Combined sediment-plastic transport model with population balance modelling approach

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Plastic pollution in the marine environment continues to be difficult to track and quantify. The inadequacy of the information on plastics' whereabouts has been a major challenge in dealing with marine plastic pollution. Complex processes of sediment-plastic interactions in the marine environment need to be accounted for in the modelling framework. It is evident that, compared to sediment quantity, plastic quantity in the marine environment remains to be marginal. As a result, plastic transport is heavily guided by sediment transport, especially in the benthic zone. Considering these facts, a comprehensive sediment-plastic transport model is essential in plastic transport studies.

In the current research under the Flemish project PLUXIN, the Belgian part of the North Sea and Scheldt estuary are studied. We make use of TELEMAC-GAIA modelling package which is a state-of-the-art hydrodynamic-sediment transport modelling tool. The existing knowledge of mixed-sediment transport of the Scheldt estuary is applied along with the microplastic transport model. The sediment transport model is implemented with a classic Eulerian modelling framework with one class each for cohesive and non-cohesive sediments. In the microplastic transport model, the size-depending processes - erosion and deposition - are implemented with the population balance modelling (PBM) approach using the Method of Moments (MoM). The PBM microplastic transport model uses the Number Density Function (NDF) which is reconstructed at every space-time instance. Subsequently, erosion-deposition flux can be computed over a full-size range of microplastics. In addition to the hydrodynamic factor, the deposition of microplastics is considered to be a function of plastic size and sediment floc size. In the same way, the erosion of microplastics from the bed layer is considered to be a function of sediment and plastic properties and the erosion behaviour of the sediment itself.

The novel approach of PBM microplastic transport model coupled to the Eulerian sediment transport model offers the modelling of a full-size range of microplastics with a limited increase of the computational expense compared to a discrete classes Eulerian modelling framework. The erosion and deposition processes of microplastics alone that are implemented with PBM show a physically meaningful evolution of the NDF. The availability of the particle size distribution enables modellers to compute complex size-dependent processes more precisely. The PBM approach has the potential to be applied to all relevant plastic transport processes and sediment transport processes such as the flocculation of cohesive sediments.

Keywords
Microplastics; Erosion; Deposition; Sediments; Population Balance Method