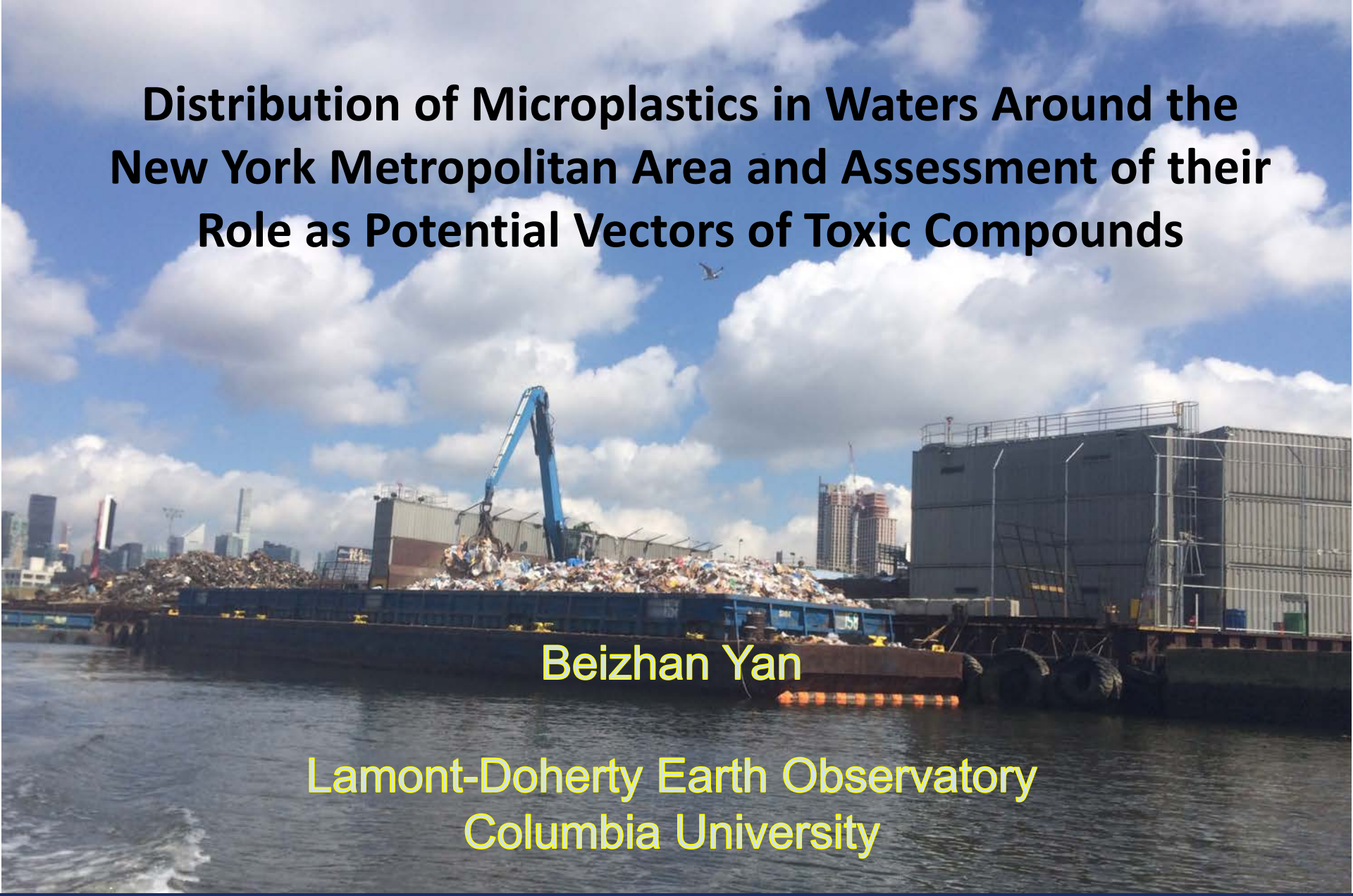
Distribution of Microplastics in Waters Around the New York Metropolitan Area and Assessment of their Role as Potential Vectors of Toxic Compounds



Beizhan Yan

Lamont-Doherty Earth Observatory
Columbia University

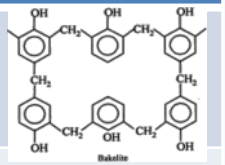
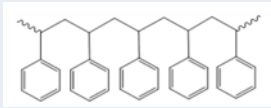
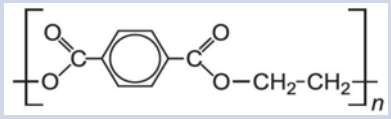
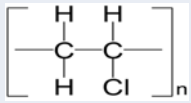
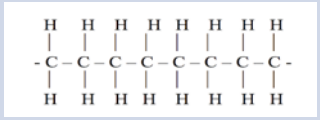
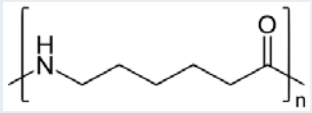
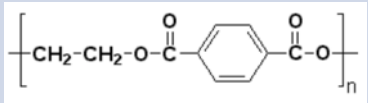
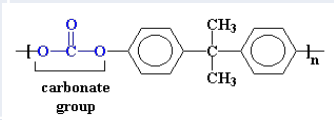
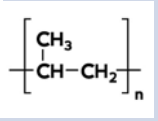
Impacts of Microplastics in the Urban Environment Conference, **03/28/2019**

LAMONT-DOHERTY EARTH OBSERVATORY
THE EARTH INSTITUTE AT COLUMBIA UNIVERSITY

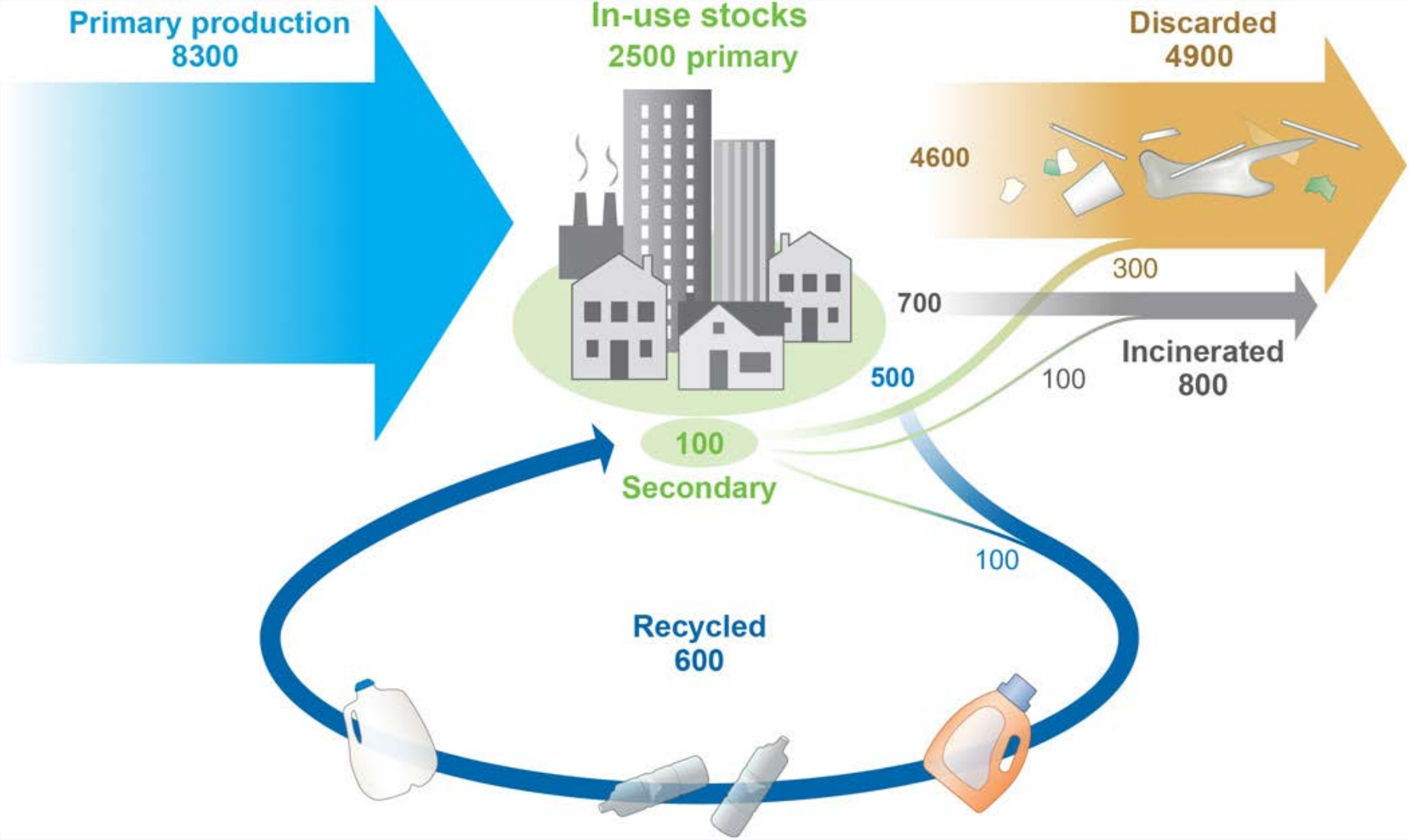
Outline

- Introduction of plastic and microplastic (MP)
- Distribution of MP in NYC waters
- In-situ experiments investigating the potential role of MP as vectors for transporting pollutants
- Microplastic contamination history reflected in sediments from Central Park Lake, NYC
- Summary

