Microplastic concentrations, size distribution, and polymer types in the surface waters of a northern European lake

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• Abstract
We examined microplastic concentrations, size distributions, and polymer types in surface waters of a northern European dimictic lake. Two sampling methods, a pump sieving water onto filters with different pore sizes (20, 100, and 300 μm) and a common manta trawl (333 μm), were utilized to sample surface water from 12 sites at the vicinity of potential sources for microplastic emissions. The number and polymer types of microplastics in the samples were determined with optical microscopy and μFTIR spectroscopy. The average concentrations were 0.27 ± 0.18 (mean ± SD) microplastics/m³ in manta trawled samples and 1.8 ± 2.3 (>300 μm), 12 ± 17 (100–300 μm) and 155 ± 73 (20–100 μm) microplastics/m³ in pump filtered samples. The majority (64%) of the identified microplastics (n = 168) were fibers, and the rest were fragments. Materials were identified as polymers commonly used in consumer products, such as polyethylene, polypropylene, and polyethylene terephthalate. Microplastic concentrations were high near the discharge pipe of a wastewater treatment plant, harbors, and snow dumping site. © 2019 The Authors. Water Environment Research published by Wiley Periodicals, Inc. on behalf of Water Environment Federation.

• Practitioner points
• Samples were taken with a manta trawl (333 μm) and a pump filtration system (300/100/20 μm)
• With pump filtration, small 20–300 μm particles were more common than >300 μm particles
• The average concentration of manta trawled samples was 0.27 ± 0.18 (mean ± SD) microplastics/m³
• FTIR analysis revealed PE, PP, PET, and PAN to be the most common polymers

• Key words
fourier-transform infrared; freshwater; Lake; microplastics; plastic pollution

INTRODUCTION

The increasing production of plastic and the accumulation of plastic waste in marine environments has raised concern on the impacts of plastics on environment (Barnes, Galgani, Thompson, & Barlaz, 2009). Because of deficiencies in the waste recycling and processing, the amount of plastic accumulating in the environment has been enormous during this “plastic era” we are living in (Jambeck et al., 2015). Microplastics (MPs) are defined as plastic debris with a particle size of 1–1,000 μm (Hartmann et al., 2019), or 1–5,000 μm (GESAMP, 2015). MPs end up to the environment by the fragmentation of plastic debris, the wear and tear of plastic items, and the leakage of intentionally manufactured small plastic particles. MPs are insoluble to water and consist
of polymer(s) and additives, such as plasticizers, colorants, and flame retardants (Hahladakis, Velis, Weber, Iacovidou, & Purnell, 2018).

Studies on MP abundance in the marine environment demonstrate their worldwide presence (Auta, Emenike, & Fauzia, 2017). The first MP studies were carried out in marine environment, but recently also freshwater bodies have gained increasing attention. Building up knowledge on (micro)plastics in freshwaters is vital, because shallow freshwater bodies are vulnerable to pollution, they provide drinking water, and may act as routes from land-based MP sources to sea (Wagner et al., 2014). To date, MPs have been studied in surface waters, for example, in Laurentian Great Lakes of the United States (Eriksen et al., 2013), Lake Winnipeg in Canada (Anderson et al., 2017), Lake Hovsgol in Mongolia (Free et al., 2014), and Taihu Lake in China (Su et al., 2016). In Europe, microplastics of lake surface waters have been studied in Swiss (Faure, Demars, Wieser, Kunz, & Alencastro, 2015) and Italian lakes (Fischer, Paglialonga, Czeh, & Tamminga, 2016), and in Hungarian natural and excavated lakes (Bordos et al., 2019).

