ABSTRACT

Microplastics have become an increasingly important environmental concern because of their widespread occurrence, long-term environmental persistence, and potential ecological impacts within aquatic and urban environments (Andrady, 2011; Cole et al., 2011; Horton et al., 2017). Urban impervious surfaces such as asphalt pavements, sidewalks, gutters, and drainage channels frequently accumulate microplastic particles originating from tire wear, synthetic materials, atmospheric deposition, roadway abrasion, and fragmented urban debris (Kole et al., 2017; Liu et al., 2019). During rainfall events, these particles may become mobilized by shallow surface runoff and subsequently transported through connected urban stormwater systems toward receiving waters and potentially groundwater recharge environments (Werbowski et al., 2021). Although previous studies have documented the occurrence of microplastics within urban stormwater systems, comparatively limited experimental information is currently available regarding how pavement texture, runoff organization, hydraulic continuity, surface composition, and temporal runoff development influence observed transport behavior directly on urban pavement surfaces under controlled rainfall–runoff conditions.

This study experimentally investigated runoff-driven microplastic transport behavior on asphalt and concrete urban surfaces under simulated rainfall–runoff conditions using four experimental runoff configurations, including branch-based asphalt runoff (T1), interval-based temporal runoff sampling (T2), confined-flow asphalt runoff (T3), and concrete paving transport experiments (T4). Three particle-size classes of polyethylene microspheres were evaluated during the experiments, including 32–38 µm, 75–90 µm, and 250–300 µm particles. The experiments were designed to evaluate how pavement texture, runoff organization, hydraulic confinement, surface

continuity, and particle size collectively influenced downstream transport persistence under shallow urban runoff conditions.

Across all experimental configurations, the smallest particle-size class consistently produced the greatest transported particle counts, whereas the largest particle-size class contributed comparatively little to observed downstream transport recovery. The results suggested that smaller particles remained mobile more effectively under shallow runoff conditions and therefore exhibited greater transport persistence during runoff development. Under branch-based runoff conditions, transported particle recovery varied substantially among asphalt surface locations because runoff frequently separated into multiple localized pathways caused by pavement irregularities and surface-texture differences. In contrast, confined-flow runoff conditions substantially increased runoff continuity and downstream transport recovery by reducing apparent branching-flow losses and localized retention behavior.

Qualitative pavement-texture observations additionally suggested that smoother asphalt surfaces generally maintained greater hydraulic continuity and more efficient downstream transport persistence, whereas rougher asphalt surfaces appeared more sensitive to localized trapping and runoff branching behavior. These observations suggested that pavement texture may substantially influence observed transport continuity during shallow urban runoff development. The concrete paving experiments further suggested that particles initially mobilized from asphalt pavement surfaces may continue moving through connected urban drainage pathways such as sidewalks, gutters, and concrete channels under rainfall–runoff conditions.

The experimental observations additionally suggested the possibility of an environmental trade-off between microplastic generation and downstream transport continuity across different pavement surface conditions. Rougher pavement surfaces containing greater exposed aggregate texture may potentially increase tire–pavement friction and mechanical abrasion, thereby contributing to greater tire-wear particle generation under real roadway conditions (Kole et al., 2017). However, these same rougher surfaces may simultaneously reduce downstream transport continuity through localized retention and branching-flow losses. Conversely, smoother pavement surfaces may potentially reduce particle generation while allowing more efficient downstream transport continuity during rainfall–runoff events. Consequently, the overall environmental influence of different pavement surface conditions may depend on the combined interaction between particle generation, local retention, and downstream transport persistence.

Although the present study did not directly quantify groundwater contamination or long-term environmental loading, the experimental framework may provide a conceptual foundation for future investigations evaluating how pavement texture, asphalt–concrete surface composition, runoff organization, hydraulic continuity, and urban drainage connectivity collectively influence long-term microplastic migration within urban environments. The findings may additionally contribute to future environmentally informed pavement-design strategies, stormwater-management approaches, and groundwater-protection investigations involving runoff-driven microplastic transport processes.

Because the experiments were conducted under controlled laboratory-scale rainfall–runoff conditions, the findings should be interpreted as experimentally informed transport observations and conceptual transport interpretations rather than direct field-scale predictive relationships. Future studies incorporating direct pavement roughness measurements, repeated transport trials, particle-generation analysis, hydrologic transport modeling, infiltration measurements, and field-scale runoff monitoring may further improve understanding of runoff-driven microplastic transport processes within connected urban stormwater systems.