Introduction of Plastic

Plastic type	Year invented	Density (g/cm^3)	% produced	Mol. Struct.
Bakelite	1907	1.3	<1	
Polystyrene	1929	1.04-1.1	<10	
Polyester	1930	1.3	<10	
Polyvinylchloride (PVC)	1933	1.2-1.6	12	
Polyethylene	1933	0.92-0.97	36	
Nylon	1935	1.15	<10	
Polyethylene Terephthalate (PET)	1941	1.35-1.45	<10	
Polycarbonate	1953	1.20	<10	
Polypropylene (PP)	1954	0.92	21	

Global production, use, and fate of plastics (1950 to 2015; in million metric tons)



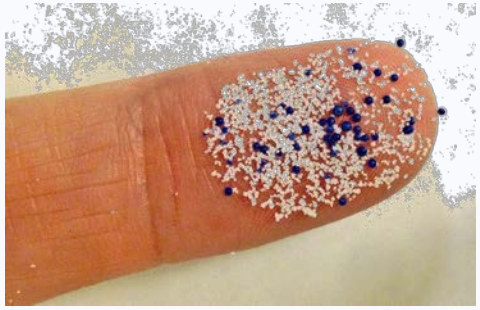
(Geyer et al., 2017)

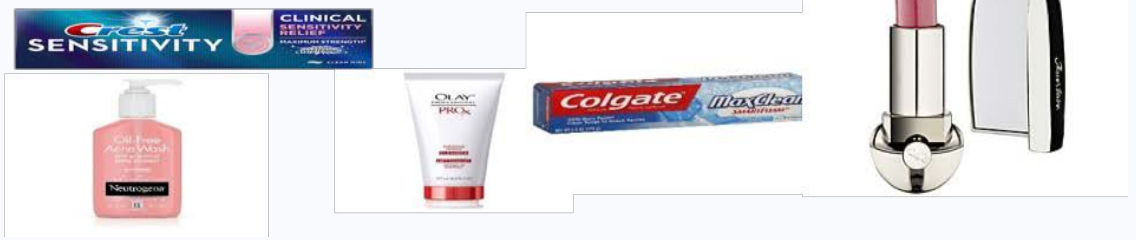
What are microplastics and major sources?

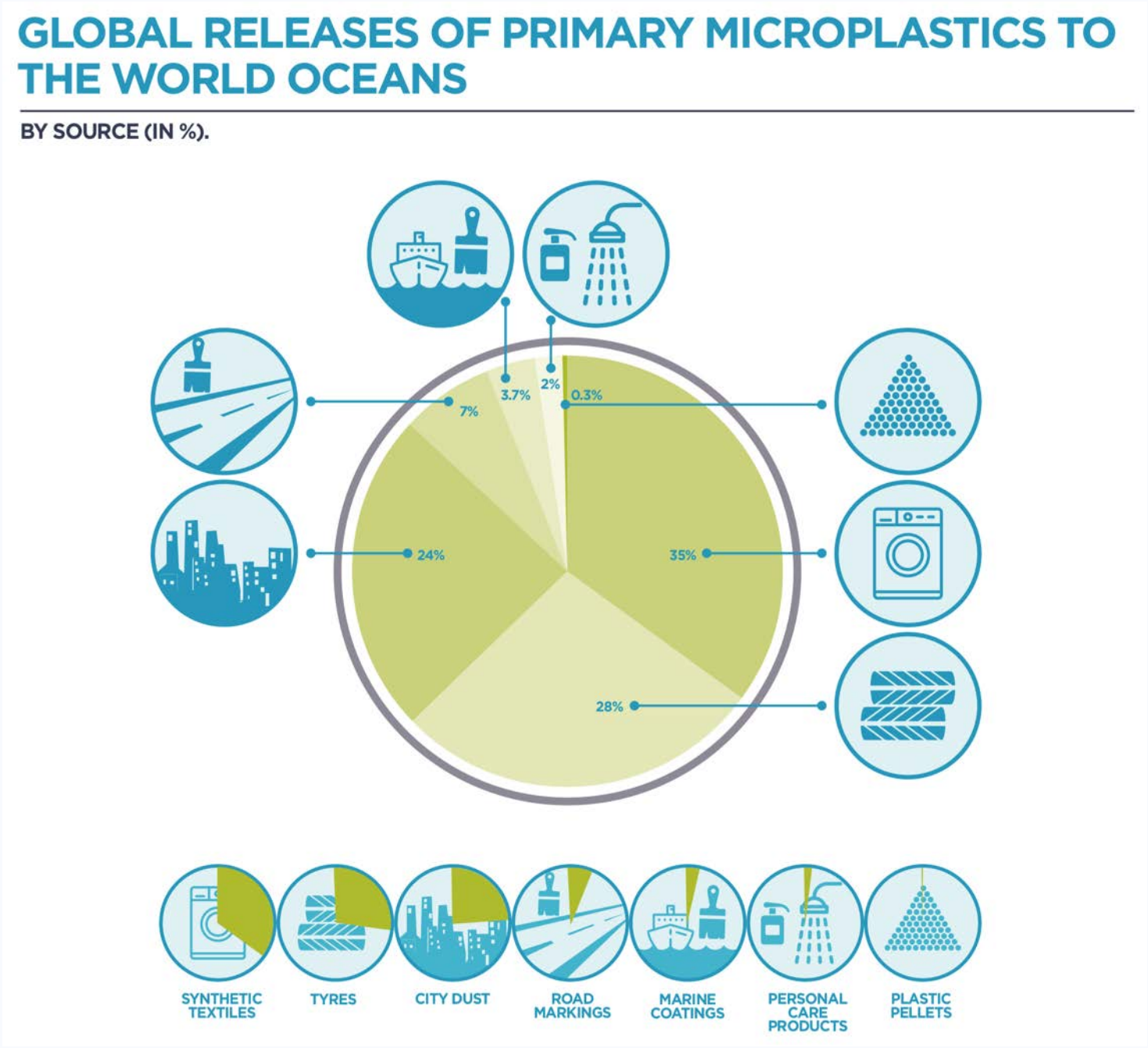
1) Manufactured plastics of microscopic size such as microbeads (typically spherical)

2) Industrial pellets that serve as precursors for manufactured plastic products (primary sources)

3) Fragments and fibers of plastics derived from physical, chemical and biological breakdown of larger plastic products (secondary sources)

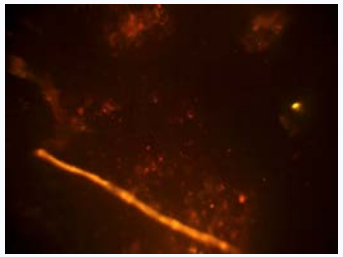


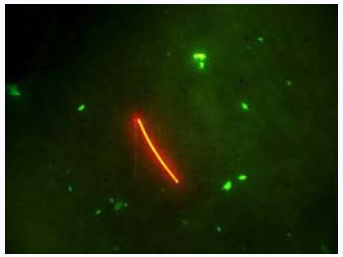


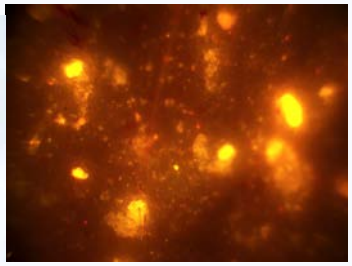


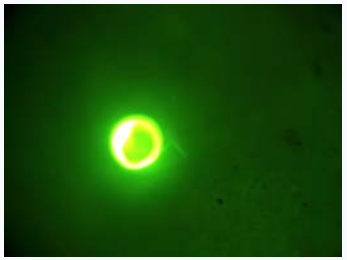
Primary Microplastics in the Oceans, International Union for Conservation of Nature, 2017

