Assessing plastics dynamics in a typical estuarine zone during full high tide cycles

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Estuaries, serving as essential transition zones between freshwater and marine environments, are considered as significant reservoirs for plastic pollution. Almost 80% of ocean-bound plastic originates from land-based sources, with estuaries being the main export route (Lima *et al.*, 2020). The remaining 20% of plastics come from overseas or derived from maritime transport activities (Morrit *et al.*, 2013, Scheinder *et al.* 2022). The Slack estuary, flowing into the English Channel at Ambleteuse (France), provides a remarkable case study.

Some plastics were collected in this estuary in order to define a set of 480 plastics, including microbeads (3-4 mm) and meso- and macroplastics (1 cm^2 to 25 cm^2), and composed of three types of polymer: PP, PE and PET. They were strategically placed along the estuarine banks in three types of quadrats with distinct substrates: gravels, sand and vegetation. The remobilization of these plastics was analyzed during six different campaigns from June 2022 to July 2023, corresponding to dry and wet seasons, with high tidal coefficients and different environmental parameters (e.g. wind, precipitation). Observations were made during a complete tidal cycle. Plastics deposited by the tides were also observed.

Results showed that over 90% of the manually deposited plastics were remobilized in water, with macroplastics exhibiting the least remobilization. Seasonal variations were significant (Kruskal-Wallis, p-value<0.05), with wet months showing a slightly higher average remobilization (115±3.57 plastics/3m^2) than dry months (113.08±4.92 plastics/3m^2). Notably, autumn exhibited the highest remobilization, whereas the lowest was observed during summer. Seasonal dynamics were influenced by hydrological parameters, with a significant negative correlation (Spearman, p-value < 0.05) observed during the dry period, highlighting the complex interaction between environmental conditions and the distribution of plastics. Consequently, we can hypothesize that, during the wet season, the hydrological parameters of fresh water velocity and flow influenced the remobilization of plastics in this estuary. Polymer analysis showed PP as the predominant remobilized macroplastics (94.44%), whereas PET exhibited the lowest remobilization rate (75.69%) during dry period.

Plastic mass analysis entering the water during complete tidal cycle exhibited an remobilization average of 2.8 ± 0.17 g of plastics during dry periods primarily macroplastic (Mmacro = 4.97 ± 0.46 g), followed by beads (Mbead = 2.1 g), and mesoplastics (Mmeso = 1.55± 0.04 g). In wet periods, 3.54 ± 0.44 g of plastics were remobilized from a 3m^2 area, dominated by macroplastics (5.06 ± 0.24 g) and mesoplastics (3.45±1.09 g). Unremobilized plastics were retained by gravels and vegetation, with vegetation exhibiting the highest retention. Vegetation accumulated 0.49 g/m^2 during the dry season (490 g over 100 m^2), and 0.2 g/m^2, during the wet season, (200 g/100 m^2). After a complete tidal cycle, 2.6 ± 2.07 plastics/m^2 was deposited especially fibers and ropes, highlighting the role of maritime activities in plastic pollution. Finally, all the results showed the necessity of understanding the remobilization and deposition of plastics along estuarine riverbanks in order to develop effective mitigation and remediation strategies.

Keywords
Plastics; Estuary; Remobilization; Deposition