Penny providing scale for size of microplastics found in the Great Lakes. Photo Credit: 5Gyres.

PRESENTATION FLOW

- History
- Microplastics characterization
- Context through local research
- Reactions, strategies, BMPs
- Moving forward, next steps

PLASTIC HISTORY

- Plastic "invented" in 1850s in Europe
- By 1860, in U.S.
- 1897 formaldehyde resins
- 1930-1940 PVC, LDPE, polystyrene, *and others*
- End of WW2 "light and durable" plastics are in high demand
  - Tupperware 1946
  - LIFE magazine "Throwaway Living" 1955
- US plastic production has grown 7.7% annually (on-average) since 1940

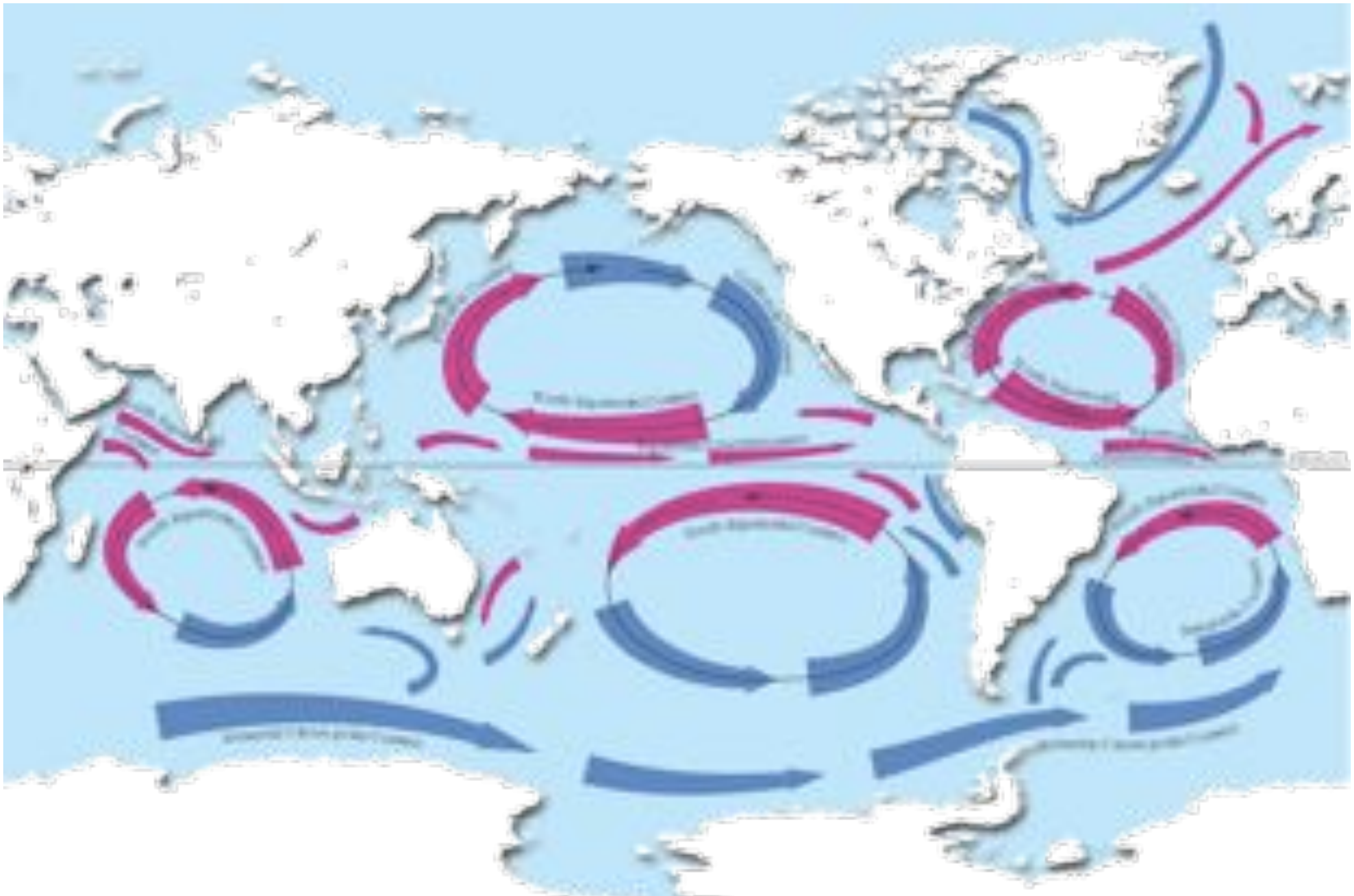
Throwaway Living

DISPOSABLE ITEMS CUT DOWN HOUSEHOLD CHORES


Jambeck et al., Science 2015
270
Global plastic production*
275
Total plastic waste
Plastic waste inputs from land into the ocean in 2010
The 192 countries with a coast bordering Atlantic, Pacific, and Indian oceans, Mediterranean and Black seas produced a total of 2.5 billion metric tons of solid waste. Of that, 275 million metric tons was plastic, and an estimated 8 million metric tons of mismanaged plastic waste entered the ocean in 2010.
99.5
Coastal plastic waste
31.9
Coastal mismanaged plastic waste
12.7
4.8
8
Million metric tons of plastic waste goes into the ocean
6,350-245,000 metric tons**
Estimated mass of plastic waste floating at the ocean surface
Generated by 2 billion people within 50 km (30 miles) of the coast
Mitigation options:
Reduce plastic in waste stream
Improve solid waste management infrastructure
Increase capture

THERMOHALINE CIRCULATION

5 GYRES



MICROPLASTICS?

- Plastic particles are generally defined as smaller than 5mm in size
- Primary: manufactured as a microplastic (beads, pellets, spheres, textiles)
  - Sources: MS4, CSO, WWTP effluent, atmospheric deposition *(29-280 particles/square meter/day)*, overland sludge application, nonpoint
- Secondary: result of larger (meso) plastics breaking-down into smaller fragments
  - Sources: MS4, CSO, nonpoint

Gasperi et al., 2015; Zubris and Richards, 2005

PRIMARY MICROPLASTICS

- Personal care and cosmetic products (PCCPs)
- Textile fibers
- Bead blasting boat hull & engine parts
- Pre-production pellets (nurdles)

