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Microplastics in the upper tidal Elbe – A comparison between sediments from the Hamburg port area and an adjacent nature reserve

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Introduction

Rivers have been identified as major pathways for plastic to marine environments, thus, they are of importance to understand the transportation and accumulation behavior of microplastic debris. Sediments may act as a sink for microplastic particles, especially when conditions of discharge and the underlying sediment substrate change within the river course.

The upper tidal Elbe, passing the harbour city Hamburg and draining into the North Sea, has so far not been thoroughly investigated with regards to microplastic abundance in sediments. This study and its findings provide a first screening of the river's sediment microplastic concentration.

Material & Methods

For the analysis of microplastic concentrations, the biogenic organic matter was removed by digestion (H_2O_2 10 % and NaClO 6-14 %). In the following, the sample was wet sieved (mesh size 63 µm) and a density separation with NaI (density: 1.5 g/cm³) was conducted. The sample was introduced into a 1 l glass column which was subsequently filled with NaI solution (Fig. 2). For homogenization, the column was shaken twelve times and left for sedimentation for 10 minutes. The sedimented material was slowly removed via a tap at the base of the column. The remaining supernatant was filtered through a paper filter (413, VWR International, 5-13 µm Retention) using vacuum filtration. For identification, the Nile red staining method in combination with fluorescence microscopy (Axioscope 5/7 KMAT, Zeiss) was applied. A subset of particles was investigated for polymer composition via µRaman spectroscopy (DXR2xi Raman Imaging Microscope, Thermo Fisher Scientific). Additionally, particles not identified by Raman spectroscopy were analyzed via Fourier-transform infrared (FTIR) spectroscopy by Thermo Fisher Scientific. Contamination was evaluated using blank samples and values were substracted from sample results. Parallel to the microplastic analysis, soil parameters like water content and organic substance were recorded.

Fig. 2: Density separation glas column when a) empty b) filled with NaI and sample material.

Study Area & Sampling

A total of 18 Elbe river sediment samples from different depths below ground level (bgl) were taken within the Hamburg port area, Germany, in cooperation with the Hamburg Port Authority (HPA) as part of the "Sullied Sediments" project funded by the European Union. The sites "Stover Strand" and "Wedel" are located upstream and downstream of the port of Hamburg, respectively, while "Köhlbrand" is located in its center. The samples were taken using a van-Veen sampler. At each sampling point 10-11 grabs were conducted resulting in sediment from 0-15 cm depth bgl. The first 0-2 cm from these grabs were removed using a stainless steel spoon and were immediately transferred into brown glasses. The residual sediment (2-15 cm depth bgl) was homogenized and three subsamples were again transferred into separate brown glasses at each location.

Additionally, sediment samples were taken in the nature reserve "Heuckenlock" located also within Hamburg and at the southern river branch traversing the city and the port. Six samples were taken using a marching spoon in different depths bgl (10 to 60 cm) and were immediately transferred into brown glasses.

