A process-based model for riverine plastic fluxes: The effect of biofouling on buoyant plastic fate in the Elbe Estuary

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Plastic pollution of water bodies, rivers and oceans is a complex issue that is not yet fully understood. In the export dynamics of plastic litter from rivers to the sea, estuarine areas hold a key position. Plastic particle pollution, especially the smaller sizes, micro-plastics (MP), is difficult to observe and study in such dynamic environments. This is firstly due to the large heterogeneity of MP types: in size (10nm to 5mm), shape (sphere, fragments, foils, foam or fibers) and density (Polyethylene PE, Polypropylene PP, Polystyrene PS, polyvinyl chloride PVC, …) but as well, to the multiple processes affecting them: horizontal transport, vertical settling, turbulent mixing, biofouling, interactions with sediments or flocs, deposition, resuspension erosion and fragmentation. Numerical modelling, especially an Eulerian classes based model, inspired by an existing sediment transport model, offers a powerful framework to study plastic dispersal and fate in water flows.

We introduce here a process-based Eulerian transport model for MPs with biofouling. This model is applied to the Elbe Estuary (from the Geesthacht weir to the North Sea). The final vertical and horizontal position of a buoyant plastic type is compared with and without biofouling.

Horizontal transport of plastics is based on a modified TELEMAC2D-GAIA allowing particle transport and exchanges over three levels: advection and diffusion in suspension, at the surface and bedload transport above the bed. Initially, plastic mass will be inserted at different locations of the tidal Elbe. The final fate of the inputted plastic mass will be compared following two scenarios: the first one with only transport and the second one with transport and biofouling. The latter effect is implemented with an additional class of plastic, characterized by its biomass size and by a biofouling (and defouling) time. These characteristic size and time values are derived from empirical studies.

The hetero-aggregate class (plastic+biomass) will be settling and will get deposed on the bed of the model. Thus, a significant portion of the initially buoyant plastic will not be exported and remain trapped inside the estuary.

This qualitative comparison highlights the importance of including specific processes altering plastic particles when trying to produce reliable estimations of MPs fate in water environments.

Keywords
Estuaries; Marine Plastic Pollution; Modelling; Biofouling