POLYMER	EXAMPLES OF FUNCTIONS IN PCCP FORMULATIONS
Nylon-12 (polyamide-12)	Bulking, viscosity controlling, opacifying (eg. wrinkle creams)
Nylon-6	Bulking agent, viscosity controlling
Poly(butylene terephthalate)	Film formation, viscosity controlling
Poly(ethylene isoterephthalate)	Bulking agent
Poly(ethylene terephthalate)	Adhesive, film formation, hair fixative; viscosity controlling, aesthetic agent, (eg. glitters in bubble bath, makeup)
Poly(methyl methylacrylate)	Sorbent for delivery of active ingredients
Poly(pentaerythrityl terephthalate)	Film formation
Poly(propylene terephthalate)	Emulsion stabilising, skin conditioning
Polyethylene	Abrasive, film forming, viscosity controlling, binder for powders
Polypropylene	Bulking agent, viscosity increasing agent
Polystyrene	Film formation
Polytetrafluoroethylene (Teflon)	Bulking agent, slip modifier, binding agent, skin conditioner
Polyurethane	Film formation (eg. facial masks, sunscreen, mascara)
Polyacrylate	Viscosity controlling
Acrylates copolymer	Binder, hair fixative, film formation, suspending agent
Allyl stearate/vinyl acetate copolymers	Film formation, hair fixative
Ethylene/propylene/styrene copolymer	Viscosity controlling
Ethylene/methylacrylate copolymer	Film formation
Ethylene/acrylate copolymer	Film formation in waterproof sunscreen, gellant (eg. lipstick, stick products, hand creams)
Butylene/ethylene/styrene copolymer	Viscosity controlling
Styrene acrylates copolymer	Aesthetic, coloured microspheres (eg. makeup)
Trimethylsiloxysilicate (silicone resin)	Film formation (eg. colour cosmetics, skin care, sun care)

Deodorants
Shampoos
Conditioners
Shower gels
Lipsticks
Hair colorings
Shaving creams
Sunscreens
Insect repellants
Anti-wrinkle creams
Moisturizers
Hair sprays
Facial masks
Baby care products
Eye shadow
Mascara

1-90% of total product!

UNEP, 2015

PARTICLE	SIZE RANGE
Microbead	$1 - 1000 \times 10^{-6}$ m
Microspheres	$1 - 1000 \times 10^{-6}$ m
Microcapsule	$1 - 2 \times 10^{-6}$ m
Nanospheres/capsules	$10 - 1000 \times 10^{-9}$ m

The Bioré and Clearasil products shown were filtered in a laboratory to determine the presence of microbeads. The products contained plastic microbeads in different quantities and of different sizes, shapes and colors, as shown by the vial of microbeads to the left of each product.

(Photo credit: State of New York, Office of the Attorney General)

Various personal care products and over the counter drugs listing "polyethylene" or "polypropylene" as an ingredient contain plastic microbeads of different sizes, shapes, colors, and quantities. Johnson & Johnson, the maker of the Neutrogena product pictured, has voluntarily committed to phasing out plastic microbeads as an ingredient in its products.

(Photo credit: 5 Gyres)

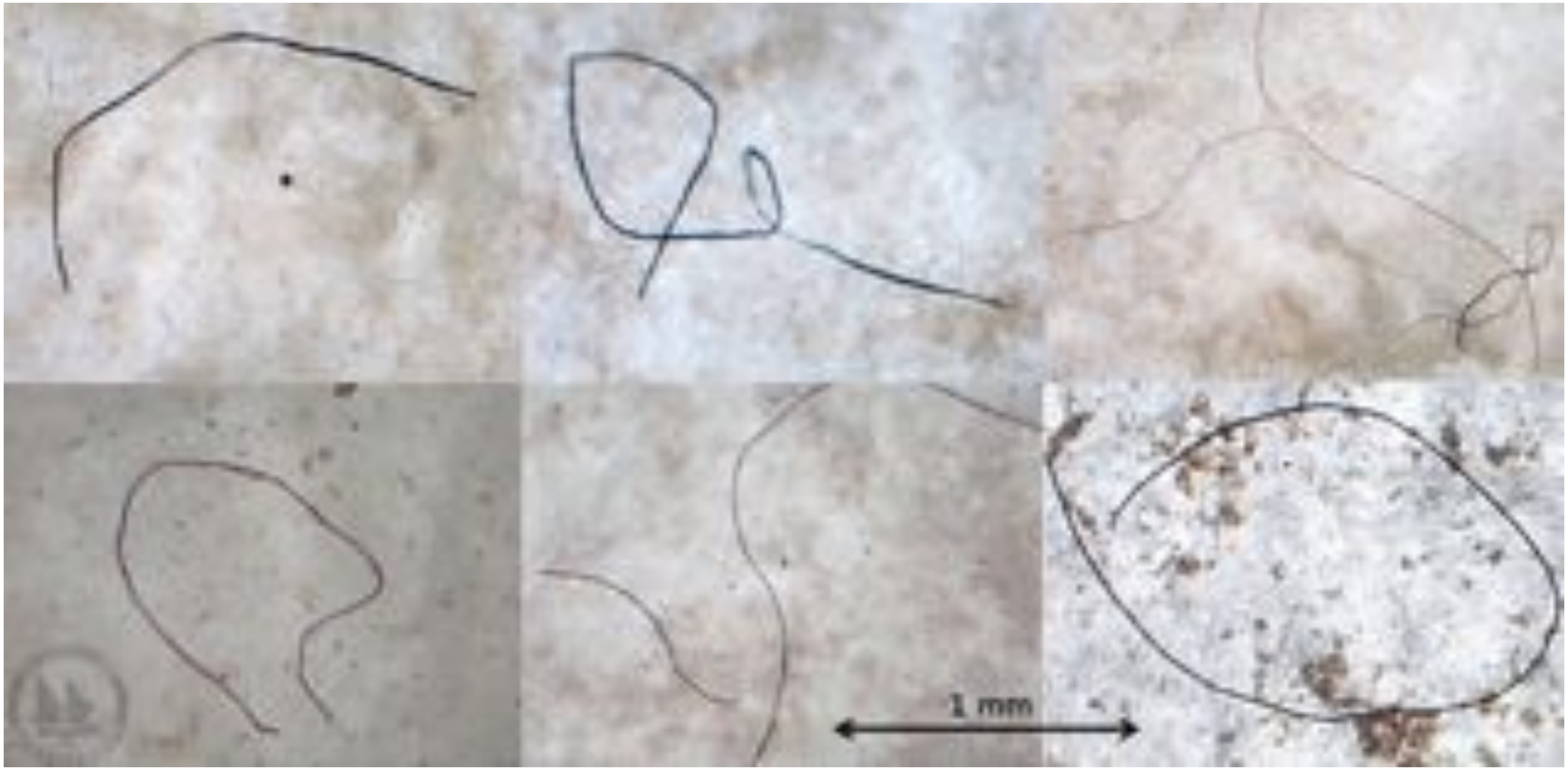


Photo Credit: Institute of Marine & Environmental Research of Aegean Sea

- Per Bowne et al., 2011:
  - **Domestic washing machine effluent can produce > 1900 fibers per wash**
  - Polyester, acrylic, polypropylene, and polyamide all found in WWTP effluent

