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Microplastics in marine suspended solids from sediment traps in the Inner Sea of the Maldives

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Introduction

- Studies on microplastic (MP) occurrences in the Maldives as well as studies on MP occurrences with the deployment of sediment traps is still very limited
- Previous studies in the Maldives focus on beach sediments, reef sediments and surface waters. For this reason, the present study represents the first study on MP occurrences in the waters of the Inner Sea from sediment traps
- By using moored sediment traps, a time component is integrated into the investigations and in general a better understanding of the vertical distribution of the MP occurrences is gained
- Samples from two mooring configurations with three sediment traps (N = northern deep trap 200 m below sea surface, Ns = northern shallow trap 80 m below sea surface, S = southern trap 200 m below sea surface) were investigated (see figure 1)
- By assuming ellipsoidal particle shapes and calculating the mass share of carbon per polymer type, both the polymer masses and the polymer-based carbon masses were determined
- Additionally, enabled by the use of sediment traps, flow rates or sedimentation rates of MPs and polymer-based carbon were obtained and related to the total flux of marine suspended solids (mss)

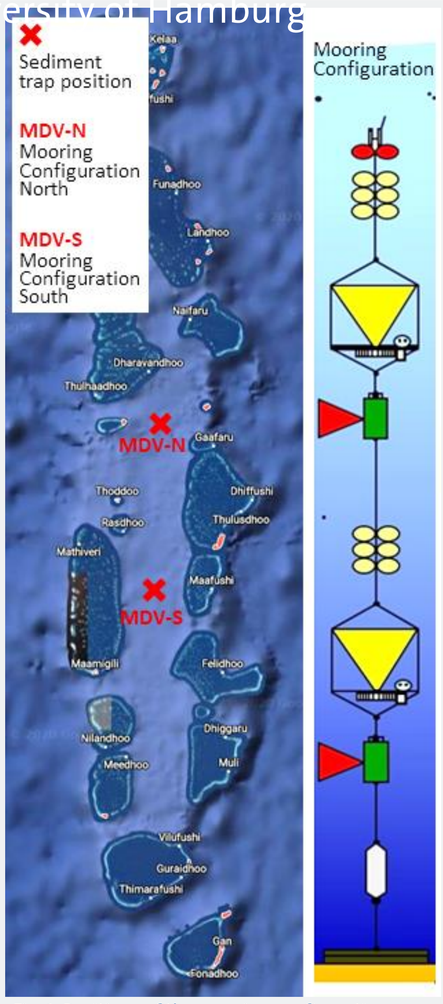

Fig. 1: Positions of the mooring configurations North and South in the Inner Sea of the Maldives (left) and a schematic layout of a mooring configuration (right).

Material and Methods

- 14 samples were examined, which together collected 252 days of mss
- The development of a laboratory analytical protocol for the digestion of biogenic matter resulted in the application of hydrochloric acid (HCl), hydrogen peroxide (H_2O_2), sodium hypochlorite (NaClO) and phosphoric acid (H_3PO_4) in different concentrations and at different application times (see figure 3)
- The samples from the Maldives contained a lot of chitinous material (see figure 2). The methods for digestion of chitin-containing structures used in MP studies so far (mainly chitinase) did not achieve the intended results
- Preliminary tests showed that 85% H_3PO_4 is a suitable chemical for chitin destruction (see figure 2). LDPE, HDPE, PP, PS and PET are hardly affected by the application of 85% H_3PO_4. However, PA is dissolved
- For particle identification, the samples were stained with Nile red (dissolved in chloroform). After filtration of the stained samples, filters were photographed and particles were counted and measured (major and minor dimension) under the fluorescence microscope. A subset of the MPs was identified by µRaman-spectroscopy (see figure 3)
- The ratio of the minor and major dimension of all particles (n = 2,365) was calculated and yielded a median value of 0.56. The unknown third dimension (thickness) was calculated assuming the ratio of the thickness and the minor dimension of the particle to be the same as the ratio of the minor dimension and the major dimension of the particle. Thus, the thickness was estimated as 56% of the minor dimension
- To determine the volume of a particle an ellipsoid shape v

