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

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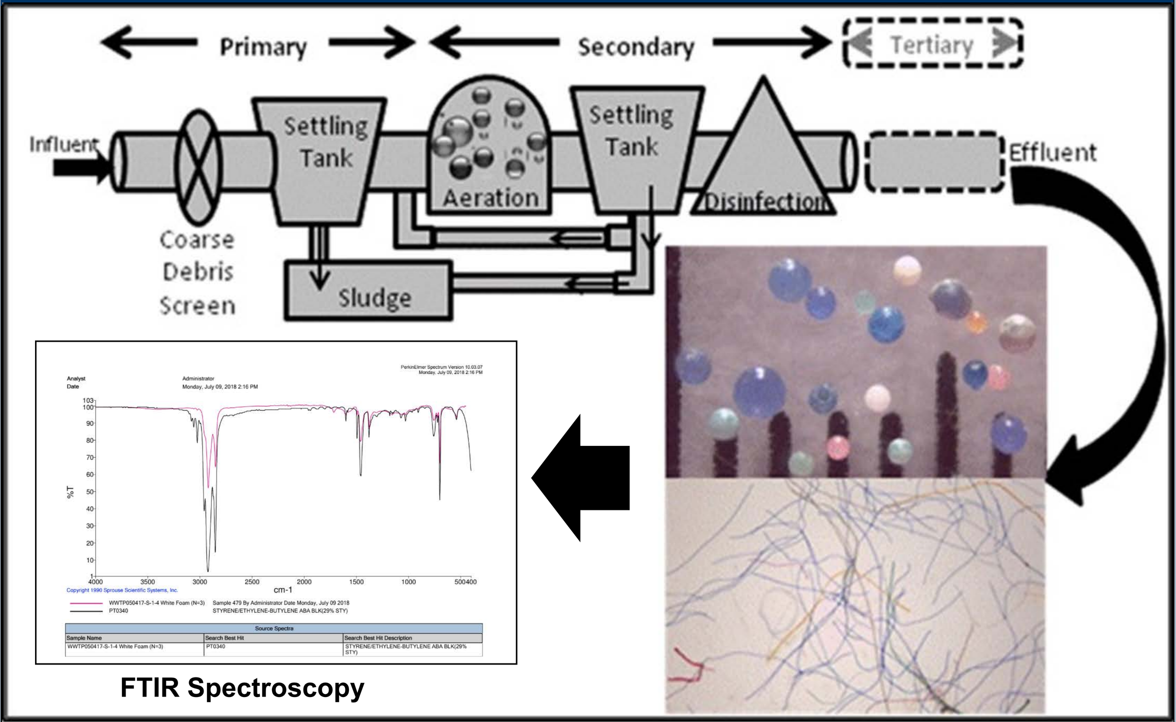
Graphical Abstract



(Adapted from Mason et al. 2016)

Background Information

- Microplastics are characterized as (A) films, (B) fibers, (C) fragments, (D) pellets/beads, and (E) foams (Fig. 1).
- Sources of microplastics may be traced to skin-care products containing exfoliating microbeads and/or from clothing, in the form of polyester and acrylic fibers derived from synthetic jackets and sweaters (Thompson *et al.* 2011; Hartline *et al.* 2016).
- 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 WWTP facilities and concluded that 4 million microplastics/facility/day and between 3-23 billion (average 13 billion) microplastic particles are being released into US waterways/day via municipal wastewater.
- Less than 66% of WWTPs in the Great Lakes Basin have tertiary treatment filtration capabilities, which may reduce microplastic loading (Driedger *et al.* 2015).
- Fourier-transform infrared spectroscopy (FTIR) is often used to identify unique microplastic polymer composition (Nor and Obbard, 2014).
- FTIR spectroscopy tests the absorption/reflection of infrared and visible light patterns from a sample and cross reference this absorbance spectrum with a database of other particulates.
- Microplastics have been identified as marine pollutants of significant concern (Ng and Obbard 2006; Cole *et al.* 2011).