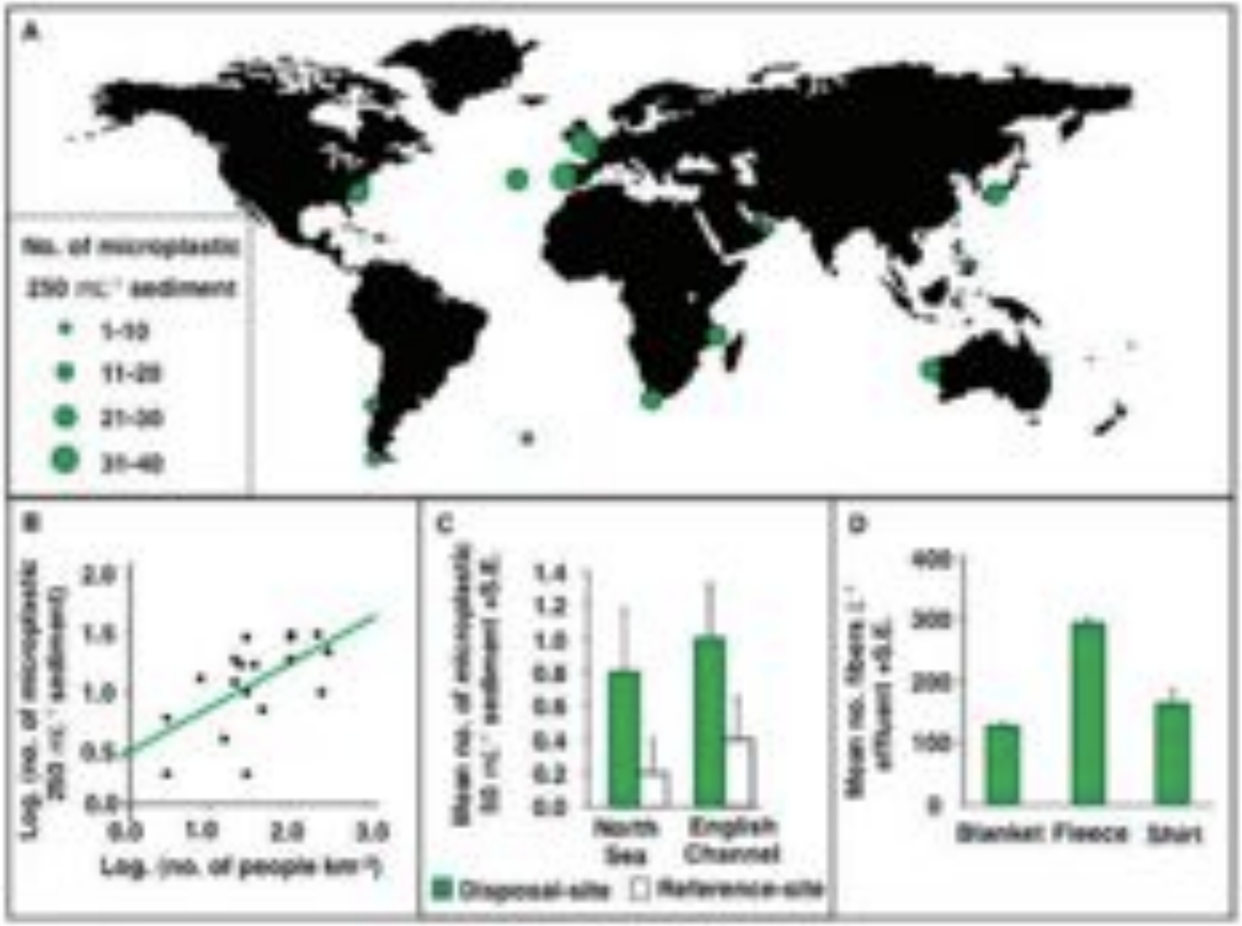


Figure 2. (A) Global extent of microplastic in sediments from 18 sandy shores and identified as plastic by Fourier transform infrared spectrometry. The size of filled-circles represents number of microplastic particles found. (B) Relationship between population-density and number of microplastic particles in sediment from sandy beaches. (C) Number of particles of microplastic in sediments from sewage disposal-sites and reference-sites at two locations in U.K. (D) Number of polyester fibers discharged into wastewater from using washing-machines with blankets, fleeces, and shirts (all polyester).

Photo Credit: Dynamic Co.

Photo Credit: Premier Logistics Solutions

SECONDARY MICROPLASTICS

MESO -> MICRO

Dutch Kills Photo Credit: queens.brownstoner.com

Dutch Kills Photo Credit: queens.brownstoner.com

Photo Credit: Wikipedia

ENVIRONMENTAL IMPACT

- Toxins migration
  - Source and sink (EPA)
- Species ingestion
  - Over 600 species (microorganisms to whales) have ingested aquatic plastic pollution (UN)
    - Newest: phytoplankton species and corals
  - Last month, UC Davis study 25% fish for human consumption w/ plastic in gut
  - Toxins desorb into species; bioaccumulation and biomagnification up the food chain
  - Blockage (corals)
- Invasive species migration (Woods Hole)
- Misc. & Bizarre: milk, sugar, honey, beer (Liebezeit et al., 2013)
- Plastic degradation physical, not chemical; 500-1,000yrs

ADSORPTION/DESORPTION

PCBs
DDTs
PAHs
Metals
Pathogens
Opportunistic/Invasive Species

RELEASE

Flame Retardants
Antioxidants (BPA)
Plasticizers (phthalates)
Anti-microbials (triclosan)
Styrenes
Alkyl Phenols

Nurdle. Photo Credit: Dr. Yonkos, Department of Environmental Sci & Tech, Univ Maryland

Barnes et al. 2009; Browne et al. 2007; Mato et al. 2001; Teuten et al. 2009; Lavers et al. 2014; Betts 2008; McCormick et al. 2014

Jambeck et al., *Science* 2015
Plastic waste inputs from land into the ocean in 2010
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LOCAL MICROPLASTIC STUDIES

