Modeling of Microplastic Emission, Transport, and Retention in Urban Stormwater Ponds

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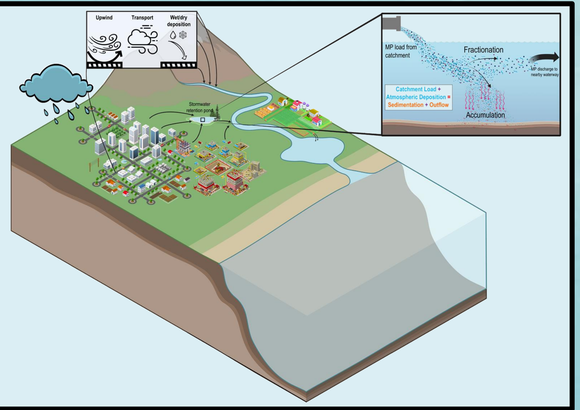
Background

Microplastic (MP) pollution is a growing concern in both aquatic and terrestrial ecosystems. Yet, there is a notable lack of comprehensive research on the effectiveness of urban stormwater management ponds (SWMPs) in this context. This study aims to quantify MPs in urban stormwater catchments and evaluate the efficacy of SWMPs in mitigating urban MP pollution.



Field Sampling and MP Analysis

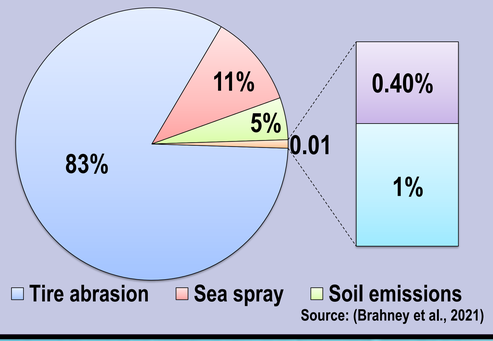
Sediment and water samples were collected from five SWMPs of different land use types (industrial, commercial, residential) in the City of Kitchener. Samples were extracted in the laboratory and subsequently analyzed using Laser Direct Infrared (LDIR) Imaging. The catchments of five SWMPs were examined to identify land use differences and their potential impact on MP emissions.

	Shirley [Industrial]	Wabanaki [Industrial]	Activa [Residential]	Zeller [Residential]	Bingemans [Commercial]
Area (ha)	59.67	25.43	33.82	47.79	18.14
Pond Surface Area (m^2)	626	336.9	350.4	416.1	858.8
Total Population - As of 2016 Census (#)	87.75	40.5	2838.5	2061	15.6
Road Length (m)	2813	612	3765	5023	1250
AADT (24 Hours)	1163.09	4190.72	1098.42	2511.73	9522.86
Road (%)	4.54	2.16	10.41	10.44	13.30
Walkway (%)	0.49	0.83	3.73	2.74	0.93
Mixed Paved (%)	28.79	40.74	18.33	14.88	25.86
Residential (%)	0.00	0.00	18.21	16.20	0.00
Commercial (%)	2.08	0.00	0.00	0.00	2.78
Industrial (%)	9.70	20.76	0.00	0.00	17.91
Imperviousness (%)	45.60	64.49	52.21	44.51	60.78
Catchment Perimeter (m)	3392.47	2166.61	3487	3132.81	3247.45
Catchment Slope (%)	7.28	5.39	3.88	7.18	6.95
Total Stormwater Pipeline (m)	3150	3904	3830	868	1723
Total Plastic Pipeline (m)	1333	0	2064	543	94

Objectives

1. Quantification of the extent of MP pollution flux originating from urban stormwater catchments and entering SWMPs.
2. Investigation of the key factors influencing MP pollution in urban environments.
3. Evaluation of the effectiveness of SWMPs in controlling MP pollution.

MP Load through Atmospheric Deposition



Source: (Brahney et al., 2021)

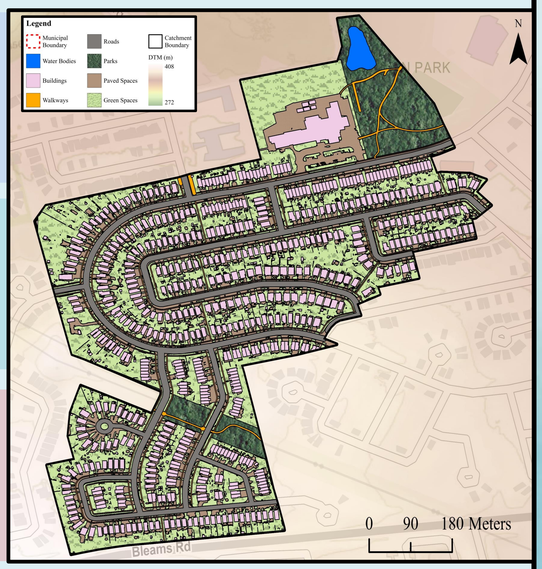
- Tire abrasion is the major source of atmospheric microplastic.
  - ↳ One of the potential sources of MP pollution.
- Our findings indicate that surface deposition does not contribute significantly to MP loads in SWMPs.