Central European lakes are typically small and lie in populated areas. Contrary, lakes of Scandinavia and Finland in northern Europe are larger, lie in less populated areas, and differ in biotic and abiotic factors. For example, boreal lakes are dimictic (the water mixes completely from surface to bottom twice a year with temperature changes) and have permanent ice cover during the winter. These unique conditions may affect MPs. Therefore, it is important to collect and publish microplastic data from northern lakes, because it is currently not available. To our best knowledge, this is the first published MP survey in Nordic lake environments and one of the few lake MP studies, which utilize spectroscopic methods for polymer analysis.

Our aim is to examine concentrations, size distributions, polymer types, and potential sources of MPs in Lake Kallavesi, located in Eastern Finland. In addition, we sampled with two methods providing complementary information and evaluated the suitability of them for lake water sampling. In the case of Lake Kallavesi, several potential sources for MP emissions are compactly located on the meandering lakeshore, which makes it an optimal sampling site for tracking MP sources.

**Materials and Methods**

**Sampling**

Lake Kallavesi is the tenth largest lake in Finland with a surface area of 478.1 km², mean depth of 9.7 m, and maximum depth of 75 m (Miettinen & Lindholm, 2018). It contains over 1,900
islands, is fed from a drainage basin of 16,270 km², and is
covered by ice on average 170 days/year. Lake Kallavesi provides
drinking water to the city of Kuopio (population: 118,000), sur-
rounded by the lake.

We collected surface water samples from Lake Kallavesi
with two methods, a manta trawl (333 μm) in autumn 2016,
and a pump with a filtration device in spring 2017. Samples
were taken before or after the dimictic mixing times, and the
sampling depth was approximately 0–16 cm. Sampling sites
(Figure 1), which represent potential local sources for MPs,
were compared with samples from open lake area (sites 1, 12).
Sampling sites were near a highway bridge (2), close to the
discharge pipe of a pulp mill (3–4), in a shallow bay (5), close to
harbors (6–7), in a snow dumping site (8), in a narrow strait
with inhabitance and ship traffic (9) and close to a wastewater
treatment plant’s (WWTP) discharge pipe (10–11). Manta trawl
samples were taken from sites 1, 2, 3, 4, 6, 7, 9, and 12, whereas
pump filtration was used at sites 2, 5, 7, 8, 10, and 11.

Because the manta trawl is a commonly used sampling
method for collecting MPs from surface waters (Li, Liu, & Paul
Chen, 2018), we chose it to sample larger particles. We used a
suitcase manta trawl (designed and manufactured by Marcus
Eriksen, 5 Gyres Institute), which has a rectangular opening
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Chen, 2018), we chose it to sample larger particles. We used a
suitcase manta trawl (designed and manufactured by Marcus
Eriksen, 5 Gyres Institute), which has a rectangular opening
of 16 cm (height) × 61 cm (width) and the net mesh size of
333 μm. The manta trawl was towed on the side of the vessel for
approximately 10 min at a speed of 2.5 knots. After the tows, net
contents were rinsed with tap water to 5 L buckets (food
handling with tweezers, (b) the color was uniform, and non-
natural or particle was colorless/transparent, (c) the shape was
equal-thick fibrous or smooth fragment. It has to be consid-
ered that the actual cutoff size was somewhat higher than 20 μm
because of the optical microscopy and manual selection step.
Despite, results are presented by filter pore sizes for clarity.

The pump filtration was conducted in addition to manta
trawling, because it was expected to be able to provide data
about smaller particles. Moreover, our study lake has several
narrow and shallow bays, where pump filtration was more
practical than trawling. In the pump filtration device, a petrol-
driven pump was used to suck surface water through a custom-
made cascade-like filtering tube made from PVC (Talvitie et al.,
2015). The tube has three screw joints, which hold three filters
vertically. The filters were cut from plankton net (nylon), and
their pore sizes were 300, 100, and 20 μm, giving particle size
fractions of >300, 100–300, and 20–100 μm. Water was pumped
to the tube via PVC hose placed on the water surface. When the
filters with smaller pores were clogged, they were removed from
the tube and the filtration was continued with the larger one(s).
The average sampled volumes in all sites were 6.2 ± 1.8 L with
20 μm, 83 ± 37 L with 100 μm, and 468 ± 75 L with 300 μm
filter. Samples were taken from the lake in duplicates, and the
results are presented as an average of the two samples. After
sampling, filters were removed from the filtering tube and
stored immediately in closed Petri dishes (Greiner CELLSTAR,
PS, 100 × 20 mm).

