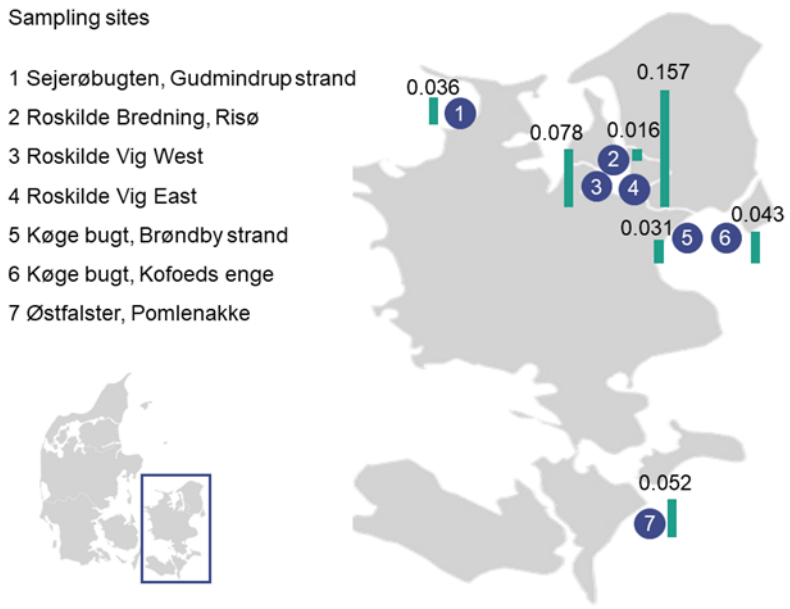


Figure 8. Total microplastic concentrations (fibres and particles) as MP per m^3 measured at each sampling location. The values at station 3 and 4 are the average values of the two duplicates collected at two different sampling campaigns. The value at station 5 and 6 are average concentrations of duplicate samples.

These results align with previous studies assessing MP concentrations in the Eastern Baltic Sea using a manta trawl, and in the Skagerrak and Kattegat regions using a ferry box for collecting microlitter, as shown in Table 1. Nevertheless, they are several orders of magnitude lower than MPs reported in the Skagerrak and Kattegat by Kuddithamby et al. (2022). However, the difference is most likely related to the different sampling techniques and mesh sizes used for filtering. The pump filtration system in the latter study collected particles down to 10 µm. In contrast, the manta trawl primarily collects larger MPs less abundant than the small MPs retained by a finer mesh.

Table 4. Examples of previously reported data for microplastic concentrations in marine waters around Denmark.

Sampling area	Sampling gear	Mesh size [µm]	MP concentration [item m^{-3}]	Predominant polymers	Reference
South Funen	Manta	300	0.04-0.09	Not applicable	Tamminga et al. (2018)
Skagerrak, Kattegat, Southern Baltic Proper	Manta	333	0.02-0.16	PE, PP	Schönlau et al. (2020)
Skagerrak, Kattegat	Pump	300 and 10	11-87	PES, PP, PE	Kuddithamby et al. (2022)
Skagerrak, Kattegat	Ferry box	100 and 500	0-1.85	PES, PP	van Bavel et al. (2020)

* Polymers: PE: Polyethylene, PP: Popylpropylene: PES: Polyester

Replicate samples show notable variability in total MP concentrations. For instance, the concentration difference between the two replicates from Køge Bugt, Brøndby Strand is ten-fold. Likewise, MP concentration is several times higher in the second trawl sample from Roskilde Vig East I than in the first trawl sample. Other studies collecting MP in replicates by manta trawl have reported similar differences. It can be related to the inherent variation of water conditions, e.g. wind and currents, that cause patchy distribution of MPs resulting in large spatial and temporal variance (Schönlau et al. 2020, Karlsson et al. 2020).

The October sampling campaign in Roskilde fjord covered both East and West transects in Roskilde Vig, the inner part of the fjord close to Roskilde town

and harbour, as well as the central part of Roskilde Bredning at Risø. MP concentrations in Roskilde Vig (0.078-0.213 item m^{-3}) were higher than in Roskilde Bredning, Risø (0.016 item m^{-3}). The difference indicates that MPs may be more abundant in coastal areas impacted by local point sources, e.g. from wastewater effluents, urban stormwater or intense sea-based activities, including ship traffic and harbours, as in Roskilde Vig.

In Roskilde Vig, two transects were sampled at the Eastern, wind-exposed, and the Western, wind-shielded side of the inner fjord. These locations were visited twice at two-month intervals, i.e. August and October. Figure 9 illustrates the measured MP concentrations in all eight samples. MPs are more abundant in the East, i.e. in the wind-exposed transects, than in the samples from the western transects, as the mean concentrations were 0.157 and 0.078 item m^{-3}, respectively. Since the normal distribution and equal variance of data were met, an unpaired two-sample t-test was performed for comparing means. The test indicates that the difference is not statistically significant ($p=0.11$), suggesting that the difference can also be explained by a natural variation in MP concentrations between the two sides of the fjord. More replicates are therefore needed for exploring such a phenomenon.