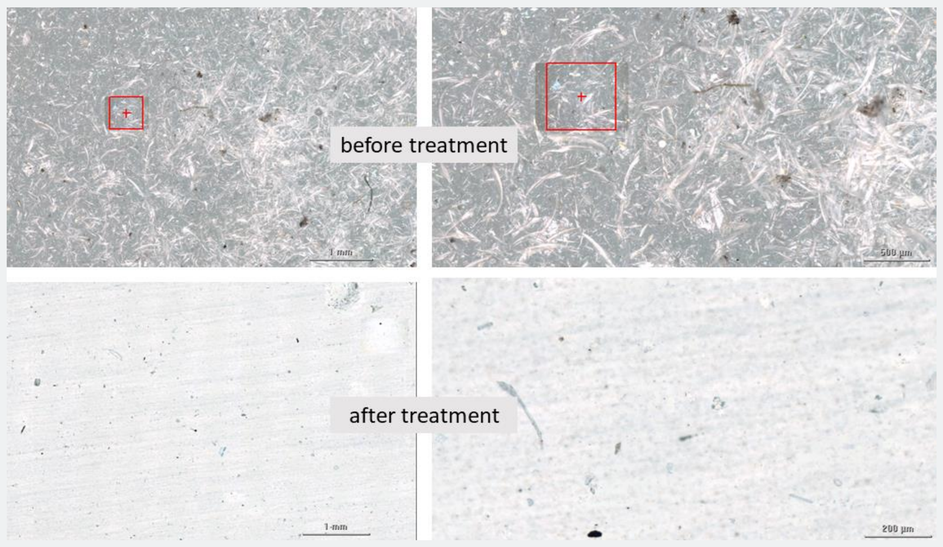

Fig. 2: µRaman-spectroscopy mosaic images of a preliminary test sample before (images above) and after (images below) treatment with 85% H_3PO_4. Chitin-sickle structures are no longer visible after the treatment.

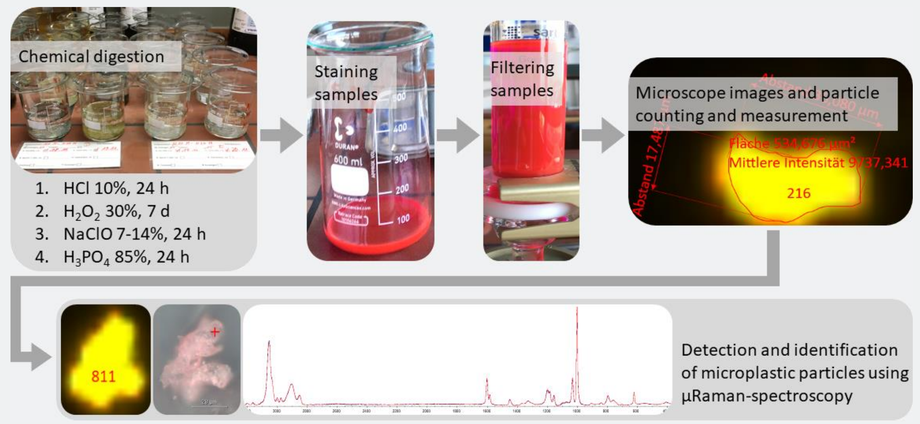

Fig. 3: Scheme of the applied laboratory protocol for the processing of marine samples from the Maldives.

Results & Discussion

MP particle numbers, sizes and concentrations

- In 14 samples a total of one microplastic fiber (see figure 4a) and 2,365 microplastic particles in quantities between 22 and 1015 particles per sample were found
- The particle shapes are dominated by irregularly shaped fragments and spherical structures (see figure 4a)
- The major dimension of all particles ranged from 20 µm to 1,900 µm. Of 2,365 particles only six have a major dimension >1 mm
- The relative frequency of particles increases as the major dimension decreases (see figure 4b). This tendency is also evident for each individual sediment trap. 98% of all counted particles have a major dimension between 20 µm and 300 µm
- The particle concentrations range from 33 particles g^{-1} dry weight (dw) mss to 870 particles g^{-1} dw mss with a mean value of 394 ± 255 (mean ± standard deviation (sd)) particles g^{-1} dw mss (see figure 5 and figure 6a)
- With southwesterly current conditions at a depth of 200 m the particle concentrations in samples with the same sampling times (N3, S3, N5, S5, N12, S12, N16, S16) or short consecutive sampling times (N1, S2) are always higher in N than in S (see figure 5). There are significant differences ($p < 0.05$) between N and S regarding the particle concentrations with prevailing southwesterly currents