GREAT LAKES STUDY #1

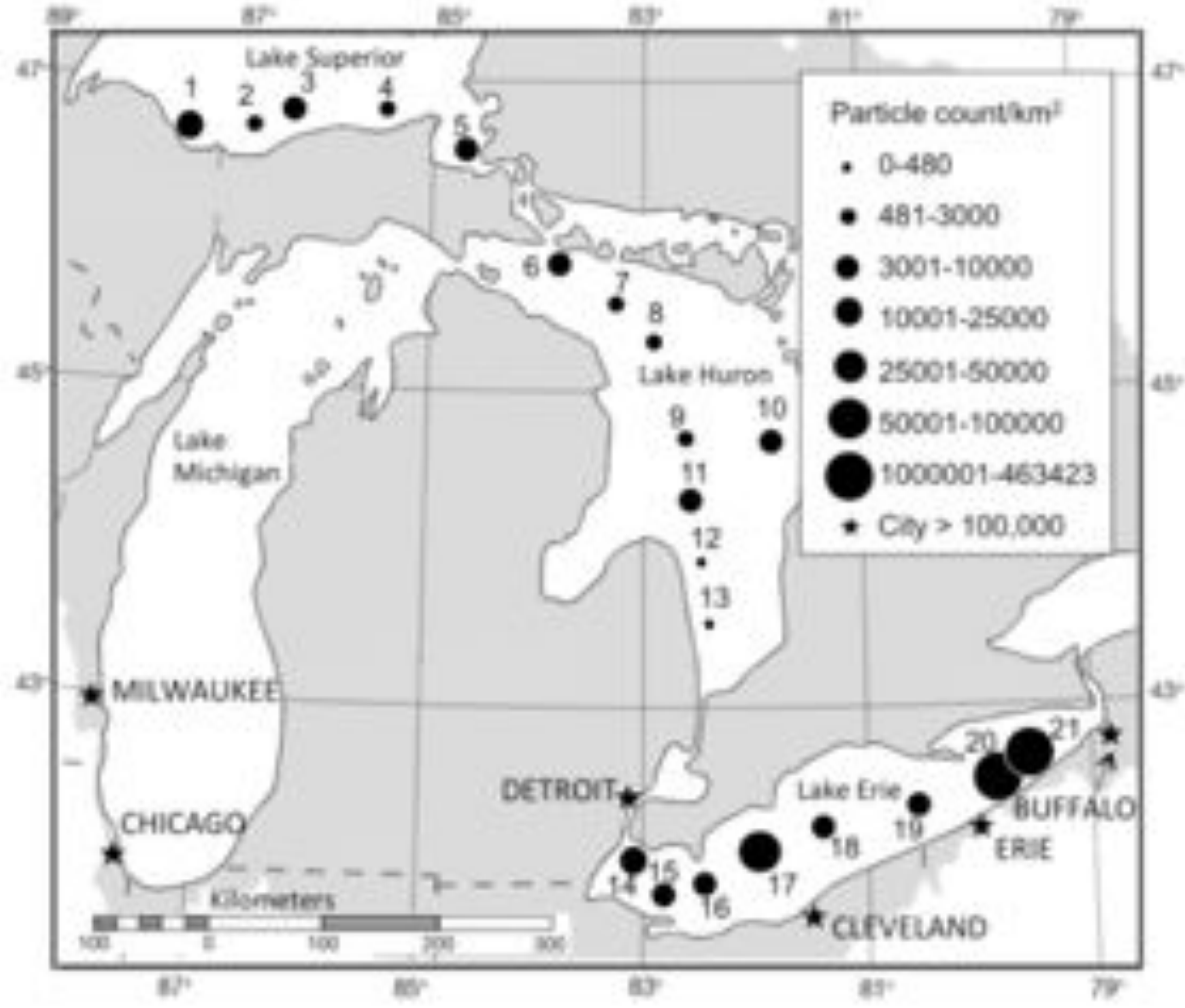
- SUNY Fredonia & 5gyres (Sherri Mason, Marc Eriksen, et al.)
- 2012 sampling conducted
- 2013 published
- 21 sites sampled with 333-micron manta trawl
  - All but one included microplastics
- Samples analyzed with scanning electron microscopy
- Max of 466,30 particles per square km
- Average of 43,000 particles per square meter
- Most smaller than 1 mm, and spherical

GREAT LAKES STUDY #1

GREAT LAKES STUDY #1

- Rectangular opening 16cm high, and 61cm wide
- 3m long 333-micron net
- 2 knot tow speed
- 60min sampling

GREAT LAKES STUDY #1



GREAT LAKES STUDY #1

Table 1
Count, location and abundance of plastic pollution from 21 stations in three of the Laurentian Great Lakes.

Count, location and abundance of plastic pollution in the Great Lakes

Sample id.	Latitude	Longitude	Count total	Tow length (km)	Abundance (count/km^2)
Lake Superior					
1	46.5737	−87.3413	15	1.94	12,645
2	46.6872	−86.6645	8	3.70	3541
3	46.7772	−86.4405	3	3.85	1277
4	46.8487	−85.2473	6	3.76	2616
5	46.5860	−84.7222	16	3.82	6875
Lake Huron					
6	45.8682	−83.7218	11	3.80	4750
7	45.6372	−83.3776	3	4.00	1229
8	45.3463	−83.0087	4	3.87	1694
9	44.7287	−82.5359	5	3.70	2213
10	44.7676	−81.9475	15	3.76	6541
11	44.3480	−82.1563	13	3.88	5192
12	43.9240	−82.5130	1	3.59	456
13	43.4134	−82.3954	0	3.83	0
Lake Erie					
14	41.8979	−83.0408	26	3.78	11,282
15	41.7523	−82.9410	9	3.15	4686
16	41.7830	−82.7569	20	3.85	8511
17	41.8953	−82.3409	131	3.76	57,122
18	42.1425	−81.5131	13	3.52	6056
19	42.2441	−80.7501	21	3.78	9112
20	42.3938	−79.9536	1101	3.87	466305
21	42.3000	−80.0210	657	3.83	280947

GREAT LAKES STUDY #1

Table 2
Abundance and type of particles in three size classes.

	Abundance of plastic particles (count/km^2) by type and size		
	0.355–0.999 mm	1.000–4.749 mm	>4.75 mm
Fragment	247,106.5	123,906.2	11,219.8
Film	3943.5	1332.2	4006.1
Foam	54,340.9	18,208.4	1810.5
Pellet	430,029.8	5614.1	420.9
Line	1328.9	2571.9	449.0
Count/km^2	736,749.6	151,632.9	17,906.3
% Of total	81%	17%	2%