Recent MP work in food purchased from local stores – results from Lamont's Secondary School Field Research Program



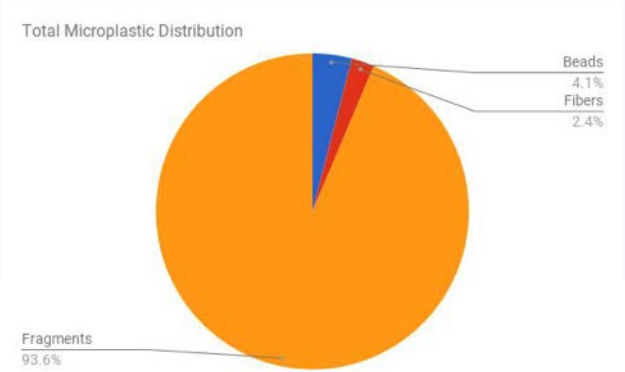




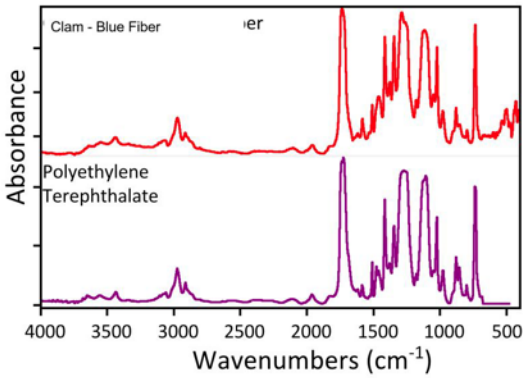


(Courtesy to Debra Magadini and her high school students)

Procedure: digesting, cleaning, staining, then UV and FTIR microscopy observations



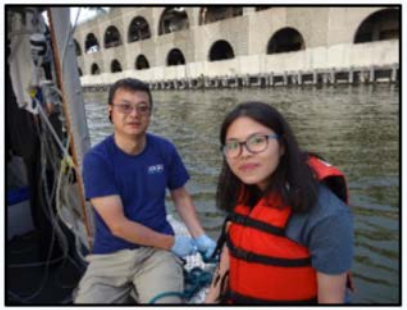
Blue fiber was woven in left over protein residue on filter. Removed and rolled out on Low-e. Identified as polyethylene terephthalate.

