Marine Pollution Bulletin xxx (2016) xxx–xxx

Contents lists available at ScienceDirect

Marine Pollution Bulletin

journal homepage: www.elsevier.com/locate/marpolbul

Distribution and abundance of surface water microlitter in the Baltic Sea: A comparison of two sampling methods

Outi Setälä [a,*], Kerstin Magnusson [b], Maiju Lehtiniemi [a], Fredrik Norén [b]

[a] Finnish Environment Institute, Marine Research Centre, P.O. Box 140, 00251 Helsinki, Finland
[b] IVL Swedish Environmental Research Institute, Kristineberg 566, SE451 78 Fiskebäckskil, Sweden

ARTICLE INFO

Article history:
Received 26 April 2016
Received in revised form 16 June 2016
Accepted 17 June 2016
Available online xxxx

Keywords:
Gulf of Finland
Litter
Monitoring
Surface area
Manta trawl
Pump
Microplastics

ABSTRACT

Two methods for marine microlitter sampling were compared in the Gulf of Finland, northern Baltic Sea: manta trawl (333 μm) and a submersible pump (300 or 100 μm). Concentrations of microlitter (microplastics, combustion particles, non-synthetic fibres) in the samples collected with both methods and filter sizes remained <10 particles m^{-3}. The pump with 100 μm filter gave higher microlitter concentrations compared to manta trawl or pump with 300 μm filter. Manta sampling covers larger areas, but is potentially subjected to contamination during sample processing and does not give precise volumetric values. Using a submerged pump allows method controls, use of different filter sizes and gives exact volumetric measures. Both devices need relatively calm weather for operation. The choice of the method in general depends on the aim of the study. For monitoring environmentally relevant size fractions of microlitter the use of 100 μm or smaller mesh size is recommended for the Baltic Sea.

1. Introduction

Litter is one of the most ubiquitous environmental pressures in both marine and freshwater environments, receiving increasing publicity and causing a lot of concern. Marine litter has most profound negative effects on the ecosystem health, but there are also negative effects on the society coupled to costs for cleaning beaches and loss of tourism (UNEP, 2009). Studies carried out during the last decade have repeatedly pointed out the pervasive occurrence of microscopic litter particles, in particular microplastics in marine environments (GESAMP, 2015). This new knowledge has raised a lot of concern because of the potential risks that different microscopic plastic polymers pose to marine organisms. Microplastics are of concern especially because they can potentially be ingested by a variety of marine organisms (Thompson et al., 2004, Besseling et al., 2014, Watts et al., 2014), and also be transferred along the food web (Eriksson and Burton, 2003, Setälä et al., 2014), and the fact that these items cannot be removed from the marine environment. In contrast: their abundances are supposed to be increasing due to direct discharge as well as the fragmentation of larger litter items with time.

Recommendations for sampling and sample treatment are presented in the monitoring guidance documents for marine litter in European Seas (Galgani et al., 2013, JRC, 2013). However, as noted in the document, all these methods are not yet harmonized. There is still lack of methods for quality assurance/quality control and a need for method development. The need for harmonized sampling methods for marine microlitter, or their optimization and inter calibration has been noted by several researchers, e.g. Magnusson and Norén (2011), Lusher et al. (2015), Syberg et al. (2015) and has also been brought up in the guidance documents. Research on microplastics is proceeding fast with numerous new studies giving more information on these topics. In the Baltic Sea, however, there is presently still relatively little information on the distribution and abundance of microlitter in different habitats (Magnusson and Norén, 2011, Magnusson, 2014, Gorokhova, 2015).

The aim of this study was to produce data for the development of harmonized methods for collecting microlitter on sea surface in the Baltic Sea region. The two methods compared in our study were the commonly used manta trawl, and a prototype of a submersed pump sampler.

The "Manta Net" was originally designed for collecting organisms and flotsam from the sea surface already in the 1980s' (Brown and Cheng, 1981). After that modifications of the early manta trawl have been used for collecting surface floating litter in world's oceans (e.g. Eriksen et al., 2013, 2014). Submerged pumps have been used for microlitter sampling on the Swedish coats since 2010 (Magnusson and Norén, 2011). The use of the submerged pump in this study also allowed us to compare how the filter size used affects the number and type of the collected microlitter.

* Corresponding author.

http://dx.doi.org/10.1016/j.marpolbul.2016.06.065
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2. Material and methods

The study was carried out during the COMBINE 3 monitoring cruise (26.–30. 8. 2013) on board the R/V *Aranda*, in the Gulf of Finland. Samples were collected from 12 sampling stations (Fig. 1.) that represented open sea conditions, except for two sampling sites (Kotka and Helsinki) that situated close to active shipping harbors.

