Citizen Science on Microplastics in the North Atlantic

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1   Introduction

The issue of marine microplastics (MPs) has been in the public eye for several years. There is a great need for accurate data on the spatial and temporal variations of global MP concentration, composition, and size distribution to understand the diverse impacts of these pollutants. On their own, marine research institutes around the world do not have the capacity to conduct such comprehensive assessments. Therefore, various approaches aim at involving committed non-scientists/-experts to broaden the database for professional institutions. In this manner, it should be possible to generate additional data of sufficient quality at lower cost and climate impact. While preparing for their tour across the North Atlantic, two sailors decided to use their free time on board the center cockpit steel yacht "Beagle" (11 m/11 tons) to try and support the planet's largest ecosystem through MP research. The analysis of the volume-reduced MP-water samples was carried out under the umbrella of the SOOP | Shaping an Ocean Of Possibilities for science-industry innovation platform (https://www.soop-platform.earth/).

2   Materials and methods

2.1   Mitigating contamination

Due to their omnipresence, mitigating procedural sample contamination is of high importance in MP analysis. The contamination with natural microparticles should be avoided as well, as they prolong the sample preparation and final measurements and can interfere with the analysis by infrared spectroscopy.

On board the Beagle, wearing clothing made of polar fleece and other synthetic fibers was avoided during sampling. In the laboratory, all clothing was made almost exclusively from cotton and wearing nail polish as well as plastic hand jewelry was avoided. Nitrile butadiene rubber gloves (Honeywell International Inc., Morristown, NJ, USA) were worn only when handling

corrosive chemicals. All the laboratory equipment was made of glass and/or stainless steel. All tools for which plastics could not be avoided were made from perfluorinated polymers. Prior to use, all instruments were thoroughly washed with ultrapure water (MQW; Merck KGaA, Darmstadt, Germany) as well as ≥ 99.8 % ethanol (Carl Roth GmbH + Co. KG, Karlsruhe, Germany) that was previously filtered over 0.4 µm polycarbonate (PC) track-etched membrane filters (Cytiva, Marlborough, MA, USA).

Dirty equipment was cleaned in a laboratory glassware washing machine (Miele & Cie. KG, Gütersloh, Germany) using MQW and neodisher® LaboClean A8 detergent (Dr. Weigert GmbH & Co. KG, Hamburg, Germany). Subsequently, all heat resistant equipment was heated to 250 °C overnight to decompose residual MPs.

The laboratories, in which the study was conducted, are especially fitted for MP analysis. Dust-Boxes® 1000 (moecklinghoff Lufttechnik GmbH, Gelsenkirchen, Germany) capture over 99.995 % of airborne micro- and nanoparticles in the room. The samples were handled inside either laminar flow benches (Spetec GmbH, Erdingen, Germany) or class II biological safety cabinets (Kojair Tech Oy, Mänttä-Vilppula, Finland) likewise equipped with high efficiency particulate air filters of the category H14. Sticky mats in front of the laboratories were meant to remove dust from the shoe soles. Surfaces were wiped regularly with MQW, filtered ethanol and low-lint cellulose wipes (Kimberly-Clark Corporation, Dallas, TX, USA) which were also seldomly used to wipe equipment when needed. If equipment was stored or transported outside of the laminar flow boxes, it was wrapped in aluminum foil (Carl Roth GmbH + Co. KG, Karlsruhe, Germany).

2.2 Sampling and treatment on board

The sampling was conducted on board the sailing boat Beagle with oceanic surface water. During a first trial, samples were collected using a microplastic net with a 300 µm mesh size and 70 x 40 cm mouth (HYDRO-BIOS Apparatebau GmbH, Altenholz, Germany; product number 438213). The net was modified with two fenders so that the upper edge was at the same level as the ocean surface, and it was fixed with four Dyneema® ropes (breaking strength 180 daN). Samples could only be collected at a Beaufort scale ≤ 3. A particularly high wave destroyed the MP net's suspension, and it was lost.

These initial test samples were treated on board with ca. 50 mL of a 10 M potassium hydroxide (KOH) solution for 84 h at 30 – 40 °C to decompose most of the organic matter. The mixture was then neutralized with 28 g citric acid in 100 mL H_2O at room temperature. Only a fraction of the fish eggs and shrimp shells could be dissolved. Therefore, and to avoid further loss of sample material, the samples taken after this test phase were treated in the laboratory.