**Sample pretreatment**
All containers and equipment were rinsed thoroughly before
use with distilled and filtered ultrapure water. Pump filtration
samples required no further pretreatments before material
characterization, because the filters contained only minor
amount of solids. Manta samples, rinsed to buckets, were
digested with NaOH (VWR International) and sodium dode-
cyl sulfate (SDS, VWR International). Digestion was done in
the same buckets to prevent contamination. First, NaOH was
added while stirring until pH reached 12. Then, SDS (1 g/L)
was added. Buckets were incubated in 50°C in a water bath for
4 hr with stirring. Thereafter, they were incubated overnight
without stirring at the same temperature. The digested sample
solution was neutralized with HCl (VWR International) and
filtered to Whatman 114 (25 μm) cellulose filters. The filters
were stored in closed Petri dishes (Greiner CELLSTAR, PS,
100 × 20 mm) in a fridge for further analysis.

**Microscopy and FTIR analysis**
All filters with samples were visually inspected with a stereo
microscope (Zeiss Stemi 508; 6.3–50× magnification; Axiocam
ERc 5s camera; Carl Zeiss Microscopy GmbH, Jena, Germany).
From every sample, all particles having plastic-like appearance
were manually selected from the filters with micro tweezers and
placed on ZnSe transmission windows. Particles were imaged
with the stereo microscope’s camera. Particles were considered
as plastic-like if they met the following criteria (Noren, 2007):
(a) the structure was elastic and durable—no breaking when
handling with tweezers, (b) the color was uniform, and non-
natural or particle was colorless/transparent, (c) the shape was
equally thick fibrous or smooth fragment. It has to be consid-
ered that the actual cutoff size was somewhat higher than 20 μm
because of the optical microscopy and manual selection step.
Despite, results are presented by filter pore sizes for clarity.

Fourier-transform infrared (FTIR) spectra were measured
from each plastic-like particle. Particles on ZnSe windows were
measured with an FTIR microscope (PerkinElmer Spectrum
Spotlight; PerkinElmer, Waltham, MA, USA) in point mode
with an MCT detector. Measurements were done in transmis-
sion, using aperture 25 × 25 μm, spectral resolution 4 cm⁻¹,
number of scans 16, and spectral range 4,000–700 cm⁻¹.
Spectra were analyzed with Thermo OMNIC 9 software
(Thermo Fisher Scientific, Waltham, MA, USA). The spectra
measured were compared to a commercial polymer library
(Hummel Polymer Sample Library, Thermo Fisher Scientific)
and a custom-made synthetic fiber library (Talvitie, Mikola,
Setälä, Heinonen, & Koistinen, 2017). The correlation search
was done from the entire spectral range, and the recognition
limit was set to 70%. However, spectra were also individually
interpreted to ensure the recognition, because some of the MPs
were weathered or dirty. Only the particles, which were con-
firmed to be plastic, were calculated to the results. Microscope
images and FTIR spectra of particles are available in the
Supporting information.

**Contamination controls**
Contamination from the laboratory environment during the
microscope and FTIR analysis was estimated with three control
samples (C1–C3). Controls were clean and dry Whatman 114
filters on open Petri dishes. They were exposed to laboratory air
for 3 hr, 1 hr and 75 min, in different days during the sample analysis. The controls were examined for the presence of MPs with the stereo microscope and analyzed with μFTIR similarly as the actual samples.

