How biofouling changes PET properties under real conditions

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Motivation

Every year, 10.5 Mt of macroplastics enter the sea, where the items potentially fragment into microplastics and further into nanoplastics. The distribution and transport of these particles are highly dependent of the density and shape of the plastic items. Biofilm growth on plastics in rivers and in the ocean plays a key role for the understanding of the location of plastic particles in the water column, but less information is known on that as input parameters for transport modelling. Most studies focus on microbiology and do not address parameters such as biofilm thickness as a function of time or biofilm density, which are relevant input parameters for transport modelling.

Aim: → Filling knowledge gaps on how biofouling affects the properties of polyethylene terephthalate (PET) as sample material

Methodology

Only limited experiments are made so far within this topic, so own experiments were conducted.

Experimental Design
Different experiments were conducted for such investigations as follows:

- Single pure PET sheets (10 x 10 x 0.1 cm) were deployed in the river on a frame
- Sample collection after 2, 4, 6, 8 weeks
- Two locations:
  - 1) near the surface (0.5 m below surface)
  - 2) near the river bed (3 m depth)
- Two seasons:
  - 1) winter (Jan–March),
  - 2) summer (July–September)

Figure 1: Experimental setup with PET sheets on a frame placed in a river

Analysis methods
Several approaches exist to analyze the material properties as well as biofilm growth separately. Here, we combined the following methods:

- **Light microscopy** for the detection of signs of weathering such as discoloration, cracks, deposits or changes in surface texture, roughness and biofilm growth
- **Weight and volume measurements**
- **UV/Vis spectroscopy** and **Raman spectroscopy** to analyze the chemical composition of the material and the biofilm
- **Contact angle measurements** for the wettability of the material surface
- Measurement of the **environmental conditions** using a multi sensor module containing measurements of the water temperature, the conductivity and the salinity over time

Figure 2: Pure PET sheets before the experiments were conducted

Figure 3: PET sheets after 2 and 8 weeks near the surface

- Australian tubeworm has grown on the PET in summer while in winter just green algae have grown
- Much more biofouling near the surface than the river bed due to more sunlight exposure

Results

- Microscopy and biofilm growth showed significant differences between winter and summer
- The water temperature varied between 8 and 20 degrees during winter and summer.

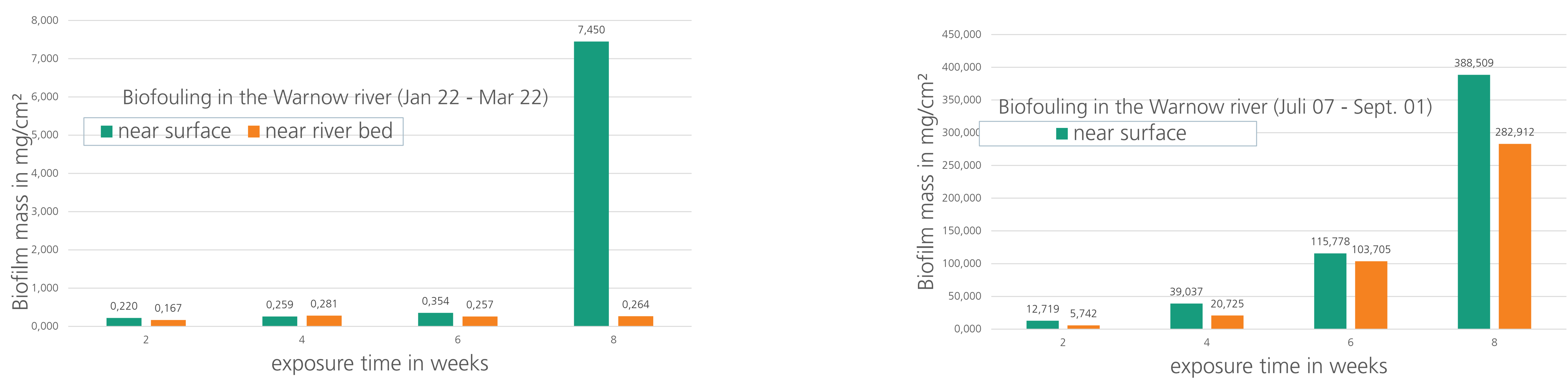

Figure 4: Biofilm mass per area of the PET sheet during the experiments in winter (left) and summer (right). Please note the different scale on the y-axis.

- Reflectivity measurements with UV/Vis spectroscopy showed no significant results. The biofilm on the PET leads to a little bit larger reflectivity than without biofilm.
- Contact angle measurements showed a decrease in angles during the weathering, which is accompanied by a steady improvement in water wettability.

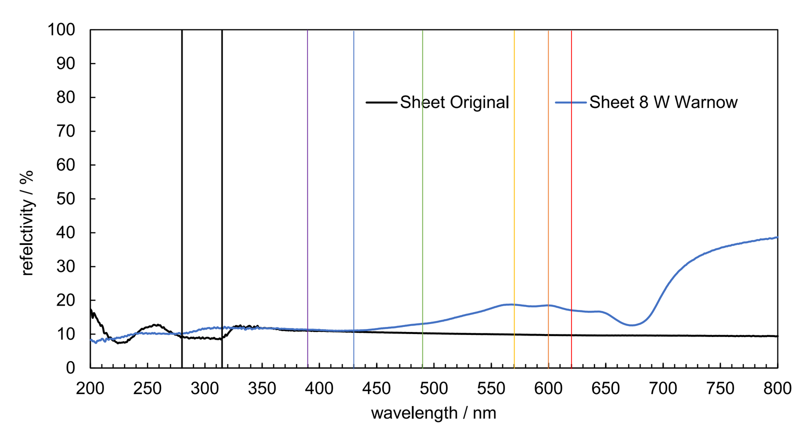

Figure 5: Reflectivity during winter derived using UV/Vis spectroscopy

Table 1: Comparison of biofilm thickness in µm during winter and summer (average density of 1.14 g/cm³)

Time (in aquatic environment)	Thickness biofilm in µm Winter	Thickness biofilm in µm Summer
2 weeks (near surface)	1.9	112
4 weeks (near surface)	2.3	342
6 weeks (near surface)	3.1	1016
8 weeks (near surface)	65	3408

Conclusions

Biofilm growth was investigated in dependence of the season of the year:

- Summer shows >50 times more biofouling than winter
- Exponentially growing biofilm in summer near the water surface, slower near the river bed
- Different species have a different influence on the weight of PET in water
  → Including kinetic of mass change in modelling is needed
  → seasonality has to be considered in modelling as well as water depth

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