In total, ten samples (S6 – S15) were collected during a trip from the Caribbean to the British Isles in April to June of 2023 using a similarly modified net with a smaller 30 x 20 cm opening which was secured with stainless-steel ropes (diameter 4 mm; cf. Figure 1).

With the updated system, samples could be collected at a Beaufort scale ≤ 4. To eliminate the influence of oceanic currents, the ship was kept at steady speeds between one and five knots. The speed measurement inaccuracy was 5 %. Across all ten samples an average distance of 1.3 ± 0.5 km (1 *SD*, *n* = 10, range 0.74 – 1.85 km) was covered per sample, equivalent to an average water volume of $(8 ± 3) \times 10$ m^3 (1 *SD*, *n* = 10, range 45 – 111 m^3). Still on board, macroscopic flora, fauna, and plastics were sorted out and the residual components of the samples were rinsed from the MP net onto a 300 μm mesh filter and subsequently transferred to polyethylene (PE) bags (Rewe Markt GmbH, Cologne, Germany).
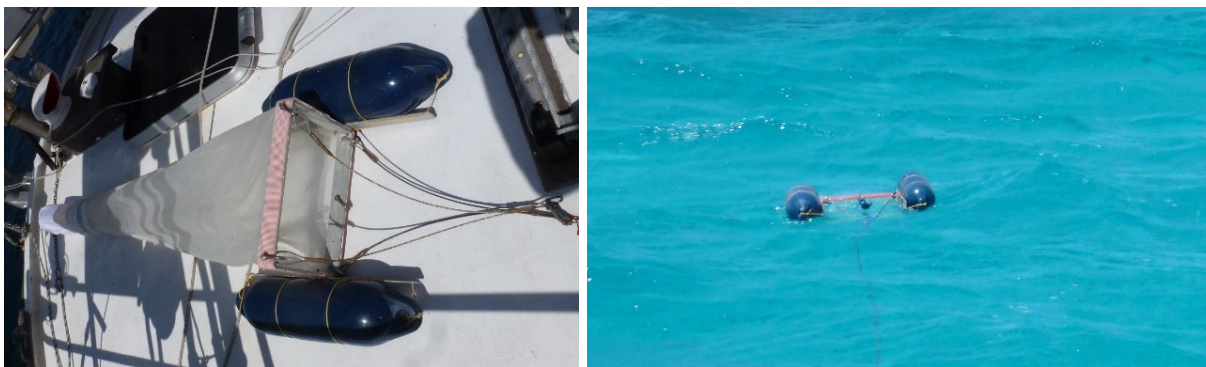
Figure 1: Modified MP net with 20 x 30 cm opening, aluminum frame, and fenders, suspended with stainless-steel ropes connected to a 25 m long, 5 mm wide Dyneema® rope (breaking strength 2600 daN).

2.3 Laboratory sample treatment

A blank was introduced in the laboratory at the beginning of the sample treatment stage. The samples were filtrated on 5 μm polytetrafluoroethylene (PTFE) filters using a stainless-steel manifold vacuum filtration system (Rocker Scientific Co., Ltd., New Taipei City, Taiwan). Using MQW and filtered ethanol, the residuals were rinsed from the PE bags that were then discarded. The samples were washed using MQW.

A 30 % (*w*:*V*) solution of hydrogen peroxide (H_2O_2; Carl Roth GmbH + Co. KG, Karlsruhe, Germany) was filtered over a 0.4 µm PC membrane. The PTFE filters with the samples were then suspended in 25 mL of this solution in 250 mL glass bottles covered with aluminum foil with a small opening. The mixture was heated to 45 °C for 24 hours on an orbital shaker and then filtrated on 5 µm PTFE filters.

Again, using MQW and filtered ethanol, the residuals were rinsed from the previous PTFE filters that were subsequently discarded. The samples were washed using MQW.

Subsequently, the samples underwent density separation. For this, a solution of zinc (II) chloride ($ZnCl_2$; Carl Roth GmbH + Co. KG, Karlsruhe, Germany) in MQW with a density of 1.7 g/mL was prepared and filtered twice over 1 µm glass fiber filters (Pall Corporation, Port Washington, NY, USA) that had previously been heated to 250 °C overnight.