**RESULTS**

**Concentrations and sizes**

**Manta samples.** The average MP concentration of manta trawl samples was $0.27 \pm 0.18$ MPs/m$^3$ (mean ± SD) (Figure 2). The highest concentration (0.66 MPs/m$^3$) was observed at site 7, near the city harbor, and the lowest (0.037 MPs/m$^3$) at site 2, under the highway bridge. Samples from sites 1, 3, 4, and 12 (open lake and pulp mill) had also lower concentrations than the average. On the other hand, samples from the sites 6 and 9 (leisure boat marina and strait with ship traffic) contained more MPs than the average.

**Pump filtration samples.** The average concentrations of pump filtration samples over all sampling sites were 1.8 ± 2.3 (>300 μm), 12 ± 17 (100–300 μm) and 155 ± 73 (20–100 μm) MPs/m$^3$ (mean ± SD) (Figure 3). The variations between sampling sites were quite high. Site 8, by the snow dumping site, had the highest MP concentration and site 7, City harbor, the lowest. Site 10, WWTP discharge pipe area, had also high concentration (Figure 3).

Generally, the amount of MPs/m$^3$ increased with a decreasing filter pore size. Pump filtration with 300 μm filter pore size provided higher average MP concentrations (1.8 ± 2.3 MPs/m$^3$) compared to the MP concentrations in samples collected with the >333 μm manta trawl (0.27 ± 0.18 MPs/m$^3$). However, manta and pump filtration datasets cannot be strictly compared to each other, because the sampling methods are different and have been utilized in different places during different seasons.

**Morphology and chemical composition**

All visually detected plastic-like particles in the samples were handpicked (495 particles), and every one of them was measured with μFTIR, which confirmed 34% of them as MPs. A total of 138 MPs were found from manta trawl samples and 30 from pump filtration samples, resulting in 168 MPs overall. Of these, 64% (107) were synthetic fibers and 36% (61) fragments. Figure 4 presents the distributions of concentrations of fibers and fragments for both sampling methods.

Fragments were irregularly shaped three-dimensional particles with various colors, such as white, blue, green, and red. FTIR analysis revealed them to be polyethylene (PE), polypropylene (PP), polymethyl methacrylate (PMMA), polyvinyl chloride (PVC), polyethylene terephthalate (PET), and polystyrene (PS) (Figure 5). PP and PE were the most common polymer types in fragments. Plastic fibers were of several colors; white, blue, red, brown, black, and green, and they consisted of PP, PET, and acryl (polyacrylonitrile, PAN).

In addition to MPs, high amount of cellulose fibers were found. Those were not taken into account, because the recognition of different cellulose materials was quite uncertain. Cellulose fibers can originate from manufactured materials, such as textiles and paper, and natural materials such as plants. Resolving the cellulose origin with FTIR would have required more insightful approach than exploited in this study, because samples contained much biological material from the lake (Comnea-Stancu, Wieland, Ramer, Schwaighofer, & Lendl, 2017). Moreover, as the contamination control indicated (see below), that risk for contamination was present especially regarding cellulose fibers.

**Contamination controls**

Control C1 contained nine fibers, which all were identified to be cellulose materials (cotton and viscose). Control C2 had only one fiber, which was cellulose. The last control C3 contained two fibers. First of them could not be identified, but the second one was composed of cellulose. The controls indicated that fibers float in the laboratory air and easily contaminate open filters. Based on this analysis, the amount of fiber contamination increases with exposure time. The open examination time of sample filters was approximately one hour or less, depending on the amount of plastic-like particles. It can be estimated that the
Fiber contamination will be small or negligible when the amount of selected particles is low. In this study, cellulose fibers were not taken into account in the analysis. Thus, we estimated the air‐borne contamination to be negligible for our results in the laboratory analysis step. Other sources of contamination, such as reagents and containers, were also possible but not examined.