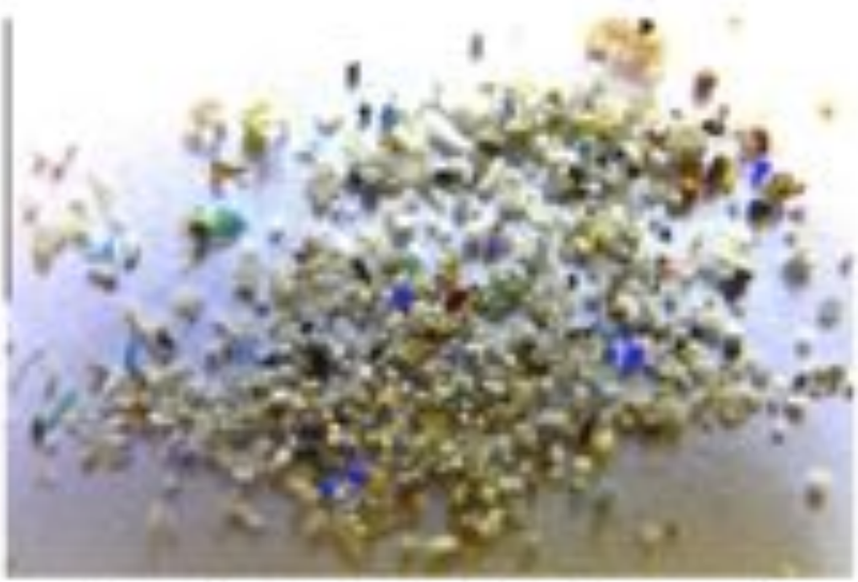
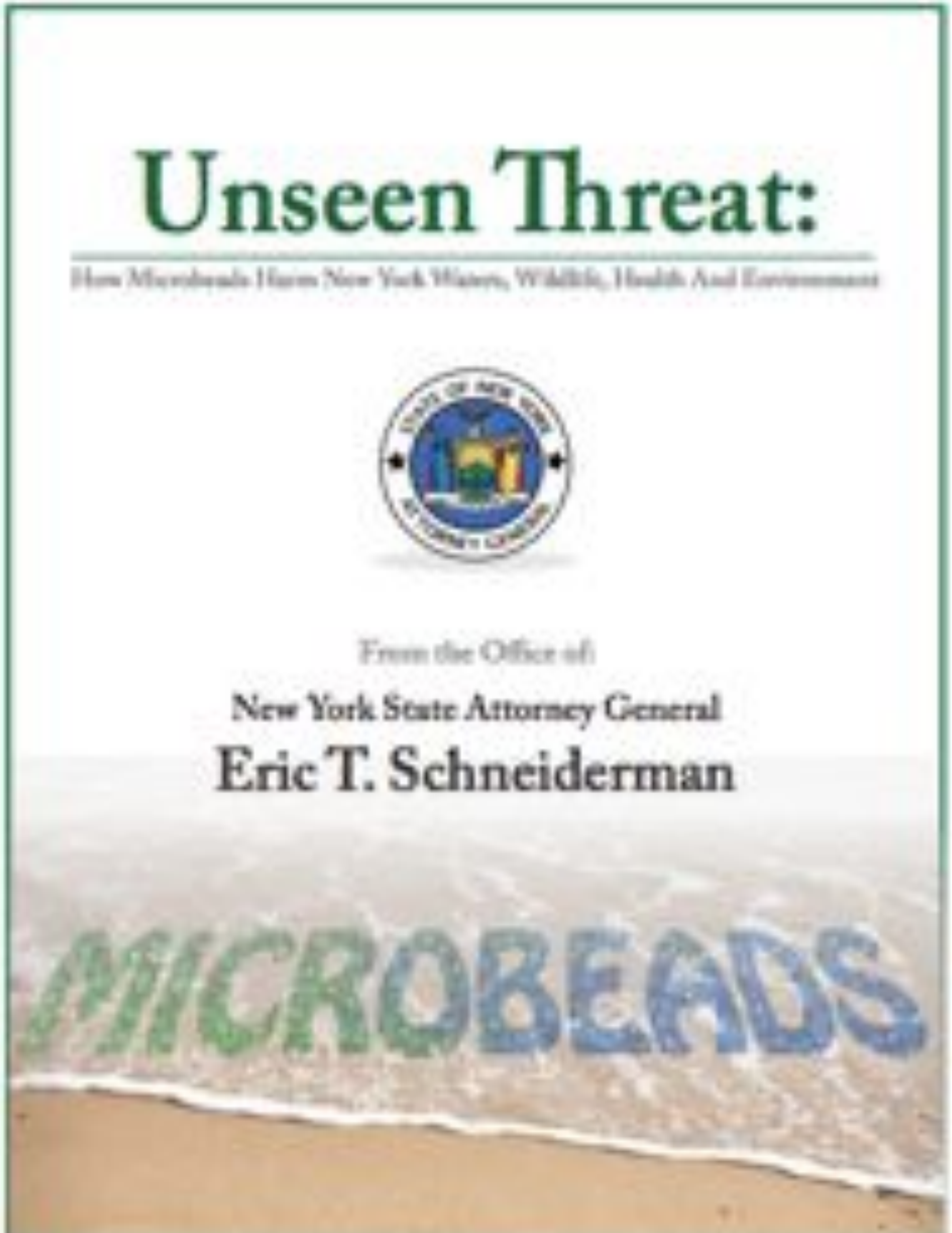


Fig. 3. Color variation among particles >1 mm from Sample 21.

GREAT LAKES STUDY #2

- USGS & SUNY Fredonia, 2014
- 29 tributaries to Great Lakes sampled, ~22% of total inflow
- Range of land uses
- 4 samples/site (2x baseflow, 2x stormflow)
- Stationary trawls from bridges with flowmeters
- Prelim findings:
  - 48 samples
  - 12,399 microplastics counted
  - 79% under 1mm, with balance under 4.75mm



Unseen Threat:

How Microbeads Harm New York Waters, Wildlife, Health And Environment

From the Office of:

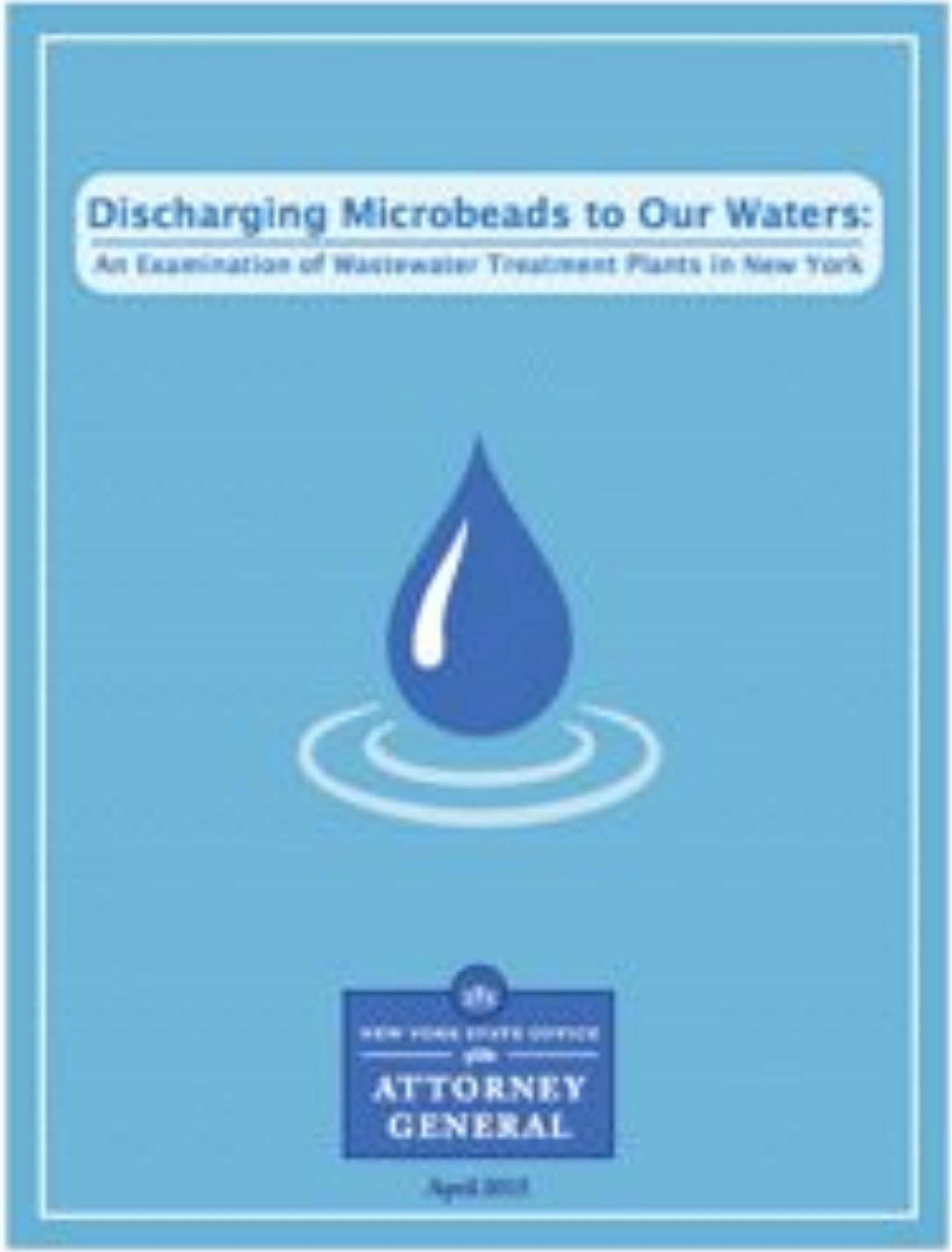
New York State Attorney General

Eric T. Schneiderman

MICROBEADS

“UNSEEN THREAT”

