Microplastic Pollution: A Survey of Wastewater Effluent in the Lake Champlain Basin

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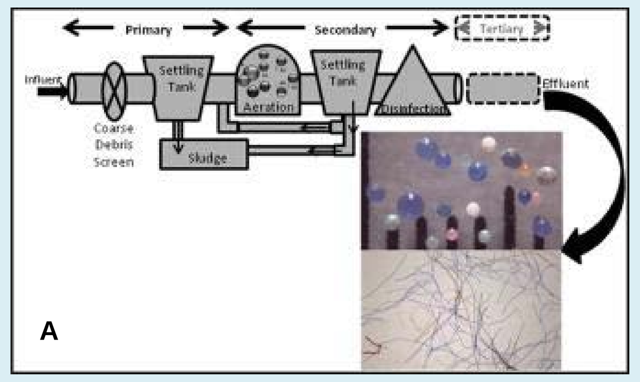
Abstract

Microplastic pollution in freshwater ecosystems is an emerging topic in aquatic pollution science. Origin of microplastics are often associated with consumer use of personal care items or the laundering of synthetic fabrics which are unable to be removed with current wastewater treatment plant (WWTP) technologies. Beginning in Fall 2015, we surveyed WWTP post-treatment effluent from the city of Plattsburgh, NY (N = 31). Effluent collection from St Albans, VT (N = 11), Ticonderoga, NY (N = 4), and Burlington, VT (N = 5) began fall 2016. Samples were processed using wet peroxide oxidation methods, followed by characterization based on type. Across the four WWTPs the majority of plastics found were fragments. Proportions between fragments and fibers were the following; Plattsburgh (51:23), St. Albans (54:15), Ticonderoga (44:40), and Burlington (65:15). On high and low flow rate days, more bead/pellet and films were collected, respectively. Plattsburgh and Burlington have a similar capacity and sized population, however the difference in average particle abundances (21:56) may be due to infrastructure updates (2013- Plattsburgh and 1994- Burlington). Differences in particle abundances between St Albans and Ticonderoga (32:49) may be due to St Albans having tertiary treatment. The highest total plastic particles per day was occurred in Plattsburgh (10,533 pp/d), followed by Burlington (9,863 pp/d). This difference may be due to differing sample sizes and the variability of particles found between high and low flow days. St. Albans and Ticonderoga plastic particles per day were found to be similar (4,844:4,593 pp/d). From the four WWTPs included in this study an estimated total of 29,833 plastic particles per day are entering the Lake Champlain Watershed, raising concern as we consider the many plants about the watershed. The findings from this research from Lake Champlain are being shared with plant operators, lake stewards, government officials, and can serve as a basis for further microplastic studies.

Microplastics

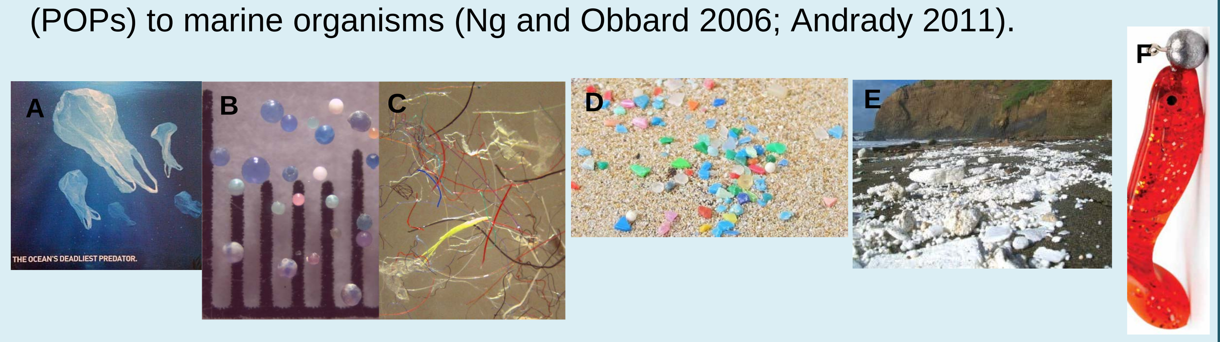
- Microplastics are characterized as films (A), pellets/beads (B), fibers (C), fragments (D), and foams (E) and are <5 mm in size (Fig. 2).
- Microplastics derive from personal care products, marine debris (e.g., fishing line, plastic lures, rope), pre-production plastic nurdles, and photo- and mechanical degradation of larger plastics, and/or from clothing, in the form of polyester and acrylic fibers (Thompson et al. 2011).
- More recent findings have suggested > 1900 fibers are emitted from washing of one item of fleece clothing (Browne et al. 2011).
- Less than 66% of wastewater treatment plants in the Great Lakes basin have tertiary treatment filtration capabilities, which might have reduced 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.