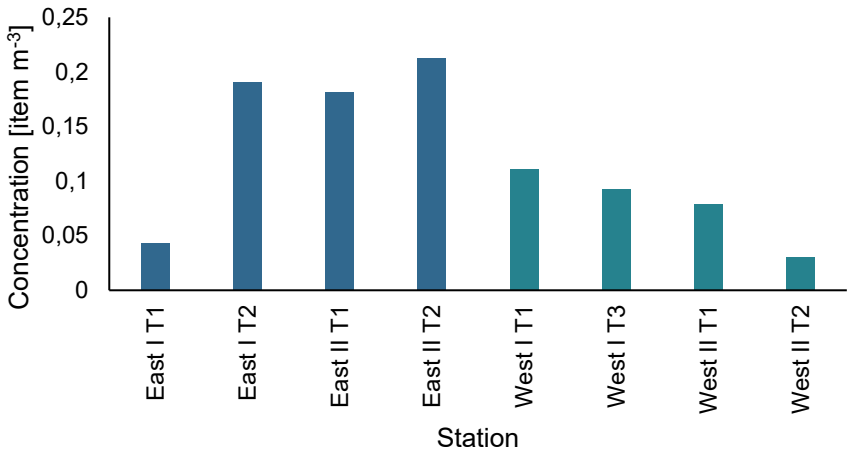


Figure 9. The total microplastic concentration (including fibres and particles) measured in Roskilde Vig in August (I) and October (II).

The role of wind in MP distribution has been investigated in the Baltic Sea, and studies have reported conflicting conclusions. For instance, Schönlau et al. (2020) found a significantly negative correlation between wind speed and MP concentrations, whereas Ory et al. (2020) found a limited wind effect on MP occurrence. On the one hand, the resuspension of sediment caused by strong winds can increase MP concentrations on the surface. However, on the other hand, wind-driven mixing can reduce MP abundance in the surface layer in shallow areas (Mishra et al., 2022, Tamminga et al., 2018). Furthermore, the wind direction can also impact MP distribution and, consequently, its concentration on the surface of the water column via coastal upwelling and downwelling (Mishra et al., 2022).

3.3 Spectroscopic characterisation

One visually identified MP from the Køge Bugt field blank, three from the laboratory blanks and 61 of 170 (corresponding to 36%) from the trawl samples were subjected to infrared characterisation for validating visual identification. As a result, the black film from the Brøndby Strand blank was identified as polyethylene. Furthermore, the black fragment in the procedural blank was polypropylene, whereas the two fibres from the air blank and procedural

blank were cellulose. As such, the fibres were falsely identified as MPs by the visual analysis.

From the 61 MP-like particles and fibres identified in the trawl samples, 55 were confirmed to be plastic, corresponding to 90% of the particles subjected to FTIR-ATR and 32% of the visually identified MPs. The rest of the MP-like particles and fibres were identified as cellulose, protein, or their material could not be determined based on their collected IR spectra.

The distribution of the different identified polymers in the trawl samples is shown in Figure 10. Most MPs were of PE (65%), including PE-acrylic acid co-polymer, while the second most abundant polymer type was PP (24%). The category "Other" includes ethylene-vinyl acetate and polycarbonate. The polymer could not be determined for 5% of the selected MPs. However, the visual identification indicated that they were of synthetic origin, and their spectra were characteristic of synthetic polymer materials.

