Still wood jams or already plastic-wood jams? Field assessment of plastic-polluted wood accumulations in rivers

Encore des embâcles en bois ou déjà des embâcles en bois-plastique? Évaluation sur le terrain des accumulations de bois polluées par le plastique dans les rivières

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RÉSUMÉ

La pollution croissante des rivières par les macroplastiques exige une meilleure compréhension des mécanismes à l'origine des zones d'accumulation dans les systèmes fluviaux. Ces connaissances sont essentielles pour évaluer les risques environnementaux et organiser efficacement le nettoyage des cours d'eau. Une découverte clé indique que les embâcles en bois, composés de morceaux de bois et de sédiments, retiennent efficacement les macroplastiques, contribuant ainsi à la formation de ces zones d'accumulation. Cependant, les processus à l'origine de ces structures, appelées embâcles bois-plastique, restent largement méconnus. Ce cadre conceptuel propose d'explorer plusieurs questions: (i) comment les crues influencent-elles la formation et la remobilisation des embâcles bois-plastique? (ii) quels sont leurs schémas de formation dans les rivières aux morphologies variées? (iii) comment ces embâcles se comportent-ils dans les systèmes fluviaux? (iv) quels risques posent-ils à la faune riveraine? En synthétisant les recherches existantes, cette approche vise à approfondir notre compréhension des interactions entre les embâcles en bois et les macroplastiques. Elle cherche à soutenir une gestion environnementale plus efficace et à limiter l'impact de la pollution plastique sur les écosystèmes fluviaux.

ABSTRACT

Understanding the mechanisms behind the formation of macroplastic accumulation hotspots within river systems is emerging as a critical research priority in plastic pollution studies. Recent findings, wood jams—a mix of wood pieces and mineral sediments—efficiently trap macroplastics within river channels, contributing to the development of localized plastic accumulation hotspots. However, the processes and patterns underlying the formation of these specific features, termed *plastic-wood jams*, remain largely unexplored. In this perspective, we synthesize current research on the bidirectional interactions between wood jams and fluvial processes within the context of macroplastic pollution. Building on this foundation, we propose a conceptual framework to address the following research questions: (i) what role do floods play in the formation and remobilization of plastic-wood jams? (ii) what are the spatial and temporal patterns of their formation in rivers with varying channel morphologies? (iii) how do plastic-wood jams behave dynamically across fluvial systems? and (iv) what risks do their presence pose to riverine biota? This framework aims to guide future research and foster a more comprehensive understanding of macroplastic dynamics in river systems, ultimately supporting more effective environmental management practices.

KEYWORDS

macroplastic, mountain river, river pollution, river restoration, wood jams

macroplastiques, rivière de montagne, pollution des rivières, restauration des rivières, embâcles en bois

1. INTRODUCTION

Plastic pollution has recently become a popular research focus across various disciplines due to its widespread negative impacts on ecosystems and human health (Stubbins et al., 2021). Macroplastics, commonly defined as particles larger than 5 mm (Hurley et al., 2020) have been entering rivers since the 1960s. Since then, it has been subjected to further downstream transport, deposition on river sediments and riparian vegetation, and repeated remobilization (Liro et al., 2020). Presence of macroplastic debris in the riverine environment creates numerous risks for aquatic and terrestrial animals (Blettler and Mitchell, 2021), increased potential for bridges and culverts clogging (Honingh et al., 2020) and decreased aesthetic value of riverine landscapes. The storage of macroplastic debris in rivers also creates a risk of its remobilization during future floods (Roebroek et al., 2021) and possibility of its presence resulting from repeated storage–remobilization cycle even after the disposal of new plastic waste to the river will be reduced or eliminated (Liro et al., 2020). During its way through the fluvial system macroplastic can undergo mechanical and biochemical fragmentation (Liro et al., 2023), resulting in the production of microplastic which is harmful for living organisms (Campanale et al., 2020; Leslie et al., 2022).

The above threats are particularly significant for mountain rivers, which typically support high biodiversity and provide numerous benefits to human populations, such as water resources (Viviroli et al., 2020; Mikuś et al., 2021). In populated areas, mountain rivers are increasingly polluted by macroplastics, which adversely affect the quality of resources and goods these ecosystems provide (Liro et al., 2022). One potential solution for mitigating this problem in the future is to gather data on macroplastic deposition hotspots in mountain rivers. Such information can guide efforts to remove macroplastics from rivers before they pose additional risks, such as ingestion by animals (Blettler and Mitchell, 2021), remobilization and downstream transport, or the production of secondary microplastics; Liro et al., 2023). Our pilot fieldwork conducted in 2022 in the Carpathian rivers revealed that wood jams—accumulations of woody debris consisting of various sizes of trees, shrubs, logs, branches, root wads, and small woody fragments—serve as hotspots for macroplastic deposition in mountain river channels (Liro et al., 2022). Specifically, the study showed that the amount of macroplastic debris stored on wood jams exceeded those found on vegetated islands, areas covered with herbaceous vegetation, and exposed river sediments by 19, 129, and 180 times, respectively (Liro et al., 2022). However, more comprehensive observations are needed to examine the spatial and temporal patterns of this process across different zones of fluvial systems. Furthermore, the mechanisms underlying the high macroplastic trapping efficiency of woody debris in river channels have yet to be quantitatively investigated. Although most plastic polymers are denser than water, macroplastic litter commonly exhibits high buoyancy due to its shape and absolute density, enabling transport by flowing water in suspension or flotation (e.g., Russell et al., 2023). Wood jams, as rough riverbed features with distinctive structures and locations within active channel zones, can efficiently trap plastic transported by rivers, both in suspension and flotation (Hoellein et al., 2024) (Fig. 1A).

