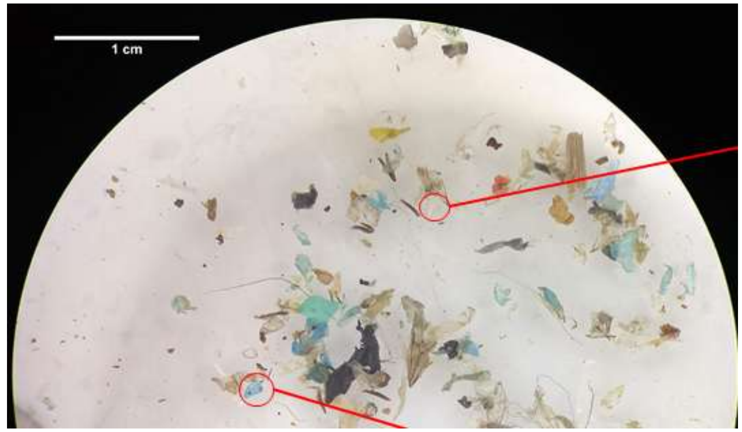



# Pathways of entry and signatures of weathering for microplastics in surface waters

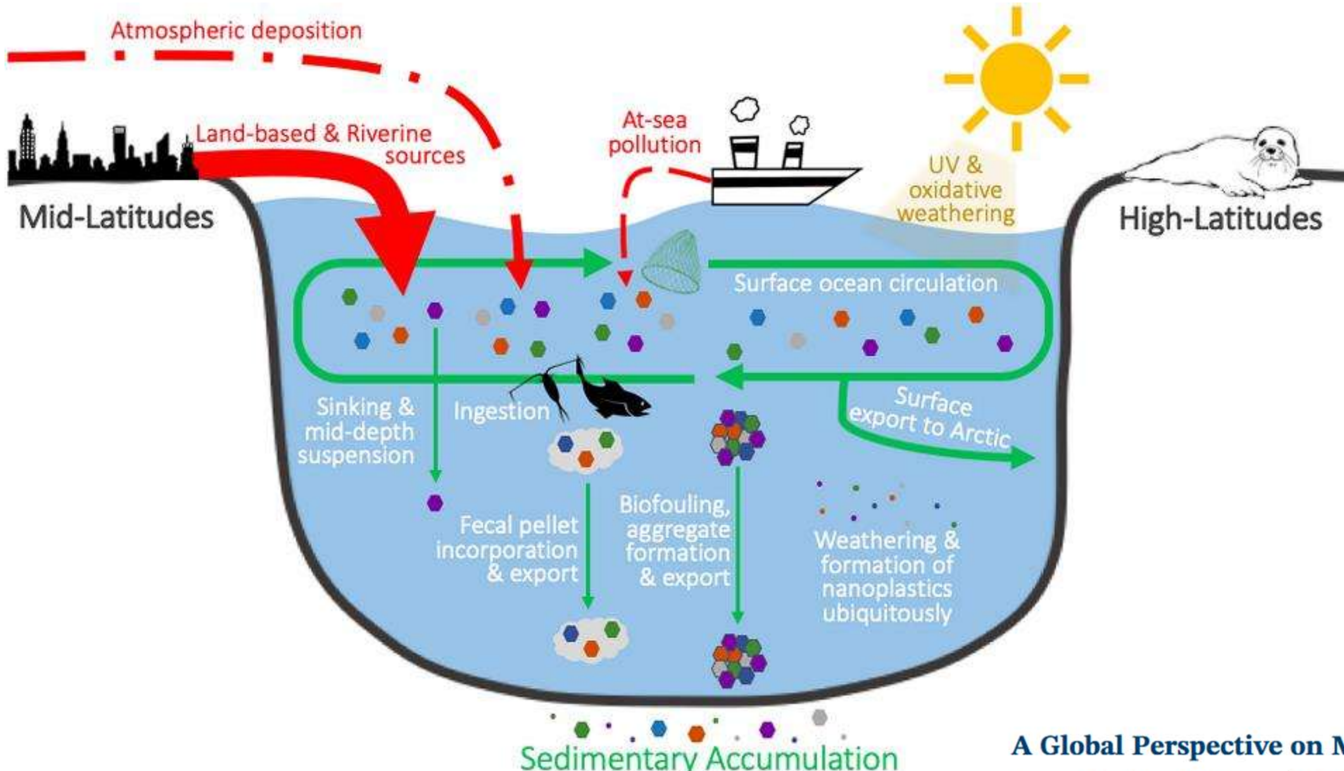
Nicole L. Fahrenfeld, Ph.D.

Professor | Civil & Environmental Engineering

Rutgers, The State University of New Jersey

nfahrenf@rutgers.edu

# Conceptual model of MP fate




**A Global Perspective on Microplastics**

Robert C. Hale[1], Meredith E. Seeley[1], Mark J. La Guardia[1], Lei Mai[2], and Eddy Y. Zeng[2]

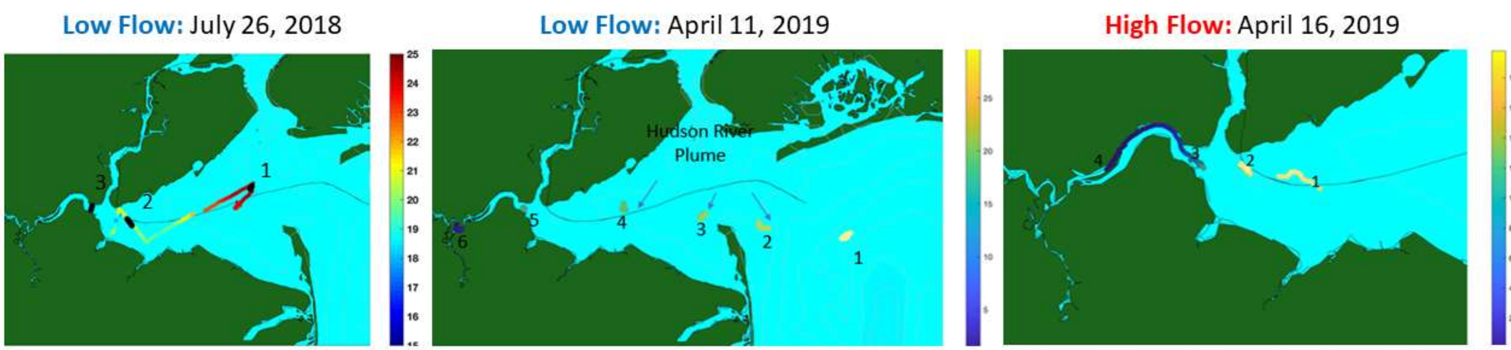
[1]Virginia Institute of Marine Science, William & Mary, Gloucester Point, VA, USA, [2]Guangdong Key Laboratory of Environmental Pollution and Health, School of Environment, Jinan University, Guangzhou, China

# Comparing surface water & pathways of entry

Bay: nets trawled 20-30min at 1-2 knots

16-65 $m^3$
80-153 μm mesh size

Wastewater influent + effluent (4L)
Stormwater
Zooplankton




(a) (b) (c)

Contents lists available at ScienceDirect
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journal homepage: www.elsevier.com/locate/chemosphere


Quantification and composition of microplastics in the Raritan Hudson Estuary: Comparison to pathways of entry and implications for fate


Kendi Bailey [a], Karli Sipps [b], Grace K. Saba [c], Georgia Arbuckle-Keil [b], Robert J. Chant [c], N.L. Fahrenfeld [a,*]