The sample was covered with this solution and scraped of the filter using a PTFE spatula. The PTFE filter was rinsed and discarded, and the sample was suspended in 70 mL of the $ZnCl_2$ solution in a 100 mL separatory glass funnel using a PTFE stopcock and a glass stopper. The separatory funnel was covered with aluminum foil and set aside for at least 24 hours. Subsequently, the bottom 50 mL containing the heavier constituent of the sample were released and the $ZnCl_2$ solution was later recycled through double filtration. The remaining suspension was filtered onto 5 µm PTFE filters and the separatory funnel as well as the sample were thoroughly rinsed and washed with 1.3 % (*w*:*V*) HCl, MQW and ethanol in that order.

2.4 Detection and analysis of microplastics

The particles > 300 µm were manually transferred to silver coated MirrIR low-e microscope slides except for some fibers. The transflection-mode infrared spectroscopic measurements were carried out using two Agilent 8700 Laser Direct Infrared (LDIR) Chemical Imaging Systems with the Agilent software Clarity version 1.6.0 beta (Agilent Technologies, Santa Clara, CA, USA). The particle sensitivity was set to 0.10 out of 0.16 as maximal sensitivity and only the particles in the size range of 20 – 5000 µm were considered. The spectra were measured with a spectral resolution of 8 cm^{-1} and the obtained spectra were compared to a spectral library provided by Agilent Technologies (Microplastic starter 2.0) that was expanded by a variety of self-generated spectra from various (semi-)synthetic polymers. Identified MPs with a hit quality index (*HQI*) > 0.85 were accepted. Generally, tire abrasion, synthetic polyamide, and rubber

were excluded from the results since the detection via LDIR imaging was not reliable enough. PTFE was excluded due to potential contamination from the utensils used.

2.5 Data evaluation

The imaging data of all identified particles was exported from the Clarity software as a comma-separated values file containing the geometrical information, polymer types, and *HQI*s. A custom written excel sheet facilitated the filtering by *HQI* and clustering by polymer type and size. The software ArcGIS Desktop 10.8.1 (ESRI Inc., Redlands, CA, USA) was used to create the map.

3 Results

3.1 Quality control

In the laboratory blank control, no MPs larger than 300 μm were detected. No blank sample was prepared on board the ship. Therefore, the influence of the working environment on board the Beagle and of the PE bags used for transport of the samples could not be determined, although the bags are not expected to release MPs larger than 300 μm into the sample. Further, the possibility of the MP net collecting PE fragments from the Dyneema® rope could not be quantified.

Microplastic quantities, composition, and particle sizes

As expected, microplastic could be detected in all samples. Figure 2 is a map of the surface MP concentration in the size range 0.3 – 5 mm for all 10 stations and their respective polymer type composition. Besides PE, acrylonitrile butadiene styrene (ABS), polyethylene terephthalate (PET), polypropylene (PP), and polyvinyl chloride (PVC) were found. No statistically significant spatial trends could be detected. The highest MP concentration was detected at station 11 with 0.16 m^{-3} and the lowest at station 9 with 0.010 m^{-3}.
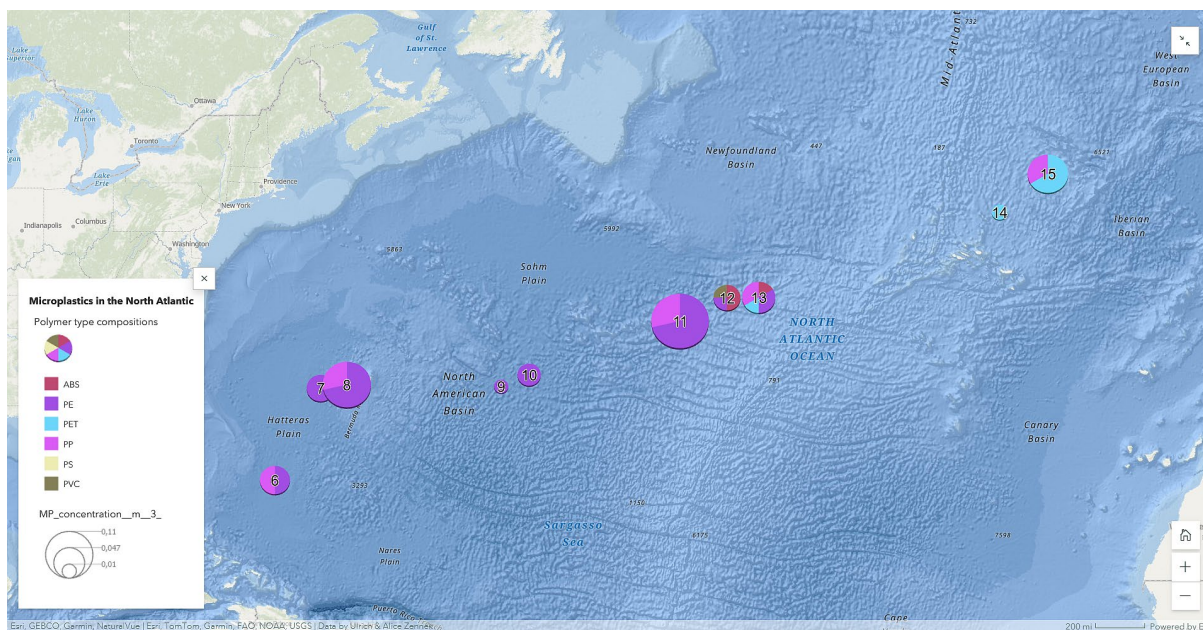
Figure 2: Map of the surface MP concentration in the size range 0.3 – 5 mm for all 10 stations and their respective polymer type composition.