Figs. 1. A) Mason et al. (2016) micobeads exiting WWTP, **B)** Story of Stuff Image posted when Federal ban on microbeads was announced.

- Microplastics have been recently 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).



Figs. 2. A) Films, **B)** pellet/beads, **C)** fibers, **D)** fragments, **E)** foams, **F)** marine debris (plastic lure).

Hypotheses

- The most common type of WWTP microplastic would be pellets/beads.
- Larger particles would be more common during higher flow events.
- WWTPs serving smaller populations would yield fewer particles per day.

Wastewater Treatment Plant (WWTP)

Table 1. WWTP specifications in Lake Champlain Watershed

WWTP Site	Plattsburgh	Ticonderoga	St. Albans	Burlington
Max (MGD)	16	3	8	15
Population Serviced	30,000	4,500	6,000	42,000+
Built	1973	1979	1930	1953
Last Updated	2013	2011	1984	1994
Discharge Point	Saranac River	LaChute River	Steven's Brook	Lake Champlain
3^0 Treatment	No	No	Yes	No
Stormwater Processing	Yes	Yes	Yes	Yes

Fig. 3. Map of WWTP sites sampled

Methods

WWTP- Sample Collection:

- Flow rates were assessed at the pump before and after collection. A pump and hose were used to divert water from the open tank for sample collection and flow rate measurements in 2015-2016.
- The hose collects post-treatment effluent over a 355 µm sieve for 24 hrs (Figs. 4A, B).
- Sieve samples received wet peroxide oxidation digests to remove organic material (Fig. 4C).

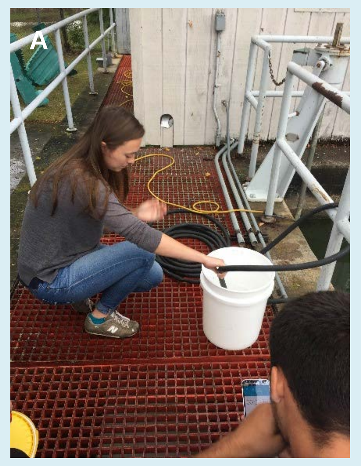


Fig. 4A. Sadie checking flow rates at Plattsburgh's WWTP.

Fig. 4B. Blue fragment captured in 1 mm sieve.

Fig. 4C. Sadie performing wet-peroxide oxidation digests on WWTP sample.

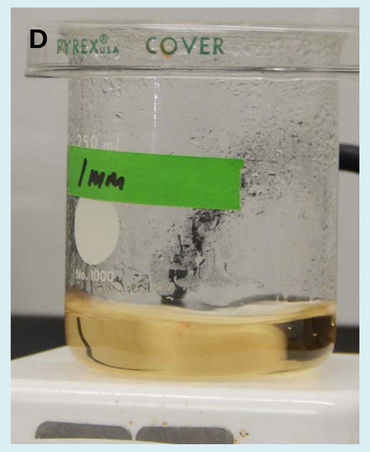


Fig. 4D. Wet peroxide oxidation.

Fig. 4E. Tom transferring particulate from sieve to begin processing.

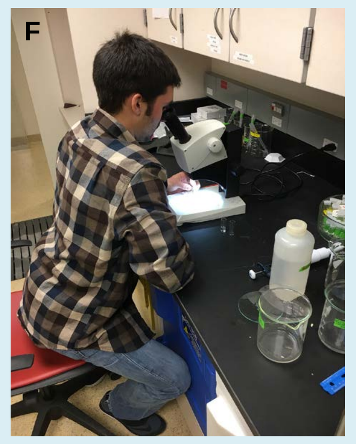


Fig. 4F. Brandon characterizing microplastics under the microscope.