- 2014 report
- Summarized Great Lakes study
- Annual per-capita consumption of microbeads from cosmetics and personal care products in the US is estimated at 0.0309 ounces per person per year.
  - 19.65 million NYS population
  - 19 tons of microplastics discharged to NY’s wastewater stream each year


Discharging Microbeads to Our Waters:
An Examination of Wastewater Treatment Plants in New York
NEW YORK STATE OFFICE
of the
ATTORNEY
GENERAL
April 2015

“DISCHARGING MICROBEADS TO OUR WATERS”

- 2015 study
- OAG, NYWEA and SUNY Fredonia
- 34 WWTPs submitted effluent samples
  - 25 discharging microbeads to receiving waters

PROCESS

Photograph 1
Treatment plant effluent samples undergoing wet peroxide oxidation.
Photo credit: OAG

Photograph 2
A small portion of treatment plant post-treatment effluent is sieved at the facility and sent to SUNY Fredonia for analysis.
Photo credit: OAG

RESULTS

Figure 2: Microbeads from Treatment Plants

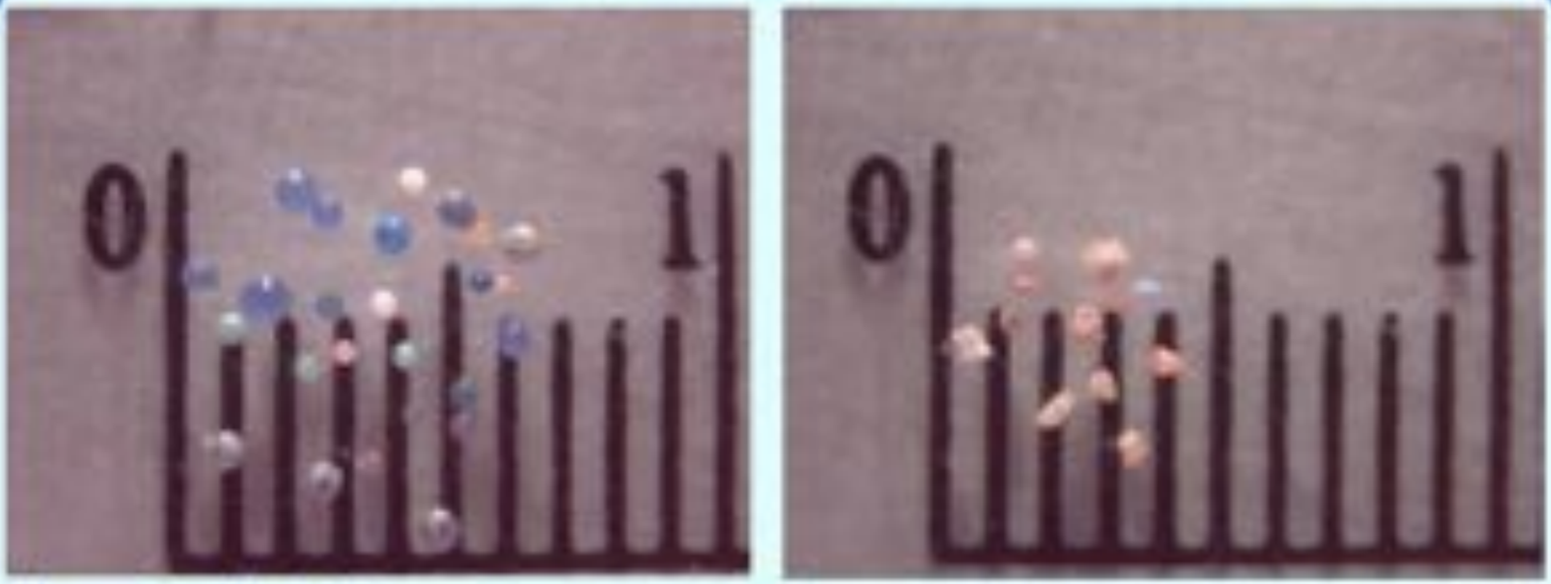


Photo Credit: OAG

Spherical (left) and speckled (right) microbeads were collected from the effluent samples of participating treatment plants and verified as the same size, shape and chemical composition as spherical and speckled microbeads removed from personal care products.

Table 1:
Treatment Plant Results by Size, Microbead Detection and Advanced Treatment Use.

Treatment Plant Design Size (Gallons/day)	Number of Treatment Plants in NYS[8]	Plants Participating in OAG Study	Plants with Microbeads Detected in Effluent	Advanced Filter in Use	Microbeads Detected in Effluent with Advanced Filter in Use
0 - 100,000	178	4	1	2	0
101,000 - 1,000,000	251	9	5	4	1
1,001,000 - 10,000,000	132	13	11	2	1
10,001,000 - 100,000,000	39	7	7	2	2
100,001,000 - 999,000,000	10	1	1	0	0
TOTAL	610	34	25	10	4

Table 2:
Filter treatment units as reported by participants of this study, as listed by categories defined by the NYS DEC report, *Descriptive Date of Municipal Wastewater Treatment Plants.*

Treatment Unit	Plants Sampled in OAG Study and Microbeads Detected	Plants Sampled in OAG Study and Microbeads not Detected
Filtration, unspecified	2	-
Microfiltration (CBUDS)	-	3
Microfiltration (Membrane)	-	2
Rapid Sand (High Rate) Filters	1	1
Continuous Backwash Sand Filter	1	-

Microbeads	Treatment Plant Facility	County	Receiving Waterbody
√	Albany County Sewer District	Albany	Hudson River
√	Mohawk View Water Pollution Control Plant	Albany	Mohawk River
	Village of Endicott Water Pollution Control Plant	Broome	Susquehanna River
√	Village of Silver Creek Treatment Plant	Chautauqua	Lake Erie
√	City of Hudson Wastewater Treatment Plant	Columbia	Hudson River
√	Village of Delhi Wastewater Treatment Plant	Delaware	West Branch of the Delaware River
	Town of Andes Sewer District	Delaware	Tremper Kill
	Village of Walton Sewage Treatment Plant	Delaware	West Branch of the Delaware River
√	Erie County Sewer District No. 3 – Southtowns Advanced Wastewater Treatment Plant	Erie	Lake Erie
√	Town of Grand Island Wastewater Treatment Plant	Erie	Niagara River
√	Erie County Sewer District No. 6 – Lackawanna Wastewater Treatment Plant	Erie	Smokes Creek, tributary to Lake Erie
√	Erie County Sewer District No. 2 – Big Sister Creek Wastewater Treatment Plant	Erie	Big Sister Creek, tributary to Lake Erie
√	Village of Lake Placid Sewage Treatment Plant	Essex	Chubb River, tributary to the Ausable River
√	Town of Westport Wastewater Treatment Plant	Essex	Lake Champlain
	Village of Chateaugay Wastewater Treatment Plant	Franklin	Chateaugay River
	Village of Hunter Wastewater Treatment Plant	Greene	Schoharie Creek
	Town of Windham Wastewater Treatment Plant	Greene	Batavia Kill