Table 1: Geospatial information, sample volume, MP counts, and share of polymer types for all ten samples in the size range 0.3 – 5 mm.

Sample	Latitude [°]	Longitude [°]	Sample volume [m³]	MP count	Polymer types (count)
6	26.98900	−70.56700	45	2	PE (1), PP (1)
7	31.91653	−67.74352	51	2	PE (2)
8	32.10243	−66.13165	61	7	PE (5), PP (2)
9	32.00718	−56.61957	100	1	PE (1)
10	32.61725	−54.89835	111	3	PE (3)
11	35.36070	−45.59473	85.6	14	PE (10), PP (4)
12	36.52727	−42.70253	111	4	ABS (2), PE (1), PVC (1)
13	36.53783	−40.74420	111	6	PE (2), PP (2), ABS (1), PET (1)
14	40.63907	−25.88847	79	1	PET (1)
15	42.41252	−22.92182	37	3	PET (2), PP (1)

The slides with samples from station 13 – 15 contained higher MP counts at smaller size ranges. Figure 3 shows the size distribution of the measurement results for these three samples. Similar results are to be expected, if the samples were not manually transferred, but suspended in 50 % ethanol and dripped onto the slide. Still, due to the 300 µm mesh size of the MP net, no quantitative conclusions can be drawn in this size range.

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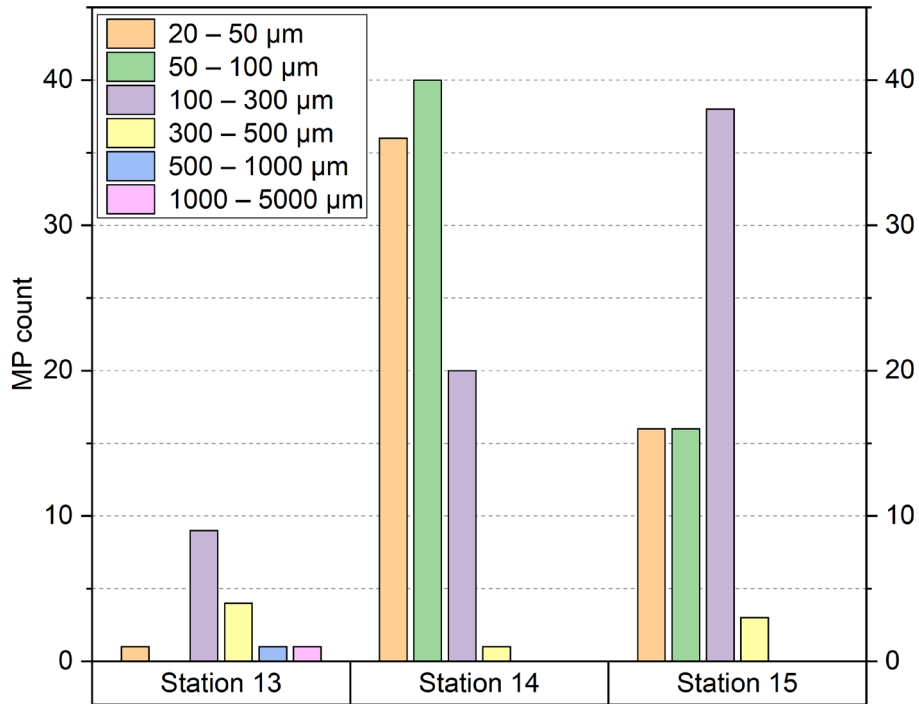
Figure 2: Size distribution of the measurement results for the samples from stations 13 – 15.

