

Abstract

Microplastic is defined as particulate <5mm in size characterized as fragments, fibers, films, foams, pellets, and beads. Microplastic pollution was first documented in the 1970s and interest has grown from initial characterization, to effects within marine and freshwater food chains, ultimately impacting human health. Due to their small size, porosity, and density variation, microplastics often escape wastewater treatment processing (WWTP). Commencing in 2015, we surveyed WWTP post-treatment effluent (N = 59) from the city of Plattsburgh, NY and beginning in fall 2016 from St Albans, VT (N = 29), Ticonderoga, NY (N = 23), and Burlington, VT (N = 9). Effluent samples were collected and digested using wet peroxide oxidation methods, followed by microscopic characterization based on type and size. Plant specifications yielded varied microplastic trends in quantity and type, specifically Plattsburgh largely emitted fibers and fragments, St. Albans emitted a majority of foam, Ticonderoga emitted mostly fibers, and Burlington emitted a majority of fragments. Estimated microplastics released per day ranged from St. Albans (30,268), Plattsburgh (14,105), Burlington (16,843), to Ticonderoga (7,841). Microplastics are an emerging concern for aquatic life as they can biomagnify and adsorb harmful chemicals which bioaccumulate up the food chain. They have been found to impair feeding and reduce survival in many aquatic species. This research further documents wastewater treatment plants as a significant source of microplastics entering Lake Champlain and serves as a basis for further microplastic studies in the Lake Champlain watershed. As plants are not designed to capture these small particulate, consumer behavior must evolve to reduce this pollution threat.

Microplastics

- Microplastics derive from personal care products, marine debris (e.g., fishing line, plastic lures, rope), pre-production plastic nurdles, and photo- and mechanical degradation of larger plastics.

- Postulated sources of these microplastics may be traced to skincare products that contain microbeads, used for exfoliation and/or from clothing, in the form of polyester and acrylic fibers such as synthetic jackets and sweaters (Thompson et al. 2011, Hartline et al. 2016)

- Microplastics are characterized as a) films, b) pellets/beads, c) fibers, d) fragments, e) and foams (Fig. 1).

- More recent findings have suggested > 1900 fibers are emitted from washing of one item of fleece clothing (Browne et al. 2011).

- Mason et al. (2016) observed 17 wastewater treatment facilities and concluded that 4 million microplastics per facility per day are being released into our waterways. Between 3-23 billion (average = 13 billion) of these microplastic particles are released into US waterways every day via municipal wastewater.

- Less than 66% of WWTP in the Great Lakes basin have tertiary treatment filtration capabilities, which may have some potential to reduce microplastic loads (Driedger et al. 2015).

- 25/34 wastewater treatment plants surveyed in NY released microbeads (NY State Office of the Attorney General, April 2015).

- Federal legislation (Microbead Free Waters Act) was passed to ban cosmetics containing intentionally-added plastic microbeads beginning on January 1, 2018, and their manufacturing beginning on July 1, 2017.



- Microplastics have been identified as marine pollutants of significant concern (Ng and Obbard, 2006; Cole et al., 2011).
→ Potential to act as vectors for the transfer of persistent organic pollutants (POPs) to marine organisms (Ng and Obbard, 2006; Andrady, 2011).



Fig. 1. a) Films, b) pellet/beads, c) fibers, d) fragments, e) foams, f) marine debris- plastic lure

Hypotheses

- We hypothesized that the most common type of microplastic would be fragments.
- The most abundant size class of microplastic would be ≥355µm (med).
- More particulate would emit from plants with higher flow and/or less recent upgrades to infrastructure.

Wastewater Treatment Plant (WWTP)

Table 1. WWTP specifications

WWTP Site	Plattsburgh	Ticonderoga	St. Albans	Burlington
Max	16MGD	3MGD	8MGD	15MGD
Services	20,000	4,500	6,000	42000+
Built	1973	1979	1930	1953
Last Updated	2013	2017	1984	1994
Discharge Point	Saranac River	LaChute River	Steven's Brook	Lake Champlain