√	Village of Athens Wastewater Treatment Plant	Greene	Hudson River
√	Newtown Creek Water Pollution Control Plant	Kings	East River
√	Frank E. VanLare Wastewater Treatment Plant	Monroe	Lake Ontario
√	Northwest Quadrant Wastewater Treatment Plant	Monroe	Lake Ontario
√	Cedar Creek Water Pollution Control Plant	Nassau	Atlantic Ocean
√	Niagara County Sewer District No. 1	Niagara	East Branch of the Niagara River
√	City of Middletown Wastewater Treatment Plant	Orange	Wallkill River
√	Port Jervis Sewage Treatment Plant	Orange	Neversink River
	Villa Roma Resort & Conference Center	Sullivan	Jones Brook
√	Village of Potsdam Water Pollution Control Plant	St. Lawrence	Raquette River
√	Ithaca Area Wastewater Treatment Facility	Tompkins	Cayuga Lake
	Lake Mohonk Mountain House	Ulster	Tributary to Coxing Kill
	Pine Hill Wastewater Treatment Plant	Ulster	Birch Creek
√	City of Glens Falls Wastewater Treatment Plant	Warren	Hudson River
√	Village of Palmyra Wastewater Treatment Plant	Wayne	Erie Canal
√	Westchester County DEF- Yonkers Joint	Westchester	Hudson River
√	Westchester County DEF- Port Chester Wastewater Treatment Plant	Westchester	Long Island Sound

HUDSON RIVER

- Alina Campbell, Clearwater, SUNY Fredonia
- Manta trawling near/along Long Dock Park, Beacon (NY)
- Dissecting microscope: fragment, film, foam, pellet, line
- Max 205,000 particles per square km
- Average 62,000 particles per square km
- Mainly film and fragment
  - ONLY 3% MICROBEADS!
- 95% less than 1mm

CURRENT LOCAL RESEARCH
(*water, sediment, sand, fish guts*)

- Newtown Creek
- Kill Van Kull
- Newark Bay
- Arthur Kill
- East River
- Upper Bay
- Lower Bay
- Sandy Hook
- NJ Shore, various

DO ALL PLASTICS FLOAT?

Table 2. Common Types of Plastics and Their Densities[a]

polymer type	density (g/mL)[38]	comment
polyolefins		
polypropylene (PP)	0.90	80–90% of floating debris[37]
polyethylene (LDPE, HDPE)	0.91–0.96	5–15% of floating debris[37]
polystyrene (PS)	≤1.05	sometimes expanded to foam (e.g., "styrofoam")
acrylonitrile-butadiene-styrene (ABS)	1.07	
nylon	1.09	
polycarbonate	1.36	
cellulose acetate	1.42	
poly(vinyl chloride) (PVC)	1.4	
polyethylene terephthalate (PET)	1.55	soda bottles; frequently entrap air

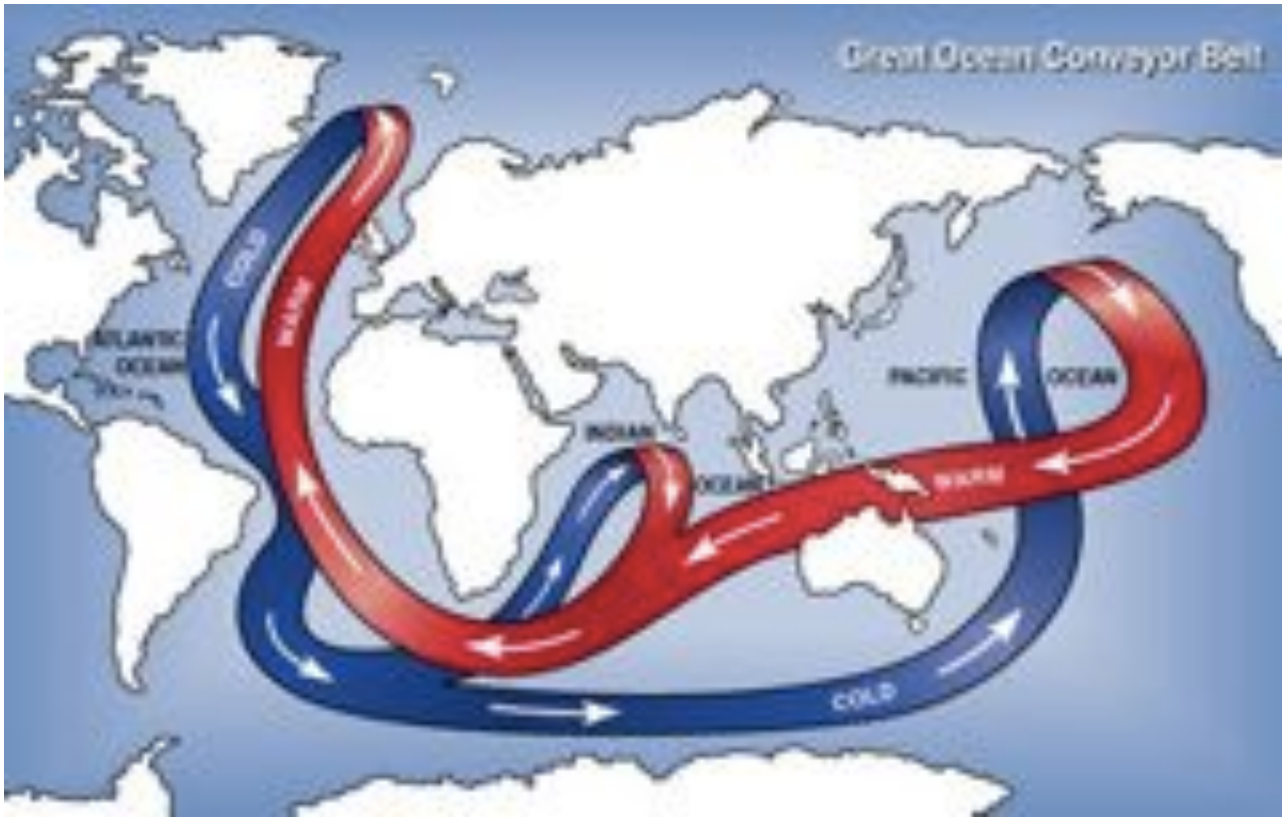
[a]Seawater density: approximately 1.02–1.03 g/mL. Note that densities can vary depending on the processing conditions.