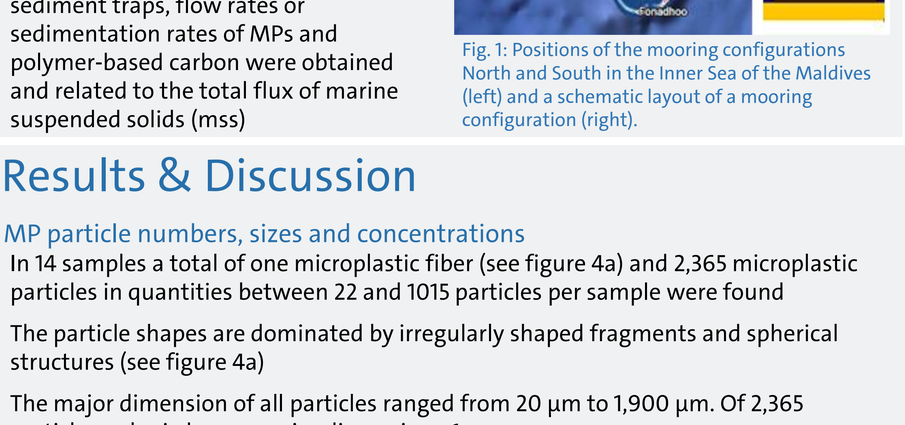

Fig. 4: a: Selection of PS, PC, PVC and EVAC polymer images taken with µRaman-spectroscopy. b: Size distribution of all counted microplastic particles as relative frequencies (%) according to their major dimension (bar width of 40 µm).

Distribution of polymer types

- Ten different polymer types were identified, with PS (72%) and PC (23%) being the most frequently found polymer types (see figure 5). Considering the density of these polymers and the demand and/or the use of these polymers on the Maldives these findings are comprehensible
- The discrepancy of the plastic occurrences e.g. of the polyolefins PE and PP between the samples from the sediment traps of this work in comparison to the occurrence of the polyolefins in beach sediments, reef sediments and surface water near the investigation area of this work is very strong. This suggests that the effects of density change (through biofouling or ingestion and subsequent excretion in faecal pellets) and biological transport mechanisms through marine organisms are only partially effective or even counteractive. Additional factors such as vertical currents or local effects that have not yet been considered may also influence the buoyancy and might even lead to reemergence of plastic particles

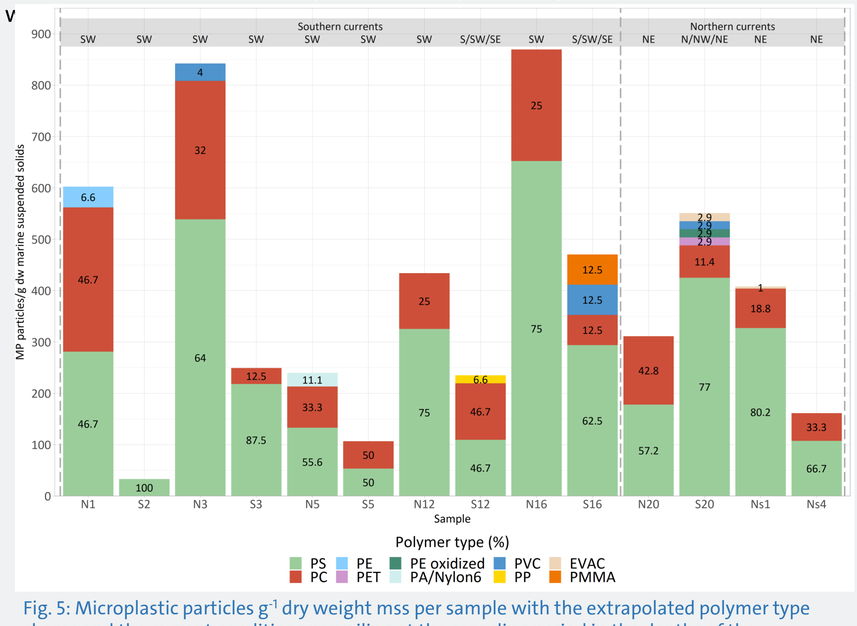

Fig. 5: Microplastic particles g^{-1} dry weight mss per sample with the extrapolated polymer type shares and the current conditions prevailing at the sampling period in the depths of the corresponding sediment trap. N = North, NE = Northeast, NW = Northwest, S = South, SE = Southeast, SW = Southwest

Flux rates and mass-specific results

- The assumption of ellipsoidal MP particle shapes proved to be valid
- In mean 67 ± 44 MP particles m^{-2} sediment daily (see table 1)
- In a simplified extrapolation, the MP sedimentation rates for Maldivian waters result in a daily sedimentation of about 860 kg MP <1 mm (see figure 6b)
- When comparing N and S at prevailing southwest currents, significant differences between the traps regarding MP particle concentration were found, but no significant differences between the traps regarding the total polymer mass per sample per initial sample weight could be found. This shows that interpretations may differ depending on the selected measure. Future studies should consider both particle number and particle mass
- In median 0.05% (mean 0.07 ± 0.07%) of the total carbon flux of mss <1 mm is polymer- based, i.e. originates from the MP (see table 1)