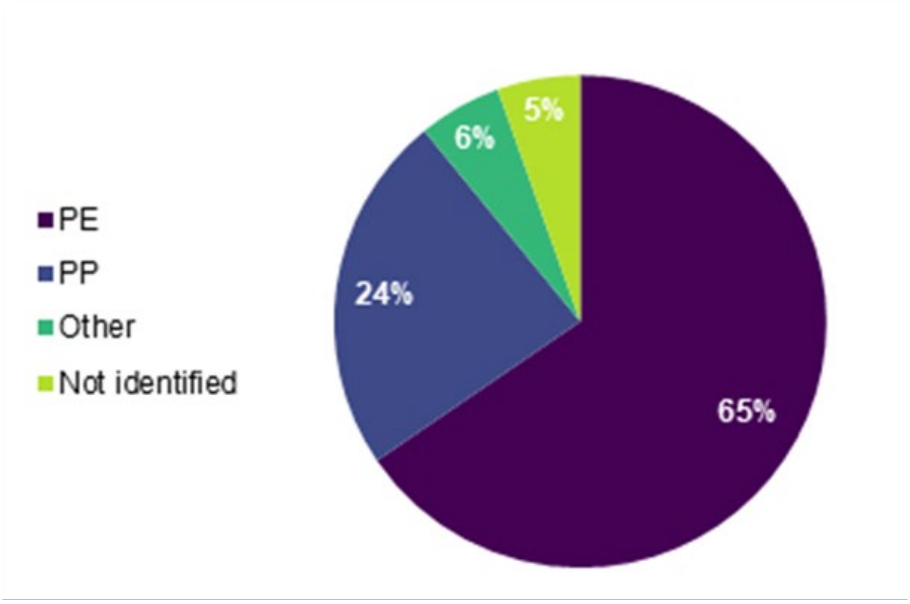


Figure 10. Distribution of polymers among the confirmed MP fibres and particles from the trawl samples subjected to FTIR-ATR analysis (N=55). The category "Other" includes ethylene-vinyl-acetate and polycarbonate. The group of PE includes PE-acrylic acid co-polymer MPs. "Not identified" spectra were characteristic to synthetic polymer materials, though they did not match any of the refence spectra.

3.4 Size and colour of MPs

Figure 11 shows the colour of the identified MPs. Most fibres and particles are black/grey and orange/red/pink. A quarter of the MP particles, while only 7 % of the fibres, are transparent. The proportion of yellow and orange/pink/red fibres and particles is similar. One-fifth of the fibres are blue/green, and 12 % of the particles are of this colour. Furthermore, a couple of fibres and particles were multicolour, brown/tan or red/black.

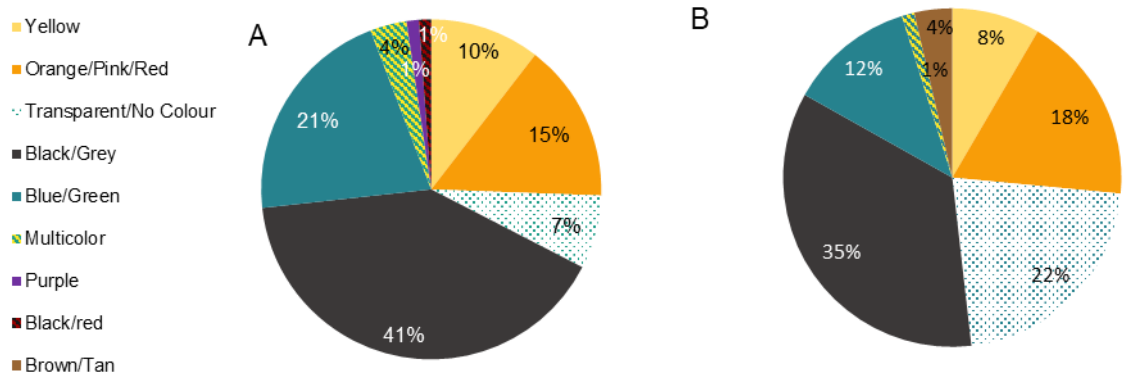


Figure 11. The distribution of colours of fibres (A) and particles (B) visually identified as microplastic. The relative proportion of each colour category is indicated.

Figure 12 shows the size distribution of all visually identified microplastic fibres and particles across the samples based on their longest dimension (length). Since the width was not recorded for all identified MPs, it is not considered for data analysis. The dashed lines denote the median length, 2000 and 1000 µm for fibres and particles, respectively, indicating that the collected particles are smaller than the fibres. Such differences can be expected, as fibres are more likely to slip through the mesh owing to their small width (3-70 µm measured in the analysed sample). The shortest fibre and particle length is 100 µm, and 7 particles and 4 fibres measure smaller or equal to the 300 µm cut-off of the manta net's mesh. In addition, the length of 4 particles and 1 fibre were between 300 and 400 µm, implying that MPs with a size close to the cut-off of the mesh may be underestimated.

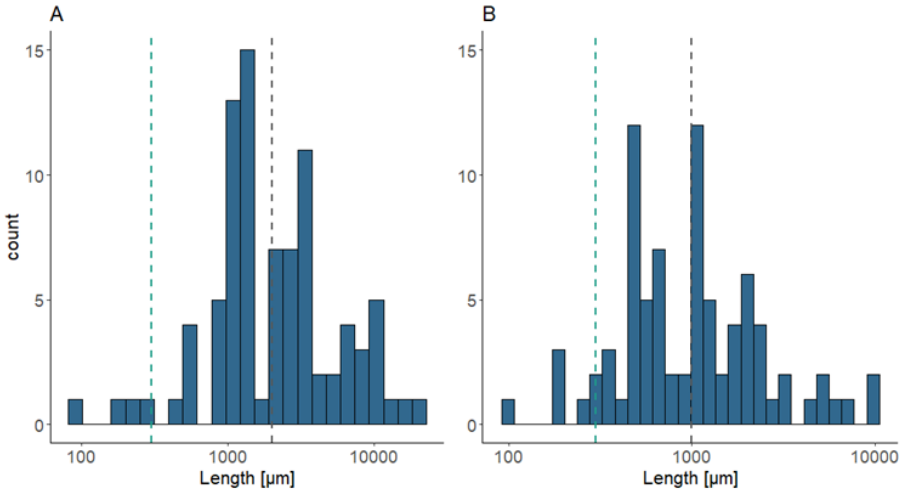


Figure 12. Size distribution of visually identified fibres (A) and particles (B) based on the longest dimension (length). The grey dashed lines indicate the median length, 2000 µm for fibres and 1000 µm for particles, while the green dashed lines the mesh size of the manta net (300 µm). Note the logarithmic scale of the x-axes.