**Discussion**

**Comparison to other studies**

Both surface trawling and pumping method have been applied in marine and freshwater environments (Fischer et al., 2016; Hidalgo‐Ruz, Gutow, Thompson, & Thiel, 2012). The average MP concentration in samples collected with the manta trawl from Lake Kallavesi (0.27 ± 0.18 MPs/m³) corresponds with the earlier study from the Baltic Sea, where in average 0.2 ± 0.2 MPs/m³ were detected (Setälä, Magnusson, Lehtiniemi, & Norén, 2016). Our pump filtration results showed that MP concentration increases with decreasing particle size, also shown by Railo, Talvitie, Setälä, Koistinen, and Lehtiniemi (2018) for the Baltic Sea. However, microplastics in the smallest two size fractions (20–100 and 100–300 μm) were found to be more abundant in Lake Kallavesi samples than what was found from the coastal waters of the Gulf of Finland (Railo et al., 2018).

Only a few studies have examined concentrations and polymer types of MPs in lake waters. For example in Italy, surface water samples from Lake Chiusi contained 2.68–3.36 and Lake Bolsena 0.82–4.42 MPs/m³ >300 μm particles (Fischer et al., 2016). MP concentrations in these small lakes in densely populated Italy were higher than in large Lake Kallavesi, which lies in a less populated area. Relatively high concentrations were also found in Hungarian surface waters of natural and excavated lakes (3.52–32.05 MPs/m³, 100 μm–2 mm particles) (Bordos et al., 2019). This result is higher than our mean pump filtration concentration for >100 μm particles.

However, when concentrations of different size fractions are compared, particle number per volume may not be the best unit for reporting. Because particles degrade continuously, it is not a conserved quantity (Simon, Alst, & Vollertsen, 2018). Although a filter with smaller pores collects higher number of particles, the overall plastic mass, which is a conserved quantity, also matters. Because particle size seems to affect MP uptake of aquatic animals (Lehtiniemi et al., 2018), particle sizes, numbers and masses per sample would all be necessary to report in future studies. In this study, the analysis method was not suitable for measuring or estimating masses.

**Variation between sampling sites**

Manta trawl and pump filtration datasets are not comparable to each other, because the sampling methods are different and have been utilized in different places during different seasons. Therefore, we discuss only the variations found within each dataset.

In the manta trawling, the highest concentrations were found near the urban areas compared to open lake. Samples from harbors had high concentrations of MPs, which were
mostly fibers (PP, PAN, PET), but also plastic fragments (PE, PP, PMMA, PS). The variety of detected polymer materials and particle morphologies was high, which indicates that they originate from multiple sources. The highway bridge sampling site showed a low amount of MPs possibly because of the strong currents below the bridge area. However, roads, road markings and especially car tires are estimated to be significant sources of MP emissions to environment (Jan Kole, Löhr, Belleghem, & Rågas, 2017). The knowledge of average tire wear particle size is limited, but they might be too small (<20 μm) to sample and analyze with the method used in this study, or so dense that they sink to the bottom. Additionally, tires contain 22%–40% carbon black, which hinders the FTIR characterization. Near the pulp mill, concentrations were close to average and MP types were fibers (PET, PAN) and fragments (PE, PP, PMMA). Fiber/fragment concentration ratio was also near the average in these sites.

In the pump filtered samples, snow dumping site had the highest MP concentrations. Snow, which contains plastic and other litter, is collected from city streets to the dumping site, located on the lakeshore. In the city of Kuopio, snow covers ground on average 160–175 days/year, and it has to be removed from the compact city center. MPs found from the lake near that site in spring after the melting of the snow were mainly PVC, PE, and PET fragments, which may originate from large plastic litter thrown to the streets. The second highest pump filtered concentration was found near the WWTP discharge pipe. In that site, all the identified MPs were acrylic and polyester fibers, which probably indicates that they result from wastewater loaded by washing of synthetic textiles (Sillanpää & Sainio, 2017), although 98%–99% of MPs are removed during the treatment process (Murphy, Ewins, Carbonnier, & Quinn, 2016; Talvitie et al., 2017). In comparison, 88% of synthetic particles found near snow dumping site were fragments. In downstream WWTP discharge pipe, concentration was lower than the average and found MPs were mainly fragments. Highway bridge and city harbor had also lower concentrations. Samples from shallow urban bay contained slightly higher concentration of MPs than average, mostly fibers.