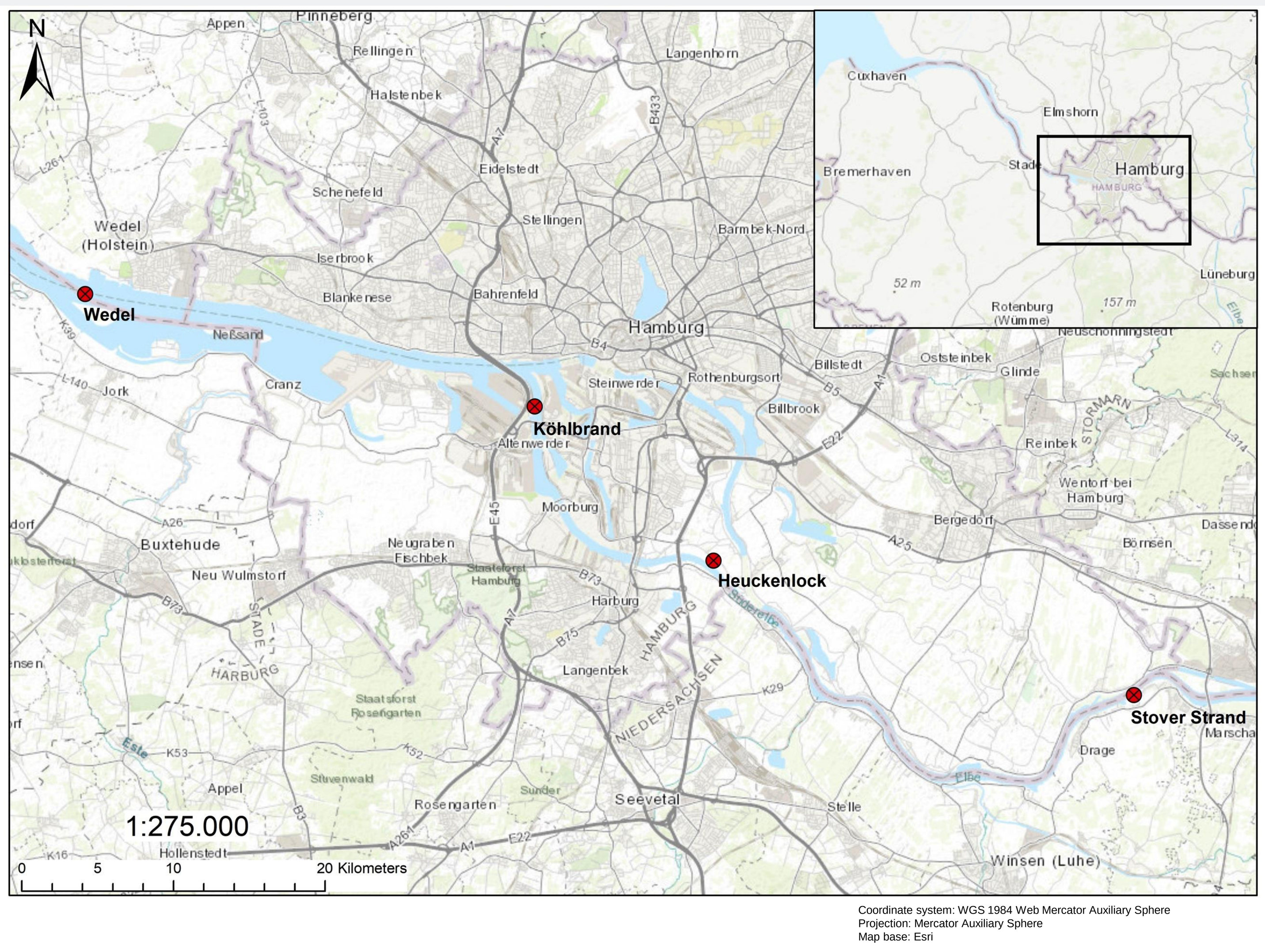

Fig. 1: Study area at the Elbe river within the wider area of the port of Hamburg. Red points mark the sampling sites.

Results & Discussion

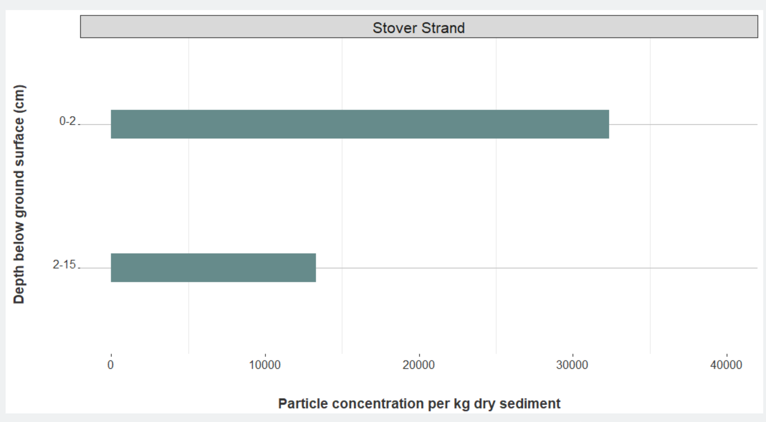

Fig. 3: Particle concentration at Stover Strand (average value for 2-15 cm depth).

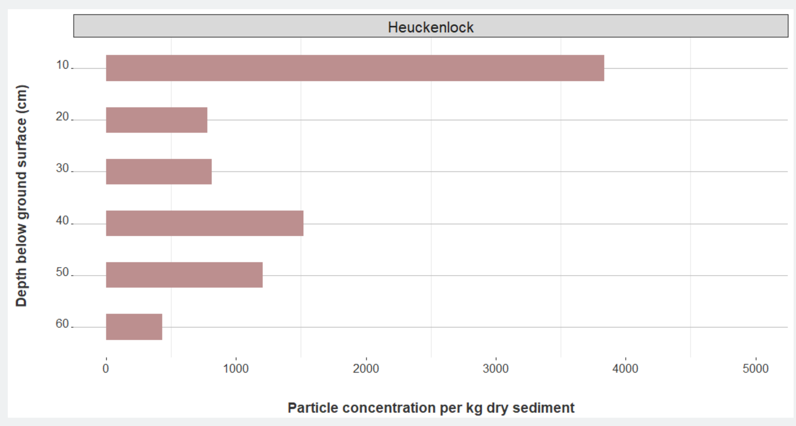

Fig. 4: Particle concentration at Heuckenlock. Change of the x-axis. particle concentration scale of the x-axis.