Laboratory analysis of samples:

- Contents of sieve were placed in beakers.
- 30 ml of 4M KOH was pipetted into samples and stirred. Contents were sieved into the 125 um sieve and rinsed with DI water and placed into a new beaker.
- 20 ml Fe_2SO_4 and 20 ml of H_2O_2 were added to beakers and beakers of post-treatment effluent were heated and stirred at 75°C on a heated stir plate (Figs. 4C, 4D).
- 20 ml of H_2O_2 were aliquoted (as needed) until all organic material was dissolved.
- Samples were filtered through a stack of sieves 1 mm, 355 µm, 125 µm, for size separation, washed with DI water, and stored in shell vials (Fig. 4E).
- All samples underwent microplastic characterization (e.g., fragment, fiber, film, foam, pellet) under a Leica dissecting microscope (Fig. 4F).
- Fourier transform infrared microscopy (FTIR) will be used for further classification to polymer type.

Microplastic Particulate

Fig. 5A. Several blue fragments and a fiber observed from a sample collected at the Plattsburgh WWTP.

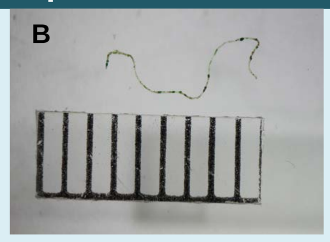


Fig. 5B. A clear/blueish fiber under the scope.

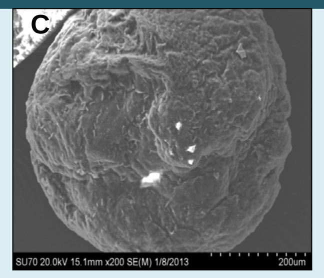


Fig. 5C. A 200X magnified microbead with UV-degradation (*Photo courtesy of Dr. Sherri Mason*).

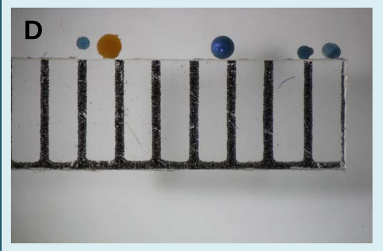


Fig. 5D. Size variation in microbeads.

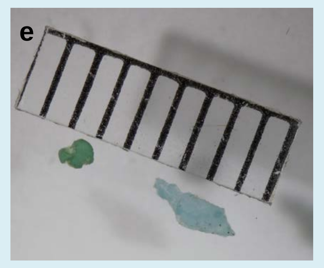


Fig. 5E. Degraded microbead and film from 1 mm sieve at WWTP.