3.5 Challenges

The latest EU and HELCOM monitoring guidelines recommend manta trawl for sampling microlitter in surface waters (HELCOM 2022; Galgani et al., 2023). The main advantage of the device is the ability to sample large volumes of water over an extended area, which decreases the variance in the data stemming from spatial and temporal variation of MPs (Lusher et al., 2014; Tamminga et al., 2019; Martinez et al., 2022). Nevertheless, one of the limitations of sampling with manta trawl is the difficulty of determining the sampled volume precisely. Varying immersion depth due to wave and wind actions and water turbulence impedes ascertaining the sampled volume (Martinez et al., 2022). The difference in the calculated values can reach 48% by only a few cm of variance of immersion depth (Karlsson et al., 2020). Although GPS-

based calculation of the towed distance can overcome such a problem, the method also has shortcomings. For instance, misinterpreting travelled distance, clogging effect or currents can lead to erroneous values (Pasquier et al., 2022).

Such limitations are reflected in the present dataset as well. The volume calculated based on the flowmeter readings also differs -50% to 70% from the values derived from GPS data in the present study (Figure 13). Sixteen times out of 23, the GPS-based calculation yields a lower volume than the flowmeter-based calculation. The deviation is greatest in the case of Køge Bugt, Brøndby Strand T1 and Østfalster, Pomlenakke T2 samples. In the latter case, the flowmeter propeller was blocked, as it was entangled in eelgrass, obstructing the measurement. As such, the GPS-based volume calculation is more reliable. The GPS-based volume was considered for calculating MP concentration from the Østfalster, Pomlenakke T1 sample, as eelgrass was also present in a vast amount that could interfere with the flowmeter operation (Figure 14A). Despite these limitations, we recommend using the flowmeter for measuring filtered water volumes, as it accounts for currents and the exact travelled distance. Furthermore, sampling in ideal conditions, i.e. calm sea, low wind speed and biomass concentration, might overcome the limitation of volume determination based on flowmeter readings (Pasquier et al., 2022). Furthermore, changing the sampling direction of replicates could counteract the effect of currents. As such, the transect length should be used for volume calculations in special cases when the flowmeter would lead to erroneous values.

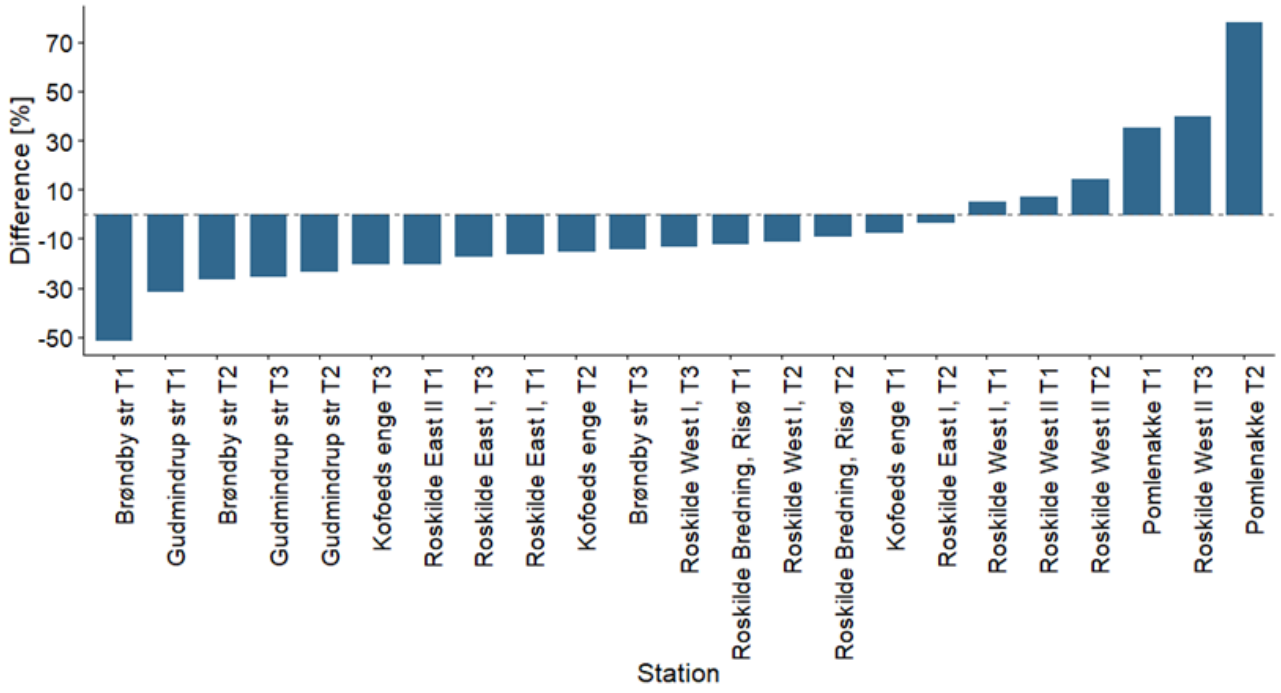


Figure 13. The difference between the sampled volume calculated from the flowmeter readings and based on the travelled distance determined by GPS coordinates.