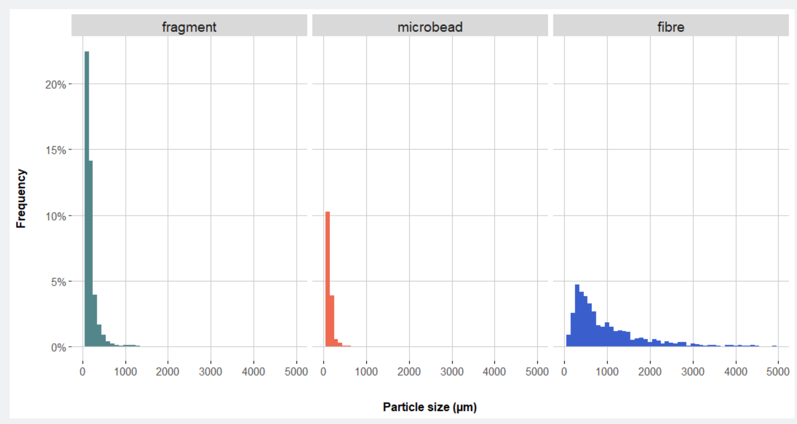

Fig. 5: Frequency distribution of particle sizes (µm) of fragments, microbeads and fibers.

Microplastic Abundance

A total number of 2,756 microplastic particles could be documented. The results were converted into particles per kilogram dry sediment (per kg DS). The highest concentration of microplastics was found at Stover Strand in 0-2 cm depth bgl (32,356 particles per kg DS) and in the three mixed samples in 2-15 cm depth bgl (mean value ± standard deviation: 13,318 ± 5,907 particles per kg DS) (Fig. 3 and 6). The nature reserve Heuckenlock showed the second highest microplastic concentration (430 - 3,835 particles per kg DS). At this location the highest concentration was found in 10 cm depth bgl (3,835 particles per kg DS) (see Fig. 4). Lower microplastic concentrations were found at the Köhlbrand site (1,114 - 2,776 per kg DS) and in Wedel (743 - 3,133 per kg DS) (Fig. 6). In this study, a significant correlation between the amount of organic matter and microplastic concentration was detected (r=0.72, p-value < 0.001). This result suggests, that an increase in organic matter leads to an increase in microplastic particle concentration in the sediment. Furthermore, fragments were the dominant microplastic shape at all sites except for Stover Strand where fibres were prevailing (Fig. 6). The frequency of particles increases with decreasing size, although this is more prominent for fragments than for fibres. This could derive from the fact, that particles within the sediment further degrade into smaller size fractions.

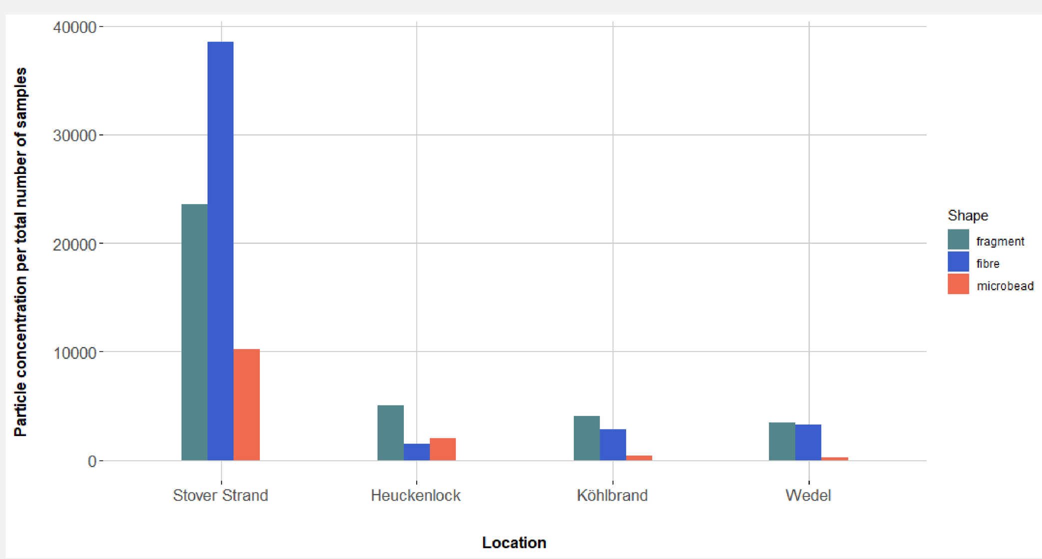

Fig. 6: Comparison of total particle concentration by shape and location (not calculated as kg per dry sediment)