→ Microplastics can act as vectors for the transfer of persistent organic pollutants (POPs) to marine organisms (Ng and Obbard 2006; Andrady 2011).

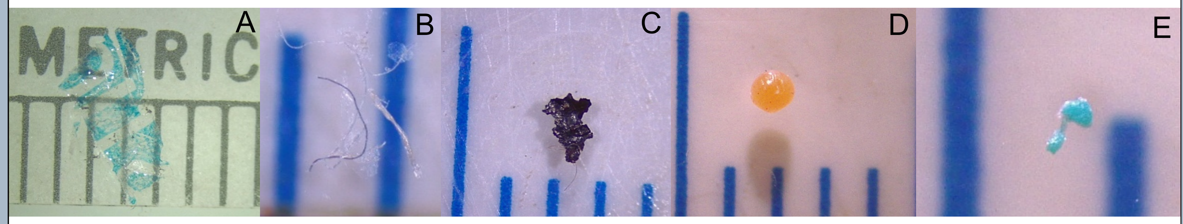


Fig. 1. Microplastic types: A) film, B) fiber, C) fragment, D) pellet/bead, and E) foam.

Goal and Hypothesis

The goal of this research was to survey local WWTP to determine the type and abundance of microplastic pollution entering the Lake Champlain Basin.

Hypotheses:

- The most common type of microplastic in WWTP would be fragments.
- The most abundant microplastic size class would be medium (≥355μm).
- More particulate would be emitted from plants with higher flow and/or less recent infrastructure upgrades.

Wastewater Treatment Plants (WWTP)

Table 1. General specifications of surveyed WWTP.

WWTP Specs	Plattsburgh	Ticonderoga	St. Albans	Burlington	Vergennes
Max flow (MGD)	16	3	8	15	0.75
Population Served	20,000	4,500	6,000	42,000+	2,500
Plant built	1973	1979	1930	1953	1964
Last Updated	2013	Currently	Currently	1994	2001
Discharge Point	Saranac River	LaChute River	Steven's Brook	Lake Champlain	Otter Creek
Tertiary Treatment	NO	NO	Yes (trickle filter) → getting **Aqua-Aerobics cloth filter disks**	NO	Yes **Aqua-Aerobics cloth filter disks**

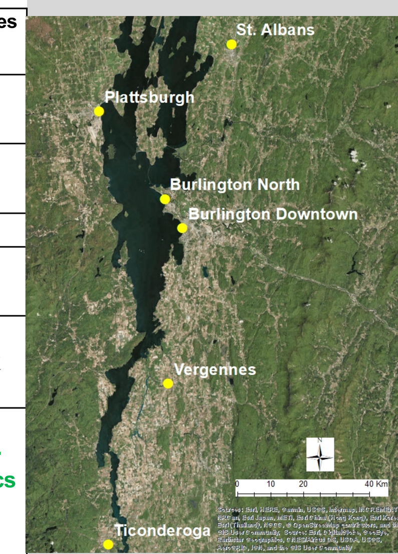


Fig. 2. Map of WWTP sites.

Methods

WWTP sample collection:

- Sump pump flow rates (bucket fill) were determined in the final stage of processing before and after 24hr collection at WWTP.
- Post-treatment effluent sample was collected using the sump pump/hose running over a 355μm sieve for 24hrs (Fig. 3A).
- Sieve contents were placed in a beaker for wet peroxide oxidation (WPO) in a fume hood (Figs. 3B, C).

