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## Pavement wear: A source of microplastics in stormwater runoff?

### L'usure des chaussées : Une source des microplastiques dans les eaux de ruissellement ?

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## RÉSUMÉ

La pollution aux microplastiques se propage dans l'environnement par plusieurs voies, y compris le ruissellement urbain. Dans cette voie, il existe plusieurs sources de microplastiques, dont une source confirmée et une proposée : l'usure des pneus et l'usure des chaussées. Une façon d'améliorer les caractéristiques physiques des chaussées consiste d'introduire des additifs plastiques. Les déchets, tels que la poudrette de caoutchouc et les microfibrilles, sont utilisés dans les mélanges d'asphalte et de béton à la place de matériaux vierges comme pratique de durabilité. La chaussée s'use et s'abrase avec le temps, ce qui génère des particules d'usure des pneus et de la route. La recherche s'est principalement concentrée sur l'usure des pneus ; cependant, on estime que les chaussées modifiées aux polymères et les marquages routiers génèrent également des microplastiques. Cette étude évalue des échantillons de ruissellement et des carottages prélevés sur trois types de chaussées (asphalte, béton et caoutchouc recyclé) près de Toronto, Canada. Des carottages et pavés de chaque matériau ont été prélevés aux trois parkings, plus des échantillons de ruissellement aux mêmes emplacements et à une chaussée. Des tests Hamburg Wheel-Track ont été effectués pour simuler l'abrasion due à la circulation. La dégradation de la chaussée contribue à la génération de microplastiques dans le ruissellement urbain et les caractéristiques des microplastiques variaient selon les types de chaussée.

## ABSTRACT

Microplastic pollution has been found to spread in the broader environment via multiple pathways including urban stormwater runoff. Within this pathway, a variety of microplastic sources exist including one confirmed and one proposed source of pollution: tire wear and pavement wear. One way to improve the physical characteristics of pavements is by introducing plastic additives. Microplastic waste, such as crumb rubber and microfibrilles, is used in asphalt and concrete mixes in place of virgin materials as a common pavement sustainability practice. Pavement wears and becomes abraded over time, which generates tire and road wear particles. Research has primarily focused on tire wear; however, polymer-modified pavement and road markings are estimated to generate microplastics as well. This study evaluates stormwater and pavement samples collected from three pavement types (asphalt, concrete, and recycled rubber) near Toronto, Canada. Pavement cores and pavers of each material type were collected from three parking lots as well as stormwater samples at these locations and at one roadway. Hamburg Wheel-Track tests were run to simulate abrasion due to traffic wheel passage. Pavement degradation was found to contribute to the generation of microplastics in stormwater and microplastic characteristics varied between pavement types.

## KEYWORDS

Microplastiques, dégradation de chaussée, l'identification des sources de pollution, ruissellement, qualité des eaux

Microplastics, pavement degradation, pollution source identification, stormwater runoff, water quality

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## INTRODUCTION

Urban stormwater runoff has been confirmed as both a pathway, a process by which contaminants enter and spread through the environment, and a source of microplastics into the downstream environment (Smyth et al, 2021). Sources of plastics in urban stormwater runoff can include plastic litter, artificial turf, paints, building materials, footwear, pre-production pellets and powders, industrial waste, spills from trash collection, landfill leachate and textile fibres from synthetic clothing (Coalition Clean Baltic, 2017). Additionally, tire wear is a source of microplastics, and the wear and tear of pavement is a related and suggested source of microplastics in stormwater (Rødland, 2019). Tire and road wear (TRWP) particles are frequently lumped together in microplastic studies as they become easily mixed in stormwater and are hard to distinguish as they may contain similar plastic polymers. Tire wear is generated from the mechanical abrasion of tire treads and shoulders with pavement surfaces. TRWP are altered in physical morphology and composition from interaction with pavement (heat, friction and incorporation of road material and vehicle-related emissions (Wagner et al, 2018). Additionally, both tires and pavements include a host of chemicals in addition to their primary materials added during the manufacturing process (e.g., fillers, antioxidants, softening/reinforcement agents, etc.) (NASEM, 2017; Wagner et al, 2018). Pavement wear occurs over time and is related to various factors including traffic conditions such as vehicle weight, traffic speed, snow plowing (where relevant), pavement properties, and environmental factors such as temperature and moisture (NIVA, 2020; Rødland, 2019).