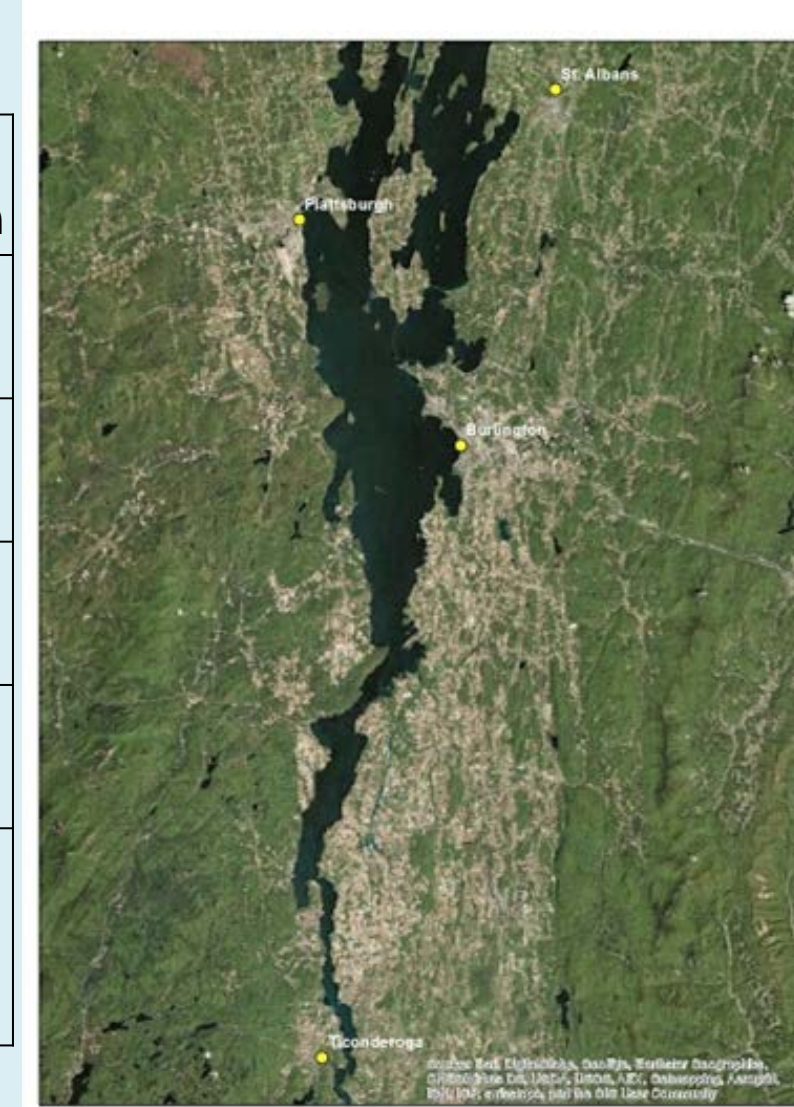


Fig. 2. Map of WWTP sites sampled

Methods

WWTP- Sample Collection:

- Sump pump flow rates were determined in the final stage of processing before and after 24hr collection at WWTP.
- The hose from the pump ran over the 355µm sieve for 24hrs (Fig. 3a).
- Sieve contents were placed in a beaker for wet peroxide oxidation in a fume hood (Figs. 3c, d).



Fig. 3a. Erin, Danny, and Melissa setting up a 24hr sampling in Plattsburgh. Fig. 3b. Microplastics remaining from the wet peroxide digestion in a 1mm sieve. Fig. 3c. Melissa performing wet peroxide oxidation digests on a WWTP sample.