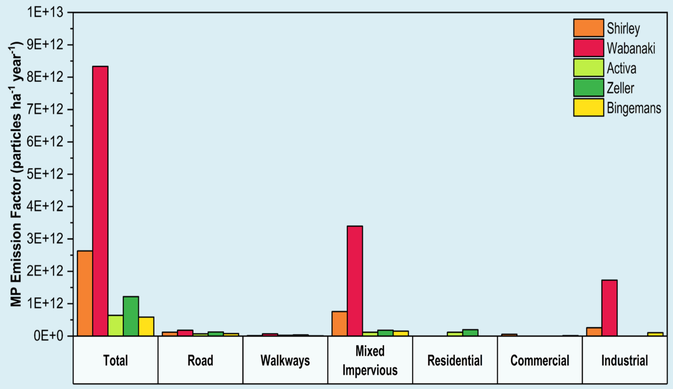
Estimation of Microplastic Emissions from Urban Catchments

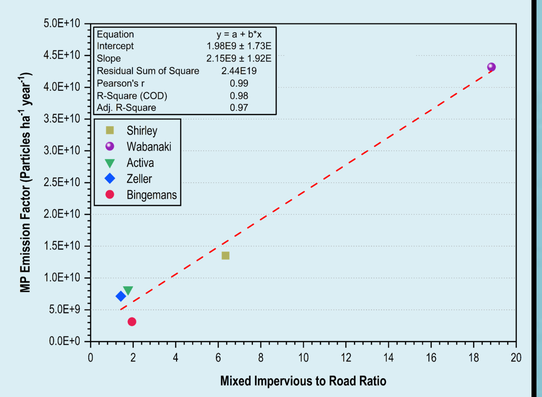
The hydrologic behavior of five stormwater catchments of different land use types (residential, industrial, commercial) was successfully simulated using the PCSWMM model, which was calibrated with water stage monitoring.

The land use types of catchments were differentiated through an analysis of aerial imagery and feature extraction, utilizing a suitable machine learning method for image processing.

MP emission factors for catchments were calculated through mass balance, incorporating simulated hydrology data and MP concentrations in SWMPs.

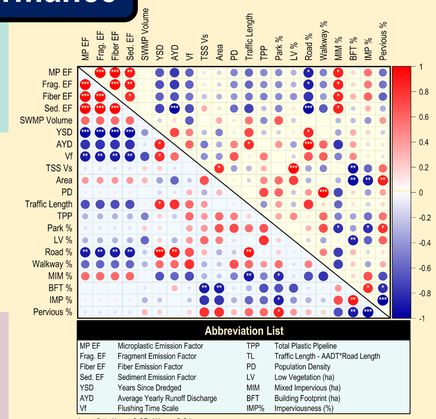






Analysis of Driving Factors and Retention Performance

- Industrial land use is the predominant factor influencing microplastic pollution.
- Parking lots exhibit a higher pollution rate compared to road surfaces.
- Additionally, sediment and MPs are retained similarly by SWMPs.
- Ratio of pond to catchment surface area is in correlation with its retention efficiency, as shown in previous studies (Pettersson, 1999).



Abbreviation List

MP EF	Microplastic Emission Factor	TPP	Total Plastic Pipeline
Frag. EF	Fragment Emission Factor	TL	Traffic Length - AADT*Road Length
Fiber EF	Fiber Emission Factor	PD	Population Density
Sed. EF	Sediment Emission Factor	LV	Low Vegetation (ha)
YSD	Years Since Dredged	MIM	Mixed Impervious (ha)
AYD	Average Yearly Runoff Discharge	BFT	Building Footprint (ha)
Vf	Flushing Time Scale	IMP%	Imperviousness (%)

* p<=0.1 ** p<=0.05 *** p<=0.01

References

Brahney, J., Mahowald, N., Prank, M., Cornwell, G., Klimont, Z., Matsui, H. and Prather, K.A., 2021. Constraining the atmospheric limb of the plastic cycle. Proceedings of the National Academy of Sciences, 118(16), p.e2020719118.

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