500-2000 μm

250-500 μm

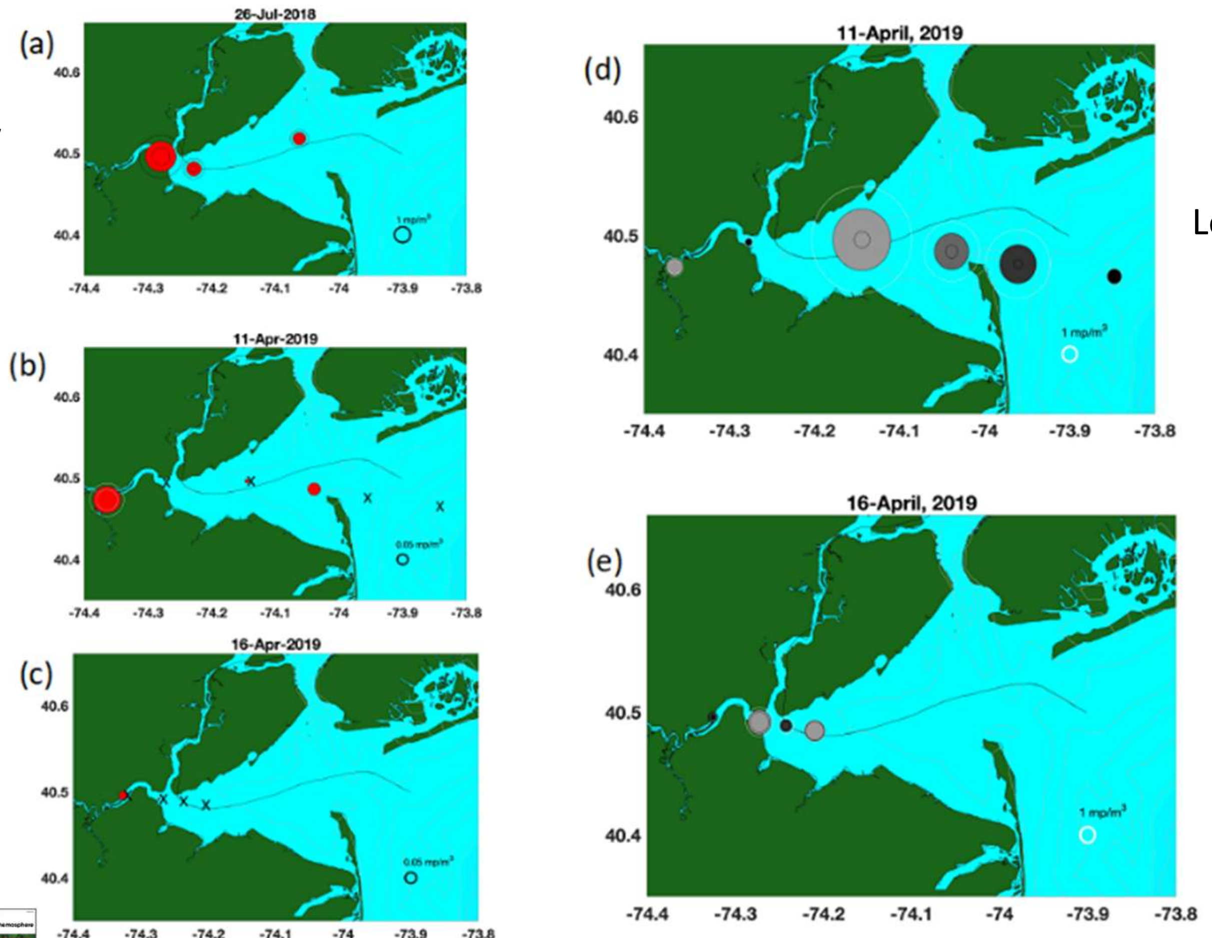
Low flow

Low flow

High flow

Low flow

High flow





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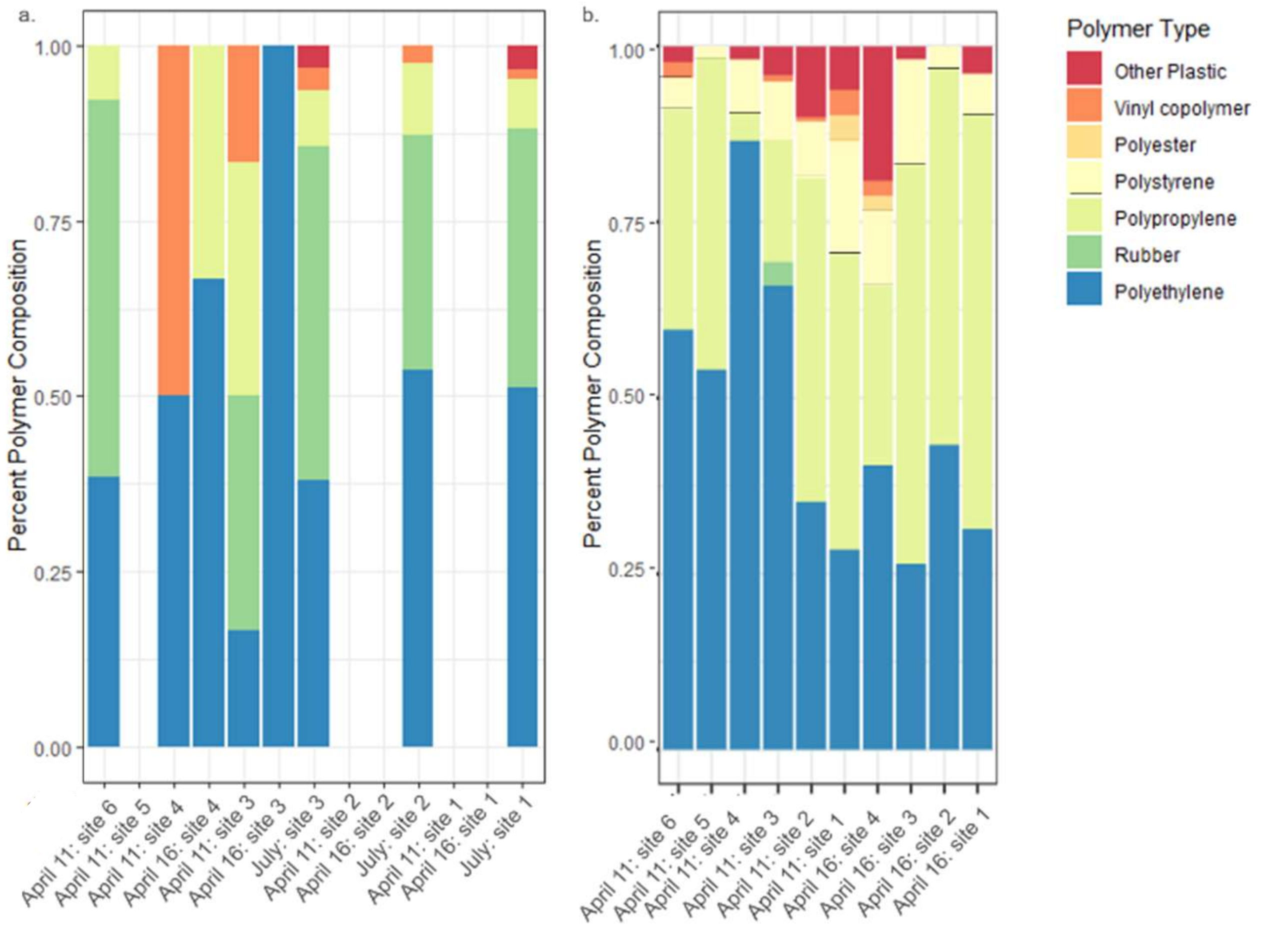
500-2000 µm 250-500 µm

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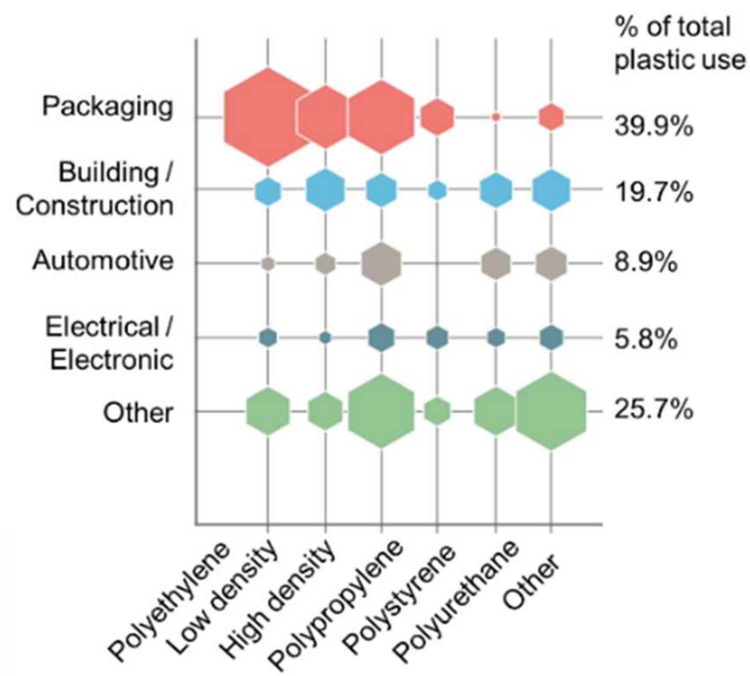
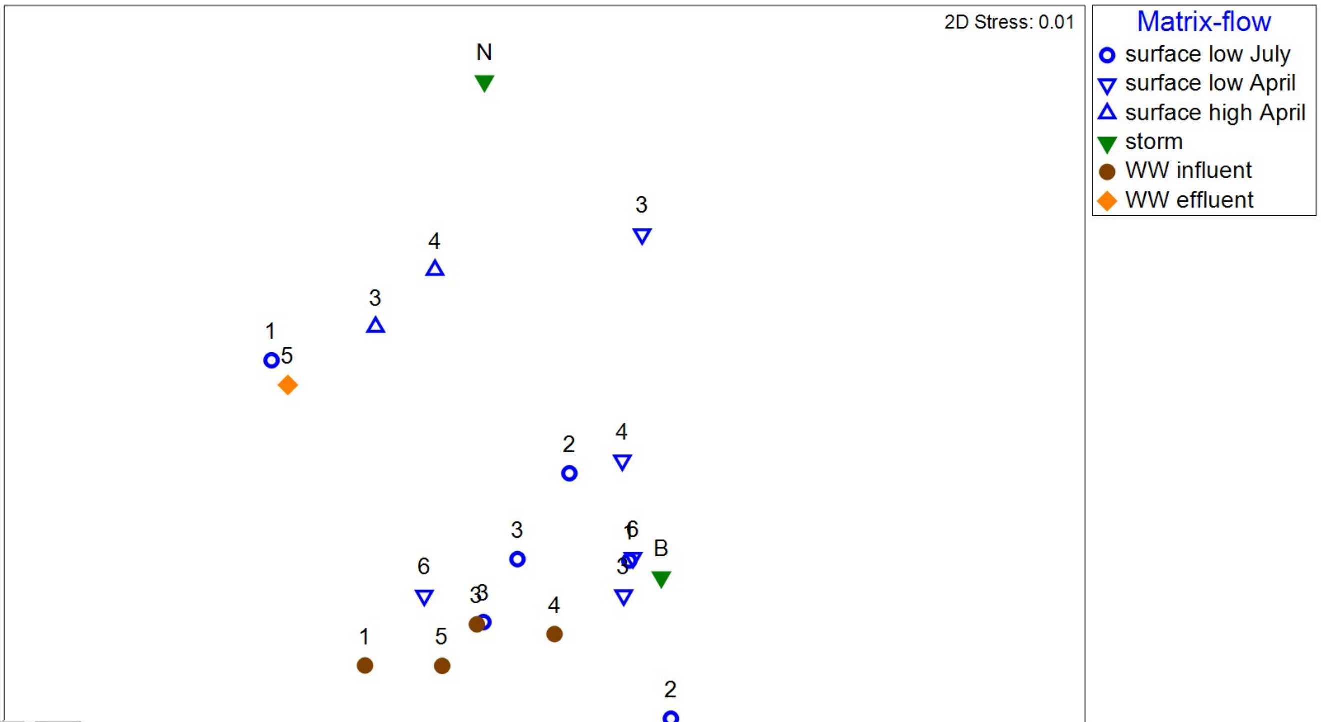
# Linking polymer type to use?




(Plastics Europe, 2016)

.... too much overlap

# Comparing polymer profiles from the estuary to pathways of entry

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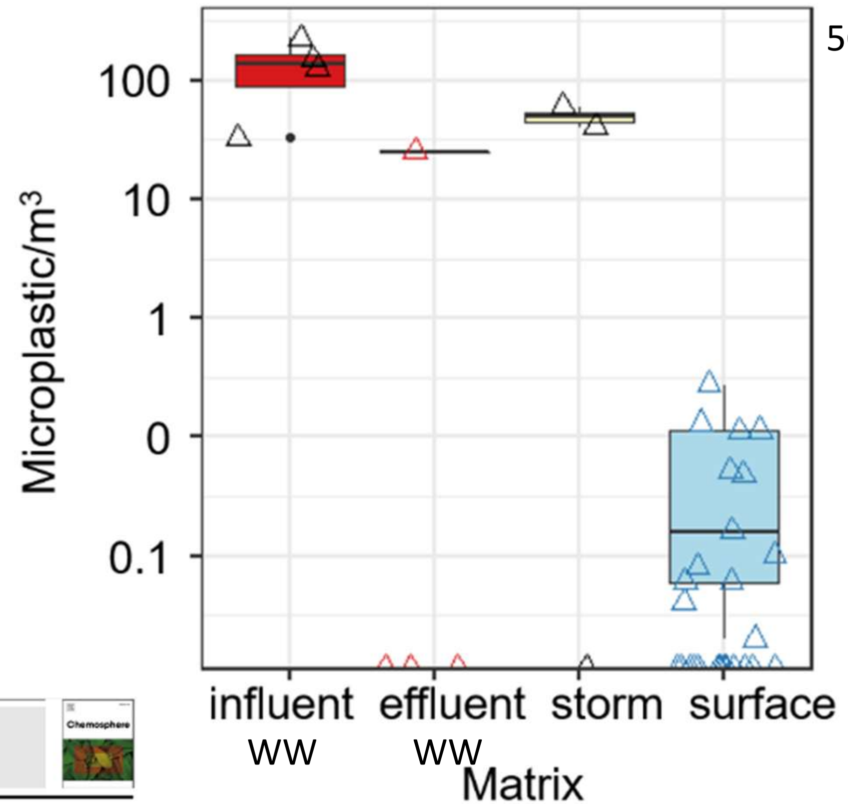
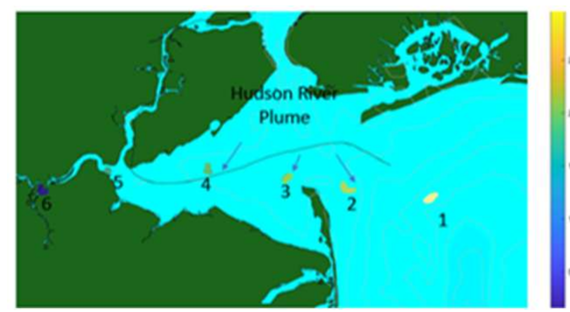
# Comparing pathways of entry to surface water MP




500-2000 µm





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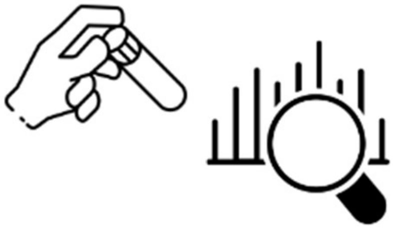
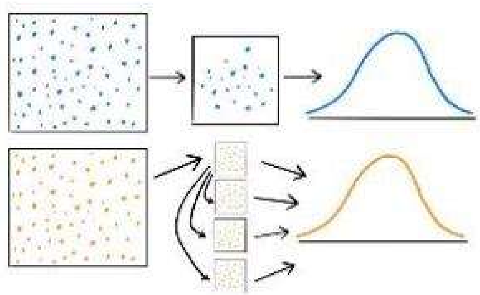