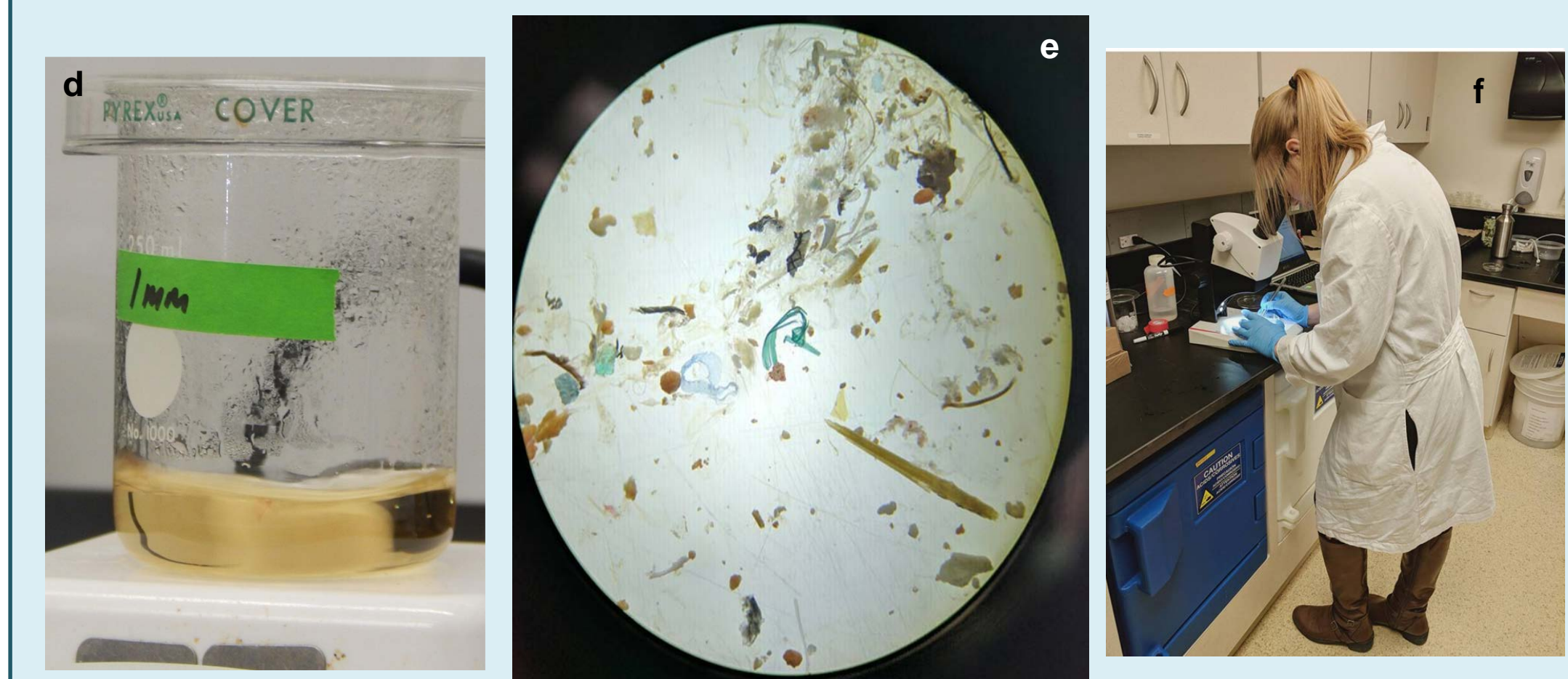


Fig. 3d. Wet-peroxide oxidation. Fig. 3e. Microplastics remaining after the chemical digest. Fig. 3f. Melissa characterizing microplastics under the scope.

Laboratory analysis of samples:

- 30 ml of 4M KOH at 65°C for 1hr and then 5 ml of H₂O₂ was added and stirred in the last 15min then set to rest for at minimum 2hrs before being processed through the 125µm sieve and rinsing with DI water.
- Contents of the sieve above were placed in a fresh beaker and 20 ml FeSO₄ and 20 ml of H₂O₂ were added for an hour stirring on a hot plate at 75°C (Figs. 3c, d).
- 20 ml of H₂O₂ were added as aliquots (every 20min) until all organic material was dissolved.
- Samples were filtered through stacked sieves 1mm, 355µm, 125µm and washed with DI water (Fig. 3b).
- All samples were processed under a dissecting microscope for characterization (Figs. 3e,f).
- All plastic are in queue for Fourier transform infrared microscopy (FT-IR) to determine polymer type.

