Evaluation of microplastic releases from roofing materials using large-scale precipitation simulations

Évaluation des rejets de microplastiques provenant de matériaux de toitures avec simulations de précipitations à grande échelle

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RÉSUMÉ

Les eaux de ruissellement urbaines constituent une source majeure de microplastiques dans les milieux aquatiques. Cependant, contrairement aux apports routiers, la contribution des matériaux de construction, y compris des toitures, reste peu documentée. Cette étude évalue les émissions de microplastiques provenant de deux systèmes de toitures végétalisées à l'aide d'un simulateur de pluie à grande échelle (9 m^2) reproduisant des épisodes de fortes précipitations sur des périodes courtes (1h) ou longues (6h). Les eaux de ruissellement ont été collectées afin d'analyser les microplastiques (25 à 300 µm) par spectroscopie micro-FTIR. Les résultats révèlent des concentrations très élevées (10^3 MP/L), la plupart des microplastiques étant constitués de caoutchoucs synthétiques (EPDM ou EPR), qui forment la membrane d'étanchéité de base des toitures. La majorité des particules mesurées étaient inférieures à 100 µm et les concentrations maximales coïncidaient avec les pics de ruissellement. De plus, le toit de type « réservoir », qui comportait le plus grand nombre de couches synthétiques, a libéré plus de particules que le système de rétention. Ces résultats fournissent la première preuve expérimentale contrôlée que les matériaux de toiture peuvent constituer une source importante de microplastiques dans les environnements urbains.

ABSTRACT

Urban runoff is a major source of microplastics in aquatic environments. However, in contrast to road runoff, the contribution of building materials, including roofing, remains poorly documented. This study assesses microplastic emissions from two green roof systems using a large-scale rain simulator (8x12 ft) that reproduces heavy rainfall events over short (1.5 hours) or long (6 hours) periods. Runoff water was collected to analyze microplastics (25 to 300 µm) using micro-FTIR spectroscopy. The results reveal very high concentrations (10^3 MP/L), with most microplastics composed of synthetic rubbers (EPDM or EPR), which form the waterproofing membrane of the roofs. Most of the particles measured were less than 100 µm, and the maximum concentrations peaked at the maximum runoff. In addition, the detention system roof, which had the highest number of synthetic layers, released more particles than the retention system. These results provide the first controlled experimental evidence that roofing materials can be a significant source of microplastics in urban environments.

KEYWORDS

Micro-FTIR spectroscopy, Microplastics, Rain Simulation, Roofing Material, Stormwater Runoff

1 INTRODUCTION

Urban stormwater is a significant pathway for microplastics entering aquatic environments (Kim and Lee, 2024). These persistent particles (1 µm-5 mm) raise concerns due to their ubiquity, potential degradation into nanoplastics, and release of toxic compounds (Rillig et al., 2021). In cities, microplastics originate from both point sources– such as wastewater effluents and sewer overflows (Kay et al., 2018; Nguyen et al., 2024)– and diffuse sources, including the fragmentation or abrasion of plastics from roads, buildings, and other artificial surfaces (Smyth et al., 2025; Sundan et al., 2025). Common polymers include polyethylene (PE), polypropylene (PP), and polystyrene (PS), although materials from construction, paints, and tires also contribute to urban signatures (Wei et al., 2023).

Recent studies on urban stormwater runoff have mainly focused on road surfaces, which often contain high concentrations of synthetic rubber microplastics from tire abrasion (Premarathna et al., 2025). In contrast, the contribution of building materials, particularly roofing systems, remains poorly documented. However, these surfaces are directly exposed to atmospheric deposition and precipitation, both of which can influence the mobilization and transport of plastic particles. Studying these processes under real precipitation conditions presents several methodological challenges. Indeed, field studies are often limited by variable weather conditions that hinder reproducibility and comparability across events.