2. TOWARDS A SYSTEMATIC EXPLORATION OF PLASTIC-WOOD JAM FORMATION

In this work, we outline four key research questions regarding the formation and functioning of plastic-wood jams, along with five hypotheses to be tested in future field studies:

Q1: What amounts (by weight and volume) of macroplastic are deposited in wood jams, and how are these amounts influenced by wood jam characteristics (e.g., size, dominant woody debris type, vegetation species contributing to woody debris)?

Q2: To what extent do river reach morphology and hydrodynamics control the amount of macroplastic trapped in different types of wood jams?

Q3: What are the predominant types of plastic found in wood jams, and do their proportions vary across different wood jam types and channel hydromorphological patterns?

Q4: What hydrological conditions favor the deposition of macroplastics in wood jams?

Based on recent observations, we propose the following hypotheses, which can guide future field investigations:

H1: Macroplastic is deposited on existing wood jams during low to moderate flood events that do not destroy or remobilize the wood jam.

H2: Wood jams located on elevated, erosion-resistant surfaces (e.g., the heads of vegetated islands) are more persistent macroplastic traps compared to those on lower, erosion-prone surfaces (e.g., gravel bars).

H3: Multi-thread river reaches trap more macroplastic (in terms of total mass and item count) than single-thread reaches.

H4: The amount of plastic stored in wood jams depends more on wood jam roughness, such as the presence of spreading crowns from trees or shrubs, than on the overall size of the wood jam.

We provide systematic framework outlining exiting gaps in plastic-wood jams interaction with fluvial

processes (Fig. 1 A,B) and the fate of this specific features in river sedimentary archive (Fig. 1C).

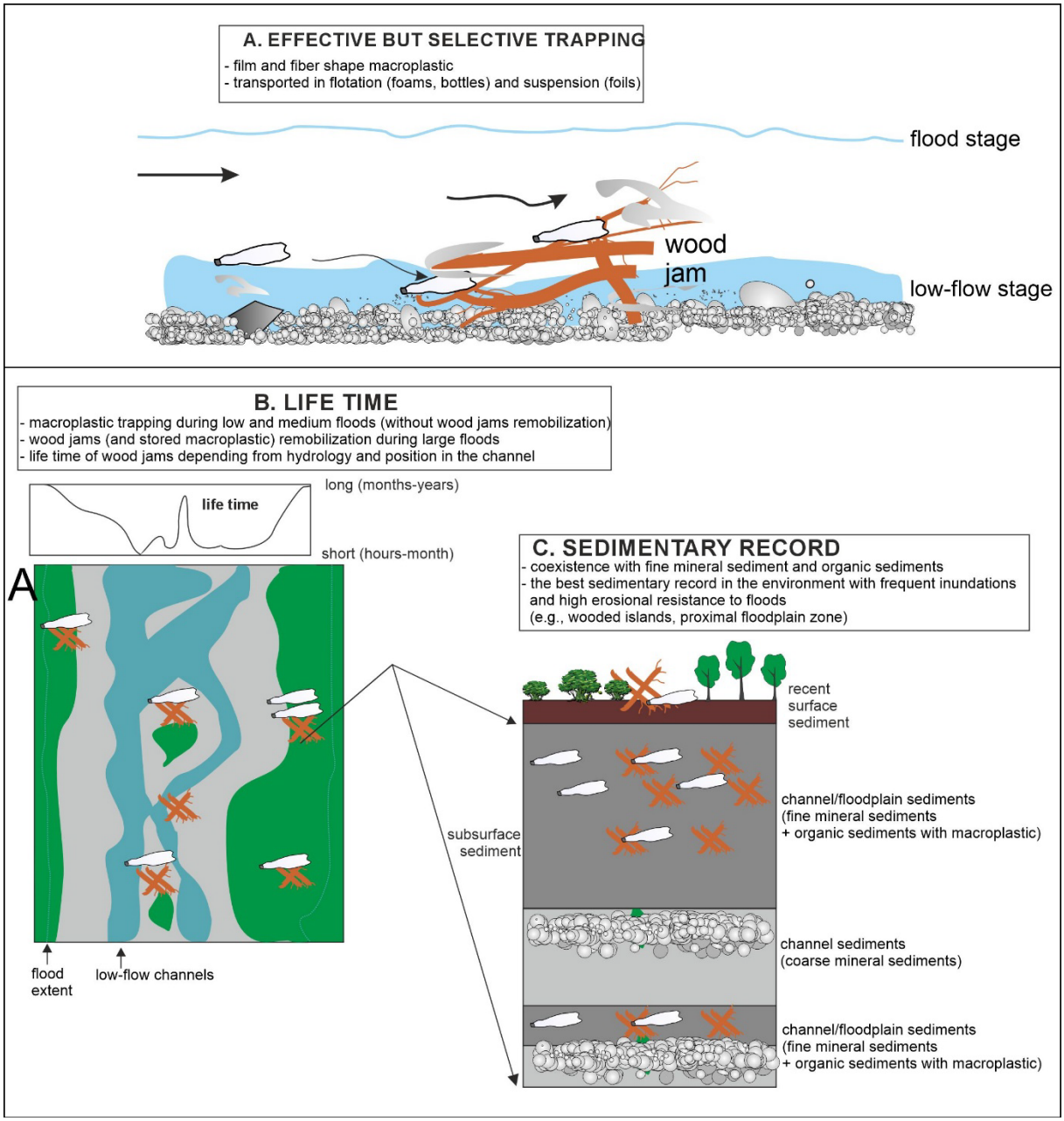

Fig. 1. Conceptual model of macroplastic deposition on wood accumulations in mountain river's active zone.

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