Results

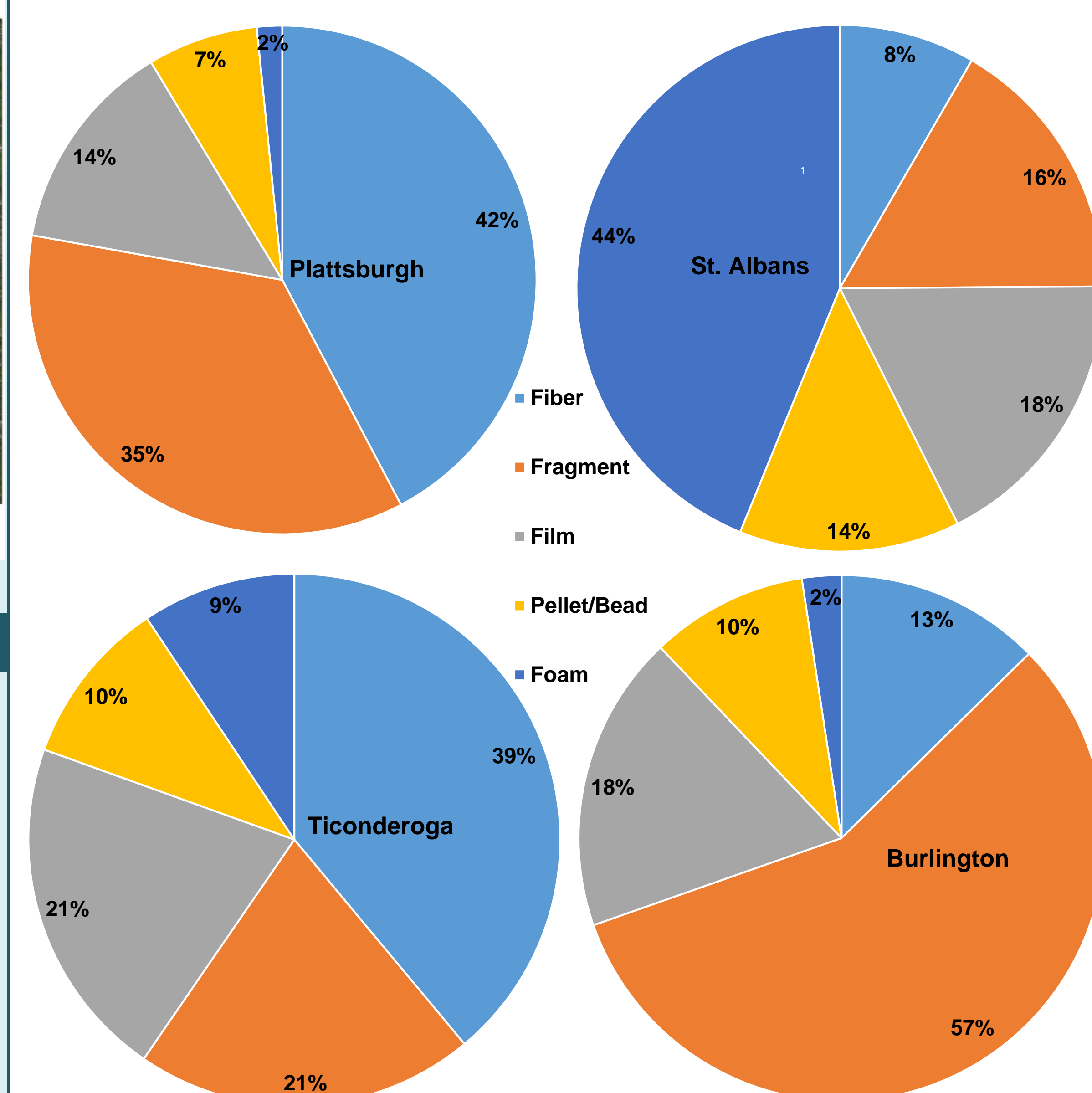


Fig. 5. Plant-specific characterization of overall microplastics from WWTP post-treatment effluent. Plattsburgh (N = 996, 59 samples), St. Albans (N = 4142, 29 samples), Ticonderoga (N = 2041, 23 samples), Burlington (N = 372, 9 samples)

- Plattsburgh microplastics were dominated by **fibers and fragments**.
- St. Albans microplastics were dominated by **foams**.
- Ticonderoga microplastics were dominated by **fibers**, and equal proportions **fragments and films**.
- Burlington microplastics were dominated by **fragments**.