Results

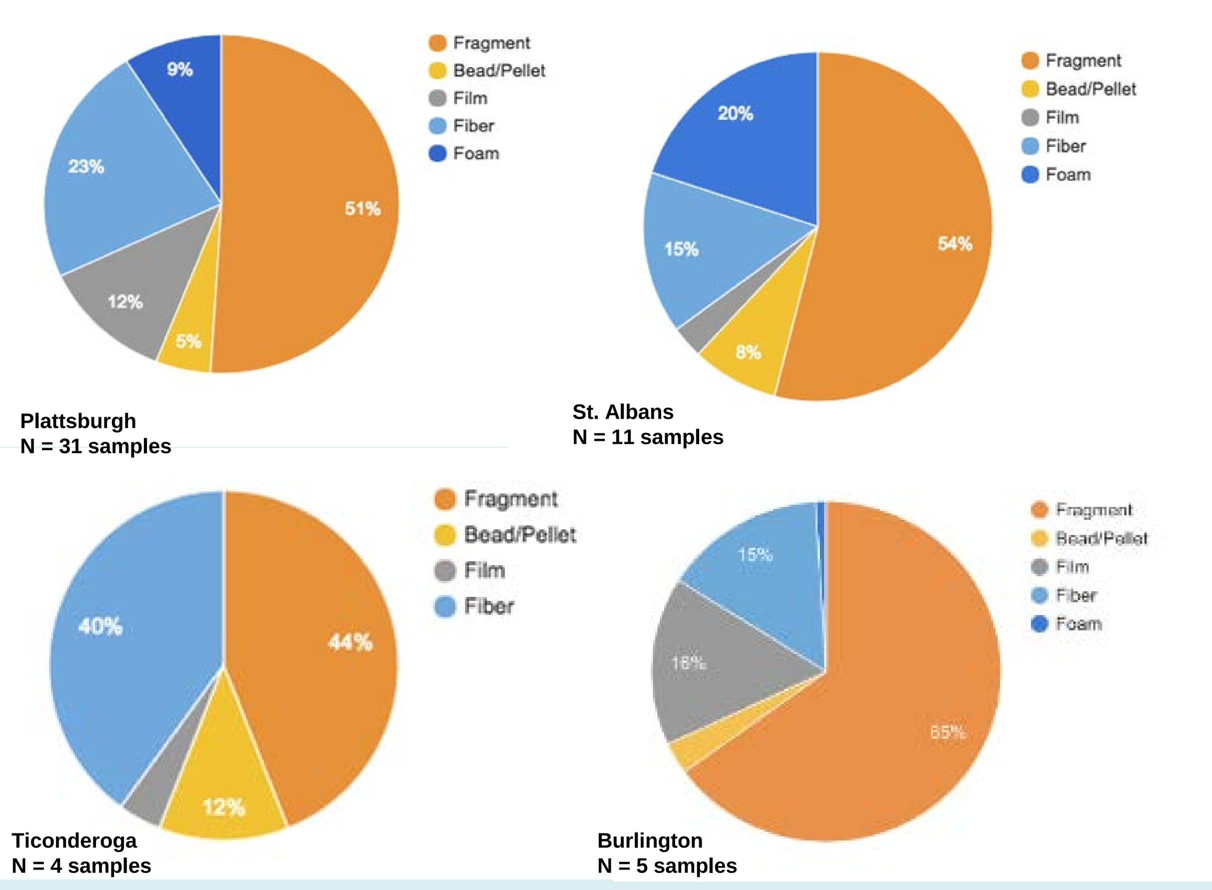


Fig. 6. Characterization of total microplastics from WWTP Plattsburgh (N = 642 particles), St. Albans (N = 352 particles), Ticonderoga (N = 105 particles) and Burlington (N = 280 particles).

→ Overall, **fragments and fibers were the most common** microplastic type captured in all sieve size classes and at all WWTP sampled sites.
→ **Foam was the least abundant** microplastic, followed by films and pellets/beads.
→ Most plastics were of **small** (125 µm) and **medium** (355 µm) size.

Table 2. Particles per day emitted at WWTP in Plattsburgh, St Albans, Burlington, and Ticonderoga. Based on particle numbers processed, particles per gallon and flow rate (mgpd).

	Particles per Gallon				Flow Rate	Plastic Particles	N samples
WWTP Plant	Average	Low	High	Std. Dev.	(mgd)	per Day	processed thus far
Plattsburgh	0.0026	0.0001	0.0082	0.0021	4.120	**10,533**	31
St. Albans	0.0023	0.0008	0.0050	0.0015	2.071	**4,844**	11
Burlington	0.0033	0.0001	0.0070	0.0031	2.960	**9,863**	5
Ticonderoga	0.0070	0.0027	0.0126	0.0042	0.657	**4,593**	4

→ From the four WWTPs included in this study an estimated total of 29,833 plastic particles per day are entering the Lake Champlain Watershed.

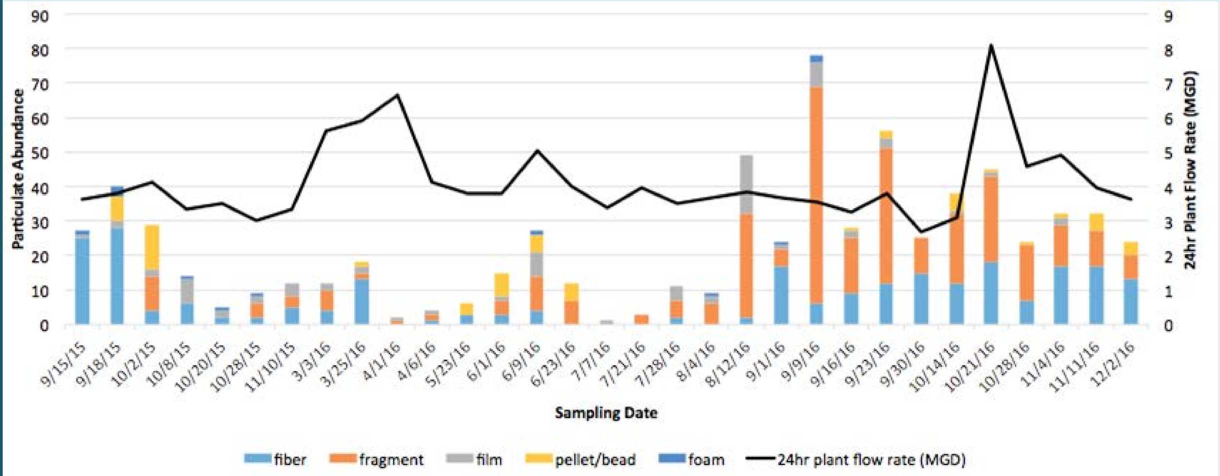


Fig. 7. Characterization of microplastics over time as a function of flow rate at the Plattsburgh WWTP.