2.1. Manta trawl

In our study we used the suitcase manta trawl (designed and manufactured by Marcus Eriksen, 5 Gyres Institute). This trawl has a rectangular opening of 16 cm (height) × 61 cm (width) and the net mesh size of 333 μm. It has two wings that keep it in balance and at surface during the tow, letting the mouth sink 0.25 m in the water. At the end of the trawl there is a removable collecting bag ("cod end"). The hood of the manta trawl deflects wave crests into the submerged net and captures volumetric measure at the sea surface. The recommended tow speed for the original prototype of manta trawl is 0.26–2.6 m s^{-1} (0.5–5 knots; Brown and Cheng, 1981), while the suitcase manta has been towed successfully with the speed between 0.5 and 1.5 m s^{-1} (Eriksen et al., 2013, 2014).

2.2. Submersed pump sampler

An electrically driven impeller pump (MEI standard 2.2 kW motor, 3 phase @ 400 V) was mounted inside a stainless steel box with 2.5″ PVC and stainless steel tubes and fittings (ASME-BPE standard, vendor www.gpa.se). The pump model was chosen due to its good suction capability and the impeller was made of silicone rubber. At the inlet side a 4″ (diam. 108 mm) stainless steel clamp holds the sampling filter between the clamp flanges. No gasket was used. This ensures that the sampled water passes through the filter before being in contact with any part of the pump, pipes or hose, which minimizes contamination from airborne particles. The pump rate was electronically controlled using an adjustable speed drive (ABB ACS355). The flow rate was measured using a ×3 flow meter mounted 700 mm downstream a straight ø50 mm PCV pipe with a total length 1000 mm. This placement ensured a more laminar flow for the flow meter impeller. The pump was attached to a flexible drainage hose (PVC coated rubber) with ø50 mm. All couplings in the systems were 2″ Camlock couplings. In this study the pump was equipped with 300 μm or 100 μm mesh size filters during sampling (referred to pump 300 and pump 100 in this study). The filters were mounted from nylon plankton net and kept clean in Petri dishes until use.

2.3. Sampling and sample treatment

The manta trawl was towed on the port side of the research vessel, the towing point situated approximately 4 m away from the hull (Fig. 2.). Care was taken not to steer the trawl close to turbulent flow coming from the ship's side propellers. Manta trawl was always deployed directly after the pumping was conducted on a station when ship was moving with the wanted speed. The calm weather conditions during the cruise were optimal for using the trawl. The manta trawl was always towed at a low speed since estimations of the sampled water volumes became inaccurate with increasing speed due to the bouncing actions of the trawl on the crests of the waves. Different towing times were tested, and for most of the times a tow lasted for 10 min at a speed of 2.5 knots. The trawl was equipped with a water flow meter (Tsurumi-Seiki 3567, Tsurumi Seiki Co Ltd) to calculate the volume of the inflowing water. After the trawl was taken up from the water it was rinsed with sea water. The sample in the collecting bag was washed thoroughly under a hood into a clean jar. Large organic particles were removed from the sample by hand with tweezers, rinsed above the jar and after that the jar lid was closed. The sample was consecutively concentrated by filtering onto a 300 μm nylon mesh, each filter placed in a pre-cleaned Petri dish and stored in an oven until dry (60 °C). One manta tow resulted in several sub-samples depending on the amount of organic material in the sample. No protocol blanks for manta were used.

The pump was deployed from the back of the vessel using the ship winch. It was lowered until the opening of the filtering manifold was just below the surface (Fig. 3). This depth varied between

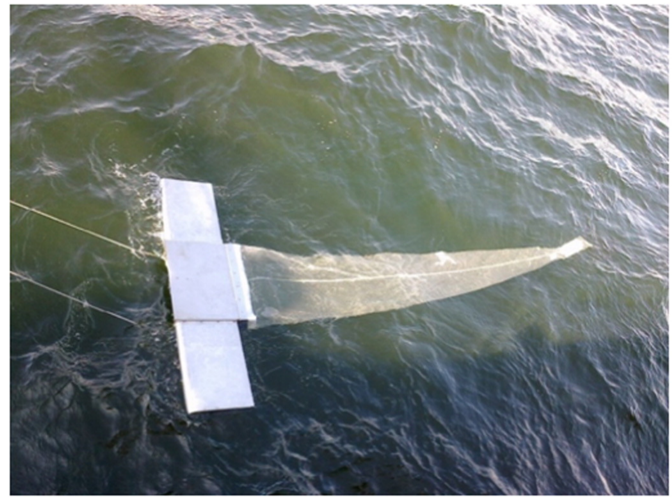

Fig. 2. Manta trawl deployed for sampling on the vessel side.