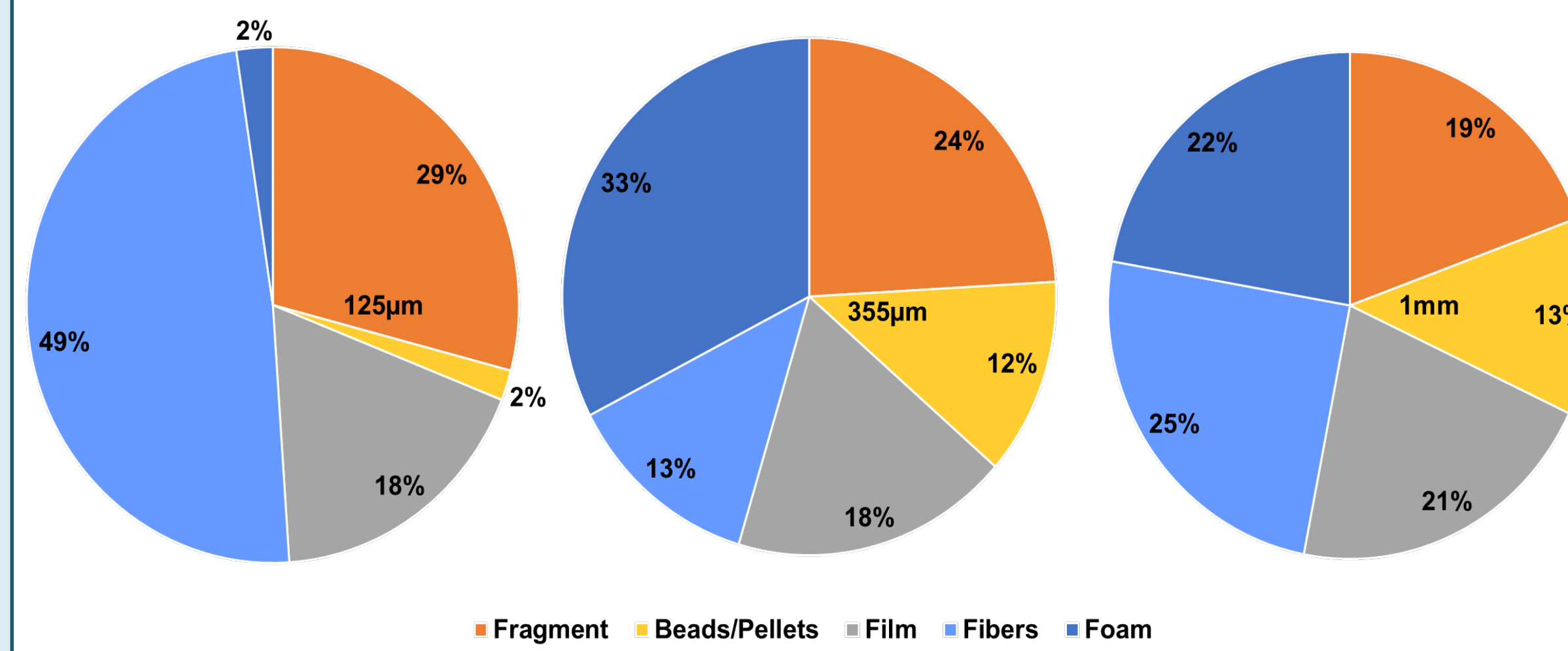


Fig. 6. Size-specific characterization of microplastics from all WWTP combined: 125µm (n = 844), 355µm (n = 4369), 1mm (n = 1756).

- Small (125µm) plastics were primarily comprised of **fibers**.
- Medium (355µm) microplastics were primarily comprised of **foams and fragments**.
- Large (1mm) microplastics were primarily comprised of **fibers and foams**.
- The **majority** of microplastics in all samples were **fibers and fragments**.

Table 2. Estimated particles released per day per WWTP

WWTP Plant	Particles per Gallon				Flow Rate (mgpd)	Plastic Particles per Day	N samples processed thus far
	Average	Low	High	Std. Dev.			
Plattsburgh	0.0033	0.0001	0.0136	0.0033	4.273	14,105	59
St. Albans	0.0120	0.0012	0.0665	0.0134	2.531	30,268	29
Burlington	0.0058	0.0002	0.0106	0.0047	2.889	16,843	9
Ticonderoga	0.0092	0.0000	0.0401	0.0091	0.851	7,841	23

Discussion

- Clothes washing** emits immense fiber loads into waterbodies, as population density has increased and synthetic clothing (e.g., fleece) is ubiquitous (Browne et al. 2011, Hartline et al. 2016).
- Hartline et al. (2016) concluded that **top-load washing machines** were found to emit **7x's** more microfibers than **front-loading washing machines** and **detergent use drastically increased fiber yield**.
- Flushable hygiene wipes** contain plastic interlocking fibers and do not completely biodegrade, harming WWTP infrastructure. In just the U.K, there was a 50% increase of these wipes found on the beaches this past year (Marine Conservation Society).
- Microplastics typically were medium (355µm)-sized particulate.
- Rarely would small microplastic particulate be captured by typical WWTP processing without tertiary treatment (Carr et al. 2016).
- Tertiary filtration treatments were not always an effective means of reducing overall microplastic discharge (Mason et al. 2016)
- As particles float throughout the environment, they can adsorb hydrophobic materials such as **PCBs/toxins** (Fendall and Sewell, 2009).
- Turner and Holmes (2014) noted that trace metals adhere to more heavily degraded microplastics.
- Studies have show food web transfer from **algae** (Gutow et al. 2016), **zooplankton** (Frias et al. 2014), to **fish** (Neves et al. 2015), and **waterfowl** (English et al. 2015), **humans** (Van Cauwenbergh and Janssen 2014- **mussels**; Liebezeit and Liebezeit 2014-**beer**; Shi et al. 2015- **sea salt**).