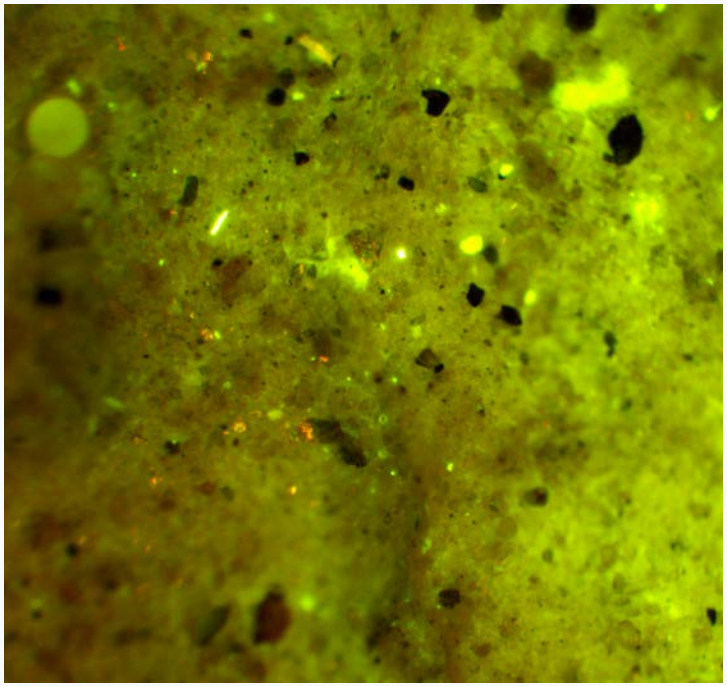


FTIR confirmation

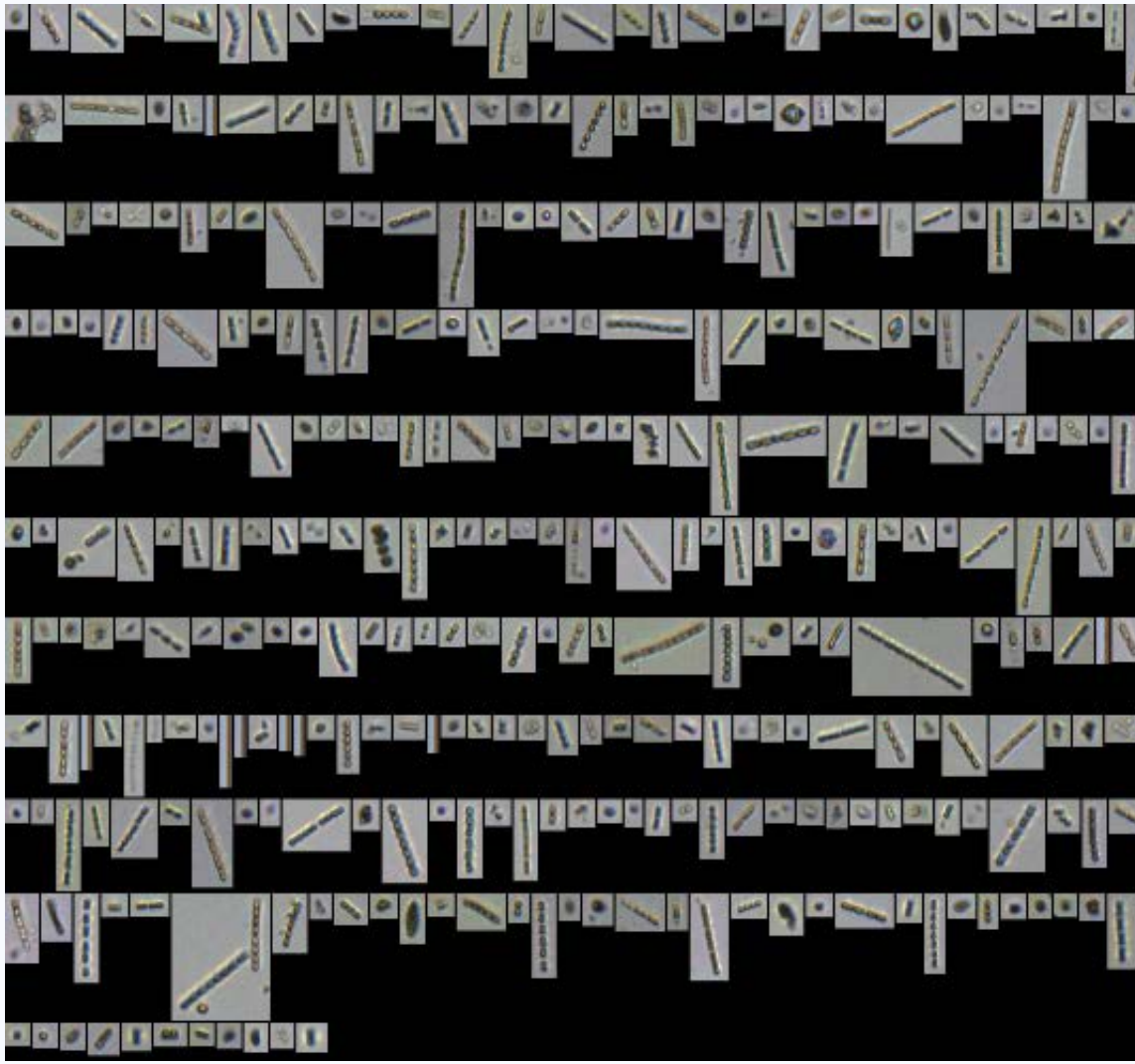
2017 Summer Field trip

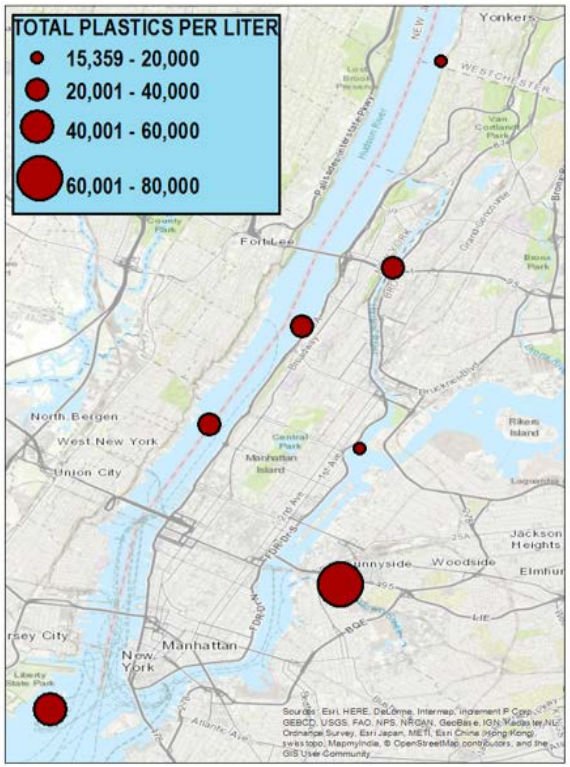
Real-time Flow cytometry
Imaging of particles
in the water



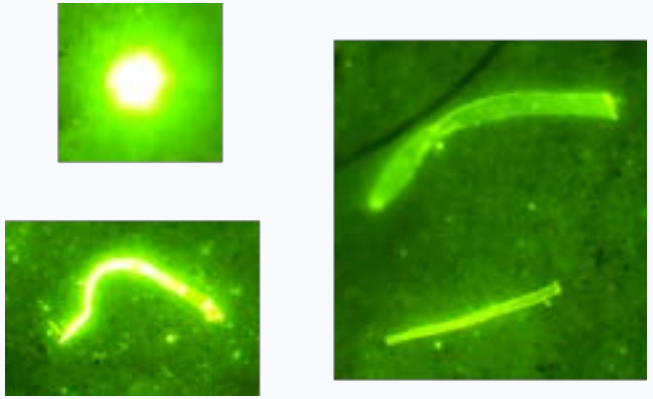


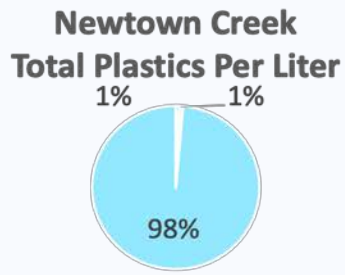
Glowing particles in this microscope image are plastics; spherical ones like the one at upper left are plastic microbeads.

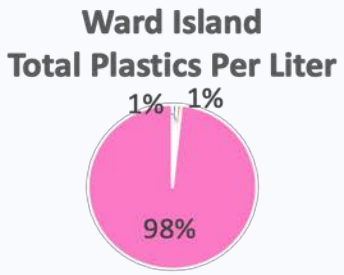


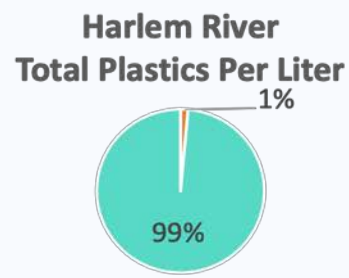


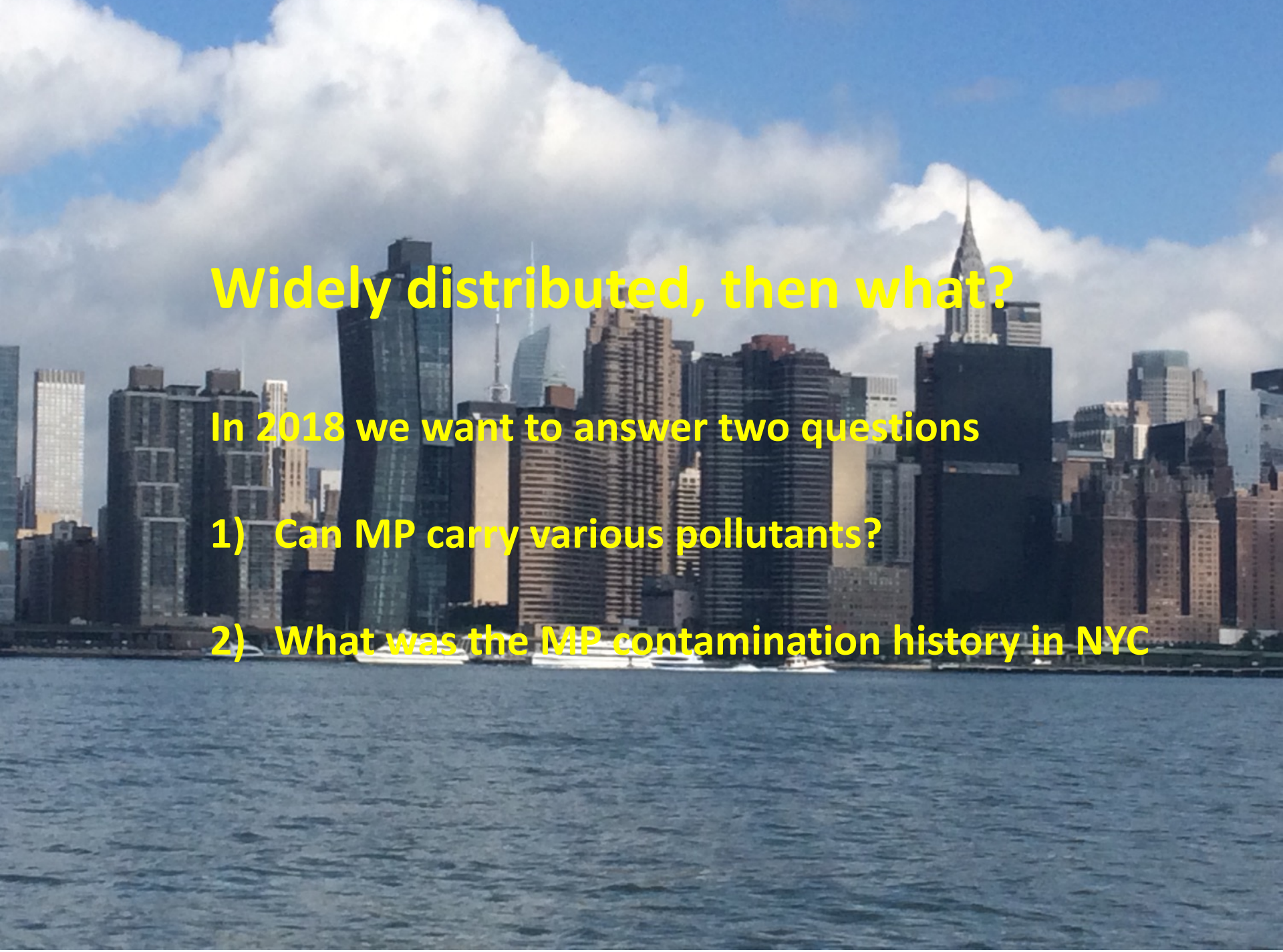
Stained MP particles or fibers











Widely distributed, then what?

In 2018 we want to answer two questions

1) **Can MP carry various pollutants?**

2) **What was the MP contamination history in NYC**

Can MP carry pollutants?

