DOES PAVEMENT WEAR GENERATE MICROPLASTICS IN STORMWATER RUNOFF?

K. Smyth (Civil and Mineral Engineering, University of Toronto), S. Tan (Chemical Engineering and Applied Chemistry, University of Toronto) T. Van Seters (Toronto Region Conservation Authority, J. Drake (Civil and Environmental Engineering, Carleton University) & E. Passeport (Civil and Mineral Engineering & Chemical Engineering and Applied Chemistry, University of Toronto)

ABSTRACT

CONTEXT

Urban stormwater runoff as a pathway allows contaminants to enter and to be dispersed through the environment and it also acts as a source to downstream areas for microplastics (Smyth et al, 2021). There are many sources of plastics within urban stormwater such as plastic litter, paints, building materials, industrial waste, spills from trash collection, and textile fibres from synthetic clothing (Coalition Clean Baltic, 2017). Another two intertwined microplastic sources in stormwater are tire wear and pavement wear (Rødland, 2019). These sources are often referred to in microplastics research together as tire and road wear particles (TWRP) as they are easily mixed and hard to distinguish based on similar polymer types present. Over time, pavement wear takes place due to a variety of factors including traffic conditions like vehicle weight, traffic speed, etc., pavement properties, and environmental conditions (NIVA, 2020; Rødland, 2019). In comparison, tire wear is created through the mechanical abrasion between tire treads and pavement surfaces. TRWP morphology and composition become altered during their interaction with pavement by factors like heat, friction, and the incorporation of vehicle emissions and road materials (Wagner et al, 2018). Beyond physical alterations, both tires and pavement contain many chemicals added during manufacturing (e.g. fillers, antioxidants, etc.) which may leach out after wear (NASEM, 2017; Wagner et al, 2018).

Since the 1930/1940's, polymer additives have been used in pavement materials. Bitumen, itself, is comprised of polymers (Thom, 2013). In asphalt and concrete pavements, synthetic polymer additives improve characteristics like curing time, durability, etc. (ACI, 2009; Mallick & El-Korchi, 2019). Elastomers including styrene butadiene (SBR), styrene-butadiene-styrene (SBS) copolymers, and ethylene-vinyl-acetate (EVA) are three of the most common asphalt bitumen-added polymers (Magnusson et al, 2016; Thom, 2013). Similarly, elastomers such as SBR and a variety of thermoplastics are used in polymer-modified concrete (ACI, 2009). One pavement sustainability practice involves using recycled matter in place of virgin materials to reduce greenhouse gas emissions associated with resource extraction and transportation (Muench & Van Dam, 2014). Example recycled material includes ground waste tires called crumb rubber and waste synthetic fibres such as polyester, acrylonitrile, lignin, asbestos, etc. used to increase pavement surface lifespan and reduce construction-associated greenhouse gas emissions (Hrušková, Hornáček, & Daučík, 2016; Mallick & El-Korchi, 2019).

Pavement wears over time despite using performance enhancing additives. In Sweden and Norway based on annual paving rates, estimated abrasion, and material contents, polymer emissions were estimated for polymer-modified asphalt (Magnusson, 2016). Sweden estimated 96.2% of their TWRP were tire-derived with polymer-modified bitumen and road markings making up the remaining particles (Magnusson, 2016). To date, most research has focused on tire-derived particles with less information on road wear-derived particles (Rødland, 2019). Other than estimates based on material inputs, it unknown if pavement degradation generates microplastics from those used as additives during manufacturing to improve pavement characteristics.

PURPOSE

The purpose of this study is therefore to identify the effects of pavement degradation on microplastics generation in stormwater between three pavement types.

METHODS

The research site was located at a conservation area, Kortright Center, in the city of Vaughan approximately one hour North of Toronto, Ontario, Canada operated by the Toronto and Region Conservation Authority (TRCA). At four locations within the site, separated by a maximum of 500 metres, both stormwater and pavement samples were collected. These locations included a poured asphalt roadway and three parking lots: poured asphalt, concrete pavers, and recycled rubber pavers. Each pavement type consisted of impermeable materials. These locations are generally lower traffic areas compared to other parts of the Greater Toronto Area. They provide parking and public access to hiking trails, a visitor centre event space, and conservation staff. Samples were collected over the Summer and Fall seasons in 2018 and 2019. Their volumes varied from 0.5 – 2 L depending on the particular rain events at each catchment outlet. Pavement specimens were collected from the three parking lots including asphalt cores, concrete pavers, and rubber pavers in June 2021.