Fig. 1. Sampling sites in the Gulf of Finland.

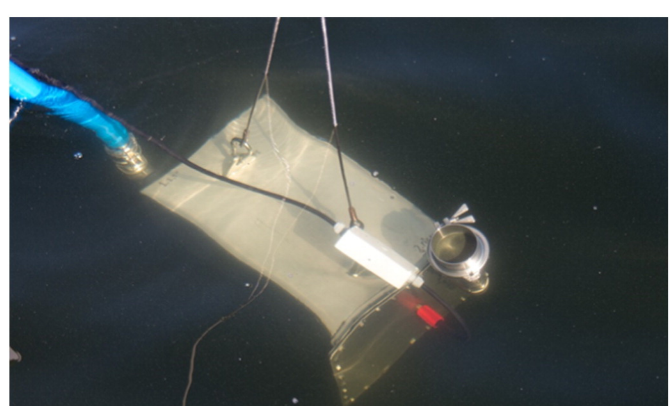

Fig. 3. The submerged pump.

approximately 0–0.5 m depending on the vertical movement of the ship. Between sampling the pump was located at the ship's deck and the filter inlet was covered with a lid to prevent dust entering the filter system. After sampling the filter was immediately removed. New laboratory gloves (pink silicone rubber) were used every time. A stainless steel tweezer was used to remove the filter and stored in a 100 ml centrifugal tube between uses. As a method control, three blank samples were taken where the procedure was exactly the same as in ordinary sampling but the pump was only started and immediately stopped before removed from the water. The volume of water sampled in the control was for the first control 139 l and for the second control 10 l and measured using the flow meter. The particles counted on the control filters was three non-synthetic textile fibres and one spherical combustion particle in the first control and one non-synthetic textile fibres in the second control. The pump was operated, using the adjustable speed drive, to maintain a constant flow rate of 3.5 l s^{-1}. The total filtered volume (2 m^3) was measured using the electronic flow meter. The flow meter was calibrated two times during the cruise. Two samples using 300 μm filter and one sample using 100 μm filter was taken on every location.

2.4. Analyses

All microparticles of anthropogenic origin that were collected on the filters were counted with light microscopy either with a stereo microscope (Wild M5; 10–50×) or an upright microscope (Olympus BHM; 100–200×). The particles were divided into the following categories: plastic fibres, plastic fragments (all plastic items except fibres), paint flakes, non-synthetic anthropogenic fibres (e.g. cotton, hereafter called non-synthetic fibres) and combustion particles. In cases where it was difficult to determine whether a particle was made of synthetic polymers a melting test was done. The selected particle was placed on an object glass which was held over the flame of an alcohol burner. Plastic polymers would melt, and then harden in a characteristic way when being cooled down.

Combustion particles were divided into spherical carbonaceous particles (SCPs) and black carbonaceous particles (BCPs). SCPs were easy to separate from all other particles due to their very characteristic shape and hard surface. Some SCPs were black and shiny whereas others were grey or whitish. BCPs were always totally black but may differ in shape and structure. Some fell apart easily when touched upon, whereas others had a more solid composition.

The differences between the results of the samples collected with Manta trawl, pump 300 μm and pump 100 μm were statistically tested with the non-parametric Kruskal-Wallis test for independent samples as the variances of the datasets were heterogenous and thus did not fulfil the assumptions for parametric tests.

3. Results

3.1. Microlitter abundances and litter types

The microlitter concentrations varied between 0.3 and 2.1 particles m^{-3} (manta), 0–3.4 (pump 300 μm) and 0–8.2 (pump 100 μm) (Sum litter particles; Table 1). Corresponding concentrations for microplastics (plastic fragments and plastic fibres) were 0–0.8 (manta), 0–1.25 (pump 300 μm) and 0–6.8 (pump 100 μm).