Urban wastewater & stormwater MP observations



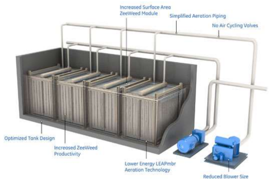
Impact of methods on polymer diversity and MP count-based concentrations

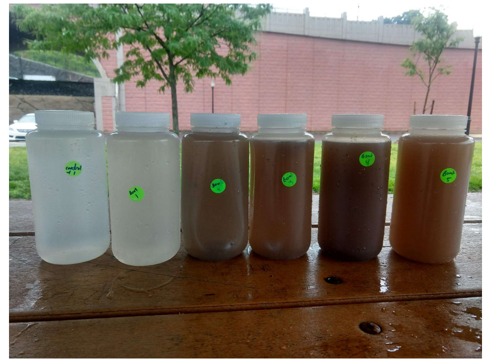

Signatures of oxidative weathering

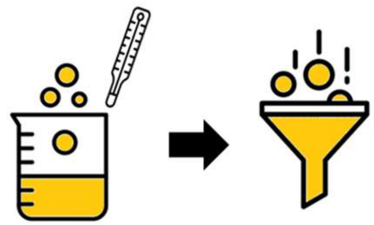
# Wastewater sampling

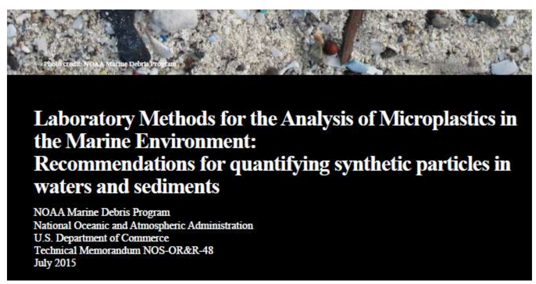
4 WWTP × 3 dates

**Influent** 6.2L → **Pre-filtration** 6.8L → **Effluent** 21L

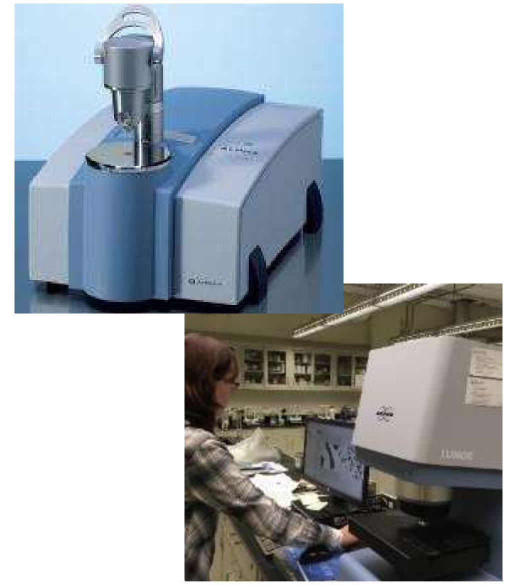


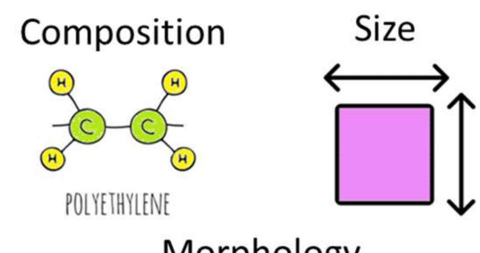





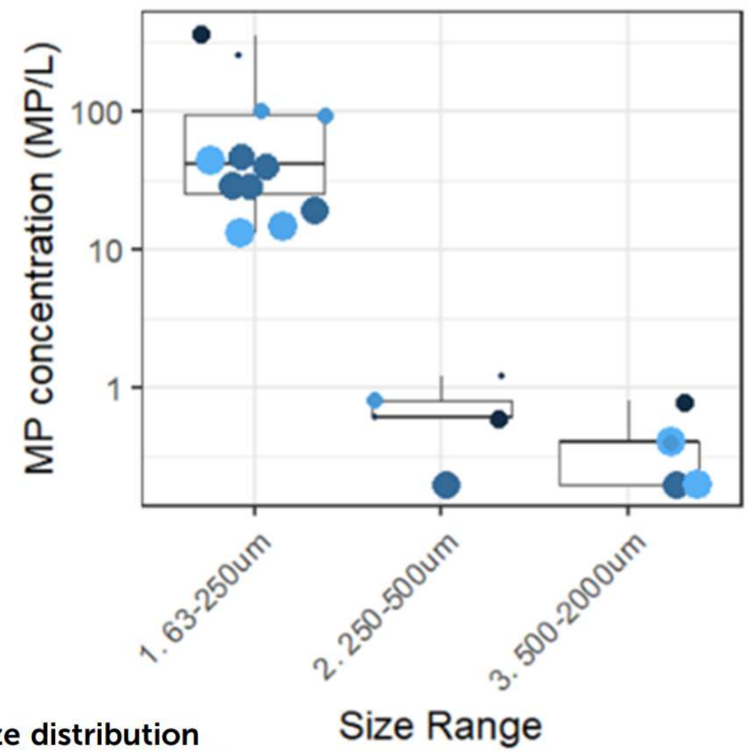


Laboratory Methods for the Analysis of Microplastics in the Marine Environment:
Recommendations for quantifying synthetic particles in waters and sediments

NOAA Marine Debris Program
National Oceanic and Atmospheric Administration
U.S. Department of Commerce
Technical Memorandum NOS-OR&R-48
July 2015



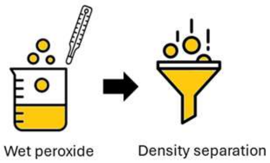



# Stormwater microplastic observations

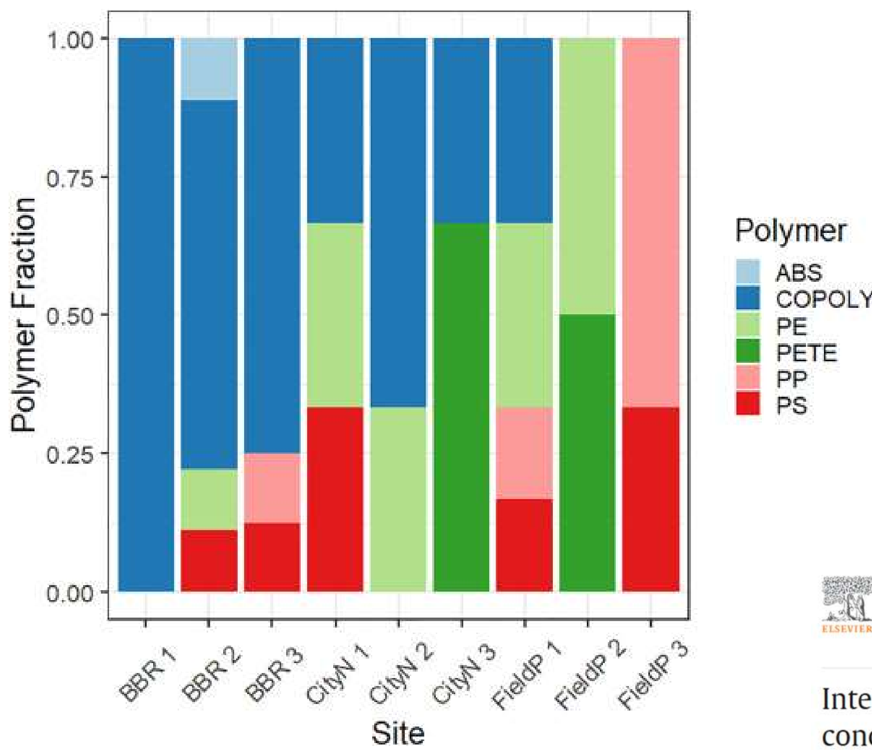



**Urban stormwater microplastic size distribution and impact of subsampling on polymer diversity†**

Swaraj Parmar,[a] Georgia Arbuckle-Keil,[a] G. Kumi[a] and N. L. Fahrenfeld*[b]




# Stormwater microplastic polymer types 250-2000 µm

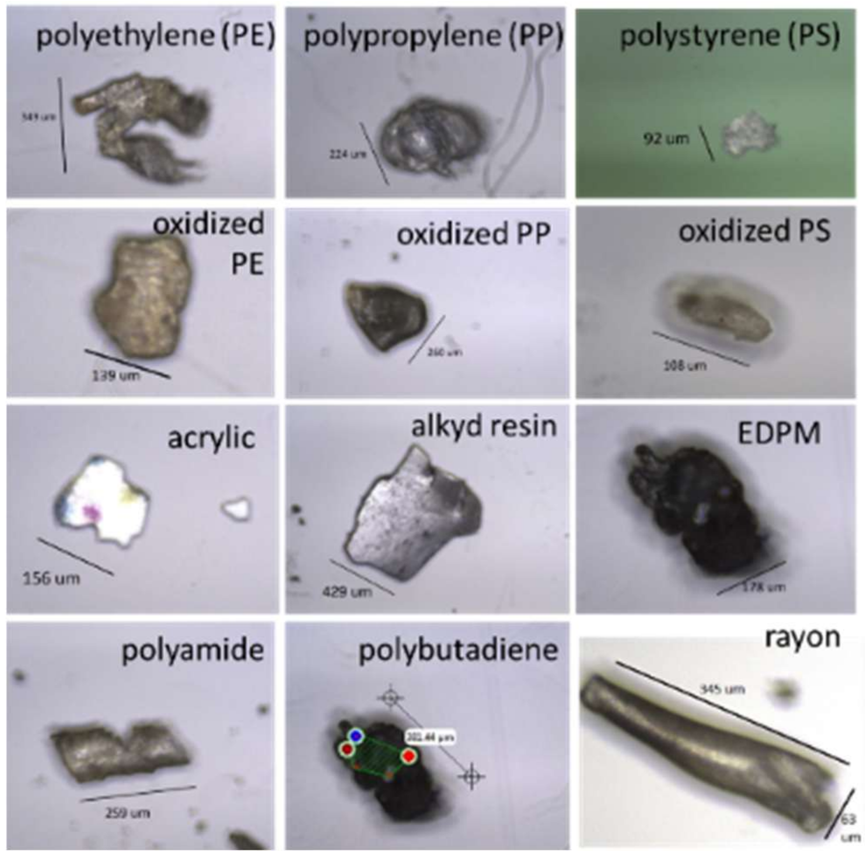



Science of The Total Environment
Volume 809, 25 February 2022, 151104

## Inter-storm variation in microplastic concentration and polymer type at stormwater outfalls and a bioretention basin

William Boni [a], Georgia Arbuckle-Keil [b], N.L. Fahrenfeld [a]