In addition, the abundance of biomass interfered with particle identification, as the applied digestion method could not eliminate all the interfering organic matter. The microparticles were occasionally entangled or cemented in the remnants of partially digested natural material (Figure 14). These agglomerates had to be pulled apart to release the microparticles. Microparticle entrapment in such aggregates should be avoided because it could bias their enumeration. Although a harsher digestion procedure could remove most of the

organic matter, elaborate sample processing is undesired due to increasing the costs and time of the analysis and potentially affecting MPs. Therefore, a sampling period with less abundant floating vegetation and organisms should be selected for future monitoring surveys. Such a period could be in spring, based on Setälä et al. (2016), who recommend sampling in May – June in the Northern Baltic Sea between phytoplankton spring bloom and the blooming of filamentous green algae. In Danish coastal waters, early spring in March – April or even May can also be a possibility for an optimal time of year for manta trawl sampling.

Figure 14. High biomass densities were present at the sampling sites. Picture A shows the collected eelgrass during the second trawl at Østfalster, Pomlenakke. Picture B demonstrates that microparticles were entangled in partially digested organic matter, limiting their visually based picking and identification in the Køge Bugt, Kofoeds enge T2 sample.

4 Recommendations

This study demonstrates that a monitoring strategy using a manta trawl for sampling floating microplastic in coastal surface waters from a small boat is feasible. Such a strategy allows for replicate sampling within the same day. However, such a monitoring strategy is more realistic in the inner Danish waters because of generally calm waters compared to the North Sea, where larger vessels are usually needed for sampling. Since the manta trawl is widely used in several European sea regions, a monitoring strategy that uses the same technique can support comparability between monitoring programs. In addition, sampling and analyses of particles >300 µm are generally regarded as robust with limited risks of contamination compared to analyses of smaller particle size classes.

A monitoring strategy can be developed that combines locations of manta trawl sampling sites with e.g. beach litter monitoring stations on the coast. The benefit of such an approach is to increase data comparability for different marine litter indicators, e.g. in integrated assessments of environmental conditions, as highlighted in article 8 of the MSFD (EU, 2022). For instance, it may contribute to establishment of better links between occurrence of marine microlitter and macrolitter in coastal areas. It may also allow better to discriminate between lower and higher impacted areas, including deriving relevant environmental threshold levels. This requires approaches for integrated data collection of floating microplastic together with other marine litter monitoring indicators (e.g. beaches, seafloor, sediment, biota).

Also placing locations for sampling stations in coastal areas more impacted by point sources, e.g. from wastewater effluents, urban stormwater or intense sea-based activities like ship traffic or fishery, should also be considered. Such a sampling strategy will strengthen assessments of the importance of local sources compared to a reference station within a prioritised water body. The number of water bodies that need to be covered within a specific temporal or spatial scale, e.g. per national (sub)region or (sub)basin, need further evaluations also considering the need for a cost-effective integration with other monitoring elements.

Regarding sampling time, sampling surveys in the spring (e.g. March-May) should be considered when biomass is less abundant to reduce the efforts required for the analytical part of detecting MP in the sample. For instance, the challenges of clogging the sampling gear, the uncertainty related to the sample volume based on the flow meter measurements and the work needed for the sample preparation procedures can be reduced.

Based on the results of this study and other published studies in the Baltic Sea about MPs >300 µm, their levels of <0.5 MP particles per cubic meter in Danish coastal waters can generally be regarded as low. This finding also confirms that a minimum sampling volume of 100 m^3 of surface water is required to collect a representative sample, as the international guidelines for manta trawl surveys recommend.

Further data analyses on larger datasets are needed to assess the statistical power for trend analyses in coastal waters, including the potential for aggregating data from different sampling events and sites within a (sub)region or

(sub)basin. Moreover, better links between such environmental data to important land- and sea-based sources (e.g. inputs from wastewater effluents and stormwater) and management measures are needed. Thus, we recommend analysing at least 2-3 replicate samples from each site if implemented more widely in monitoring frameworks. Additionally, more than one sampling event per year per site should also be considered to contribute to a growing dataset allowing for such assessments. The frequency of sampling events and the number of sites depends on the main objective of a national monitoring strategy, e.g. if the focus is on achieving a higher spatial coverage or performing temporal assessments in fewer representative areas.