Bitumen, itself, is comprised of polymers (Thom, 2013). Polymer additives have been used since the 1930/1940's in pavement materials. They are commonly added to asphalt and concrete pavements enhance desirable characteristics like durability, workability, curing time etc. (ACI, 2009; Mallick & El-Korchi, 2019). Three of the most common asphalt bitumen-added polymers are elastomers including styrene butadiene (SBR), styrene-butadiene-styrene (SBS) copolymers and ethylene-vinyl-acetate (EVA) (Magnusson et al, 2016; Thom, 2013). Similarly, polymer-modified concrete additives include elastomers like SBR among others and various thermoplastics (ACI, 2009). Pavement sustainability practices often involve reducing greenhouse gas emissions by using recycled materials to reduce virgin materials and associated non-renewable resources consumed in transportation, resource extraction, etc. (Muench & Van Dam, 2014). For example, crumb rubber from ground waste tires, and synthetic fibres such as polyester, acrylonitrile, lignin, asbestos and others derived from wastes are used in asphalt and concrete pavement mixtures to increase their surface lifespan while also reducing greenhouse gas emissions associated with construction (Hrušková, Hornáček, & Daučík, 2016; Mallick & El-Korchi, 2019).

Regardless of additives used to improve their performance, pavement wears over time. Two reports in Sweden and Norway estimated polymer emissions from polymer modified asphalt based on annual paving rates, estimated abrasion and material contents (Magnusson, 2016). In Sweden, 96.2% of tire and road wear particles were estimated to come from tires, while the remaining particles were estimated to come from polymer-modified bitumen and road markings (Magnusson, 2016). Less information is available on road wear particles from road markings and polymer-modified bitumen compared to tire wear particles (Rødland, 2019). Beyond estimations based on polymer-modified pavement material inputs, it is unknown whether released particulate matter from pavement degradation includes microplastics from those added to pavement to improve physical characteristics. Despite making up an estimated small proportion of TRWP, it is important to investigate road-wear derived particles to: best inform pavement sustainability practices, determine road wear-derived microplastic concentrations relevant to ecotoxicology and identify a possible point source of microplastics entering the environment via stormwater. The goals of this research are therefore to determine the effects of pavement degradation on microplastic generation in stormwater between different pavement types.

## 1 METHODS

### 1.1 Site Description

The study site, located at Kortright Center, is a conservation area operated by the Toronto and Region Conservation Authority (TRCA), in the city of Vaughan around 1 hour North of Toronto, Ontario, Canada. Both stormwater and pavement samples were collected from four locations within the conservation area, separated by at most 500 metres. These included a poured asphalt roadway and three parking lots: poured asphalt, concrete pavers, and recycled rubber pavers. All parking lots and the roadway are made of impermeable materials. They provide public parking and access to hiking trails, a visitor centre, event space and conservation staff in a generally lower traffic region compared to other city spaces in the

Greater Toronto Area. Stormwater samples in the range of 0.5 – 2 L were collected depending on the particular rain events from each catchment outlet over the Summer and Fall seasons in 2018 and 2019. Pavement specimens were collected in June 2021 from the parking lots including asphalt cores, concrete pavers and rubber pavers. No pavement specimens were collected from the roadway.

## 1.2 Pavement Testing and Sample processing

Pavement specimens from the asphalt lot, concrete lot and rubber lot were shipped to specialized test facilities in Saskatoon, Saskatchewan to undergo degradation testing with a Hamburg Wheel apparatus. This device consists of loaded steel wheels which roll on pavement specimens to test their rutting and moisture susceptibility at a constant temperature and set number of wheel passes. Testing followed the AASHTO T324 standard (AASHTO, 2011). Pavement specimens were cut to fit the apparatus molds. Testing was run while specimens were saturated with tap water. After the 40,000 wheel cycles were completed for each specimen, the apparatus bath was drained and any suspended particles in it were filtered onto pieces of copper mesh (80- $\mu\text{m}$  pore size). Between tests, the apparatus bath was thoroughly pressure-washed to avoid cross contamination. Filtered particulate matter on copper mesh pieces were shipped to the University of Toronto for further processing and microplastic analysis.

After collection, stormwater samples were dosed with isopropyl alcohol to reduce microbial growth. They were size-fractionated, density separated and for some sample types, organically digested. Stormwater samples were split into four size fractions of 106–300  $\mu\text{m}$ , 300–500  $\mu\text{m}$ , 500  $\mu\text{m}$ –1 mm, and > 1 mm. Rubber pavement-derived stormwater was density separated with 1.4 g/cm<sup>3</sup> calcium chloride solution. They did not receive organic digestion treatment as they contained visibly less organic matter than other stormwater samples. Stormwater derived from the other three locations (asphalt lot, asphalt roadway and concrete lot) were first digested using Fenton's reagent adapted for stormwater samples and then density separated with 1.8 g/cm<sup>3</sup> zinc chloride solution. Similarly, pavement degradation derived particulate samples from Saskatoon were size fractionated to 106 - 500  $\mu\text{m}$  and > 500  $\mu\text{m}$ , then digested and density separated in the same way as the later three stormwater sample types.