Source: Engler, 2012

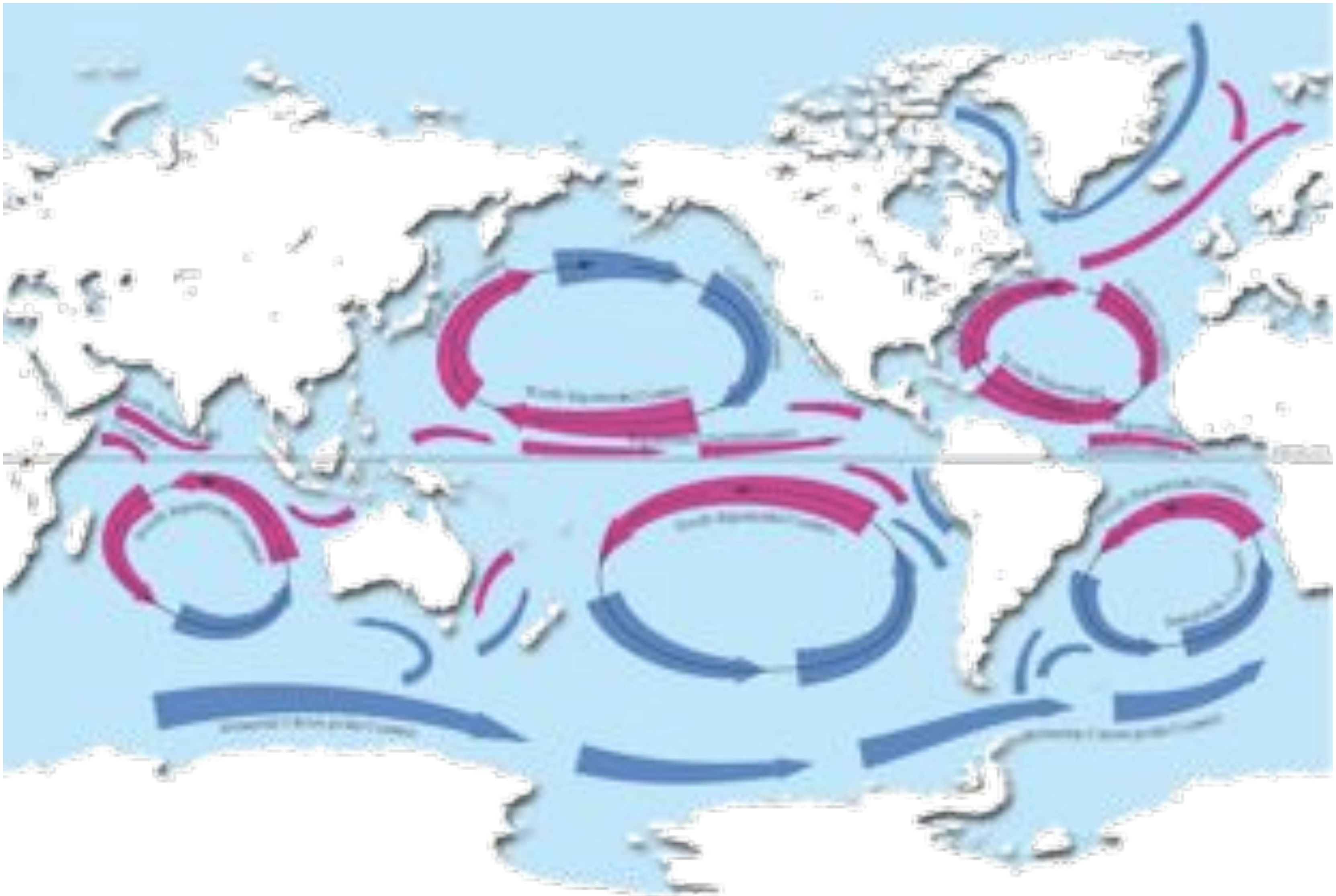
INDIAN OCEAN FLOOR

- *The Deep Sea is a Major Sink for Microplastic Debris (Woodall et al, 2014)*
- FTIR spectroscopy
- 4 billion plastic textile fibers per square kilometer
- Polyester, nylon, acrylic

THERMOHALINE CIRCULATION



5 GYRES



SOLUTIONS, PREVENTION?

UPSTREAM/MID-STREAM/DOWNSTREAM
MESO vs. MICRO

MESO PLASTICS

- 14 floatables “impaired” waterbodies in NYS
- NYS narrative water quality standard for trash – “none in any amounts”, *per NYS Regulation 6 NYCRR Part 703*

MESO PLASTICS

- UPSTREAM:
  - Education & outreach (community groups; source reduction!)
  - Street sweeping
  - Litter fine enforcement
  - Waste receptacles (placement, auditing, adjustment)
  - Bans: bags, expanded polystyrene (foam)
- MID-STREAM:
  - Catch basins: insert filters, sumps, hoods (w/ siphons, outlet screens (5mm resolution), annual inspection, cleaning before 60% sump volume; retractable curb inlet protectors/screens

MESO PLASTICS

- DOWNSTREAM:
  - Outfall nets (O&M)
  - Outfall booms (only floatables; installation; O&M)
  - Outfall baffle boxes
  - Pre-outfall hydrodynamic separators ($$; O&M)
  - Shore cleanups (Riverkeeper's Riversweep; American Littoral Society; Ocean Conservancy)

NEW YORK STATE OF OPPORTUNITY | Department of Environmental Conservation

FACT SHEET

For

NEW YORK STATE
DEPARTMENT OF ENVIRONMENTAL CONSERVATION
SPDES PERMIT
for
STORMWATER DISCHARGES
from
Municipal Separate Storm Sewer Systems
of
New York City

Permit No. NY-0287890

Issued Pursuant to Article 17, Titles 7, 8 and Article 70
of the Environmental Conservation Law

July 31, 2015

Control of Floatable and Settleable Trash and Debris – The permit requires NYC's stormwater program to target and control floatable and settleable trash and debris. To meet this permit requirement, NYC will be required to first develop a methodology to determine baseline load and identify the best available control technologies that can be implemented within NYC. NYC must also evaluate its existing programs and determine how/if they should be modified to meet the objective of minimizing the discharge of floatable materials from its separate storm sewer system. Once the methodology is approved, NYC will have two years to commence the study to determine the baseline load. During the interim NYC is required to implement existing catch basin programs and implement a floatable and settleable trash and debris reduction media campaign to further educate the public on trash and debris control issues. The permit allows NYC to prioritize waterbodies and drainage areas and consider the relative impacts with non-MS4 sources and planned controls for those sources.

PRIMARY MICROPLASTICS

- Education & outreach (community groups; Operation Clean Sweep; source reduction!)
- Washing machine filters
- Bans: microbeads (watch for biodegradable “loophole”)
  - Suffolk: passed assembly
  - Erie: passed
  - Chautauqua: passed
  - Monroe: introduced
  - Albany: introduced
  - Cattaraugus: introduced
  - NYC: introduced

  - States Passed: NJ, IL, CO, CT, WI, ME

ANY RESIN MANUFACTURERS, SUPPLIERS, OR USERS **IN YOUR MUNICIPALITY**?

EPA INVOLVEMENT?

EPA INVOLVEMENT

- Trash Free Waters Program & Partnership
- Grants to reduce aquatic plastic trash pollution
- Species and human health impact published research synthesis and analysis
- Conduct new research: species impact; human health impact; new materials
- Instruct/support citizen science
- Review/comment MS4 general permits and WWTP SPDES discharge permits

EPA REGION 2 GOAL?

TRASH FREE WATERS BY 2025

(zero point source trash discharge to surface waters)

THE END

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US EPA

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