Conservation Implications and Suggestions

- Plastics in consumer products are not completely captured in typical WWTP processing. Though grants can help WWTP upgrade technology and infrastructure, **it rests on the individual consumer's behavior to reduce plastic purchases upstream**.
→ Chang (2015) surveyed students, residing in UC Berkeley residence halls, and noted that 5,000g of microplastics (approx. 2,500 Ziploc bags) were contributed annually to waterbodies from their campus.

- Continued studies on microplastics in the digestive tracts of organisms are on-going (e.g., mysids, amphipods, zebra mussels, fish, and double-crested cormorants).

- Incentives should be made to encourage washing machine manufacturers, engineers, and **innovative students/faculty to develop new filters for current appliances and innovative solutions to mitigate the microplastic problem**.

- Fibers are ubiquitous** and perhaps pose greater threat than microbeads biomagnifying through the aquatic food chain.
→ Browne et al. (2011) noted > 1900 fibers can be emitted from a synthetic garment.



(Browne et al., 2011)

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Literature Cited

Browne MA, Crump P, Niven SJ, Teuten E, Tonkin A, Galloway T, Thompson R. 2011. Accumulation of Microplastic on Shorelines Worldwide: Sources and Sinks. *Environ. Sci. Technol.* 45:9176-9179.

Carr SA, Liu J, Tesoro AG. 2016. Transport and fate of microplastic particles in wastewater treatment plants. *Water Res.* 91:174-182.

Chang M. 2015. Reducing microplastics from facial exfoliating cleansers in wastewater through treatment versus consumer product decisions. *Mar. Pollut. Bull.* 101:330-333.

Driedger AGJ, Dior HE, Mitchell R, Van Cappellen P. 2015. Plastic debris in the Laurentian Great Lakes: a review. *J. GL. Lakes Res.* 41:9-19.

Engel R, Inghel P, Sigurdson W, Gagnon P, Gagnon P, Tassin B, Lacroix C. 2015. Beyond the ocean: contamination of freshwater ecosystems with microplastic particles. *Environ. Chem.* 14:2017-2020.

English M, Robertson G, Gendron L, Sobczak K. 2016. Experimental Evaluation of Seawater as a Vector for Microplastics into Marine Food Webs. *Environ. Sci. Technol.* 50:915-923.

Frias A, Wiper O, Chiriac M, Bouchard A. 2015. Plastic and metal ingesters in three species of coastal waterbird wintering in Atlantic Canada. *Mar. Pollut. Bull.* 98:349-353.

Gutow L, and Burton H. 2002. Origin and biological accumulation of small plastic particles in far seals from the Macaronesian Islands. *Mar. Pollut. Bull.* 55:280-284.

Franz JPL, Chen Y, Scharf P. 2014. Evidence of microplastics in samples of zooplankton from Portuguese coastal waters. *Mar. Environ. Res.* 95:90-95.

Shi X, Eisenreich S, Gendron L, Sobczak K. 2016. Experimental Evaluation of Seawater as a Vector for Microplastics into Marine Food Webs. *Environ. Sci. Technol.* 50:915-923.

It's A Wipe Out On UK Beaches As Consumer Demand For Convenience Cleaning Impacts Our Shores. 19th March 2015 | Marine Conservation Society. [accessed 2016 Apr 21]. <https://www.mcsuk.org/news/16019>

Johnson R, Browne MA, Crump P, Niven SJ, Teuten E, Tonkin A, Galloway T. 2011. Accumulation of Microplastic on Shorelines Worldwide: Sources and Sinks. *Environ. Sci. Technol.* 45:9176-9179.

Thompson R, Browne MA, Crump P, Niven SJ, Teuten E, Tonkin A, Galloway T. 2011. Accumulation of Microplastic on Shorelines Worldwide: Sources and Sinks. *Environ. Sci. Technol.* 45:9176-9179.

Zhang K, Gong W, Lv J, Xiong X, Wu C. 2015. Accumulation of floating microplastics behind the Three Gorges Dam. *Environ. Pollut.* 204:117-123.