Using the pump with 300 μm filter gave higher total microlitter concentrations than manta (Table 1, Fig. 4), and the pump with 100 μm filter gave the highest total microplastic concentrations (Table 1). However, although the total concentration of microlitter particles measured with the pump 100 were higher than with manta or pump 300, the difference was not significant due to high variance in the results between the sampled stations (Kruskal-Wallis test: $p > 0.05$). There were observed differences in the performance of the devices regarding microlitter types: fragments and fibres. Plastic fragments were caught in 11/12 stations with manta, 2/12 stations with pump 300 and 1/12 with pump 100. Fibres were found from all stations when collected with manta, 11/12 stations with pump 300 and 8/12 stations with pump 100 (Fig. 5a–c). The highest number of fibres (sum of synthetic and non-synthetic) was found from pump 100 samples (7.71 particles m^3; station LL6). The total number of fibres was not significantly different between the three sampling methods (Kruskal-Wallis test: $p > 0.05$). Number of plastic fragments and combustion particles caught with the three methods differed significantly (Kruskal-Wallis test: $p = 0.001$, $p = 0.02$, respectively) with pump 100 μm catching the most. In overall, fibres were the most common microlitter type, the total number of all fibres (synthetic and non-synthetic) per station varying between 0.2 and 2.1 particles m^{-3} for manta, 0–3.2 particles m^{-3} for pump 300 μm and 0–7.7 particles m^{-3} for pump 100 μm.

3.2. Litter from the research vessel and other ships

Paint flakes suspected to derive from the research vessel were found in all manta trawl samples (Table 2). The maximum concentration of litter from vessel was found at stations XIV3 and Kotka. In contrast, vessel generated litter was only found in one sample taken with the submerged pump. All paint flakes were excluded from the comparison-part, since their sources cannot be confirmed; whether coming from R/V *Aranda*, general maritime traffic or both.

3.3. Distribution of microplastics in the Gulf of Finland

No clear trend was observed in the distribution of microlitter across the study area from east to west. The average total microlitter

Table 1
Concentration of microlitter (particles m^{-3}) at each sampling station sampled with manta trawl or submerged pump (300 and 100 μm filters). Concentration in particles per m^3. Data from submerged pump (300 μm) are average of two samples.

	Plastic fibres			Plastic fragments			Non-synthetic fibres			Combustion particles			Sum litter particles		
Station	Manta	Pump 300	Pump 100	Manta	Pump 300	Pump 100	Manta	Pump 300	Pump 100	Manta	Pump 300	Pump 100	Manta	Pump 300	Pump 100
XVI	0.0	0.5	1.0	0.0	0.0	0.0	0.5	0.2	0.0	0.1	0.0	0.0	0.6	0.7	1.0
LL3A	0.3	0.0	0.5	0.0	0.0	0.0	1.3	3.2	0.0	0.0	0.2	0.5	1.7	3.4	1.0
LL6	0.1	1.0	2.9	0.1	0.0	0.0	0.2	0.5	4.8	0.0	1.2	0.5	0.4	2.7	8.2
LL7	0.7	1.0	4.8	0.0	0.0	1.9	1.3	0.5	1.0	0.0	0.2	0.5	2.1	1.7	8.2
LL9	0.1	0.5	1.5	0.1	0.0	0.0	0.4	0.0	0.0	0.0	1.5	0.0	0.6	1.9	1.5
Ajax	0.0	0.2	0.0	0.0	0.2	0.0	0.3	1.1	4.7	0.0	0.0	0.0	0.3	1.5	4.7
LL12	0.1	1.0	0.0	0.3	0.0	0.0	1.5	0.0	0.0	0.0	0.0	1.5	1.8	1.0	1.5
F62	0.0	0.2	2.9	0.3	0.0	0.0	0.8	0.0	1.0	0.1	0.0	1.0	1.2	0.2	4.8
Kotka	0.1	0.0	0.5	0.1	0.0	0.0	0.6	0.0	0.0	0.0	0.0	1.0	0.8	0.0	1.5
XIV3	0.1	0.8	0.0	0.1	0.5	0.0	1.1	0.3	0.0	0.0	0.0	1.9	1.2	1.5	1.9
GF1	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.2	0.0	0.0	0.0	1.5	0.4	0.2	1.5
Helsinki	0.0	0.7	0.0	0.1	0.0	0.0	0.2	0.2	0.0	0.0	0.5	0.0	0.3	1.5	0.0

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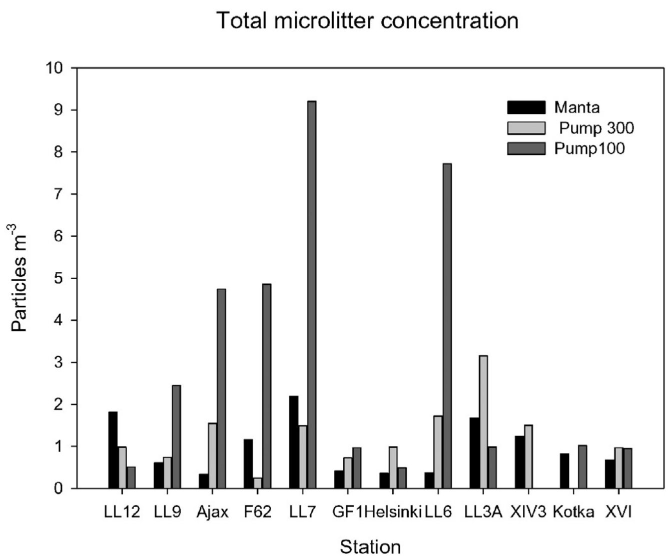

Fig. 4. Total microlitter concentrations collected with the different method from west (station LL12) towards eastern parts of the Gulf of Finland (station XVI).