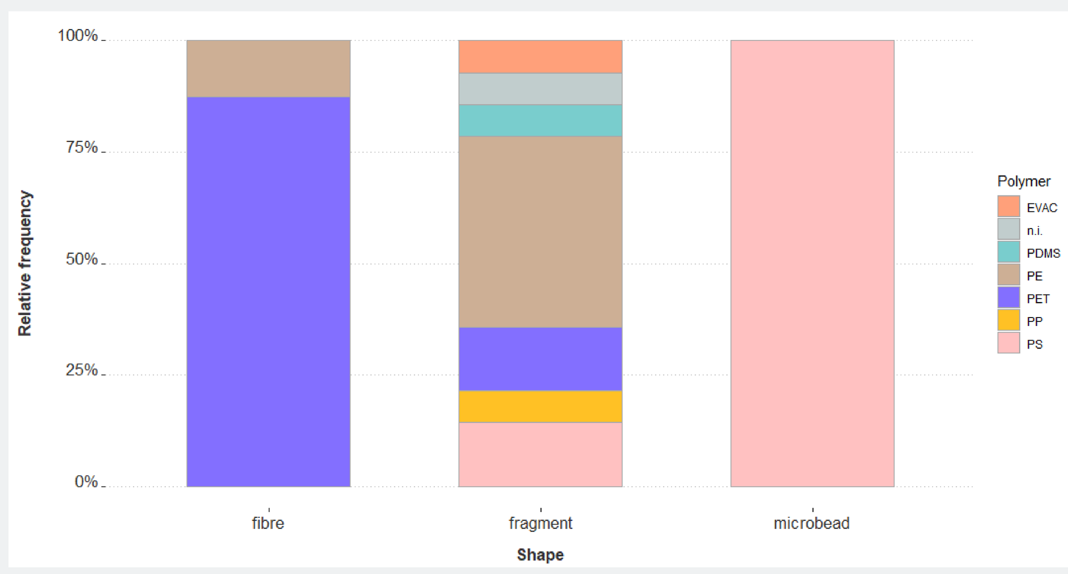

Fig. 7: Comparison of the relative frequency of polymer types by shape (n.i. = not identified)

Spectroscopic Results

For the analysis via µRaman spectroscopy, 34 particles were analyzed from which 33 (97 %) were identified as plastic. The polymer types PS (41 % of all particles), PET (26 %) and PE (21 %) were identified as dominant polymer types (Fig. 7). EVAC, PP and PDMS were found in minor amounts (3 % each). High percentages of low density plastics in the sediment may result from biofouling on particles. Furthermore, 22 particles (11 fragments and 11 microbeads) not identifiable via Raman spectroscopy, were analyzed by FTIR spectroscopy. For the fragments PVC (36 %) was the predominant polymer type followed by PE (18 %), PET (9 %), PS (9 %). The rest of the fragments were not identified as plastic (27 %). Additionally, all 11 microbeads were identified as PS (100 %).

Microbeads

High numbers of microbeads have been discovered at all investigated sites. The polymer type of microbeads typically used in personal care products is predominately PE, more rarely PP or other polymers (Heger et al. 2014). In this study, the microbeads analyzed via µRaman and FTIR spectroscopy were all identified as PS. Consequently, the microbeads in the sediments of the Hamburg Elbe River did not originate from personal hygiene products but rather have an industrial origin since other potential sources could be cleaning products, printer toners and industrial products such as abrasive media (Sundt et. al. 2014). As for PS microbeads in specific, they are also frequently used as ion-exchange resin beads (Scherer et. al. 2020).

Conclusion

- Microplastics could be identified in all samples
- A significant positive correlation between organic matter and particle concentration could be demonstrated
- River sections with low flow capacity could be possible hotspots for the accumulation of microplastic
- A wide occurrence of PS microbeads was documented
- For future studies, hydrological and pedological parameters (e.g. flow velocity and particle size analysis) should be recorded to examine further impacts on microplastic abundances in rivers

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