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Plastic Journey of Pathogens in a Mountain River: How Hydrological Conditions and Riverbed Morphology Influence Their Transport?

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Abstract

Riverine litter poses a significant environmental challenge, with plastics being particularly problematic due to their persistence, potential to degrade into microplastics, and ability to act as vectors for pathogens, facilitating the spread of harmful bacteria in river ecosystems. This study investigated the types of litter deposited in a mountain gravel-bed river, the pathogens colonising these materials, and the influence of riverbed morphology and flow conditions on macroplastic transport and deposition. This research employed field mapping, tracer experiments with PET bottles, and microbiological analysis, and utilised probabilistic methods to describe bottle transport and deposition. Field mapping revealed that plastics were the most frequently deposited materials in the riverbed (up to 86%), with plastic foils comprising about 50% of all plastic materials. Microbiological analysis showed that the litter biofilm was colonised by fecal indicator bacteria and pathogenic bacteria. Tracer experiments indicated that PET bottle deposition was strongly influenced by discharge, river depth, and channel morphology, varying across different river sections. As flow rates decreased, the probability of bottle passage diminished, while the cumulative hazard of retention increased.

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1. INTRODUCTION

Litter in rivers is a significant environmental challenge, impacting ecosystems, human health, and the economy (van Emmerik and Schwarz 2020). Plastics are especially concerning due to their durability and their tendency to break down into microplastics, which enter the water and are consumed by animals. Additionally, plastic waste can host pathogens, facilitating the spread of harmful bacteria within river ecosystems (Pow et al. 2025). This study investigated the types of litter deposited in a mountain gravel-bed river, the pathogens colonising these materials, and the influence of riverbed morphology and flow conditions on macroplastic transport and deposition. Specifically, we aim to link the deposition and transport behaviour of plastics with their potential role in the spread of harmful pathogens within river ecosystems.

2. STUDY SITE AND METHODS

The study was conducted in the braided channel of the Białka River, which sources in the High Tatras (Fig. 1). The designated river section is located in the town of Białka Tatrzańska and is 95 m long and has an average width of 9.4 m. The riverbed consists of granite cobbles, ranging from 16 to 32 cm in size. The study reach was divided into five sections based on channel geometry and morphological features. The channel contains woody debris, gravel bars, riffles, pools, and riparian vegetation.

The research consisted of field mapping of litter (including mesoplastic and macroplastic), microbiological analysis on selective media of swabs taken from selected waste items and two tracer experiments with PET bottles in natural river channel. The experiment was conducted under low ($Q = 0.63$ m^{3}s^{-1}) and average discharges ($Q = 1.24$ m^{3}s^{-1}) and aimed to determine the likelihood of bottle passage and trap in different sections of the river channel. Each experiment consisted of 10 trials with the point injection of 20 bottles. The transport and deposition of the bottles were analysed using probabilistic methods, including Kaplan–Meier survival analysis and cumulative hazard functions (Kaplan and Meier 1958). A pairwise Chi–Square test was used to compare cumulative trapping probabilities, identifying significant differences in trapping rates across sections. The survival probabilities of bottles under average and low flow conditions were compared using the Mantel–Cox test to evaluate the impact of flow conditions on bottle passage (Bland and Altman 2004).

Fig. 1. Study site location.

3. RESULTS

3.1 Litter mapping

The field mapping revealed that the plastics (e.g., PET, PVC, PUR, PE, PP) were the most frequently (up to 86%) deposited materials followed by metal, textiles, and glass. The study showed that plastic foils (PE, PP) accounted for approximately 50% of all plastic materials in the riverbed. These items were often found in riffles, frequently within the main current, while other types of litter tended to accumulate along the outer bank of river bend, often on woody debris.

3.2 Microbiological analyses

Microbiological analysis revealed that the litter was covered with a biofilm hosting numerous bacteria. The most prevalent species were fecal *streptococci* (*Enterococcus faecalis* and *E. faecium*). Additionally, the presence of *E. coli*, *Staphylococcus* spp., and *Klebsiella* spp. was confirmed. Bacteria within the biofilm have the potential to act as carriers of antibiotic resistance, as demonstrated by the growth of bacterial colonies on selective media designed for isolating *ESBL-positive bacteria* and *methicillin-resistant staphylococci*. The swabs collected from biofilms on materials such as foams, foils, rigid plastics (PET) and pebble (for comparison) revealed that *Enterococcus* and *E. coli* were found on all tested materials, *Staphylococcus* spp. was present on most surfaces, except foam; *Klebsiella* spp. appeared on harder surfaces (PET and pebble); *Staphylococcus aureus* was detected only on foil and foam.