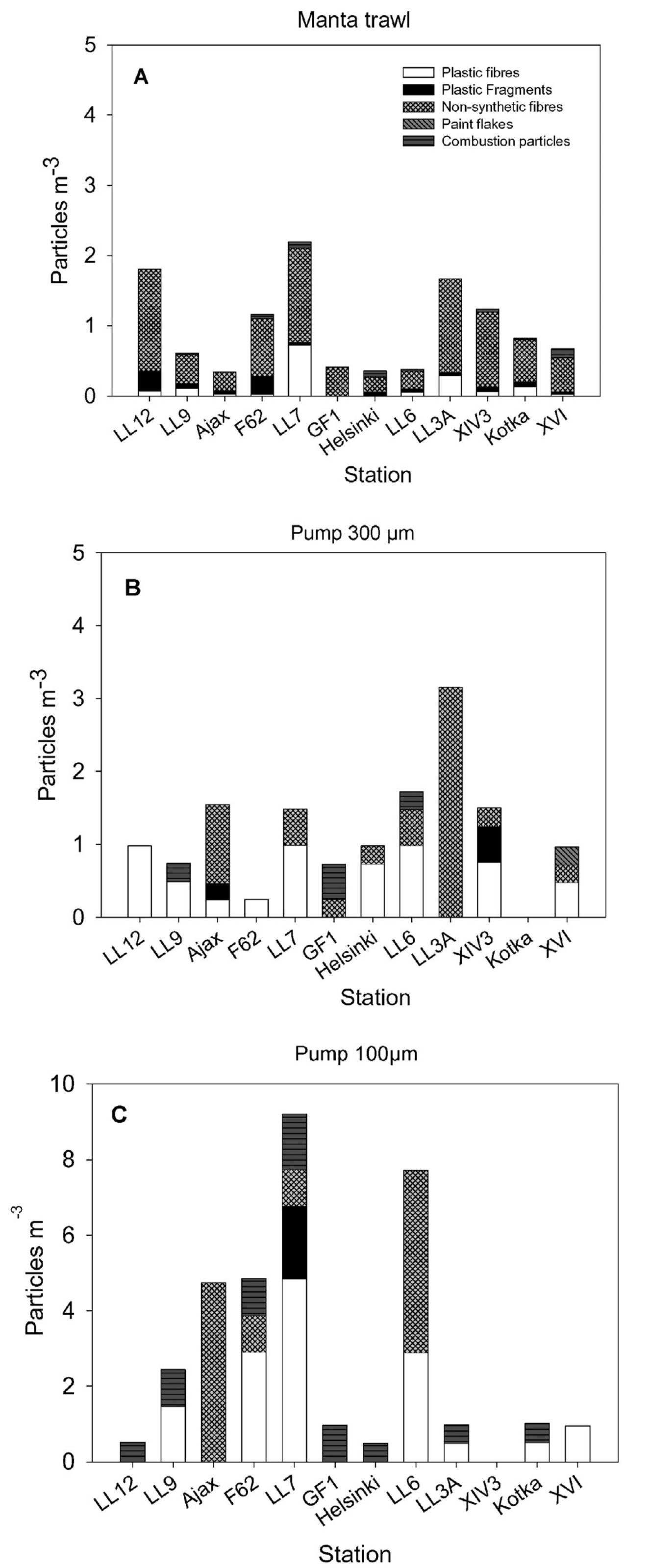

Fig. 5. Concentration of different microlitter types per m^3 in samples taken with A = manta trawl, B = pump 300 μm and C = pump 100 μm. The total number of particles per m^3 in a sample is indicated as the bar height.

concentrations estimated for the western, central and eastern areas are shown in Table 3 and show differences between areas and sampling devices. The average concentration of microlitter in the surface waters of Gulf of Finland calculated from our data was 1.0 ± 0.6 for manta, 1.5 ± 1.0 for pump 300 μm and 3.4 ± 2.7 for pump 100 μm. To enable comparison with other studies that give estimates for microplastics only, the corresponding microplastic concentrations were calculated, giving averages of 0.2 ± 0.2 for manta, 0.6 ± 0.4 for pump 300 μm and 1.3 ± 1.9 for pump 100 μm.