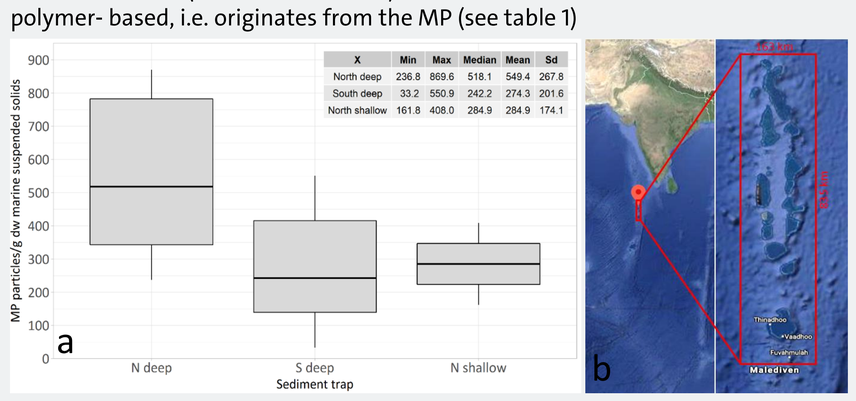

Fig. 6: a: Distribution of MP particle concentrations in MP particles g^{-1} dw mss per sediment trap with descriptive statistic. b: Theoretical rectangular sea area (835 x 163 km^2) around the Maldives to illustrate the extrapolated and simplified results of about 860 kg MP <1 mm which sediment every day in this area

Tab. 1: Descriptive statistics on the total polymer mass per sample per initial sample weight, the MP particle masses of different size fractions per sample, the MP particle sedimentation rate per sample (only for N and S, as these represent the final sedimentation levels of this work), the daily MP particle sedimentation mass per square meter and sample for MP particles <1 mm (only for N and S), the total polymer-based carbon mass per sample per initial sample weight, the polymer-based carbon content based on the initial carbon weight or the initial total carbon flux per sample for MP particles <1 mm and the daily sedimented polymer-based carbon mass per square meter for MP particles <1 mm (only for N and S)

	Min	Max	Median	Mean	Sd
Total polymer mass per sample per initial sample weight (all sizes) (ng mg^{-1})	6.1	268.6	39.5	75.6	± 85.4
Average MP particle mass per sample (all sizes) (ng)	40.7	479.8	126.2	182.3	± 141.8
Average MP particle mass per sample (particles <1 mm) (ng)	40.7	479.8	94.7	137.4	± 116.6
MP particle sedimentation rate per sample (particles <1 mm) (m^{-2} d^{-1}) (only N and S)	19.6	156.0	64.0	66.9	± 43.6
MP Particle sedimentation weight per sample (particles <1 mm) (µg m^{-2} d^{-1}) (only N and S)	1.1	30.8	6.8	9.4	± 8.7
Total polymer-based carbon mass per sample per initial sample weight (all sizes) (ng mg^{-1})	5.1	245.0	34.9	68.6	± 78.2
Polymer-based carbon content of initial carbon weight per sample or initial total carbon flux per sample (particles <1 mm) (%)	0.01	0.22	0.05	0.07	± 0.07
Polymer-based carbon sedimentation weight per sample (particles <1 mm) (µg m^{-2} d^{-1}) (only N and S)	1.3	27.5	5.8	8.4	± 7.8

Conclusion

- The application of 85% H_3PO_4 for the destruction of chitin represents a possible alternative to enzymatic digestion with chitinase or lysozyme for future MP studies with chitin-containing sample material
- A combination of current conditions, location of the sediment traps and the island morphology may influence the particle concentrations per sample
- Most likely, the MP occurrence is made up of plastic from the Maldives itself and plastic that is introduced into the Inner Sea from further away by currents
- For a better understanding of the spatial and temporal distribution of MP, the dynamic behaviour of MP, the polymer type distribution or the influence of e.g. currents or effects like biofouling, sediment traps are best suited and therefore highly recommended for increased application. Permanent installations with an annual evaluation rhythm as well as the establishment of the MP particle mass as an additional, reasonable and target-oriented measure for MP studies could provide interesting insights

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