5 Acknowledgments

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7 Supplementary material

Table S1. Sampling date and time and the start and end coordinates of the sampled transects.

Station name	Trawl #	Date	Start time	End time	Lat start	Long start	Lat end	Long end
Kofoeds enge, Køge bugt	1	05.08.2022	11:22	11:35	55 34.237'	12 32.471'	55 33.636'	12 32.938'
Kofoeds enge, Køge bugt	2	05.08.2022	11:52	12:05	55 34.237'	12 32.471'	55 33.674'	12 32.937
Kofoeds enge, Køge bugt	3	05.08.2022	12:27	12:40	55 34.237'	12 32.471'	55 33.674'	12 32.937
Roskilde vig, Øst I	1	01.08.2022	14:52	15:05	55 40.087	12 04.961	55 39.476	12 04.927
Roskilde vig, Øst I	2	01.08.2022	-	15:45	55 40.087	12 04.961	55 39.619	12 05.013
Roskilde vig, Øst I	3	01.08.2022	16:27	16:40	55 39.939	12 05.121	55 39.399	12 04.924
Roskilde vig, Vest I	1	01.08.2022	12:20	12:40	55 39.467	12 3.583	55 40.0	12 03.833
Roskilde vig, Vest I	2	01.08.2022	13:27	13:40	56 39.467	13 3.583	56 40.0	13 03.833
Roskilde vig, Vest I	3	01.08.2022	14:14	-	57 39.467	14 3.583	57 40.0	14 03.833
Sejerøbugten	1	04.08.2022	11:40	11:53	55 54.430	11 31.099'	55 53.779'	11 30.996'
Sejerøbugten	2	04.08.2022	12:12	12:24	55 54.430	11 31.099'	55 53.868'	11 30.954
Sejerøbugten	3	04.08.2022	12:41	12:53	55 54.430	11 31.099'	55 53.868'	11 30.954
Brøndby strand, Køge bugt	1	02.08.2022	13:15	13:30	55 36.398	12 24.270'	55 36.441	12 25.303
Brøndby strand, Køge bugt	2	02.08.2022	13:55	14:10	55 36.383'	12 24.374'	55 36.441	12 25.303
Brøndby strand, Køge bugt	3	05.08.2022	13:24	13:37	55 36.383	12 24.374	55 36 441	12 25.303
Roskilde vig, Vest II	1	04.10.2022	13:24	13:34	55 39.467	12 03.583	55 40.000	12 03.833
Roskilde vig, Vest II	2	04.10.2022	13:52	14:04	55 39.467	12 03.583	55 40.000	12 03.833
Roskilde vig, Vest II	3	04.10.2022	14:21	14:28	55 39.467	12 03.583	55 39.758	12 03.752
Roskilde vig, Øst II	1	04.10.2022	11:50	12:06	55 39.939	12 05.121	55 39.476	12 04.927
Roskilde vig, Øst II	2	04.10.2022	12:48	13:00	55 39.939	12 05.121	55.39.619	12 05.0.13
Risø, Roskilde bredning	1	04.10.2022	10:12	10:26	55 41.582	12 04.704	55 42.214	12 04.804
Risø, Roskilde bredning	2	04.10.2022	10:50	11:05	55 41.582	12 04.704	55 42.214	12 04.804
Pomlenakke, Østfalster	1	12.10.2022	11:30	11:46	54 48.544	12 07.884	54 47.974	12 07.290
Pomlenakke, Østfalster	2	12.10.2022	12:06	12:20	54 48.544	12 07.884	54 47.974	12 07.290

Table S2. The recorded environmental parameters at the sampling locations.