# Example urban stormwater MPs (63-250 µm)



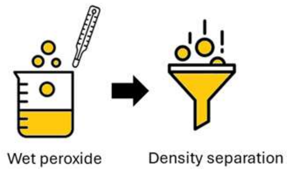


Environmental Science Processes & Impacts

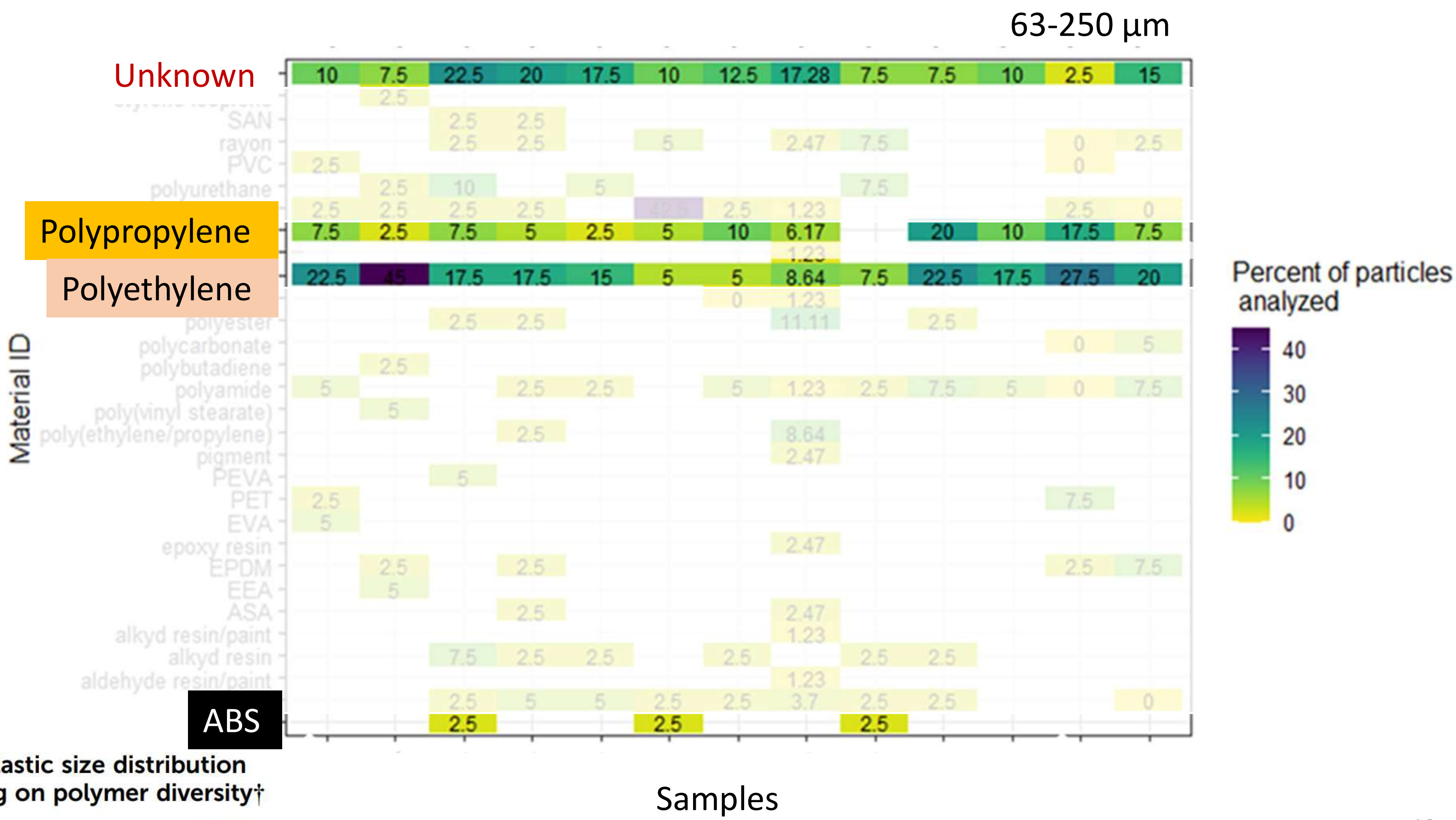
ROYAL SOCIETY OF CHEMISTRY

PAPER

Urban stormwater microplastic size distribution and impact of subsampling on polymer diversity†




# Stormwater polymer types

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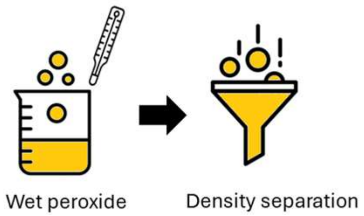
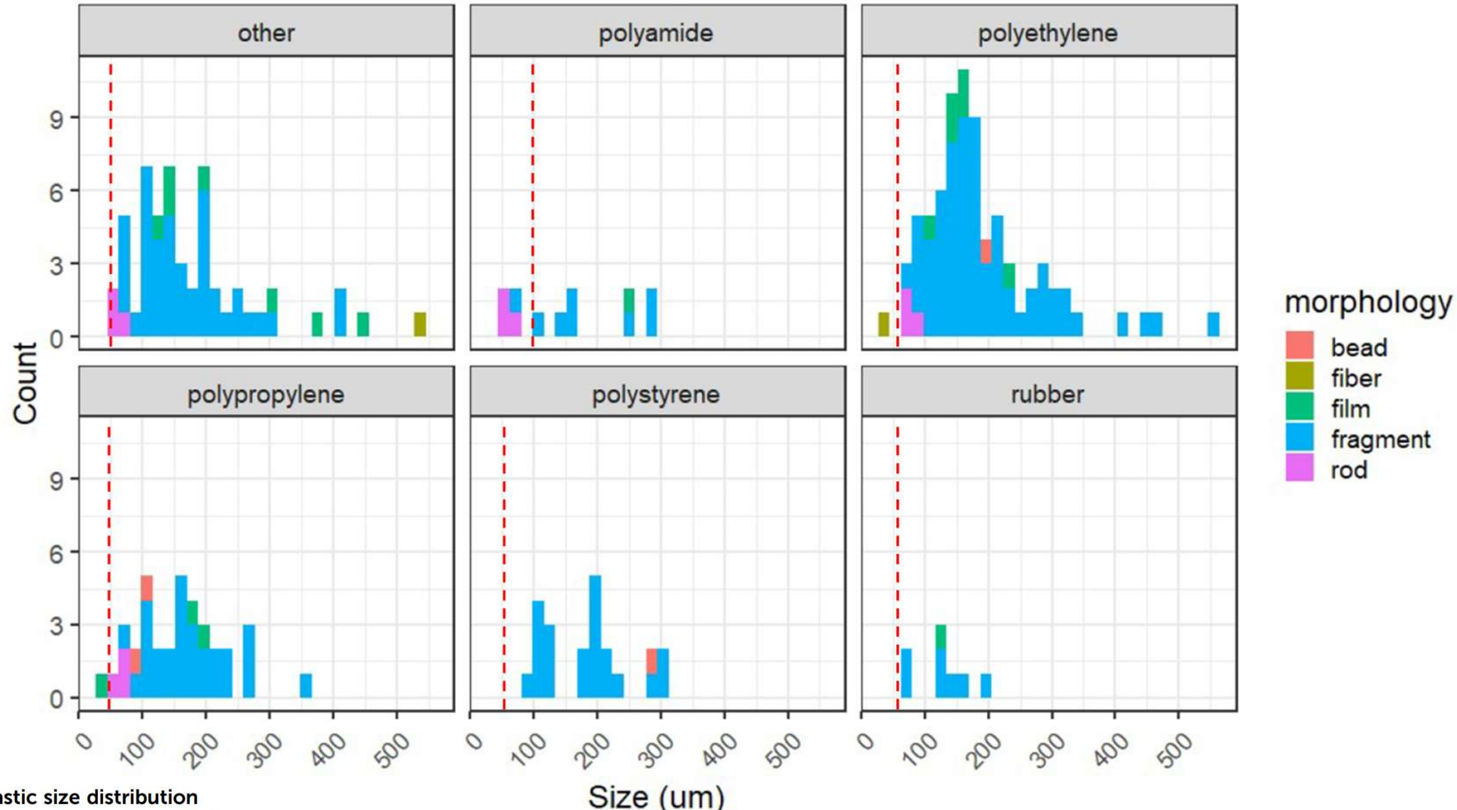



# Moving beyond size bins for MP…

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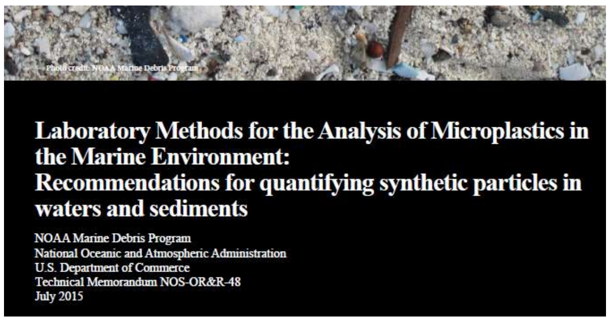
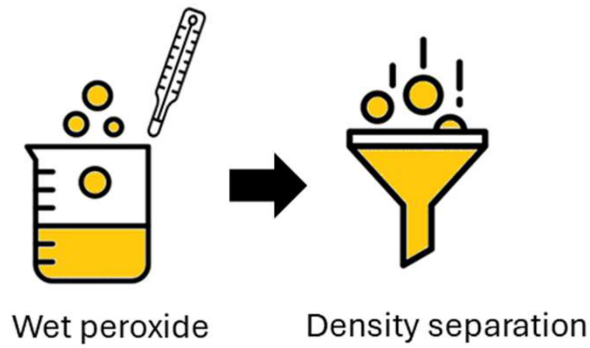
# Evolving extraction methods

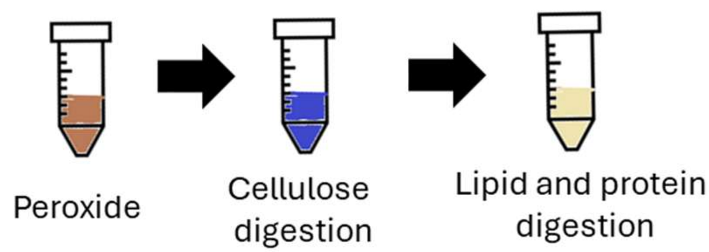


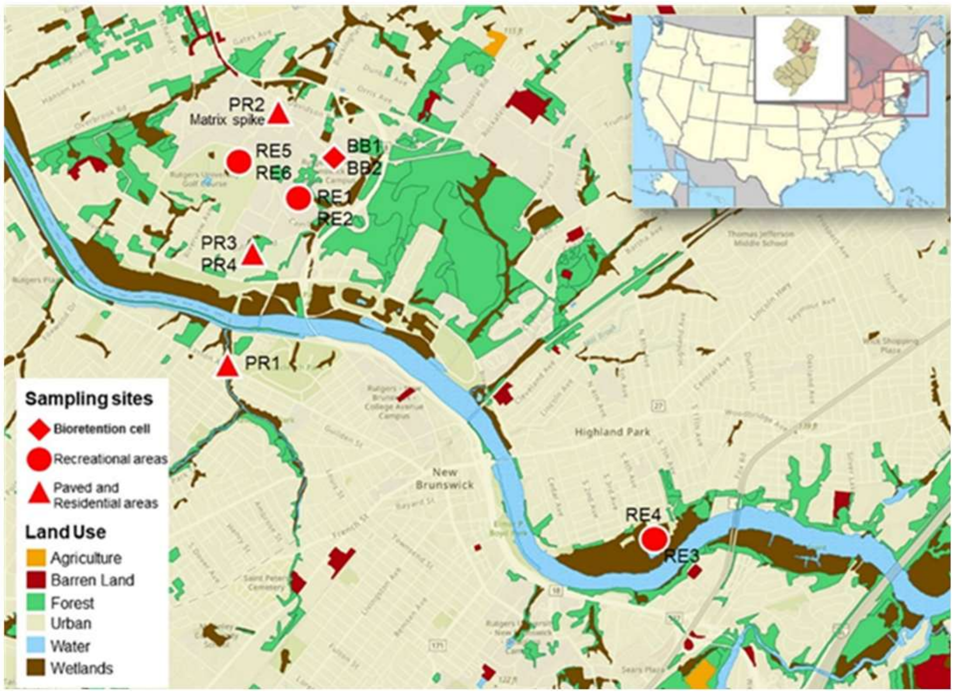

- Losses due to heating?
- Losses of dense polymers?