No practical methods to collect MP in water and then measure adsorbed pollutants

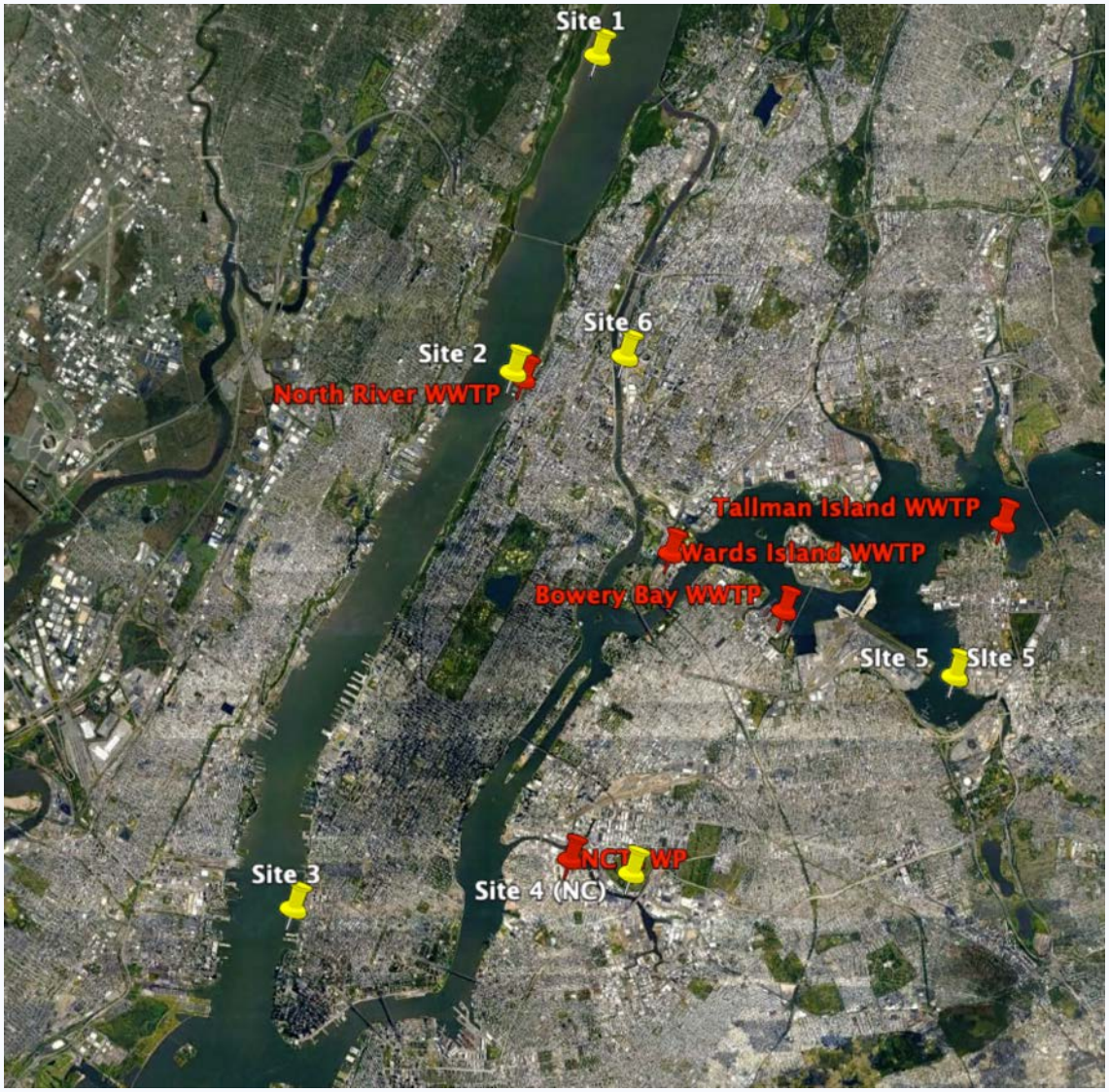
1) Because of relative low concentration of pollutants onto surface, grams of MP need to collect from waters, which needs to filter more than 10 m^3 of water

2) Difficulty to separate MP while not interfering adsorbed pollutants.

Our solution is use the in-situ experiments: Providing MP particles (9-10 types) , then measure adsorbed pollutants

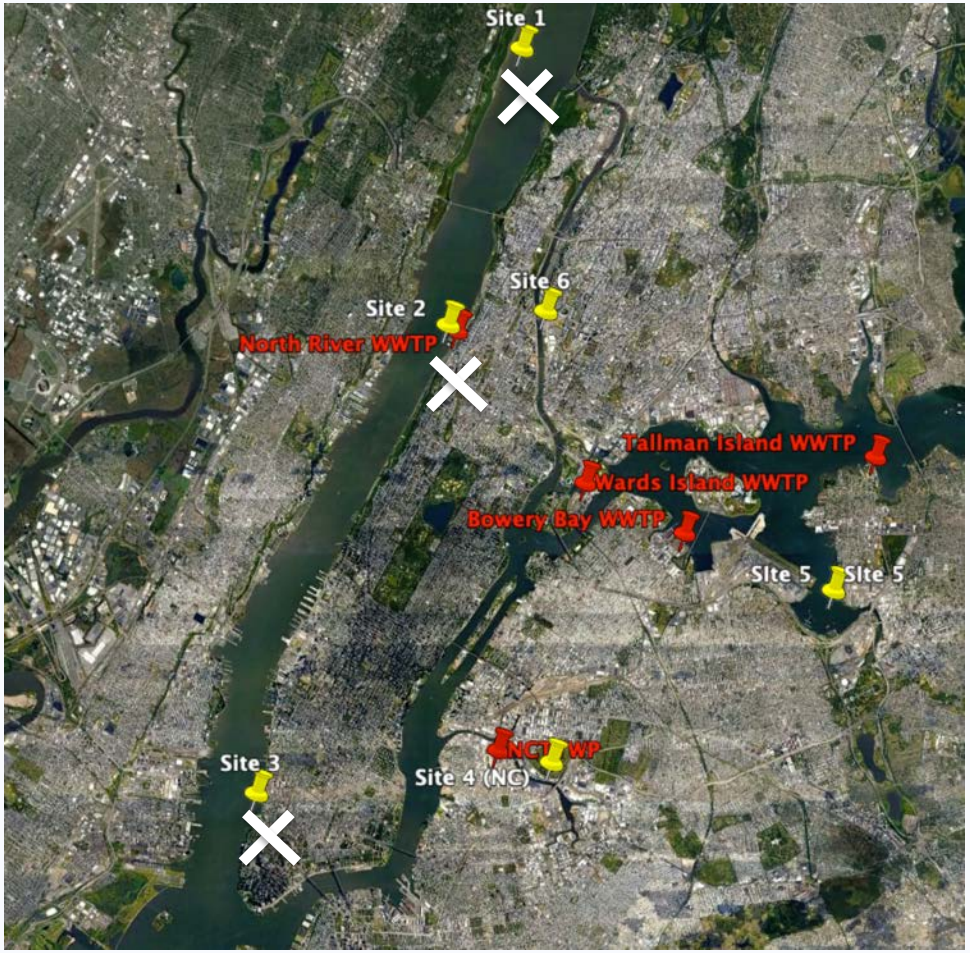
PETE: Polyethylene Terephthalate,
HDPE: High-Density Polyethylene,
PVC: Polyvinyl Chloride,
LDPE: Low-Density Polyethylene,
PP: Polypropylene,
PF: Plastic Fragments,
PS: Polystyrene,
GB: Glass Beads,
PST: Plastic Straws,
PB: Plastic Bags.

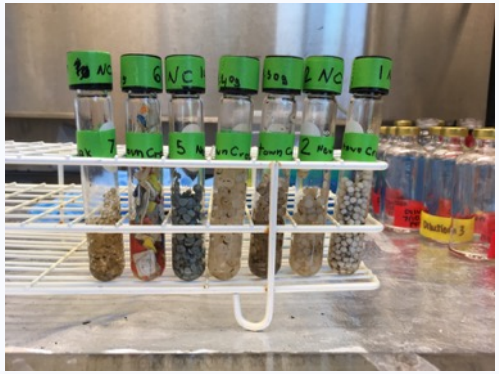
This project aims to quantify the sorption of three different pharmaceuticals to 9 different types of plastics in the waterways of New York City