3.3 Tracer experiment

Tracer experiments showed that the cumulative probability of bottle passage was decreasing with decreasing flow while the cumulative hazard increased significantly under low flow conditions, especially in downstream sections (Fig. 2). The cumulative trapping probabilities var-

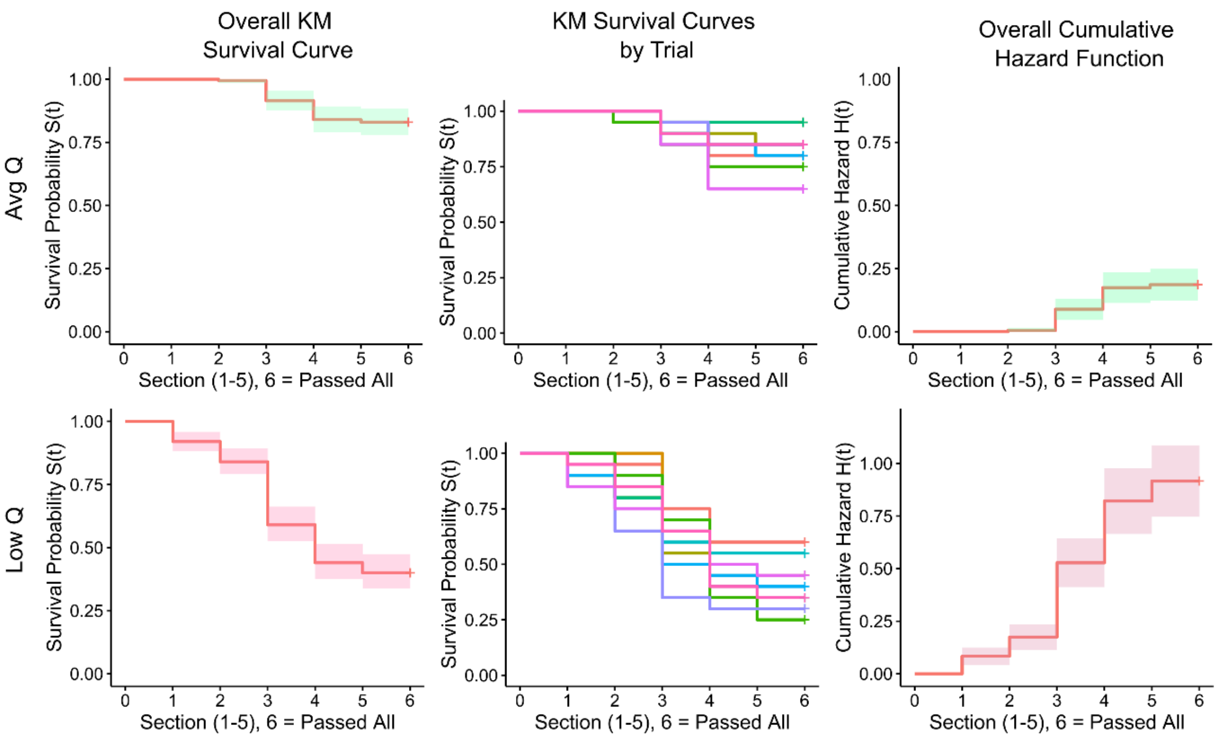

Fig. 2. Kaplan–Meier survival curves and cumulative hazard functions for average and low discharges. The x-axis is labeled with river sections (1–5), with 0 marking the start and 6 representing the final endpoint.

ied significantly across river sections, closely linked to the distribution and characteristics of channel morphological features. At average flow, most bottles accumulated in the middle and downstream sections of the river bend, while at low flow, deposition was more evenly spread across sections. In both scenarios, the highest number of bottles was deposited on either gravel bars or protruding cobbles, followed by woody debris. The Mantel–Cox test revealed significant difference in the survival probability curves obtained for average and low discharges, suggesting that the flow conditions have a substantial effect on the passage of bottles in the river.

4. CONCLUSIONS

The tracer experiments demonstrate that PET bottle deposition is significantly influenced by discharge and riverbed features, with the highest trapping occurring on gravel bars and woody debris. The microbiological findings highlight the potential health risks posed by biofilms on litter, which harbour bacteria, including antibiotic-resistant strains. Additionally, the study suggests that bacterial colonisation varies by material type, with harder surfaces supporting a more diverse microbiome. These results highlight the importance of addressing both the physical and microbiological impacts of plastic pollution in rivers to develop effective environmental management strategies.

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References

Bland, J.M., and D.G. Altman (2004), The logrank test, *BMJ* **328**, 7447, 1073, DOI: 10.1136/bmj.328.7447.1073.

Kaplan, E.L., and P. Meier (1958), Nonparametric estimation from incomplete observations, *J. Am. Stat. Assoc.* **53**, 282, 457–481, DOI: 10.1080/01621459.1958.10501452.

Pow, C.J., R. Fellows, H.L. White, L. Woodford, and R.S. Quilliam (2025), Fluvial flooding and plastic pollution – The delivery of potential human pathogenic bacteria into agricultural fields, *Environ. Poll.* **366**, 125518, DOI: 10.1016/j.envpol.2024.125518.

van Emmerik, T., and A. Schwarz (2020), Plastic debris in rivers, *WIREs Water* **7**, 1, e1398, DOI: 10.1002/wat2.1398.