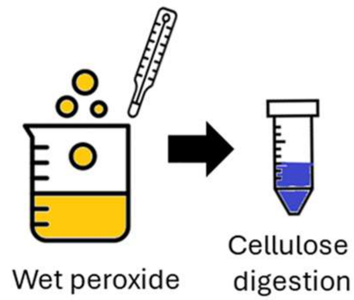
Designation: D8333 – 20

Standard Practice for
Preparation of Water Samples with High, Medium, or Low Suspended Solids for Identification and Quantification of Microplastic Particles and Fibers Using Raman Spectroscopy, IR Spectroscopy, or Pyrolysis-GC/MS[1]

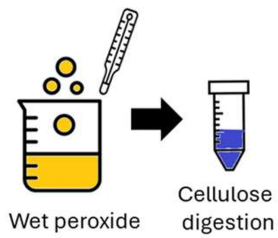



- Limited adoption in the literature to date



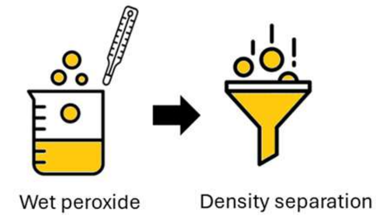




**~ASTM**
10-20L sampled
Wet peroxide oxidation
Cellulose Digestion
~~Density separation~~
Smallest sieve size = 500 µm

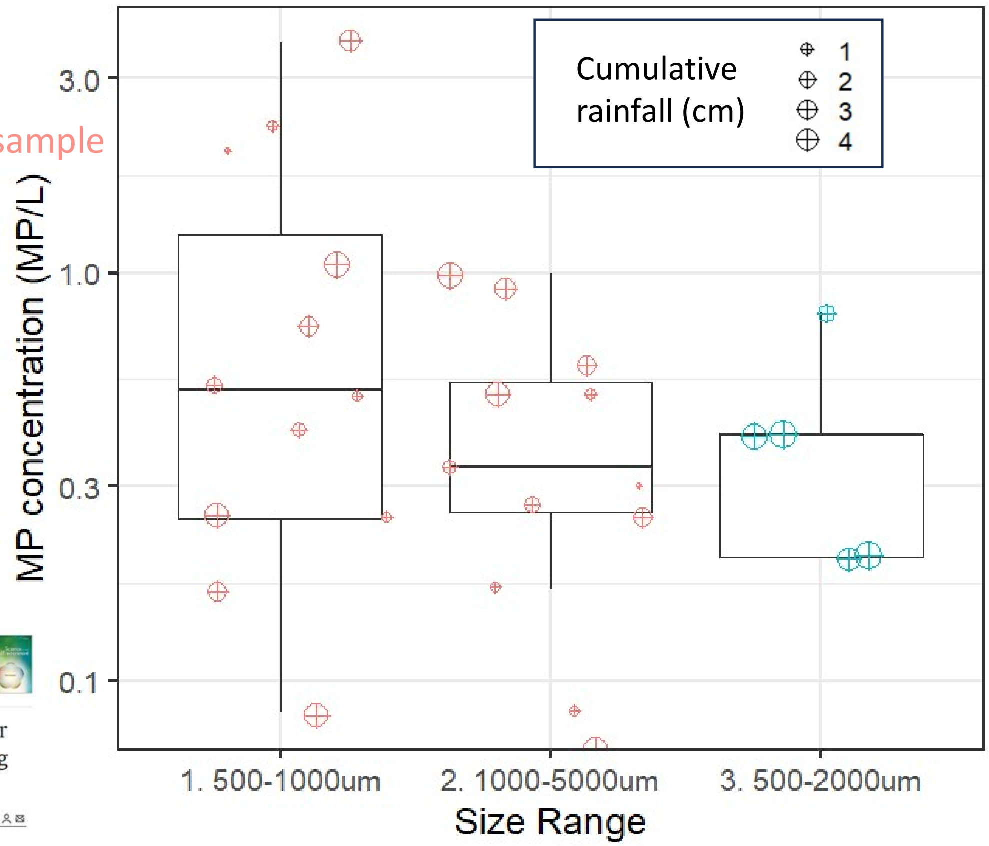



**~ASTM**
10-20L sampled
Wet peroxide oxidation
Cellulose Digestion
~~Density separation~~

**NOAA**
5L sampled
Wet peroxide oxidation
~~Cellulose Digestion~~
NaCl density separation




1-14 polymer types per sample




1-4 polymer types per sample


Science of The Total Environment
Volume 929, 15 June 2024, 172485


Stormwater runoff microplastics: Polymer types, particle size, and factors controlling loading rates


Lilia Ochoa [a], Julianne Chan [a], Caitlyn Auguste [b], Georgia Arbuckle-Keil [b], N.L. Fahrenfeld [a]



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Inter-storm variation in microplastic concentration and polymer type at stormwater outfalls and a bioretention basin


William Boni [a], Georgia Arbuckle-Keil [b], N.L. Fahrenfeld [a]

# Estimating MP loading

**Watershed delineation**

**ArcGIS Pro**

- Digital Elevation Model (DEM)
- USGS Water Boundary Data

**Flow direction, flow accumulation → Boundaries of the watershed**

**Curve number (SCS-CN)**

**ArcGIS Pro and Arc Hydro**

- Digital Elevation Model
- Land Use/Land Cover
- Soil data

**Runoff**

$$Q = \frac{(P - I_a)^2}{P - I_a + S}$$

**MP load**

$$\mathbf{L = C * Q}$$

*Where: L is MP load [MP/m²], C is MP concentration [MP/L], Q is runoff [mm]*


1. Tahmasebi Nasab, M. (2023). *Create curve number CN raster using Archhydro tools in Arcgis Pro*. Retrieved from https://www.hydromohsen.com/create-curve-number-cn-raster-for-a-watershed
2. Piñon-Colin, T., Rodriguez-Jimenez, R., Rogel-Hernandez, E., Alvarez-Andrade, A., & Toyohiko-Wakida, F. (2020). Microplastics in stormwater runoff in a semiarid region, Tijuana, Mexico. Science of The Total Environment, 135411.

# Results

**Precipitation and Microplastics Loads:**

- Positive **correlations** with **accumulated precipitation** and **rainfall intensity**.
- No significant correlation between MP load and antecedent dry days

**Runoff and Microplastic Loads:**

- Dependent on accurate precipitation data.
- MPs loads are influenced by watershed characteristics (land use and soil types).

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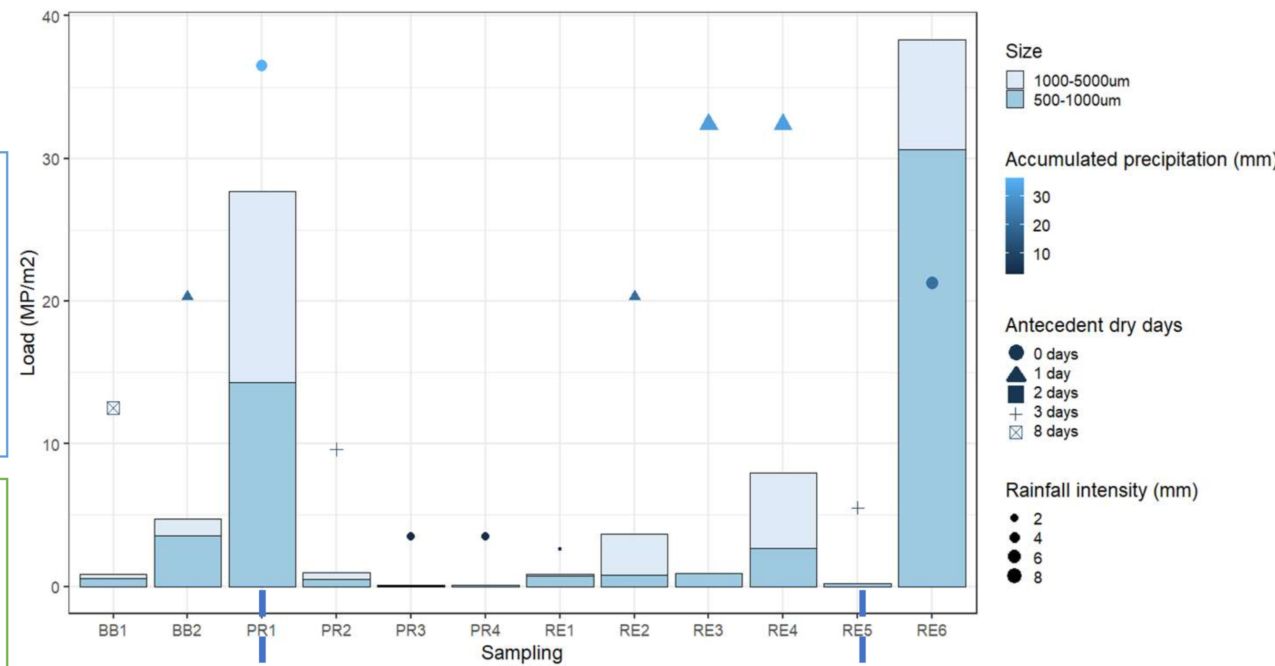
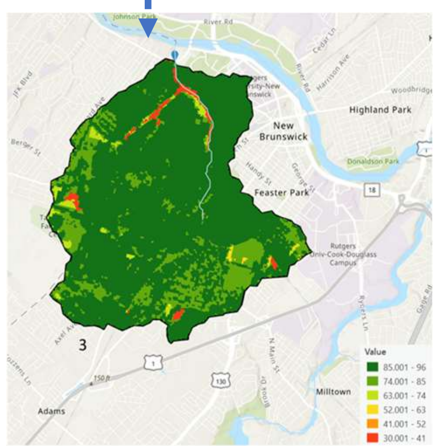
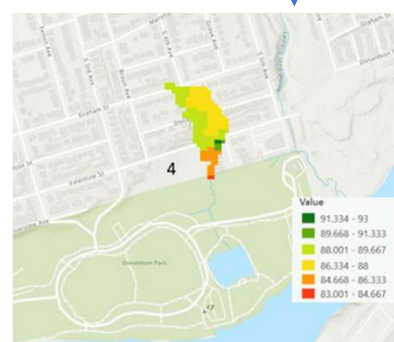
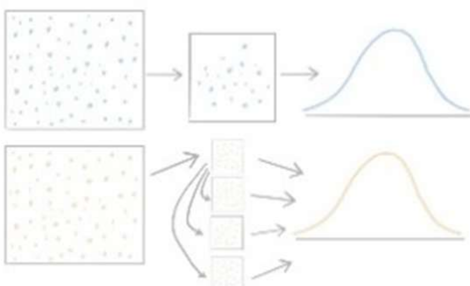