This study addresses these limitations by investigating microplastic release from green roof systems under controlled rainfall using a large-scale simulator (8x12 ft). Two configurations– a detention and a retention system– were tested under short- and long-duration simulated storms. Runoff samples were analyzed for microplastics (25-300 µm) by micro-FTIR spectroscopy to assess the influence of roof design and rainfall dynamics on particle release.

2 MATERIAL AND METHODS

2.1 Roofing Materials

Two green roof systems were installed on the simulator: a detention and a retention system, both using an ethylene propylene diene monomer (EPDM rubber) base membrane. The detention system included six layers: sedum blanket, growing medium (engineered soil), mineral wool, plastic reservoir structure, detention mat, and roof barrier. The retention system comprised only a sedum blanket on a growing medium. All synthetic layers were analyzed by ATR-FTIR to identify polymer composition.

2.2 Rainfall Simulation and Runoff Sampling

The simulator is located in an indoor laboratory and consists of a 8x12 ft roof equipped with six nozzles supplied by a tap water reservoir. The roof has a 2% slope that drains into a gutter equipped with a flow meter at the outlet. Two simulated rainfall events were tested: Event A, lasting 60 minutes (flash flood conditions), and Event B, lasting 360 minutes. The rainfall patterns represented a typical 100-year storm for Canadian climates. Runoff was collected in 4-liter glass bottles before, during, and after peak flow. To reduce the number of analyses, some samples were combined before processing, resulting in three composite samples per simulated event (Figure 1).

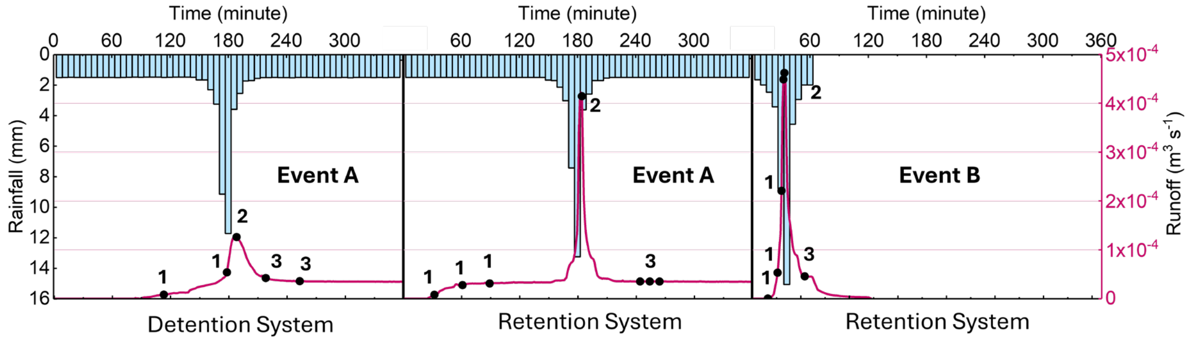

Figure 1 - Rainfall and runoff patterns tested with detention and retention systems. The numbers (1, 2, 3) represent the composite samples collected for analysis.

2.3 Microplastic Analysis

2.3.1 Sample preparation

Water samples were filtered through 25 µm stainless-steel filters, treated with 30% hydrogen peroxide for 24h, and subjected to sodium iodide density separation (1.6-1.7 g cm^{-3}). Residues were sieved at 300 µm and filtered onto 0.2 µm alumina membranes (Anodisc® filters). To minimize laboratory contamination, glassware and materials were calcinated at 500°C for 2h or rinsed three times with ultrapure water before use. Procedural blanks were prepared by filtering 4L of ultrapure water through 25 µm stainless steel filters and subjecting them to the same treatment steps as the samples.