4. Discussion

4.1. Manta vs. pump – comparison of our results

The implementation of MSFD monitoring programme in the regional seas requires assessment of microlitter amount and distribution (EC, 2010). For holistic assessments in the regional seas and for the development of indicators harmonized methods for sampling and analyses must be developed and also implemented. This will take time, and meanwhile monitoring should already be going on and preferably also the targets and threshold values set. Manta trawl has been one of the first devices used for assessing microlitter in the water column/sea surface (Eriksen et al., 2013, 2014, Lusher et al., 2015). In spite of its wide and successful use, manta may also be criticised, because of the likely inaccuracy when converting the amount of collected litter particles into concentrations per water volume, or because of the actual size fraction that manta is able to collect, which is restricted to >333 μm. However, since the use of manta for monitoring purposes has obvious advantages, we carried out a study where the use of manta was compared with an alternate sampling device, a specifically designed submerged pump.

Regarding the feasibility of the method for routine monitoring use, two different points of view are considered: practical issues concerning the sampling on board a research vessel and the reliability of the data. In addition, one task was also to evaluate the actual costs of implementing the methods as resources for monitoring are cut and as low additional costs (incl. ship time) as possible would be required.

Our study aimed to assess the amount of microlitter, not only microplastics, since that is what actually should be monitored in the European regional seas according to the MSFD criteria. The majority of the field surveys that have been carried out in different sea areas around the world on marine microlitter have been focusing on microplastics and comparison between our results and data from other studies is done for synthetic particles only. Furthermore, since methods for monitoring are not harmonized, most studies give estimates for microplastics per area and some per volume.

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Table 2
Paint flakes from ships sampled with manta trawl or submerged pump (300 and 100 μm filters) Concentration in particles per m^3.

Station	Paint flakes from ships		
	Manta	Pump 300 μm	Pump 100 μm
XVI	0.1	0.0	0.0
LL3A	0.1	0.0	0.0
LL6	0.1	0.0	0.0
LL7	0.2	0.0	0.0
LL9	0.1	0.2	0.0
Ajax	0.1	0.0	1.9
LL12	0.1	0.0	0.0
F62	0.0	0.0	0.0
Kotka	0.6	0.0	0.0
XIV3	0.3	0.0	1.0
GF1	0.1	0.0	0.0
Helsinki	0.0	0.0	0.0

All the three methods gave similar results, the concentration of the sum of all microlitter particles being always <10 particles m^{-3}. Although the submerged pump equipped with the 300 μm filter gave higher estimates of the concentration of microlitter than manta, the difference was minor, and the results were actually surprisingly similar to each other. Instead, clear differences were seen when the filter was changed to a finer mesh size, 100 μm net. The difference was especially pronounced for fibres, which were clearly more numerous in the 100 μm samples. This has also been previously noted by Magnusson and Norén (2011). Fibres pass easily the relatively coarse >300 μm filters but are more efficiently trapped on the smaller mesh. However, it is likely that even the mesh size of 100 μm does not give a thorough estimate on fibres in the surface waters, since the diameter of many fibres, especially from clothing is small (around 20 μm). However our study suggests that fibres are actually the most common microlitter type in the surface waters of the open Baltic Sea, and analysis methods should thus be able to measure fibre concentrations.

The manta trawl proved to be a practical device for collecting microlitter. Using the manta during monitoring cruises for estimating marine microlitter has some advantages. The manta trawl can be used without stopping the ship and the towing time with low speed is short, which both save expensive ship-time. However, no additional time for the use of the pump is needed either, if the pump is used at the same time as the routine hydrographical sampling. The manta collects particles from a wider area and a larger volume of water, and thus suits well for the monitoring of sparse litter particles with concentrations less than particle ~1 m^{-3}. The use of a manta on board a large research vessel for microlitter studies causes some problems and is challenging due to a potential contamination risk. One such source of contamination can be the ship itself. Manta trawl samples included rust and paint flakes that may have come from R/V *Aranda* itself. There is always loose paint or metal particles on board the ship deck, and although careful sampling is performed, operating the trawl on board exposes it to ship-based particles. It is not possible to identify the source of ship-generated paint flakes (R/V *Aranda* or other vessels), and thus comparing the results of paint flakes does not serve the purpose of this study. It seems probable that there were also other sources for this litter than the research vessel itself, since the highest concentration of ship paint flakes in manta samples was captured close to Kotka shipping harbour.