Start sea state	End sea state	Average boat speed	Start wind direction	End wind direction	Start wind speed [m/s]	End wind speed [m/s]	Flow-meter start	Flow-meter end	Width of manta (cm)	Flow direction	Salinity	Temperature
1	1	3	W/NW	W/NW	2.8	1.8	52932	57290	70	E	11	17.5
1	1	3	W/NW	W/NW	1.8	2.2	57299	61703	70	E	11	18
1	1	3	W/NW	W/NW	2.7	2.6	61703	66311	70	E	11	18
2	2	3	NW	NW	4.37	5.16	18565	22949	70	NW	13	20
2	2	3	NW	NW	4.97	5.81	22962	25957	70	NW	13	20
1	2	3	NW	NW	3.6	4.76	26281	30250	70	NW	13	20
1	1	3	NW	NW	2.17	5	3999	7225	70	NW	13	19.5
1	1	3	NW	NW	3.43	4.22	10926	14689	70	NW	13	19.5
1	1	3	NW	NW	3.6	4.51	14698	18547	70	NW	13	19.5
1	1	3	SW	SW	2.7	2.1	38983	44272	70	NE	19	20.5
1	1	3	SW	SW	2.15	0.9	44272	48566	70	NE	19	21
0	1	3	SW	SW	0.9	1.2	48566	52932	70	NE	19	20.5
2	2	3	E/SE	E/SE	4.7	4.2	30254	34840	70	W/NW	11	19.5
2	2	3	E/SE	E/SE	4.5	5.4	34852	38979	70	W/NW	11	19.5
0	0	3	W/NW	W/NW	2.9	2.4	66313	70050	70	0	10	20.5
0-1	0-1	3	SW	SW	4.1	4.1	86815	90154	70	Not recorded	14	13
0-1	0-1	3	SW	SW	4.1	4.1	90154	93259	70	Not recorded	14	13
0-1	0-1	3	SW	SW	4.1	4.1	93259	94544	70	Not recorded	14	13
1	1	3	SW	SW	3.6	3.6	79095	82639	70	Not recorded	15	13
1	1	3	SW	SW	3.6	3.6	84619	NA*	70	Not recorded	15	13
1	1	3	SW	SW	3.1	3.1	70049	74437	70	Not recorded	16	13
1	1	3	SW	SW	3.1	3.1	74446	78716	70	Not recorded	16	13
1	1	3	SW	SW	4.1	4.1	94547	97193*	70	Not recorded	15	13
1	1	3	SW	SW	4.1	4.1	97194	98109*	70	Not recorded	15	13

Table S3. The sampled volume and area calculated from the flowmeter readings and the travelled distance based on GPS coordinates. (*) Analysed samples. (**) The volume used for calculating microplastic concentrations.

Sample name	Calculated distance [m]	Calculated area [m^2]	Sampled volume by flowmeter [m^3]	Sampled volume by distance [m^3]
Køge bugt, Kofoeds enge, T1*	1220	854	183**	171
Køge bugt, Kofoeds enge, T2*	1150	805	185**	161
Køge bugt, Kofoeds enge, T3	1150	805	194	161
Roskilde Vig, East I, T1*	1130	791	184**	158
Roskilde Vig, East I, T2*	870	609	126**	122
Roskilde Vig, East I, T3	1020	714	167	143
Roskilde Vig, West I, T1*	1020	714	135**	143
Roskilde Vig, West I, T2	1020	714	158	143
Roskilde Vig, West I, T3*	1020	714	162**	143
Sejerøbugten, Gudmindrup, T1*	1210	847	222**	169
Sejerøbugten, Gudmindrup, T2	1050	735	180	147
Sejerøbugten, Gudmindrup, T3	1050	735	183	147
Køge bugt , Brøndby Strand , T1*	909	636	193**	127
Køge bugt , Brøndby Strand, T2*	982	687	173**	137
Køge bugt , Brøndby Strand, T3	982	687	157	137
Roskilde Vig, West II, T1*	1080	756	140**	151
Roskilde Vig, West II, T2*	1080	756	130**	151
Roskilde Vig, West II, T3	645	452	54	90
Roskilde Vig, East II, T1*	883	618	149**	124
Roskilde Vig, East II, T2*	604	423	-	85**
Roskilde Bredning, Risø, T1*	1180	826	184**	165
Roskilde Bredning, Risø, T2	1180	826	179	165
Østfalster, Pomlenakke, T1*	1230	861	111	172**
Østfalster, Pomlenakke, T2	1230	861	38	172

Table S4. The concentration of visually identified microplastics (counts per volume as m^3) by each size class in the 15 analysed samples, the date of sampling, the travelled distance, and the filtered water volumes used for calculating MP concentrations. The size classes are defined by the measured longest dimension (length) of the particles and fibres according to Galgani et al. (2023).