- **High flow rates→ higher pellet/bead abundance**
- **Low flow rates→ high film abundance**
- **Bimodality in microplastic release**, peaking in mid-September 2015 and 2016 and late March, 2016. Local industry practices changed, reflecting higher fragments and fibers.

Discussion

- **Fragments and fibers were the most common** microplastic particulate in WWTP effluent across the four sampling sites. Plattsburgh (51:23), St. Albans (54:15), Ticonderoga (44:40), and Burlington (65:15). Plants with tertiary treatment had a smaller average number of particulates compared to those without, 32 particulates/sample (St. Albans) vs 49 particulates/sample (Ticonderoga).

- Plants in the **Lake Champlain** basin are emitting between **5-11,000 particles/day** with **29,833 particles/day from those 4 plants alone.**
- Higher values in Plattsburgh and Burlington may result from increased population associated with local **colleges**.
- Consider additional loading from all other plants around the watershed. Particulate inputs are substantial.

Fiber Sources:
→ **Clothes washing** emits immense fiber loads into waterbodies, as population density has increased (Browne et al. 2011). Plattsburgh and Burlington are college towns.

- **Flushable hygiene wipes** contain plastic and interlocking fibers which do not biodegrade. In the U.K, there was a 50% increase wipe debris along beaches this past year (Marine Conservation Society).
- **Microplastics typically were small (125 µm) to medium (355 µm)-sized,** as compared to larger (1 mm) sieves.
- Rarely would small microplastic particulate be captured by typical WWTP processing without tertiary treatment (Carr et al. 2016).
- Mason et al. (2016) supports that flow rate was not associated with microplastic particulate type in WWTP post-treatment effluent.
- **Polyethylene and polypropylene** plastics float on the water surface.
- Studies have shown 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 Cauwenberghe and Janssen 2014- **mussels**; Liebezeit and Liebezeit **2014-beer**; Shi et al. 2015- **sea salt**).

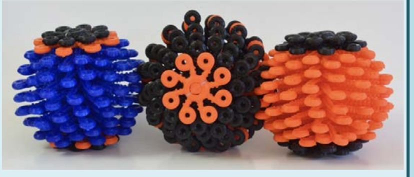
Conservation Implications and Suggestions

Plastics in consumer products are not completely captured in typical WWTP processing.
→ Chang (2015) surveyed students, living in UC Berkeley residence halls, and noted that 5,000 g of microplastics (approx. 2,500 Ziploc bags) were contributed annually to waterbodies from their campus.

Washing machine design influences number of fibers emitted
→ Hartline et al. (2016) found top loading washers contributed approximately 7X more in fiber mass than front loading machines.

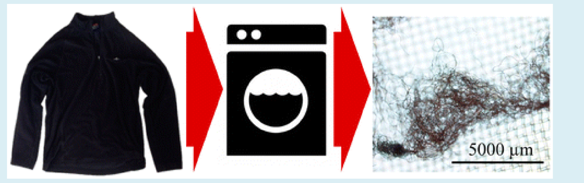
http://guppyfriend.com/

Products such as the **Cora Ball** (Rozalia Project) or **Guppy bag** (Patagonia) aim to **reduce fibers on the consumer end.**



http://rozaliaproject.org/stop-microfiber-pollution/

Fibers are ubiquitous and perhaps pose an even more dangerous threat than microbeads.
→ Browne et al. (2011) noted **> 1900 fibers can be emitted from washing a synthetic garment.**



(Harline et al. 2016; figure above)

Incentives should be made to encourage **washing machine manufacturers, engineers, and innovative students/faculty to develop more/effective filters for current appliances.**

WWTP facilities should be **upgraded** to meet higher standards when possible in order to reduce microplastics loads into waterbodies.

Continued studies on microplastic bimagnification in the digestive tracts of organisms is on-going (e.g., Mysids, Zebra Mussels, fish).

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