*High CN values indicate less permeable soils*

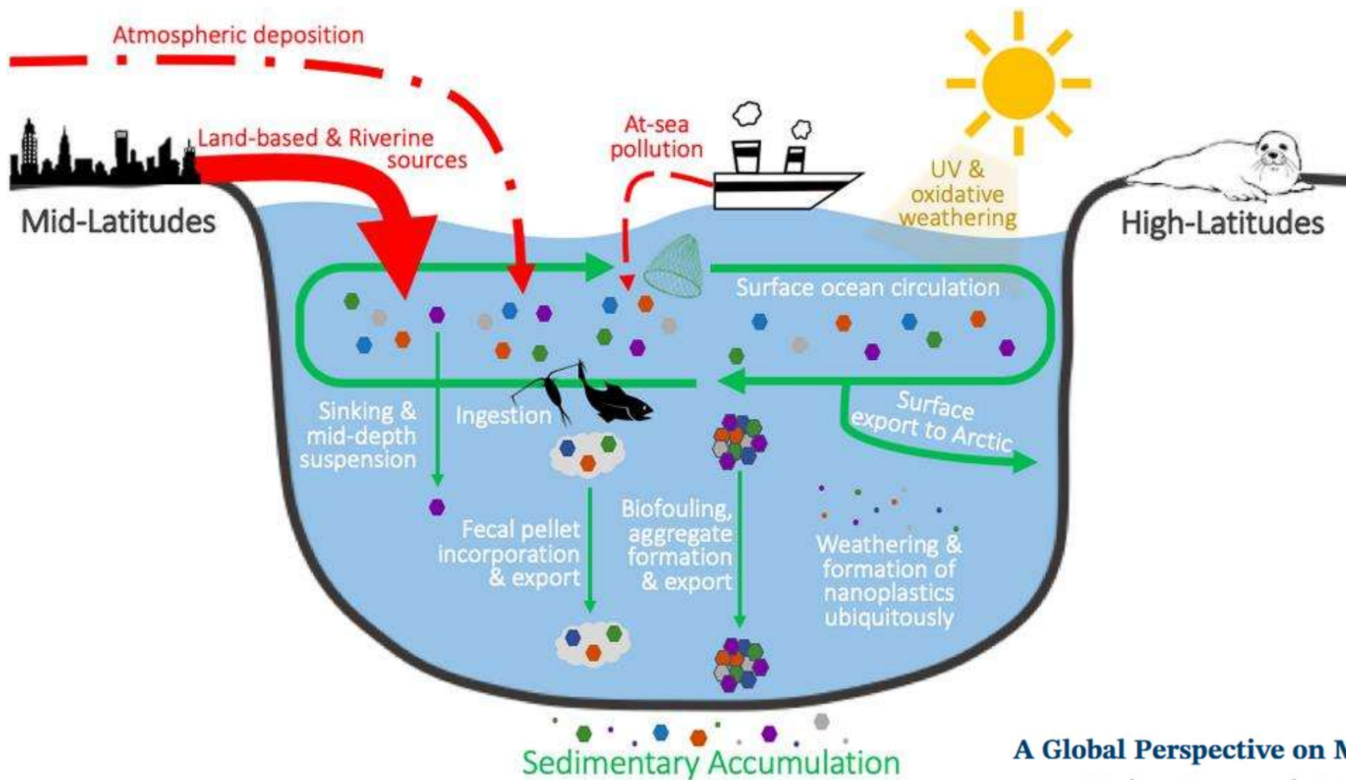
Urban wastewater & stormwater MP observations



Impact of methods on polymer diversity and MP count-based concentrations in stormwater


Signatures of oxidative weathering

# Conceptual model of MP fate

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[1]Virginia Institute of Marine Science, William & Mary, Gloucester Point, VA, USA, [2]Guangdong Key Laboratory of Environmental Pollution and Health, School of Environment, Jinan University, Guangzhou, China

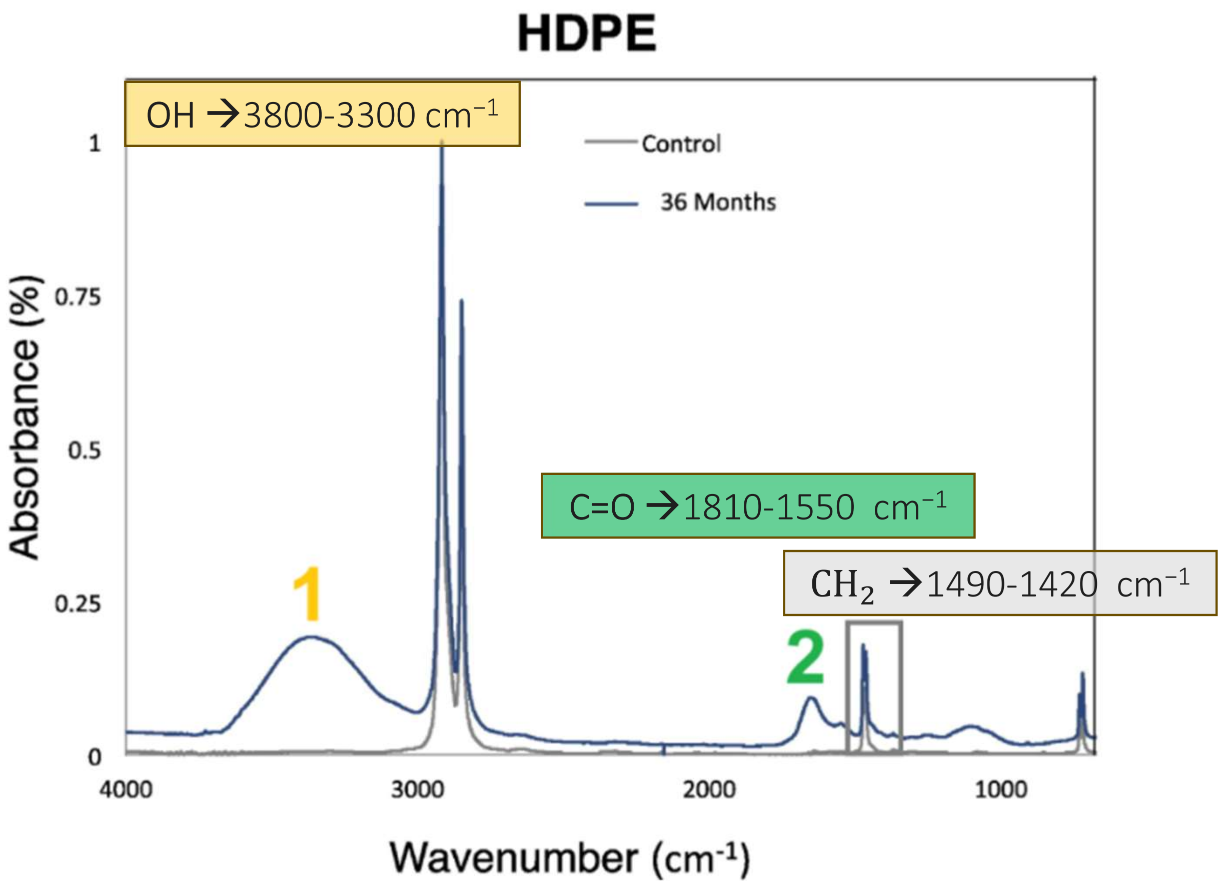
# Vibrational spectroscopy can provide insight into weathering

**Bond indices**

Reference peak ($CH_2$)

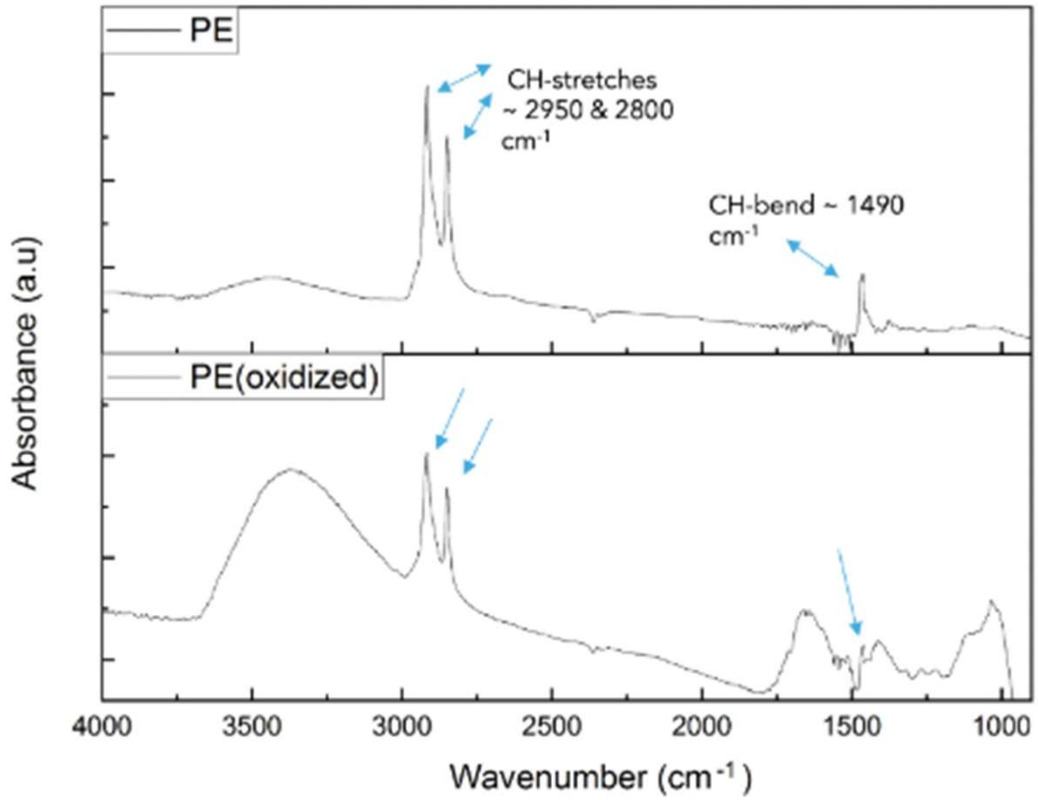
$$1.\ \boldsymbol{Hydroxyl\ Index\ (HI)} = \frac{\text{Maximum absorbance of OH}}{\text{Maximum absorbance of } CH_2}$$

$$2.\ \boldsymbol{Carbonyl\ Index\ (CI)} = \frac{\text{Maximum absorbance of C = O}}{\text{Maximum absorbance of } CH_2}$$




Brandon, J., Goldstein, M., & Ohman, M. D. (2016). Long-term aging and degradation of microplastic particles: Comparing in situ oceanic and experimental weathering patterns. Marine Pollution Bulletin, 110(1), 299–308. doi:10.1016/j.marpolbul.2016.06.048