Wet peroxide oxidation (WPO):

- Samples were placed in 30ml of 4M KOH at 60ºC for 1hr and then 5ml of H_2O_2 was added, while stirring for the last 15min. Samples were soaked for between 2hrs to 5 days.
- In preparation for WPO, KOH soaked samples were sieved (125μm) and rinsed using DI water.
- Contents of the sieve underwent WPO by adding 20ml $FeSO_4$ and 20ml of H_2O_2 to sample on a stirring hot plate at 75ºC for 1hr (Figs. 3B, 3C).
- If organic material remained, 20ml of H_2O_2 was aliquoted into the sample every 20min until dissolved.
- Samples were size-separated using a sieve stack (1mm, 355μm, 125μm) and were washed with DI water.
- All samples were processed under a dissecting microscope for characterization to type (Fig. 3D).

FTIR spectroscopy:

- Petri dishes were dried (56ºC) in a VWR Symphony incubator for 24 hrs.
- Particulate were photodocumented in FTIR archives.
- Each individual microplastic particulate was scanned using the FTIR (Perkin Elmer, FTIR Spectrometer Spectrum Two)(Fig.3E).
- Particles were cross-referenced in a polymer library database (*e.g.*, POLYAD, FiberFTIR, & fiber FBI) looking for a best match.

Fig. 3A. WWTP effluent collection at Plattsburgh plant.

Fig. 3B. Lucas performing wet peroxide oxidation (WPO).

Fig. 3C. WPO of WWTP sample.

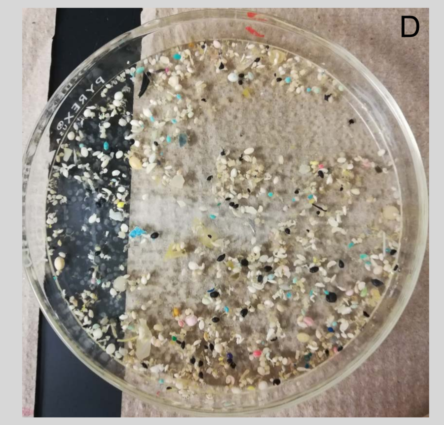


Fig. 3D. Size-separated (1mm) St. Albans WWTP sample post WPO.

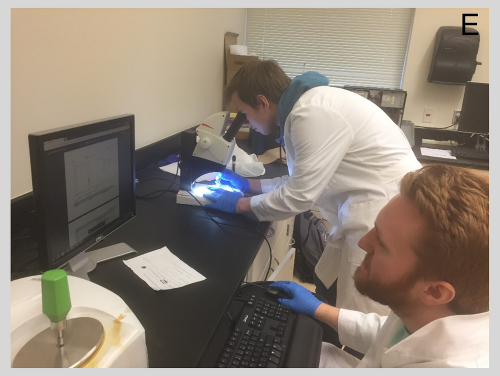
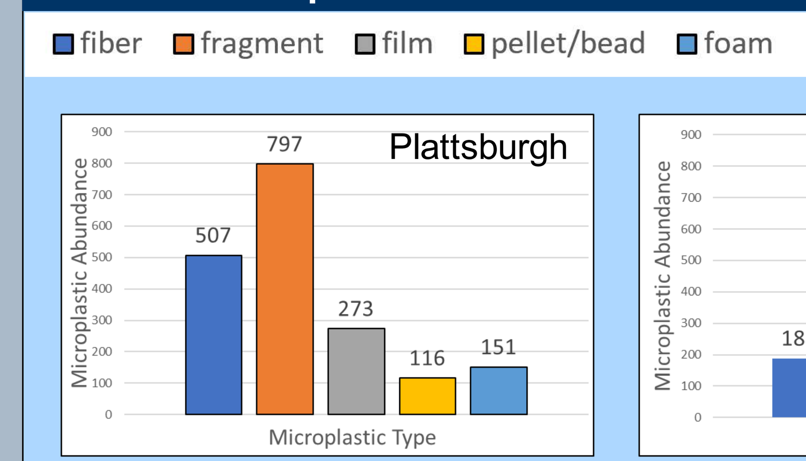
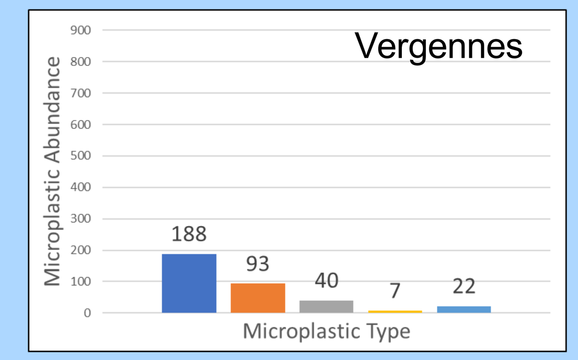
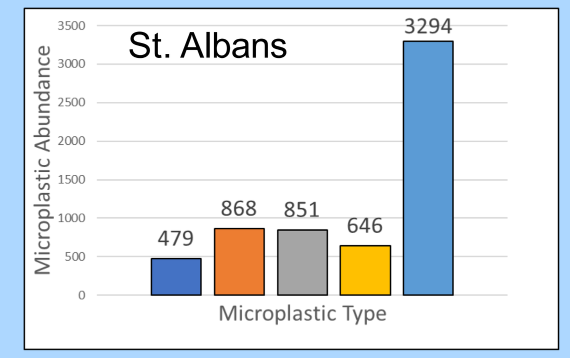


