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Methodology to Study Plastic Transport Through Vegetated Channels

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Abstract

Observing the actual behaviour of floating plastic litter in the presence of vegetation in natural conditions should provide unique insights into the details of flow-biota-plastic interactions, needed for evaluating conceptual and numerical models. Therefore, a comprehensive approach to investigating the river plastic transport processes must include a description of various physical aspects. To address this, we propose a methodology encompassing in-situ measurements in a vegetated channel coupled with physical experiments in a controlled, full-scale laboratory channel. Both approaches will be used to prepare a numerical model and evaluate simulations of plastic transport.

1. STATE OF THE PROBLEM

There are significant research gaps on the subject of plastic transport processes in rivers (Al-Zawaidah et al. 2021), where riparian vegetation plays a major role (e.g. Cesarini and Scalici 2022). To date, only a limited number of studies with physical experiments have investigated this aspect, e.g. Valyrakis et al. (2024) explored how stem density affects the trapping of differently sized plastic pieces. The variability of plastic abundance along river channels is largely stochastic. However, several other factors can significantly influence plastic transport. The three most important deterministic factors at the catchment scale are flow regime, precipitation, and wind conditions (Roebroek et al. 2021). Then, narrowing the view on the phenomena of the river plastic transport to a river reach scale, aspects of vegetation and plastic properties will come into play on top of the channel hydrodynamics.

2. DESIGNED METHODOLOGY

To study plastic transport through a vegetated channels, we designed the following methodology, focusing on three work packages (WPs, Fig. 1).

The task WP1 is to gather hydrometric data about the water level and discharge through a hydrological year in a small, vegetated urban stream. Simultaneously, monitoring of plastic litter occurrence along the channel reach will be performed to determine influx, hotspots, and spatiotemporal changes in the plastic accumulation, concerning vegetation cover. The goal of this WP is not only to compile gathered data but also to provide necessary input for building and validating a numerical model of the flow and subsequently, particle transport.

The WP2 task is to conduct laboratory experiments in a channel with real vegetation, prepared according to preliminary surveys of the investigated stream, simulating it in a 1:1 scale. A series of experiments with various water depths and velocities will be conducted during two stages of plants' vegetative cycle and representative types of plastic litter will be released in uniform batches. The goal is to observe and analyze litter paths by utilising particle tracking velocimetry. Litter travel time and identified accumulation zones in relation to channel conditions will then be compared to field surveys.

The WP3 has two goals: to build a 2D mathematical model of floating plastic transport and to reproduce in numerical simulations (like Delft 3D) both laboratory experiments and investigated channel hydrodynamics. Detailed experiments describing the real behaviour of plastic litter and field data will primarily serve as calibration/validation material for the models. Such an approach will allow us to immediately determine whether numerical simulations can reliably predict the dynamics of plastic transport and accumulation hot spots.

The results of this project will provide a more objective view of the floating plastic transport phenomenon in rivers. By combining different approaches to the problem, a new, detailed and evaluated description will be produced, with the ability to simulate and predict floating plastic transport. Understanding the locations and mechanisms of plastic accumulation within vegetated rivers will contribute to the optimization of existing and the development of novel plastic removal techniques, and to the preparation of enhanced accumulation maps, particularly in areas where remote sensing data is limited.

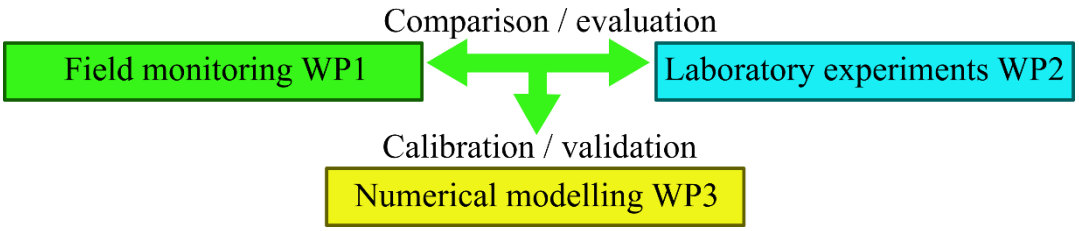

Fig. 1. Methodology scheme.

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