# Many stormwater MP spectra show signs of oxidative weathering




**Urban stormwater microplastic size distribution and impact of subsampling on polymer diversity†**

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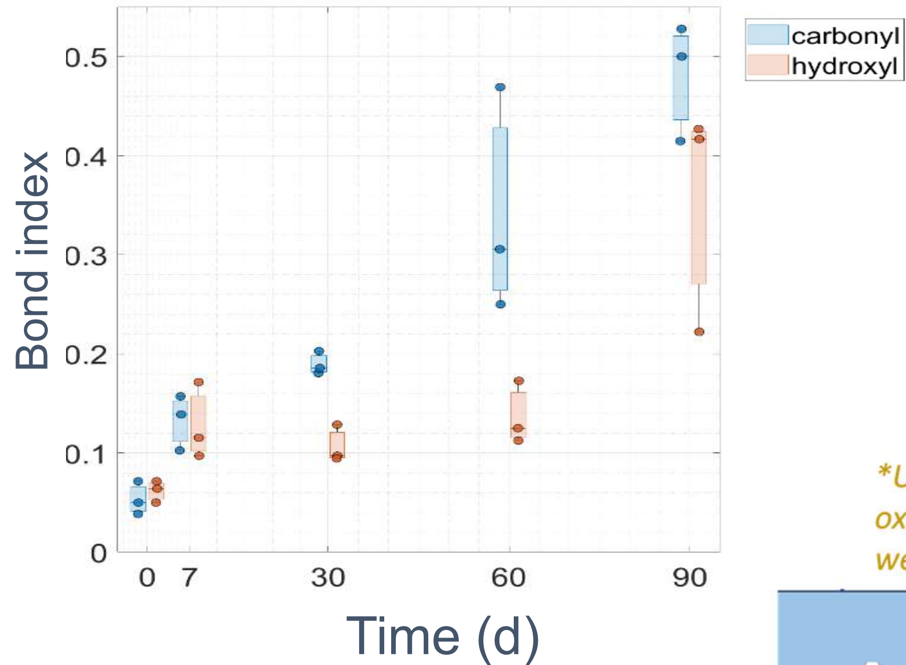
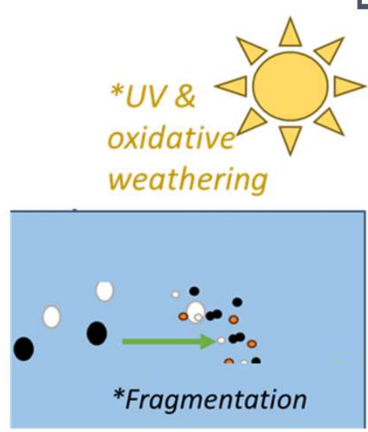
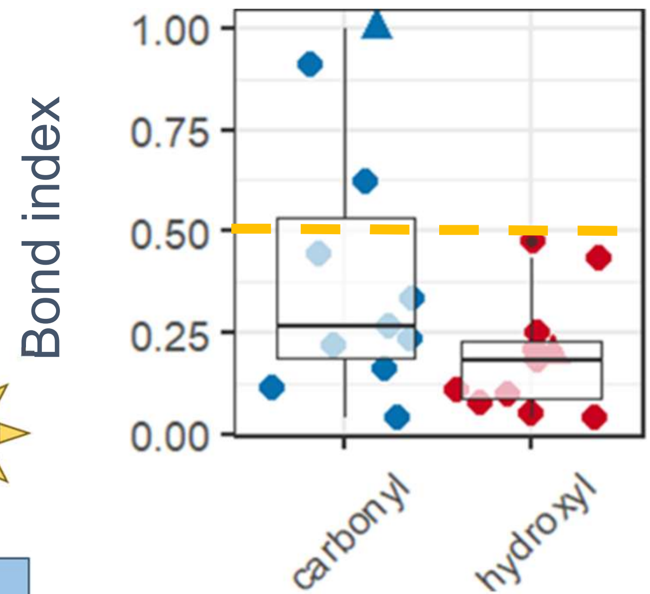
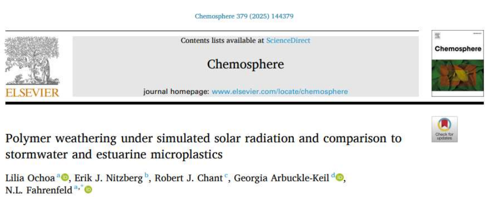
Lab weathered polypropylene

Stormwater polypropylene



Chemosphere 379 (2025) 144379

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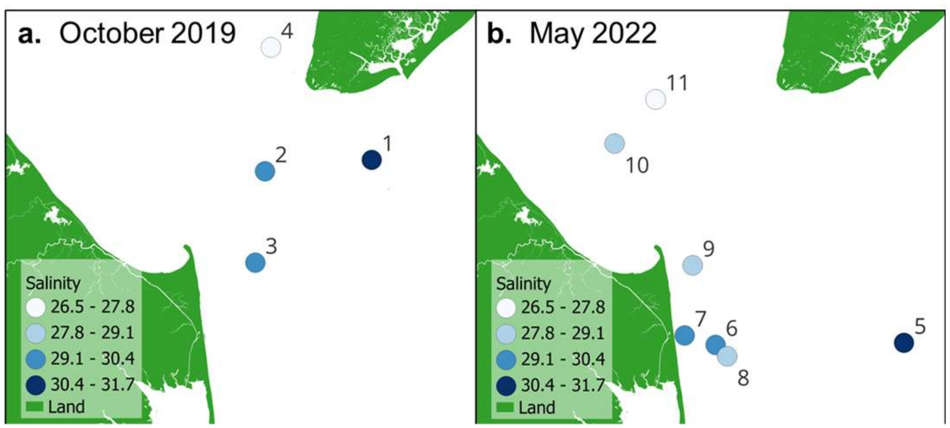
journal homepage: www.elsevier.com/locate/chemosphere

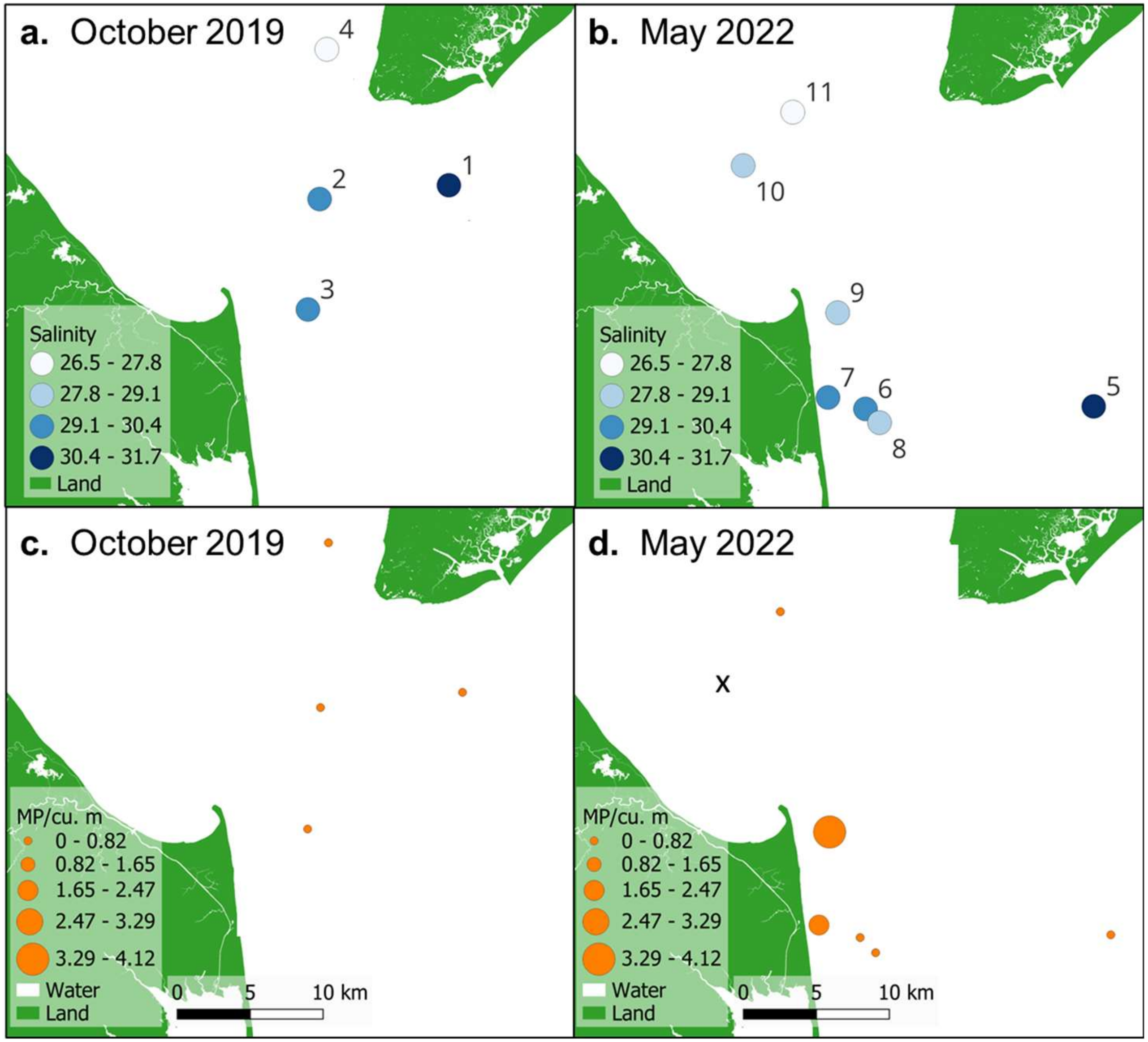

Polymer weathering under simulated solar radiation and comparison to stormwater and estuarine microplastics


Lilia Ochoa [a], Erik J. Nitzberg [b], Robert J. Chant [c], Georgia Arbuckle-Keil [d], N.L. Fahrenfeld [a,*]

# Delaware Bay

Bay: nets trawled 20-30min at 1-2 knots
4-120 m$^3$
20, 80, 153 μm mesh size







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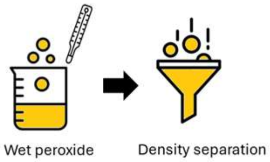


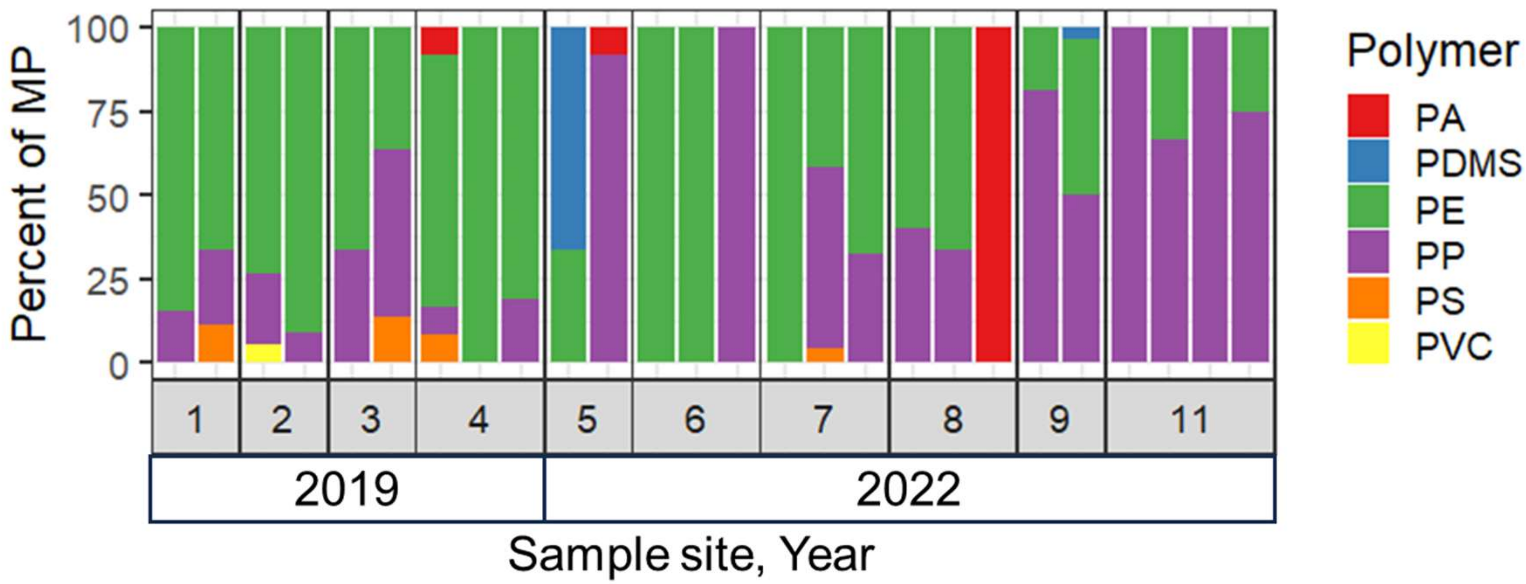


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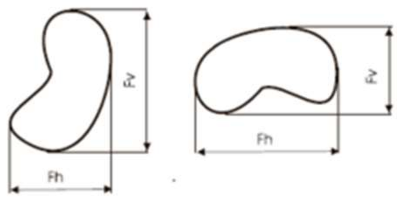