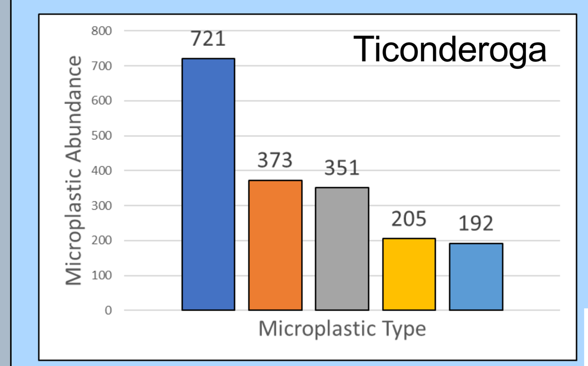
Fig. 3E. Lucas (front) and Nathaniel (back) characterizing microplastics to polymer using the FTIR.

Microplastic Abundance & Characterization









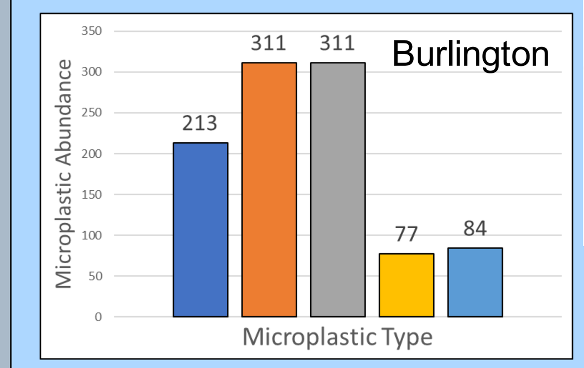


Fig. 5. Microplastic abundance per plant.

Plattsburgh (N = 1844, 62 samples)
→ Fragment dominated

St. Albans (N = 6138, 77 samples)
→ Foam dominated

Ticonderoga (N = 1842, 27 samples)
→ Fiber dominated

Burlington (N = 996, 21 samples)
→ Fragment and film dominated

Vergennes (N = 350, 20 samples)
→ Fiber dominated

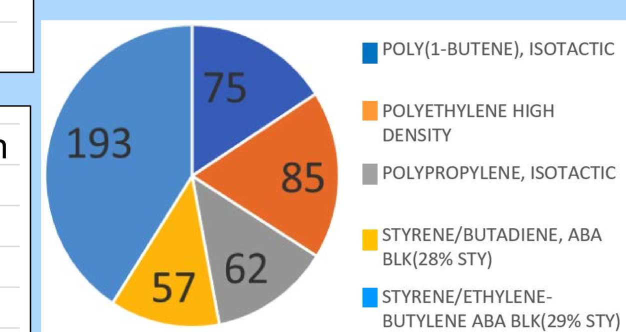


Fig. 6. Overall top 5 most abundant polymer types at all WWTP plants combined.