The city harbor had the highest concentration in manta samples, but the lowest in pump filtration. Moreover, the ratio of concentrations of fibers and fragments was different between the sample sets. Manta samples were taken with larger mesh from a long transect in autumn, whereas pump filtration was done with multiple mesh sizes from one point in spring. In addition, filtered volumes were smaller in pump filtration. Some or many of these factors affect the results prominently. Possibly, MP concentrations are higher in autumn than in spring, or the harbor contains larger particles more than smaller. However, resolving the reason behind this would require more sampling with both methods concurrently.

Polymers types and morphology

In all samples, fibers were more common than fragments. Fibers consisted of PET, PAN, and PP polymers, which are used, for example, in textiles and industrial processes (GESAMP, 2015). Fiber lengths varied largely, and some of them were shiny and uniform, whereas others had breaks and small branches. Therefore, MP fibers were difficult or impossible to distinguish from natural fibers with optical microscopy and only the μFTIR step revealed the chemical composition of the particles.

All of the fragment polymers (PP, PE, PMMA, PVC, PS, and PET) are commonly used in consumer products, such as packages, bottles, coatings, films, and construction materials (GESAMP, 2015). Symmetrical or spherical MPs were not observed, but because primary MPs, such as manufactured microbeads, can be also irregularly shaped (Fendall & Sewell, 2009), categorization of MPs to primary or secondary was impossible. Most of the found MP fragments were PE and PP polymers, which float on the water surface. Denser polymers, which should sink toward the bottom, were less common in surface water samples.

Most of the previous MP studies of lake surface waters have not utilized spectroscopic methods and do not provide information about chemical composition. However, in Hungarian freshwaters PE, PP, PS, and polyester were the most common polymer types (Bordos et al., 2019). Additionally, in Lake Superior, the United States, the most common polymers were PE, PET, PVC, and PP, analyzed with FTIR (Hendrickson, Minor, & Schreiner, 2018). Nevertheless, MPs in lake sediments have more widely been characterized spectroscopically. In Canadian Lake Ontario, PE, PS, polyurethane (PU), PP, and PVC were the most common polymer types in sediment samples (Anderson et al., 2017). Comparably, sediments of Italian Lake Garda contained primarily low-density polymers such as PS, PE, and PP and smaller amount of polyamide (PA) and PVC (Imhof, Ivleva, Schmid, Niessner, & Laforsch, 2013). PE, PP, and PET were also abundant in our study, but we found only a couple of PS particles.

PU and PA were not found in our study. PA might have degraded in sample treatment process, left unidentified with FTIR, or it is not very common in our sampling area. Manta samples were treated with NaOH, which has been reported to degrade PA (Roch & Brincker, 2017). Besides, PA is often difficult to recognize with FTIR if biofilm covers it. Biological material contains amino acids linked by amide bonds, thus it has similar features in FTIR spectrum than PA, which may cause misidentifications.

Method validity and accuracy

The manta trawl and a similarly functioning pump filtration system than utilized here have previously been compared and discussed in detail for marine sampling (Setälä et al., 2016). In freshwater sampling, both sampling methods had pros and cons. The manta trawl is suitable for filtering larger water volumes from longer area, but the pump filtration is suitable for collecting also smaller particles and many size fractions simultaneously. The cascade-like structure of filtration tube helps to prevent the clogging of smallest pored filters, and largest (pre)filter can be analyzed too. Comparing the two sampling methods, manta trawling is suitable for open water areas, whereas pump filtration is more practical in small water bodies and coastal sampling. Thus, the choice of sampling method...
depends on the geography of sampling site and target particle size(s).