2.3.2 Micro-FTIR analysis

Anodisc filters were analyzed by micro-FTIR spectroscopic imaging using a Nicolet iN10 MX microscope (Thermo Fisher Scientific). Prior to spectral acquisition, ten 9 mm^2 areas were randomly selected, corresponding to approximately 25% of the total filter area. Particle detection was performed using the *Particles Wizard* function of the *OMNIC™ Picta™* software, which enables automated targeting of particles based on image contrast. For each detected particle, an infrared spectrum was acquired in transmission mode using the cooled MCT detector in the 4000-1200 cm^{-1} spectral range. The spectra were compared to the *OMNIC™ Picta™* software library with a threshold match score at 65% based on Corami et al., 2020 procedure.

3 RESULTS

ATR-FTIR analysis was used to identify the composition of the roofing layers. The detention system was found to include polyethylene terephthalate (PET) in the fabric supporting both the sedum blanket and the detention mat. The other layers consisted of polypropylene (PP) for the reservoir structure and polyethylene (PE) for the root barrier. In the retention system, the sedum blanket fabric was made of PP.

High concentrations (10^3 MP L^{-1}) and were observed in the runoff samples (Figure 2). A wide diversity of polymer was observed, among all samples, EPDM was the most prevalent polymer, followed by EPR (ethylene propylene rubber) and alkyd resins. Polymers commonly used in building materials, such as PVC, PU, and PMMA, were also detected in significant amounts. Future analysis of the simulator components and tests on bare roofs will provide a better understanding of the origin of these materials. PP and PE were present in lower concentrations (10 to 20 MP L^{-1}). These microplastics could be released from the reservoir structure and the root barrier. Small amounts of PP were detected in the retention system, even though it uses PP fabric. This may be due to the low detectability of fine fibers, which have a diameter of under 10 µm, below the detection limit of the micro-FTIR instrument.

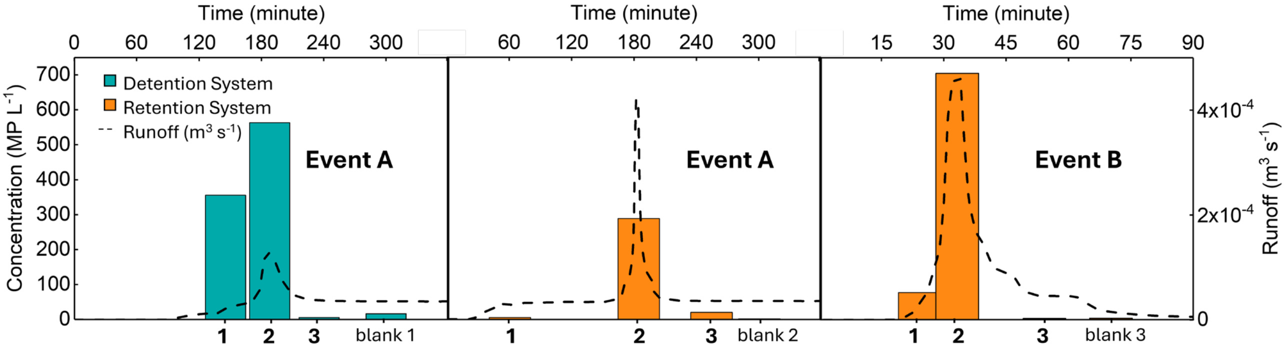

Figure 2 - Microplastic concentration vs runoff in detention and retention systems, long term (Event A) and short-term (Event B) rainfall events.

A clear correlation was observed between runoff and microplastic concentrations, with the highest concentrations occurring during periods of peak runoff. For the retention system, the intensity of the events appeared to influence the number of particles released by a factor of three. Under similar rainfall conditions, but with different roofing materials, the retention system released more microplastics, likely due to additional plastic layers present.

4 CONCLUSION AND PERSPECTIVE

This study is the first to show that roofs can release significant amounts of microplastics during heavy rainfall, particularly EPDM, a widely used waterproofing material that remains relatively unexplored in microplastic research. Future tests will evaluate other roofing materials under common rainfall conditions to better understand their contribution to microplastic emissions. Sampling existing roofs under real-world conditions will also help determine how aging affects the release of microplastics.

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