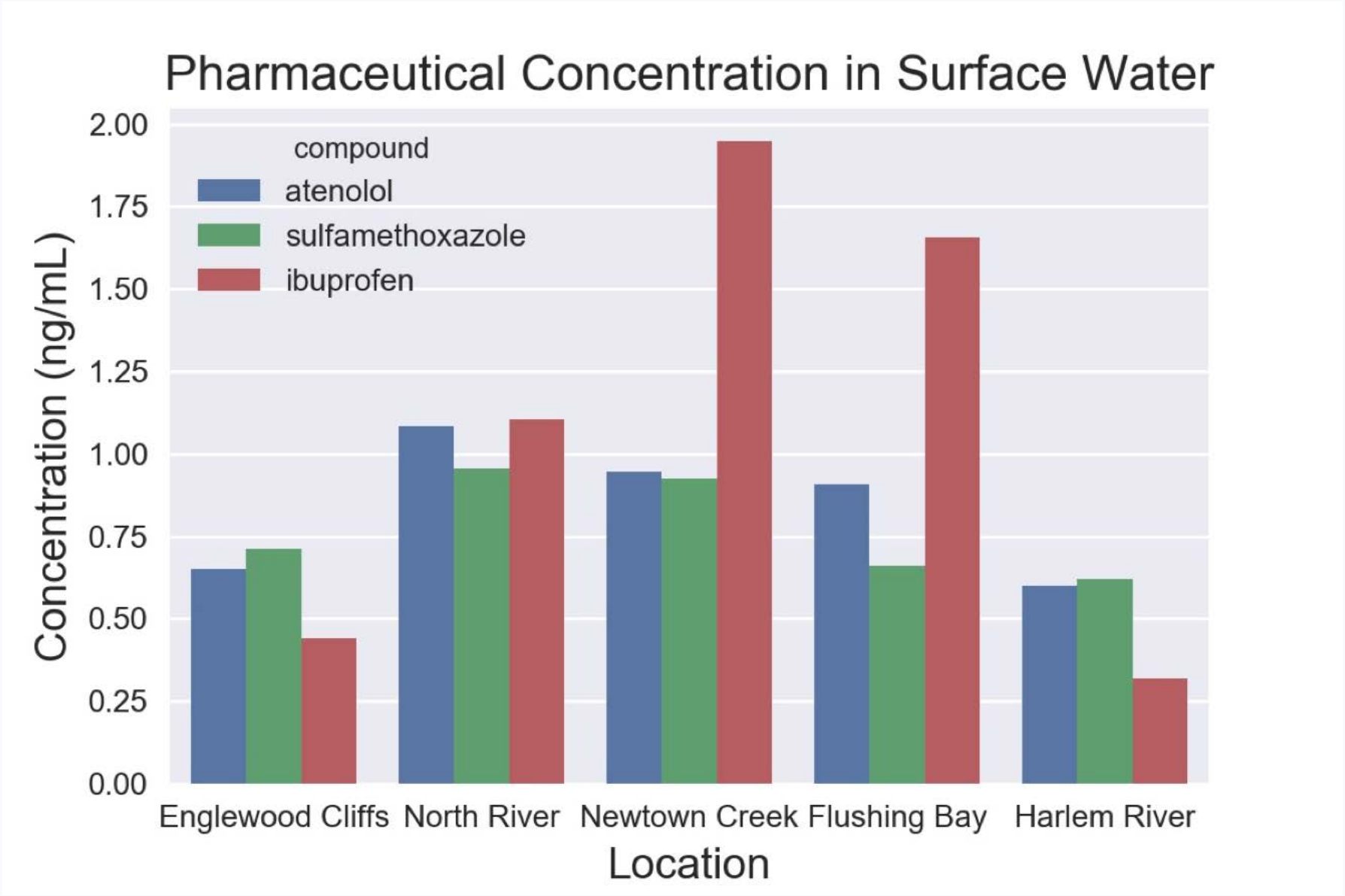


Six sites:
Englewood Cliff,
The North River WWTP
Pier 25, Newtown Creek
Flushing Bay, Harlem River

Three weeks later

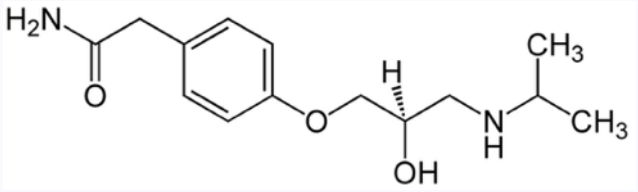






Sciex Qtrap 6500+ used for Pharmaceutical analysis

Partitioning coefficients (solid-water phases)



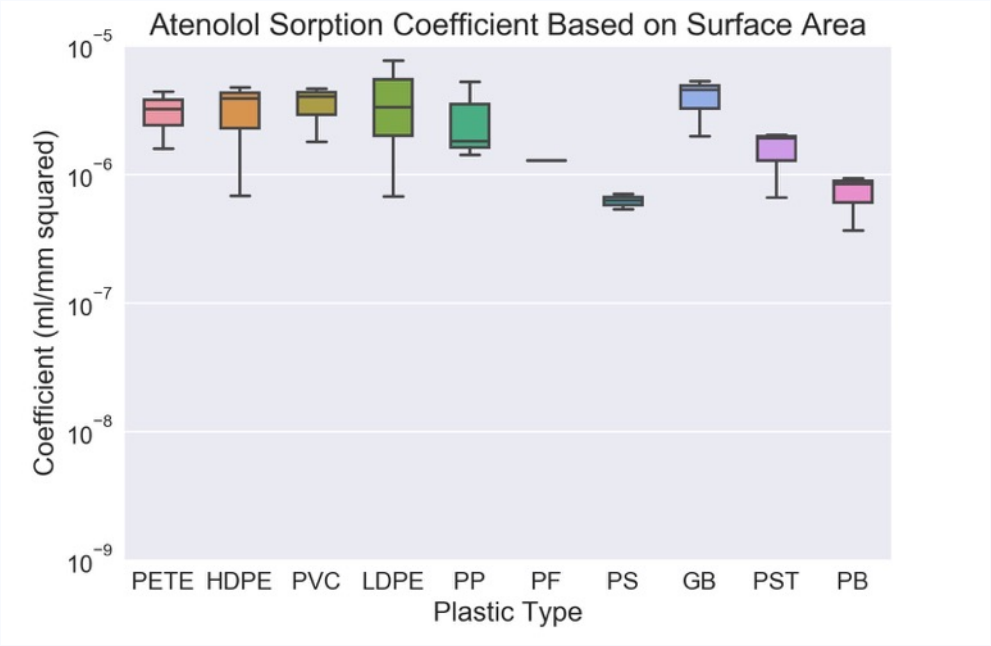
26.7mg per mL

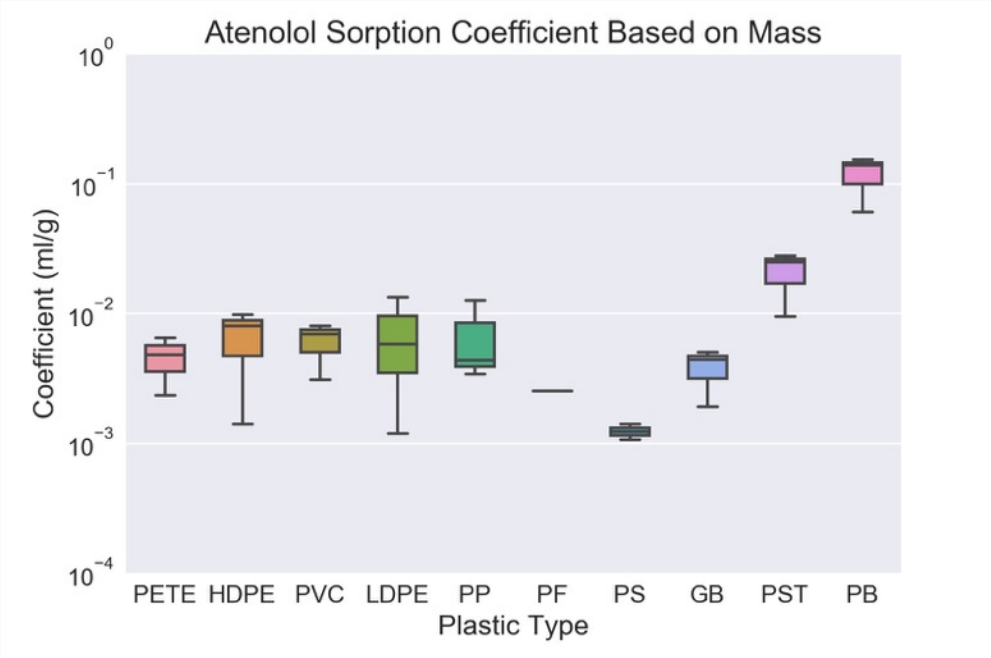
Sorption Coefficient Equation:

$$\mathbf{Kd_{SA}} = \frac{\text{Conc. on MP surface (ng/mm}^2\text{)}}{\text{Conc. In water (ng/mL)}}$$

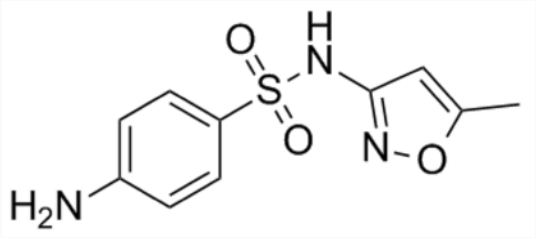
$$\mathbf{Kd_{MASS}} = \frac{\text{Conc. on MP (ng/g)}}{\text{Conc. In water (ng/mL)}}$$

PETE: Polyethylene Terephthalate,
HDPE: High-Density Polyethylene,
PVC: Polyvinyl Chloride,
LDPE: Low-Density Polyethylene,
PP: Polypropylene, PF: Plastic Fragments,
PS: Polystyrene, ***GB: Glass Beads,***
PST: Plastic Straws, PB: Plastic Bags.