Figure 3 shows the polymer type composition of the samples from stations 13 – 15 in the size range 20 – 5000 µm. It is apparent that not only higher MP counts, but a higher diversity of polymer types can be detected at larger size ranges. The results also include polymethyl meth-acrylate (PMMA), polyoxymethylene (POM), polystyrene (PS) and polyurethane (PU).
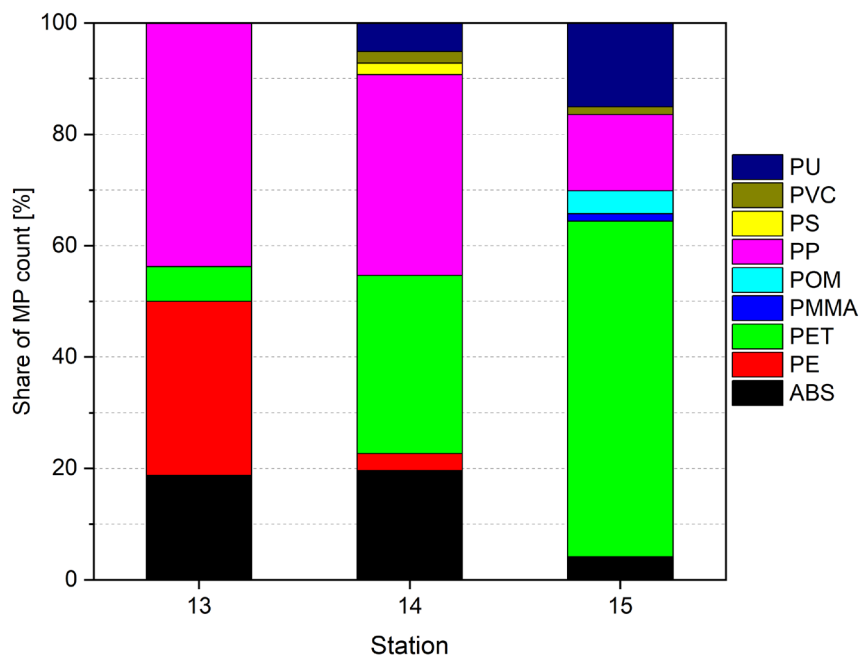
Figure 3: Polymer type composition of the samples from stations 13 – 15 in the size range 20 – 5000 µm.

4 Limitations of the experimental design

There are several factors limiting the statistical significance of these results. Firstly, the comparability of the MP concentration among the stations is impeded since the MP net was clogged by flora (e.g. Sargassum) and fauna (e.g. Cnidaria) at many stations (cf. Figure 5). Therefore, the sampling system's resistance varied across the stations, and it is unclear by how much the sampling volumes were overestimated in each case. Furthermore, the different currents' influence on the sampling volumes were not figured in, and some fibers were not transferred for measurements in the laboratory. This also hinders inter-study comparison.

Figure 4: MP net containing sample 9 (left) and sample 11 (right).

The comparatively large mesh size and a small mouth of the MP net are necessary when sampling during a sailing trip on a center cockpit yacht. This limits the amount of information that can be gathered during a campaign. The extrapolation of MP counts towards smaller particle sizes along an exponential function has been described in literature but comes with large uncertainties. Furthermore, mild weather is necessary with small waves and continuous winds. For instance, only two samples could be collected between the Azores and the British Isles due to strong winds.

As stated before, it could not be assessed whether the transportation in the PE bags and usage of Dyneema® ropes were a limiting factor in the measurement accuracy, since no blank sample was taken on board the ship. Another restraining factor is the imperative absence of replicate samples when sailing.

5   Outlook

It is rather difficult to collect MP samples during a sailing trip due to the high dependence on the weather conditions. This emphasizes the need for more advanced MP sampling tools that can be utilized by non-scientist/-experts to gather information of higher statistical significance in the future. For example, collecting the samples with a small pump filter cascade system in sub-surface waters would yield more information. Conversely, it would also be much more resource intensive and costly. The results from this study might help navigate this trade-off in future investigations.