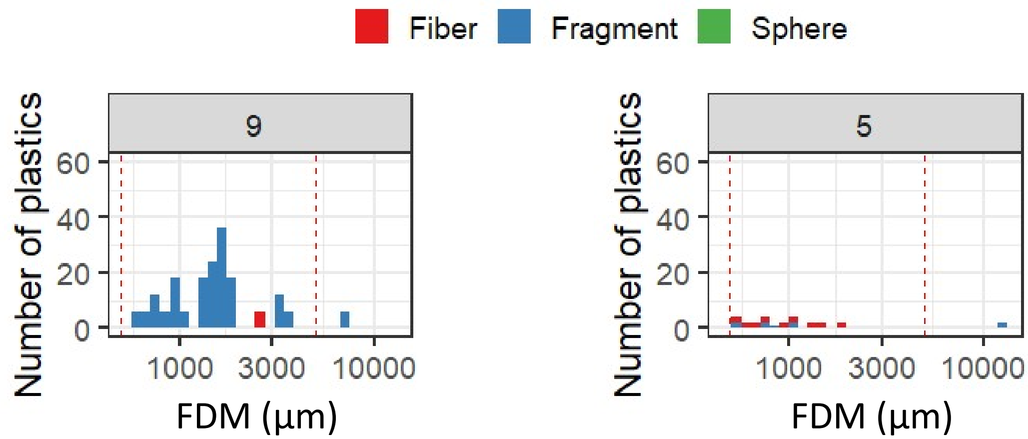


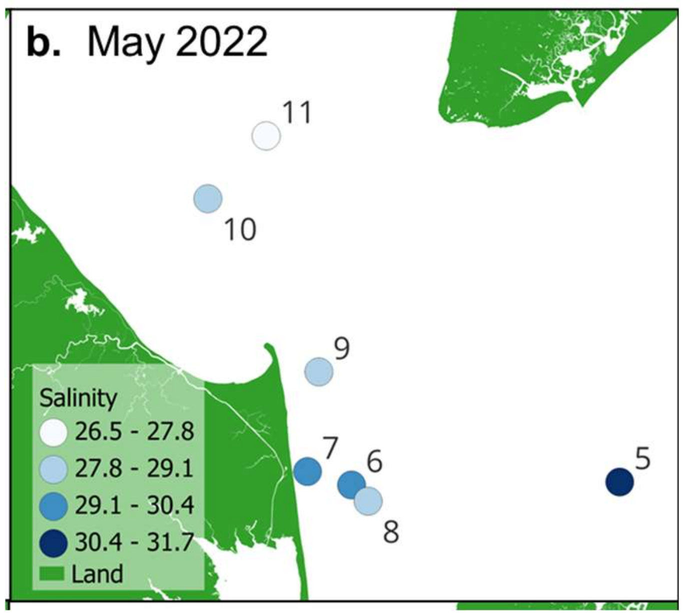


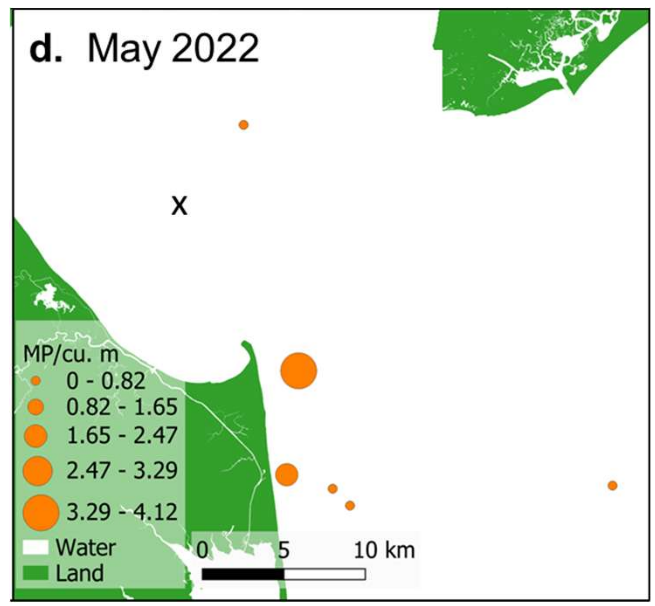


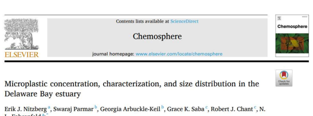
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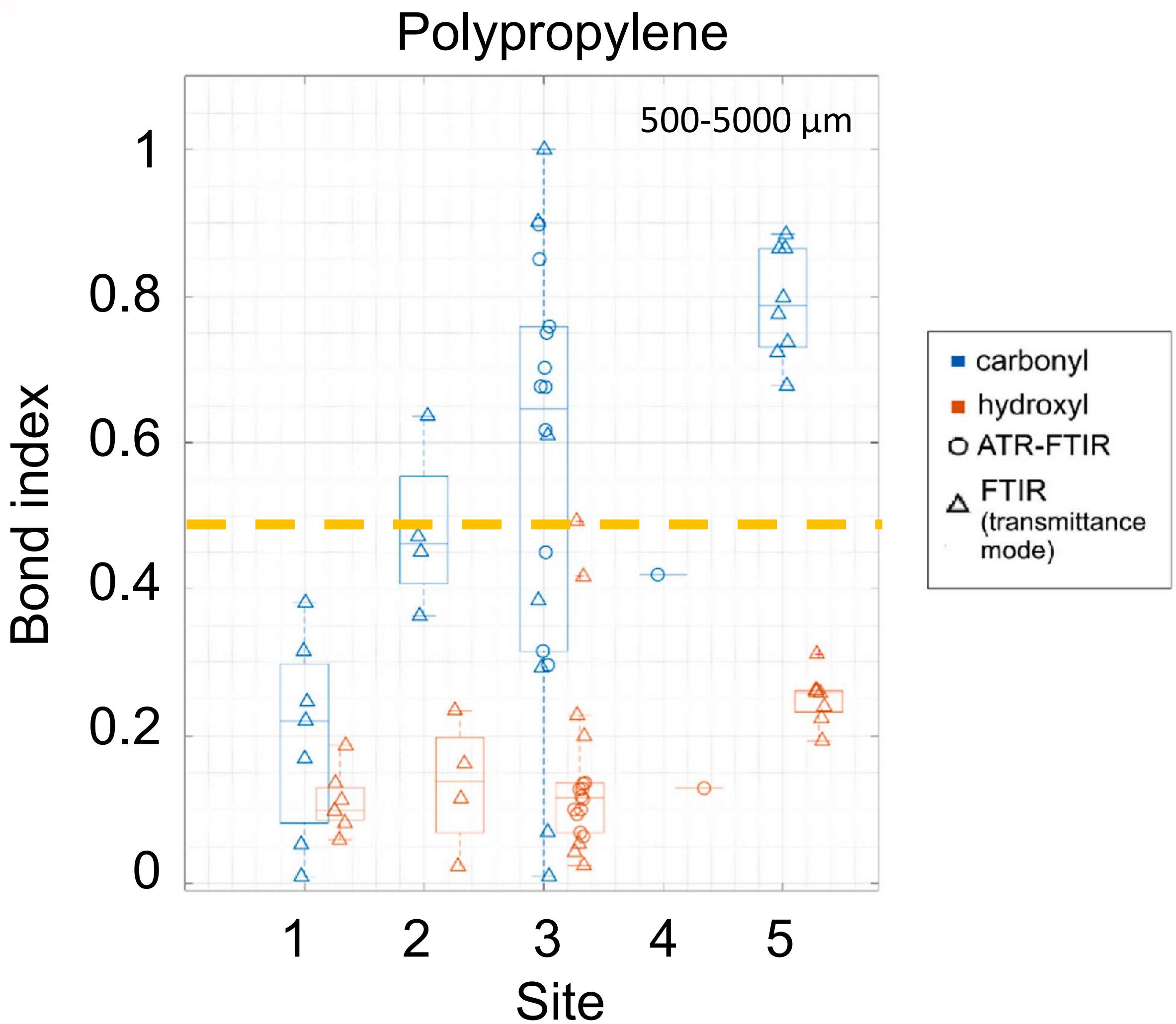


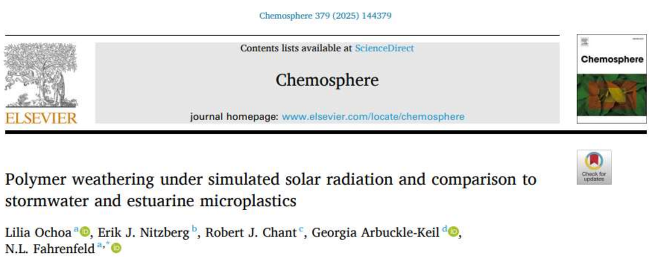
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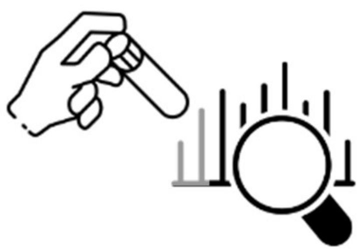
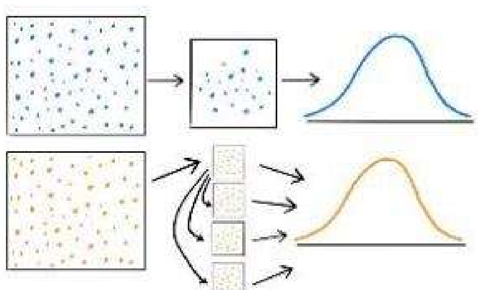
Polymer weathering under simulated solar radiation and comparison to stormwater and estuarine microplastics

Lilia Ochoa [a], Erik J. Nitzberg [b], Robert J. Chant [c], Georgia Arbuckle-Keil [d], N.L. Fahrenfeld [a,*]



PE, PP, and polyester fibers and fragments most prevalent in wastewater; PE, PP, PS fragments in urban stormwaters, but many others…



Sampling volume, extraction techniques, target size, and subsampling will impact reported polymer diversity!


Range of surface oxidation which impacts other properties…

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Kendi Bailey, Will Boni, Karli Sipps, Raj Parmar, Erik Nitzberg, Lilia Ochoa, Julianne Chan, Alexandra Mondzrick, Isabella Dela Cruz

Georgia Arbuckle-Keil, PhD, Robert Chant, PhD, Grace Saba PhD

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Quantification and composition of microplastics in the Raritan Hudson Estuary: Comparison to pathways of entry and implications for fate

Kendi Bailey [a], Karli Sipps [b], Grace K. Saba [c], Georgia Arbuckle-Keil [b], Robert J. Chant [c], N.L. Fahrenfeld [a,*]

**Quantitative and qualitative impacts of nitric acid digestion on microplastic identification via FTIR and Raman spectroscopy, implications for environmental samples**

**Karli Sipps[1,2] · Shreya Patil[3,4] · Lilia Ochoa[3] · Julianne Chan[3] · Caitlyn Auguste[1] · Georgia Arbuckle-Keil[1] · N. L. Fahrenfeld[3]**

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Science of The Total Environment
Volume 809, 25 February 2022, 151104

Inter-storm variation in microplastic concentration and polymer type at stormwater outfalls and a bioretention basin

William Boni [a], Georgia Arbuckle-Keil [b], N.L. Fahrenfeld [a]

**Urban stormwater microplastic size distribution and impact of subsampling on polymer diversity†**

Swaraj Parmar,[a] Georgia Arbuckle-Keil,[a] G. Kumi[a] and N. L. Fahrenfeld[*b]

Science of The Total Environment
Volume 929, 15 June 2024, 172485

Stormwater runoff microplastics: Polymer types, particle size, and factors controlling loading rates

Lilia Ochoa [a], Julianne Chan [a], Caitlyn Auguste [b], Georgia Arbuckle-Keil [b], N.L. Fahrenfeld [a]