These pavement specimens were shipped to Saskatoon, Saskatchewan where they underwent specialized testing with a Hamburg Wheel instrument. Specimens were subjected to loaded steel wheels which rolled on their surface to test rutting and moisture susceptibility for a predetermined amount of wheel passes at a fixed temperature. The AASHTO T324 standard (AASHTO, 2011) was used. During tests, pavement specimens were saturated with tap water. Following each test completion of 40,000 wheel cycles, the apparatus bath was emptied and strained with pieces of copper mesh (80-µm pore size) to capture any suspended particles in the effluent. Copper mesh containing filtered particulate matter was shipped and further analyzed for microplastics at the University of Toronto.

After collecting stormwater samples, they were size fractioned, density separated and for some samples were also organic digested. Sizes categories included 106–300 µm, 300–500 µm, 500 µm–1 mm, and > 1 mm. For rubber pavement-derived stormwater, a 1.4 g/cm^3 calcium chloride solution was used for density separations. No organic digestion was applied to these samples as less organic matter was visible than other stormwater samples. Stormwater from the other three locations (asphalt lot, asphalt roadway, and concrete lot) first underwent a digestion step with Fenton's reagent, and then a density separation with 1.8 g/cm^3 zinc chloride solution. Lastly, two size fractions of 106 – 500 µm and > 500 µm were used for the pavement degradation-derived particulate samples from Saskatoon which were similarly digested, and density separated as the later three stormwater types.

All stormwater and degradation particulate samples were quantified visually for microparticles by a team of students with dissection microscopes. Typical microplastic morphologies, colour, and size fractions were used to categorize the microparticles, i.e. visually identified microplastics. Glucose solution was used to plate 10% of these microparticles on glass slides in preparation for polymer identification using a Bruker Optics µFTIR with a Hyperion 3000 microscope connected to a Tensor II spectrometer. Analysis was done in attenuated total reflectance (ATR) mode using various synthetic polymer and natural material spectral libraries. Key quality assurance and quality control measures included various controls in the field and the lab as well as wearing 100% cotton lab coats.

FINDINGS

Two separate sampling techniques in addition to site-specific variability in rainfall collection led to differences in the number of rainfall events sampled at each pavement location.

There were 18 runoff events collected by autosampler in the rubber lot. Additionally grab sampling was used to collect 11 runoff events in the asphalt lot and concrete lot each, as well as 7 events at the asphalt road site. Of the stormwater samples, the largest quantity of 1,664 ± 1,423 microparticles was found in the asphalt parking lot. The asphalt road, concrete lot and recycled rubber parking lots comparatively had average quantities of 778 ± 374 microparticles, 581 ± 429 microparticles and 287 ± 71 microparticles, respectively. Field controls had an average of 14 microparticles for the asphalt road, asphalt, and concrete lots and an average of 70 microparticles for the rubber lot. Fibres and suspected rubber particles were the most prominent microparticle morphologies in the stormwater samples as opposed to primarily fibres in blanks. The μFTIR analyzed microparticles were grouped into seven categories: plastic, semi-synthetic, anthropogenic cellulose, other anthropogenic, paint, natural and unknown. Between stormwater locations, microparticle material types were proportionally varied.

At the asphalt lot, 58% of microparticle material types included plastic, semi-synthetic polymers namely rayon, and paint (generally plastic including acrylic and alkyds). Polyester was the most frequently observed plastic. A further 16% of microparticles were anthropogenic cellulosic like cotton. Natural compounds and unidentifiable results due to poor spectra, analysis time exceedance or lost particles made up the remaining 26% of microparticles analyzed for this site. During pavement abrasion testing, specimen rut depth was measured and found to be largest for asphalt, moderate for concrete, and smallest for rubber. An opposing trend in microparticle counts between pavement types was found for abraded pavement compared to stormwater samples. Pavement degradation was found to contribute to stormwater-based microplastic generation and microparticle characterization varied with pavement type.

SIGNIFICANCE

Though they make up an estimated small proportion of the total tire and road wear particles, investigating road-wear derived particles is important to: identify a possible point source of microplastics within the stormwater environmental pathway, best inform sustainability practices regarding pavement and determine ecotoxicology-relevant concentrations of road wear-derived microplastics.

KEYWORDS

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

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