Table 3
Average total microlitter concentrations in the open sea areas of the Gulf of Finland. Concentration in particles per m^3 Western area: stations Ajax, LL12, F62 Central area: stations LL9, LL7, GF1 Eastern area: stations LL3A, XIV3, XV1. Samples that were collected close to the city harbors (stations Helsinki and Kotka) are not included.

Sea area	Sum litter particles (m^{-3})		
	Manta	Pump 300 μm	Pump 100 mm
Western	1.1 ± 0.7	0.9 ± 0.7	3.7 ± 1.9
Central	1.0 ± 0.9	1.3 ± 0.9	3.7 ± 3.9
Eastern	1.2 ± 0.50	1.9 ± 1.4	1.3 ± 0.5
Whole GoF	1.0 ± 0.6	1.5 ± 1.0	3.4 ± 2.7

4.2. Technical performance of the devices

The weather conditions during the cruise were suitable for the manta trawl because of the calm weather. This was essential for the comparison of the results. Besides weather conditions, the processing of the samples from the collecting bag introduced potential sources of contamination due to handling and rinsing procedures. There were also some minor technical problems when using the manta on board R/V *Aranda*. The beam where the towing wire was attached was 5 m above the water surface resulting in a towing angle so steep that it affected the movement of the trawl. This could be adjusted by lowering the ship speed, but in case of rough weather that is not helpful. Wind velocity and wind direction as well as wave height had a great impact on the performance of the manta trawl. On board R/V *Aranda* the manta trawl can only be towed against the wind when the wave height is less than approximately one meter. When towed along the wind direction the waves can be higher, up to 2 m, but this depends also on their sharpness. These problems can probably be solved simply by changing the location where the towing wires are attached to the trawl. When the same manta trawl was used during a research cruise in the northern Baltic Sea with a smaller research vessel, R/V *Muikku* (Magnusson, 2014), there were no problems and the net was easier to handle than on board a relatively large research vessel.

When using manta trawl under the conditions that prevails in the northern Baltic Sea, not only the wind and wave conditions, but also seasonality must be taken in account. During winter it is not possible to use the manta because of rough weather and partial ice-cover. During autumn when the waters are clear it is also often too windy for towing the manta. During spring and summer phytoplankton blooms, especially surface accumulations of cyanobacteria may cause problems. Best time for towing manta in the northern Baltic Sea is probably the time window in May–June; between the phytoplankton spring bloom (April–May) and the blooming season of the filamentous blue-green algae (late July–August). The pump method is not so sensitive to partial ice coverage but the pump will also get clogged during heavy plankton blooms, especially the 100 μm filter.

For the use of the pump the ship must stay at the station. In our study the pump sampling was done during the routine standstill of the boat on every station and did therefore not increase the time spent at the stations. Care must be taken that the pump opening where the water enters the pump, stays on the desired depth and does not grab air, but caution is also needed when operating a manta trawl which sometimes goes above the water surface. This is only possible in a rather calm weather as waves make the back of the vessel move vertically (up and down) several meters, which makes it impossible to keep the filtering part of the pump under the water surface in high waves. One additional benefit is that with the pump it is possible to sample water from a defined location (even from different water layers if needed), compared with manta. The measurements of the volume of the filtered water volume were accurate, which is not possible with manta. The amount of contaminating particles could also be estimated using method controls. This is especially important when working with low concentrations, where even one misinterpreted contaminant particle can bias the results. The use of the pump enables the use of different filter sizes. The pump can also easily be constructed from any other submersible pump type, as long as the filter is located on the suction side of the pump.

4.3. Comparison of the results from other studies

Volumetric estimates of surface microplastic concentrations from other sea areas using towable nets (>333 μm) have given microplastic concentrations in the same range (<10 particles m^{-3}) as what was found in our study (Moore et al., 2002; Lattin et al., 2004, Lusher et al., 2015). Lusher et al. (2015) also used two methods for estimating microplastic concentration: a manta net for surface sampling and a submerged pump for subsurface sampling. The results of both methods were comparable with our data, the pump from 6 m giving slightly higher concentrations (0–11.5 particles m^{-3}) compared to surface trawl results of the study (0–1.31 particles m^{-3}). However, the mesh size of the filter used in their study was not reported.