	Station ID	**Brøndby strand**	**Brøndby strand**	**Sejerøbugten**	**Kofoeds enge**	**Kofoeds enge**	**Østfalster**	**Risø**	**Roskilde East I**	**Roskilde East I**	**Roskilde West I**	**Roskilde West I**	**Roskilde West II**	**Roskilde West II**	**Roskilde East II**	**Roskilde East II**
Counts per km^2	Date	02.08.2022	02.08.2022	04.08.2022	05.08.2022	05.08.2022	12.10.2022	04.10.2022	01.08.2022	01.08.2022	01.08.2022	01.08.2022	04.10.2022	04.10.2022	04.10.2022	04.10.2022
	Transect length [m]	909	982	1210	1220	1150	1230	1180	1130	870	1020	1020	1080	1080	883	604
	Sampling area [m^2]	636	687	847	854	805	861	826	791	609	714	714	756	756	618	423
	Sample ID	T1	T2	T1	T1	T2	T1	T1	T1	T2	T3	T1	T1	T2	T1	T2
> 5000 µm	Fragments/Flakes	0	0	1311	0	0	0	0	1163	3310	0	4160	1296	0	0	2411
	Filaments/Fibres	4855	0	0	0	1149	1199	0	0	0	2723	0	2593	0	1688	2411
	Films	0	0	0	0	0	0	0	0	0	1361	0	0	0	3134	0
	Granules/Beads	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Foam	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Pellets	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Other	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Total MP [item km^{-2}]	4855	**0**	1311	0	1149	1199	0	1163	3310	4311	4160	3889	0	4822	4823
1000-4999 µm	Fragments/Flakes	0	1511	0	0	5056	0	1337	0	11586	2723	0	1296	0	9644	4823
	Filaments/Fibres	6373	0	7077	1071	0	5793	2450	3722	11586	9756	8319	6667	3955	9644	2411
	Films	3035	0	0	1071	1149	0	0	0	0	1361	1324	0	0	8197	4823
	Granules/Beads	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Foam	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Pellets	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Other	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Total MP [item km^{-2}]	9407	1511	7077	2357	6205	5793	3787	3722	22966	14067	9832	7963	3955	27485	11856
300-999 µm	Fragments/Flakes	0	0	0	0	7354	3396	0	2559	8276	1361	2836	1296	0	1688	21300
	Filaments/Fibres	3035	0	1311	0	0	0	0	2559	4966	0	2836	1296	1376	0	4823
	Films	0	0	0	0	0	0	0	0	0	0	1324	0	0	3134	0
	Granules/Beads	0	0	0	0	2528	0	0	0	0	0	0	0	0	6510	0
	Foam	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Pellets	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Other	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Total MP [item km^{-2}]	3035	**0**	1311	0	9882	3396	0	5118	13034	1361	6996	2593	1376	11332	25922
300-5000 µm	**Total MP [item km^{-2}]**	17297	1511	9436	2357	17466	10388	3787	10003	39310	19513	20987	14630	5331	43639	42600

Table S5. The concentration (counts per area as km^2) of visually identified microplastics by each size class in the 15 analysed samples, the date of sampling, the travelled distance, and the filtered water volumes used for calculating MP concentrations. The size classes are defined by the measured longest dimension (length) of the particles and fibres according to Galgani et al. (2023).

Counts per km^2	Station ID	Brøndby strand	Brøndby strand	Sejerøbugten	Kofoeds enge	Kofoeds enge	Østfalster	Risø	Roskilde East I	Roskilde East I	Roskilde West I	Roskilde West I	Roskilde West II	Roskilde West II	Roskilde East II	Roskilde East II
	Date	02.08.2022	02.08.2022	04.08.2022	05.08.2022	05.08.2022	12.10.2022	04.10.2022	01.08.2022	01.08.2022	01.08.2022	01.08.2022	04.10.2022	04.10.2022	04.10.2022	04.10.2022
	Transect length [m]	909	982	1210	1220	1150	1230	1180	1130	870	1020	1020	1080	1080	883	604
	Sampling area [m^2]	636	687	847	854	805	861	826	791	609	714	714	756	756	618	423
	Sample ID	T1	T2	T1	T1	T2	T1	T1	T1	T2	T3	T1	T1	T2	T1	T2
> 5000 µm	Fragments/Flakes	0	0	1311	0	0	0	0	1163	3310	0	4160	1296	0	0	2411
	Filaments/Fibres	4855	0	0	0	1149	1199	0	0	0	2723	0	2593	0	1688	2411
	Films	0	0	0	0	0	0	0	0	0	1361	0	0	0	3134	0
	Granules/Beads	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Foam	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Pellets	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Other	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Total MP [item km^{-2}]	4855	**0**	1311	0	1149	1199	0	1163	3310	4311	4160	3889	0	4822	4823
1000-4999 µm	Fragments/Flakes	0	1511	0	0	5056	0	1337	0	11586	2723	0	1296	0	9644	4823
	Filaments/Fibres	6373	0	7077	1071	0	5793	2450	3722	11586	9756	8319	6667	3955	9644	2411
	Films	3035	0	0	1071	1149	0	0	0	0	1361	1324	0	0	8197	4823
	Granules/Beads	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Foam	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Pellets	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Other	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Total MP [item km^{-2}]	9407	1511	7077	2357	6205	5793	3787	3722	22966	14067	9832	7963	3955	27485	11856
300-999 µm	Fragments/Flakes	0	0	0	0	7354	3396	0	2559	8276	1361	2836	1296	0	1688	21300
	Filaments/Fibres	3035	0	1311	0	0	0	0	2559	4966	0	2836	1296	1376	0	4823
	Films	0	0	0	0	0	0	0	0	0	0	1324	0	0	3134	0
	Granules/Beads	0	0	0	0	2528	0	0	0	0	0	0	0	0	6510	0
	Foam	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Pellets	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Other	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Total MP [item km^{-2}]	3035	**0**	1311	0	9882	3396	0	5118	13034	1361	6996	2593	1376	11332	25922
300-5000 µm	**Total MP [item km^{-2}]**	17297	1511	9436	2357	17466	10388	3787	10003	39310	19513	20987	14630	5331	43639	42600

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