## 1.3 Sample analysis

Processed stormwater and degradation particulate samples were visually quantified for microparticles by a team of students using stereo microscopes. Microparticles, visually identified microplastics, were categorized based on typical microplastic morphologies and colour within their respective size fractions. Identified microparticles were plated on glass slides with glucose solution. A 10% subsample of microparticles by shape and colour categories were analyzed for polymer identification using a Bruker Optics  $\mu\text{FTIR}$  with a Hyperion 3000 microscope connected to a Tensor II spectrometer. Analysis was done in attenuated total reflectance (ATR) mode and various plastic and natural spectral libraries were used. Several quality assurance and quality control measures were taken such as wearing 100% cotton lab coats and taking various blanks to reduce microplastic contamination throughout the sampling campaigns and lab work.

## 2 RESULTS

Different totals of rainfall events were sampled per pavement location due to two distinct sampling techniques as well as site-specific differences in rainfall collection. These included 18 total runoff events in the rubber lot collected with autosamplers. It also included 11 runoff events in the asphalt lot and concrete lot, and 7 events at the asphalt road all collected by grab sampling. For stormwater samples, the asphalt parking lot was found to have the largest quantities of microparticles present with an average of  $1,664 \pm 1,423$  microparticles (Figure 1). In comparison, the asphalt road, concrete lot and recycled rubber parking lots had average counts of  $778 \pm 374$  microparticles,  $581 \pm 429$  microparticles and  $287 \pm 71$  microparticles, respectively. Field blanks corresponding to the asphalt road, asphalt and concrete lots contained an average count of 14 microparticles versus an average of 70 microparticles for the rubber lot. The most common microparticle morphologies were fibres and suspected rubber particles in stormwater samples versus mainly fibres in blanks. Following  $\mu\text{FTIR}$  analysis, analyzed microparticles were categorized into seven groups including plastic, semi-synthetic, anthropogenic cellulose, other anthropogenic, paint, natural and unknown. Microparticle material types varied proportionally between stormwater locations.

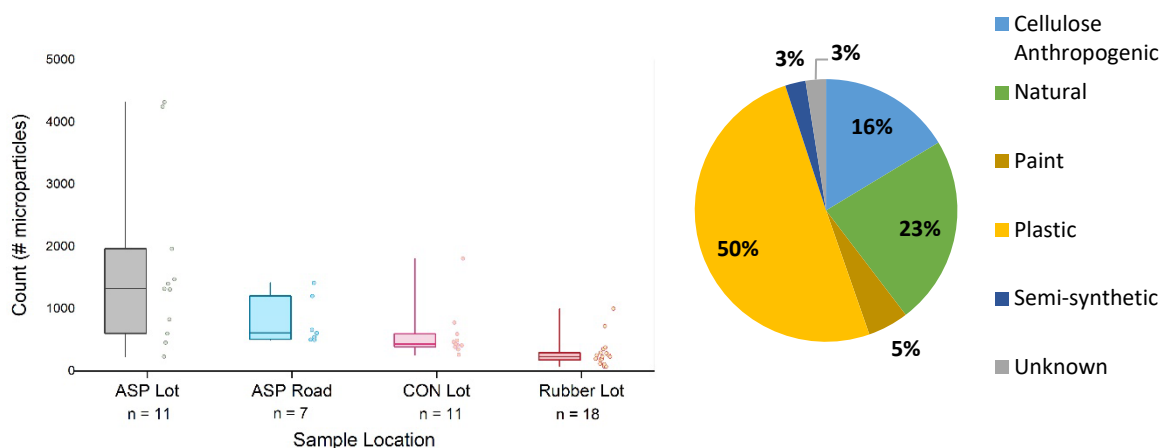


Figure 1. Left: Microparticle counts by pavement location where ASP: asphalt & CON: concrete; Right: Preliminary FTIR results for Asphalt lot

Figure 1 shows the distribution of microparticle materials in the asphalt lot where plastic, semi-synthetic polymers namely rayon, and paint (generally plastic including acrylic and alkyds) account for 58% of the analyzed microparticles. The most common plastic polymer found in stormwater was polyester. Beyond this, 16% of microparticles were found to be anthropogenic cellulose products such as cotton, and the remaining 26% were natural compounds, or they were unable able to be analyzed due to poor spectra, exceeding analysis time limits per microparticle or several lost microparticles during testing or between quantification and FTIR analysis. Pavement specimen rut depth measured during abrasion testing was highest for asphalt, moderate for concrete and lowest for rubber. Abraded pavement followed an opposite trend between pavement types for microparticle counts than stormwater samples. We found that pavement degradation contributes to microplastic generation in stormwater and that microparticle characterization varies between pavement types.

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