Considering contamination and method validation, the pump filtration tube, which is a closed system, is less sensitive to contamination and can be validated with procedural blanks (Talvitie et al., 2015). It is also possible to do recovery tests for the tube with spiked samples, and we have previously studied that the MP recovery of a similar pump filtration tube for tap water samples was 91% (unpublished results). However, the hose and tube are made of plastic (PVC), which may cause contamination. In this study, five PVC particles were found from three sampling sites. Snow dumping site contained three PVC particles, others only one. Because the amount of PVC particles was quite low, it is likely that sampling system does not release many larger >50 μm particles during one sampling event. Especially when the analysis method can detect very small particles, it is still important to wash and rinse the sampling system well before use and do always blanks to ensure that the tube and hose do not contaminate samples.

The exact estimation of contamination is impossible when using the manta trawl, because it is not possible to take a blank sample with it. Additionally, it is not possible to do recovery tests for manta sampling. On the other hand, the pump filtration data might be more vulnerable to random variation, because the filtered water volumes and detected MP numbers were rather low, compared to the manta samples. Because of clogging, the average pumped water volume in 20–100 μm samples was only 6.2 ± 1.8 L (mean ± SD), which might not be representative for m3. Despite this, results of 20–100 μm fractions were reported per m3 to ease the comparison with other fractions. In the future, the filter combinations could be adjusted for filtering larger volumes by changing the smallest pore size to, for example, 50 μm, or using 100/50/20 μm filter set for collecting small particles. We used plankton net filters made from nylon, but stainless steel filters have also been used for freshwater sampling (Bordos et al., 2019).

We collected each particle suspected to be of plastic origin and analyzed the polymer type of every single particle. The analysis showed that only about 34% of visually selected particles were actually MPs. This procedure emphasizes the need to examine microliter by spectroscopic or other suitable analytical method, as pointed out previously (Rocha-Santos & Duarte, 2015). Recent studies report fully automatic µFTIR spectroscopic analysis with a focal plane array detector (Primpke, Wirth, Lorenz, & Gerdts, 2018). That procedure could be, when applicable, the most efficient and accurate method for MP determination, if MPs can be satisfyingly isolated and recovered from the sample matrix.

In our analysis method, the risk of false negative was remarkably high, because potential plastic particles were selected by visual inspection. Manta samples contained large amounts of algae, insects, and other biological material and particles were selected from the partially digested matrix remains, consisting mainly of chitin. More efficient digestion method, which dissolves also chitin, could ease this problem (Löder et al., 2017). Additionally, the digestion step made the manta method more prone to contamination than the pump method. All of the collected particles were spectroscopically identified to be plastic or other materials with sufficient accuracy. The risk of false positive was therefore very low without counting the possible contamination. However, contamination from equipment and reagents was not analyzed, and the controls likely underestimated the amount of contamination coming from the whole sampling and analysis process.

Conclusions

Microplastic concentrations and polymer types in dimictic northern European lakes have not been studied before. This study fulfills the gap by providing data about concentrations and polymer types in surface waters of a Finnish lake. Currently, researchers analyze MPs with a wide variety of methods. For freshwater sampling, both manta trawling and pump filtration are suitable, depending on what kind of areas and particle sizes are on the focus. However, the pump and filtration method is more versatile, because pore sizes of filter sets can be easily adjusted and the system allows method validation with blanks and spiked samples. Micro-spectroscopic methods are appropriate for MP analysis, because they can provide information on both chemical composition and particle size. In the future, more comprehensive monitoring would be necessary for wider knowledge of the spatial and temporal patterns of MP abundance.

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Conflicts of Interest

The authors declare no conflicts of interest. Data are available on request from the authors.

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RESEARCH ARTICLE

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