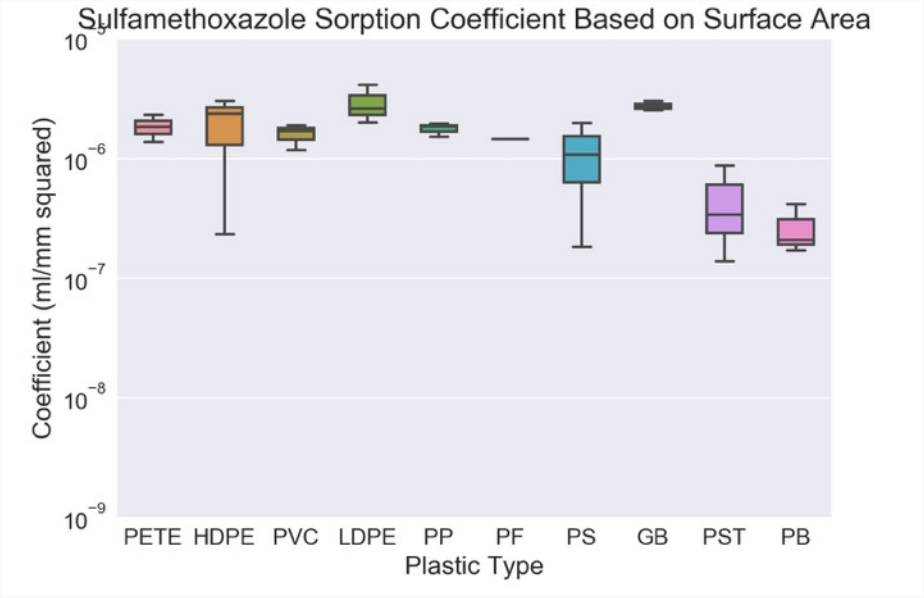




Sulfamethoxazole



Solubility ~0.5 g/L



Used to treat a wide variety of bacterial infections (such as middle ear, urine, respiratory, and intestinal infections)

The means and standard deviations of the sorption coefficients for atenolol based on surface area for 10 different plastics at three different sites.
PETE: Polyethylene Terephthalate,
HDPE: High-Density Polyethylene,
PVC: Polyvinyl Chloride,
LDPE: Low-Density Polyethylene,
PP: Polypropylene,
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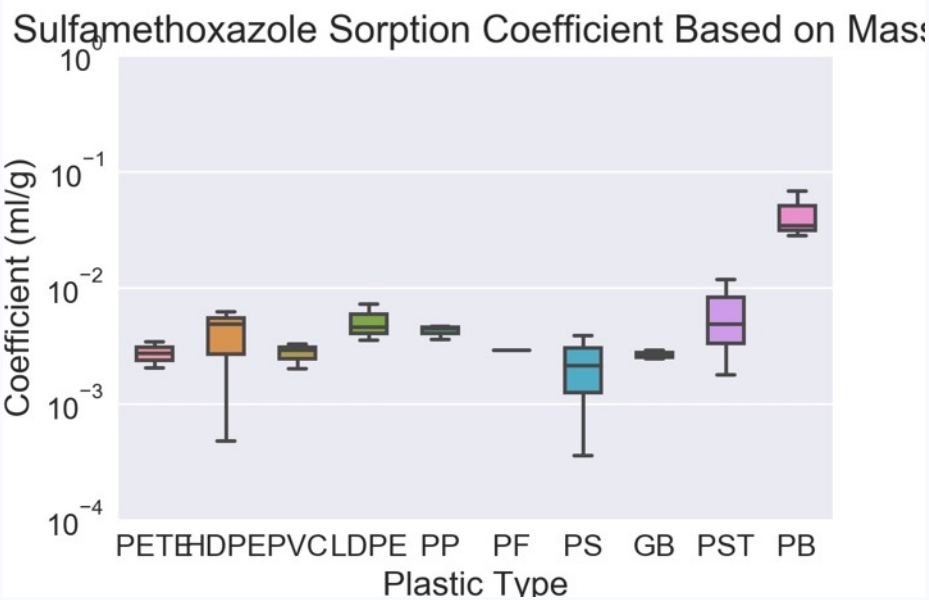
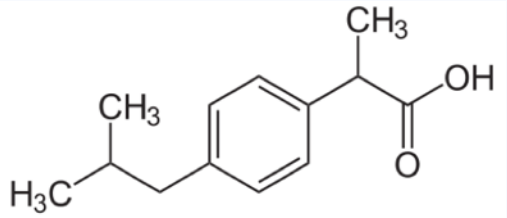


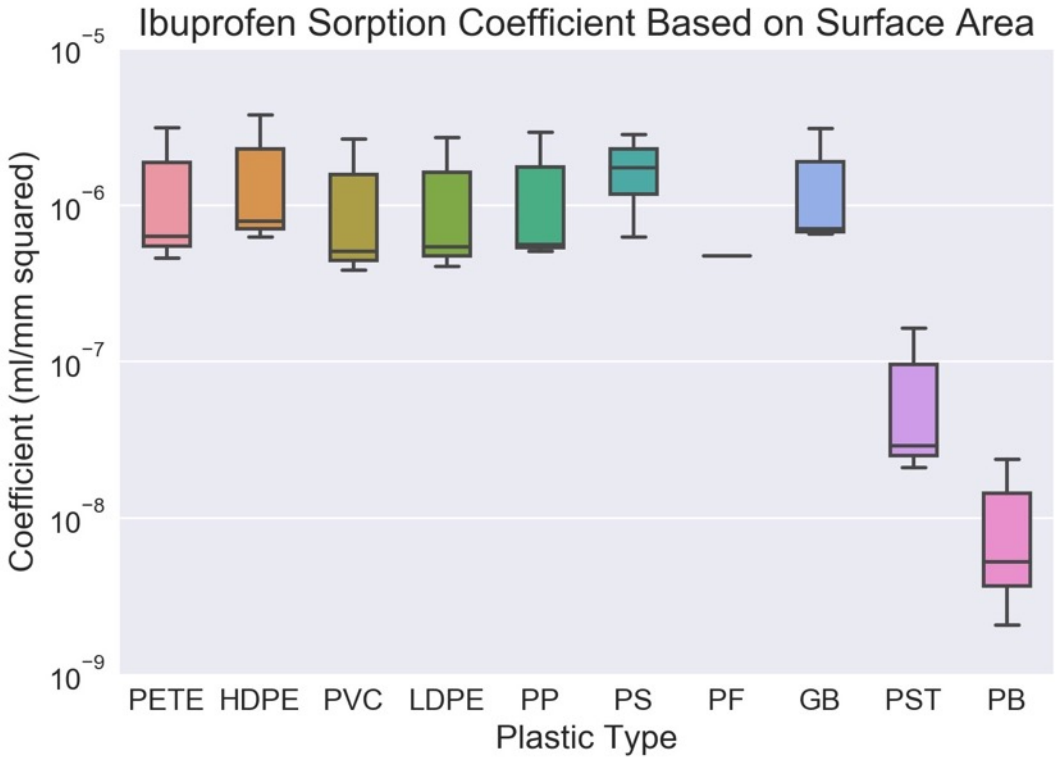
Ibuprofen



Ibuprofen treats minor aches and pains caused by the common cold, headaches, toothaches, back or muscle aches, etc.