A recent approach (Reisser et al., 2015) with a specially designed multi-level trawl that is able to sample from 0 to 5 m water column at 0.5 m intervals gave comparable results to the abovementioned results: median value 1.69 particles m^{-3} with maximum concentrations (<-6 particles m^{-3}) at the surface. In opposite to this are studies that show how the microplastic concentrations increase with depth (Lattin et al., 2004, Gorokhova, 2015). In the study of Lattin et al. (2004) the results from the bottom layers in the offshore were comparable to ours (<7 particles m^{-3}), while their reposted concentrations in the surface layers were lower (<2 particles m^{-3}). Interestingly, their results from the near shore were one order of magnitude higher (<19 particles m^{-3}).

Studies of Doyle et al. (2011) and Gorokhova (2015) used routinely collected historical zooplankton data for enumerating microplastics. The results of Doyle et al. (2011) from the Northeast Pacific ocean reveal microplastic concentrations between 0.004 and 0.19 particles m^{-3} (towable surface net with mesh size of 0.505 mm). An exception to all these studies is the recent work of Gorokhova (2015) in the Baltic Sea where vertical zooplankton samples (>90 μm) from one sampling station on the Swedish east-coast were analysed for microplastics. In this study microplastic concentrations were from 100 to 7.5×10^3 particles m^{-3}, which is order of magnitude higher than most studies with towable nets (including our study). Very high microplastic concentrations (mean of all sampling sites 2080 ± 2190) were also found in the waters of North-eastern Pacific Ocean (Desforges et al., 2014). The authors concluded that the high concentrations were the result of oceanographic conditions that trap and concentrate debris, possibly deriving from the 2011 tsunami event.

4.4. Applicability of the results for assessing harm of microlitter in the Baltic Sea ecosystem

Manta gives a quick and relatively reliable picture of the overall litter load in a larger area. However, especially the microlitter items that have raised most of the attention recently, synthetic textile fibres and beads from personal hygiene products, cannot be caught with manta. For those particle types the use of a device, such as the pump, equipped with 100 μm filter or smaller, is required. This is an important notification especially in the Baltic Sea ecosystem. One special feature of the fauna inhabiting the brackish waters of the Baltic Sea is the relatively small size of the organisms, both in plankton and benthos. The Baltic zooplankton communities consist of 100–300 μm sized rotifers, and crustaceans (cladocerans and copepods) that for the most are <1–1.5 mm in size, and unable to feed on the particles that are caught with the commonly used >300 μm mesh size equipment. Likewise in plankton, organisms in benthic communities of the Baltic Sea are relatively small. For example the blue mussels inhabiting the brackish waters of the Baltic Sea (*Mytilus trossulus*) are markedly smaller than the blue mussels (*Mytilus edulis*) inhabiting North Sea and the Danish straits (Väinölä and Strelkov, 2011). Moreover, experimental work with the local zooplankton and benthic communities in the northern Baltic Sea (Setälä et al., 2014, 2016) have already shown the efficiency of planktonic and benthic animals to ingest relatively small plastic microspheres of 10 μm in size, which are in the size range of their natural food, phytoplankton and small zooplankton. To better estimate the hazards that microscopic litter particles pose to marine organisms, it is evident that also the smaller fractions should be included in the sampling protocols (Syberg et al., 2015).

5. Conclusions

Based on only our data neither of the methods can be recommended over the other. The evident benefit of the use of a towable sampling net is the large area and water volume that can be covered during sampling. The manta is regularly used in microlitter research and comparative data are available from many sources and areas. The manta has a drawback in the fact that the contamination, especially of the smaller particles such as textile fibres, can't be estimated. This again is estimated in the pump method, that also giver accurate volumetric values. The use of pump enables the use of different type and sized filters. This is especially important if smaller particles are the purpose of the sampling. A pump can also be used for sampling of different depths. The choice of method should depend on what is the study target and in which environmental conditions the device will be used, bearing in mind particularly also the ecosystem structure and the key organisms of the area. For the assessment of the potential harm, or target/reference levels of microlitter from an ecological relevant perspective in the Baltic Sea, the use of 100 μm mesh size, or preferably even smaller is recommended. In order to follow the EC recommendations and to collect comparable data, the use of 333 μm mesh is justified, since it gives a good overall assessment of the distribution of microlitter. However, this size limit overlooks the concentrations of smaller fractions and most likely also fibres, which especially in the case of the Baltic Sea are more important for the invertebrate communities than particles larger than 300 or 333 μm.

Acknowledgements

We thank the crew and technical staff, especially Pekka Kosloff, onboard the R/V *Aranda* during the monitoring cruise for their assistance and invaluable help. The work was funded by the Finnish Ministry of Environment (project MERIROSKA), Swedish Research Council Formas and the Swedish Research Council for Environment, Agricultural Sciences and Spatial Planning and Foundation for IVL Swedish Environment Research Institute.

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