Insoluble in water –
desorption –adsorption difficult

Active surface area of PST and Plastic bags are overestimated
-plastic sheets clumped together in the water (less surface area).



MP contamination History in NYC

- Prior work indicated that metals CP Lake sediments (collected in 1996) largely reflect atmospheric deposition from the late 1860s

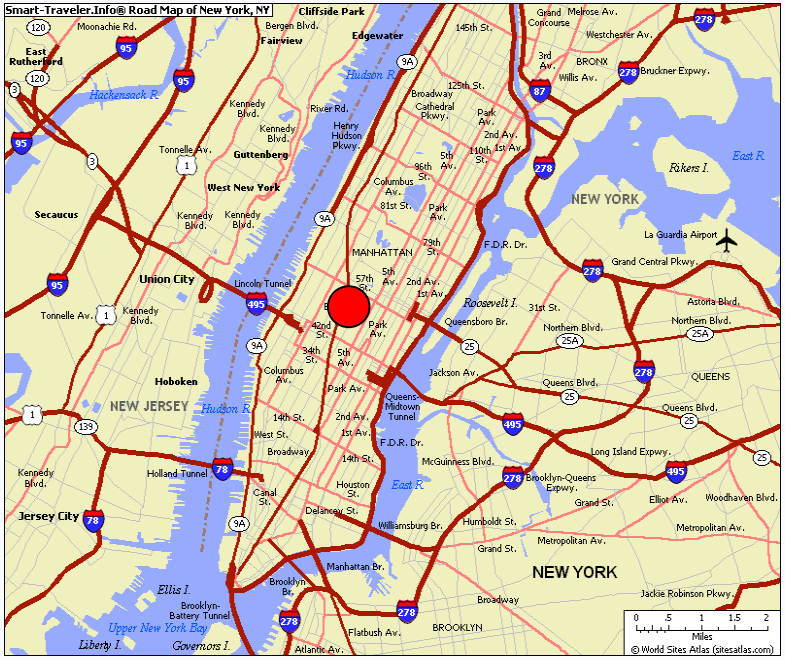
- Known history of plastic usage in NYC
  a) In 1958, plastic bags began to use
  b) In 1969, NYC promoted plastic trash bags for curbside pickup.
  c) By 1996, 4/5 grocery bags used were made from plastic.

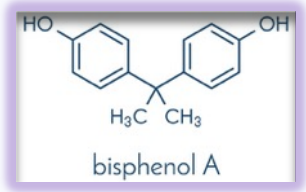
- Airborne MP particles (< 10 μm) may be too small for Raman and FTIR, thus we selected BPA as a surrogate.

- BPA has been used commercially since 1957

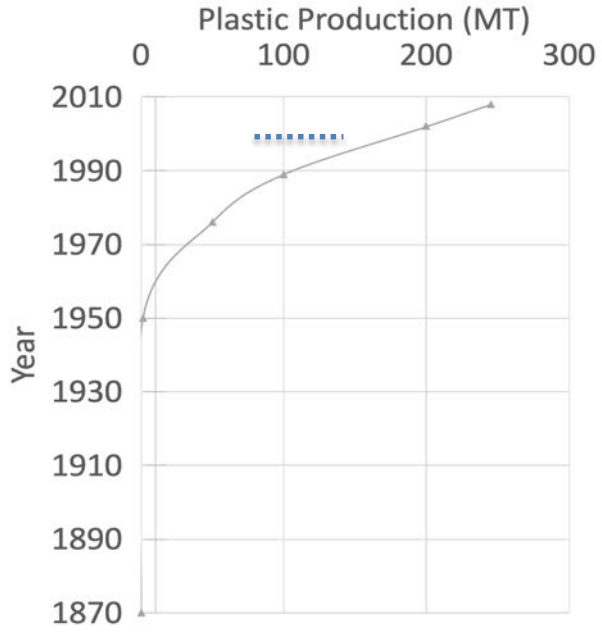
- BPA, because it is an endocrine disrupted chemical, was banned in baby bottles and infant formula packaging around 2008.

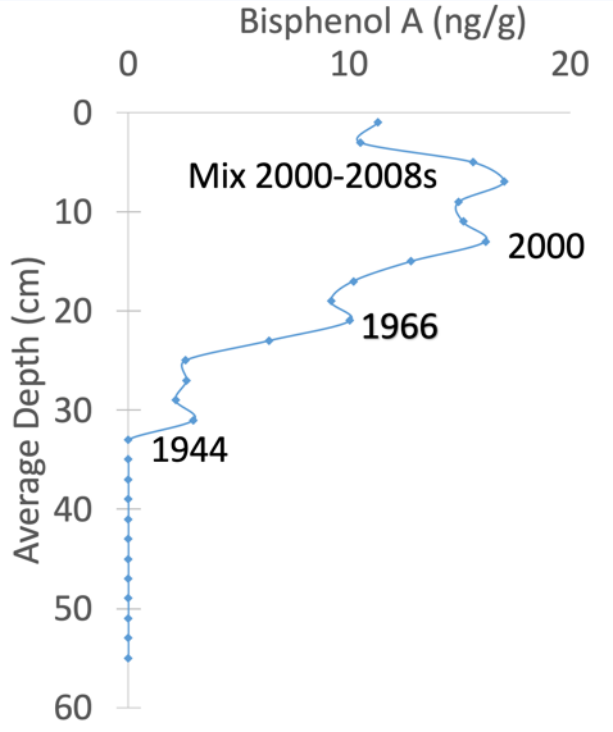
- In 2015, an estimated 4 million metric tons of BPA were produced for manufacturing plastic,

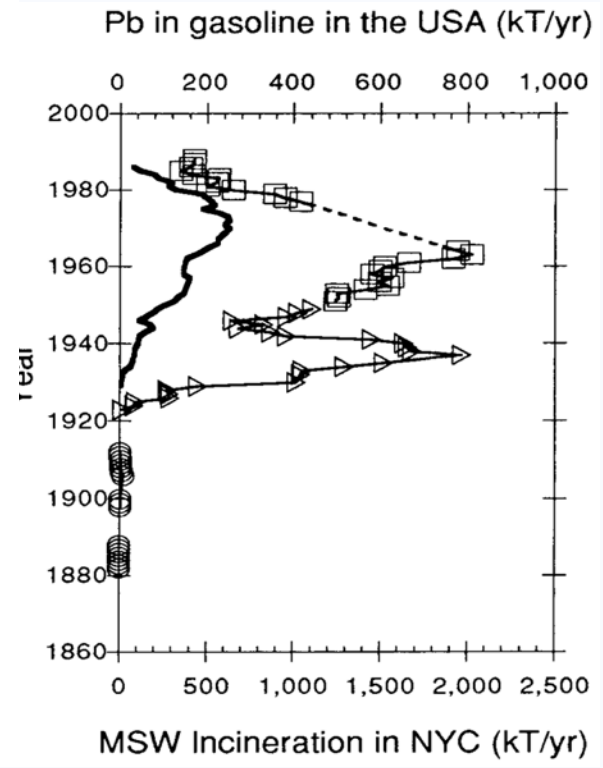




The MP occurrence in NYC since 1950s







Summary

- Widespread distribution of MP in NYC water – needs for control and removal efforts
- Pharmaceuticals were present in surface water at all five sites sampled
- High levels of pharmaceuticals in surface water at Newtown Creek were likely due to discharge of wastewater treatment plants and CSO in those areas
- Plastic bags and plastic straws had a much higher sorption coefficient based on mass
- Plastic pellets all had similar sorption coefficients indicating that plastic type does not play as large a role in sorption as surface area to mass ratio
- This study provides evidence that plastics can serve as vectors for transport of pharmaceuticals and in the long run be detrimental to the environment, marine life and human
- The trend of BPA in CP Lake (through atmospheric delivery) with plastic is consistent with that of plastic production, indicating that MP can enter the air and affect health through inhalation.

Acknowledgement

John Lipscomb from Hudson Riverkeeper

Debra Magadini

Dr. Joaquim Goes

Masha Pitiranggon (now at NYDOH)

2017 and 2108 Summer Interns

NSF and CU Earth Institute Summer Intern Programs and NIEHS Environmental Health Center for Northern Manhattan