Polymeric Characterization (FTIR)

Table 2. WWTP-specific common polymer types. These samples were analyzed using FTIR spectroscopy. Plattsburgh N = 56, St. Albans N = 597, Ticonderoga N = 134, Burlington N = 246, and Vergennes N = 113.

Plant	Best Match/ Polymer Type	Abundance
Plattsburgh	POLY(VINYL ALCOHOL) 100% HYDR(NMW 86K)	10
	POLYETHYLENE HIGH DENSITY	9
St. Albans	STYRENE/ETHYLENE-BUTYLENE ABA BLK (29% STY)	192
	POLY(1-BUTENE), ISOTACTIC	74
Ticonderoga	SUNOLITE(R) 160 REFINED PETROLEUM WAX (WITCO)	21
	PROPYLENE GLYCOL RICINOLEATE	18
Burlington	POLYETHYLENE HIGH DENSITY	43
	SUNOLITE(R) 160 REFINED PETROLEUM WAX (WITCO)	32
Vergennes	ALPHA CELLULOSE (99.5% PURE)	13
	PHENOXY RESIN	12

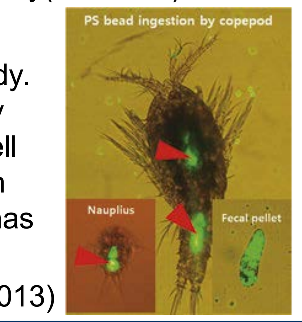
Estimated Daily Microplastic Lake Champlain Loading

Table 3. Plant-specific estimated daily microplastic load. Green shading indicates WWTP with tertiary treatment facilities.

	Particles per Gallon						
WWTP	**Average**	**Low**	**High**	**Std. Dev.**	**Flow Rate (MGD)**	**Plastic Particles per Day**	**N samples processed**
Plattsburgh	0.0034	0.0001	0.0136	0.0033	4.302	**14,665**	62
St. Albans	0.0099	0.0012	0.0665	0.0106	2.535	**25,014**	77
BTV Downtown	0.0051	0.0001	0.0241	0.0060	3.818	**19,629**	14
BTV North	0.0021	0.0008	0.0042	0.0014	0.767	**1,616**	5
Ticonderoga	0.0093	0.0000	0.0401	0.0092	0.987	**9,218**	27
Vergennes	0.0017	0.0000	0.0038	0.0012	0.343	**580**	20

Discussion

- **Microbeads-Free Water's Act (2015) is working→ lesser microbeads.**
- Our results suggest tertiary filtration treatments may reduce microplastic loading.
- Large particles (1mm) are comprised of 22%, 17%, 13%, 17%, 31% fibers, fragment, pellet/beads, films, and foams (N = 2737 particles). **Medium** particles (355μm) are most common and are comprised of 11%, 22%, 11%, 18%, and 39% fibers, fragment, pellet/beads, films, and foams (**N = 6053 particles**). **Small** particles (125μm) are comprised of **44%**, 25%, 3%, 15%, and 13% **fibers**, fragment, pellet/beads, films, and foams (N = 1492 particles).
- Most common polymers by type are fibrous magnesium silicate (textiles), polyethylene high density fragments (**HDPE**), **styrene**/ ethylene-butylene ABA BLK (29% STY) foams, polypropylene isotactic (**PP**) films, and poly(1-butene), isotactic pellet/beads.
- **Polystyrene is the most common polymer type** in our study. Impacts of ingesting buoyant styrene include lesser fecundity and increased mortality in copepods (Lee *et al.*, 2013), as well as liver damage, behavioral changes, and metabolic stress in small fish (Lu *et al.*, 2016; Mattsson *et al.*, 2015). Research has shown increased system-wide mortality (Chae, 2017).



(Lee et al., 2013)

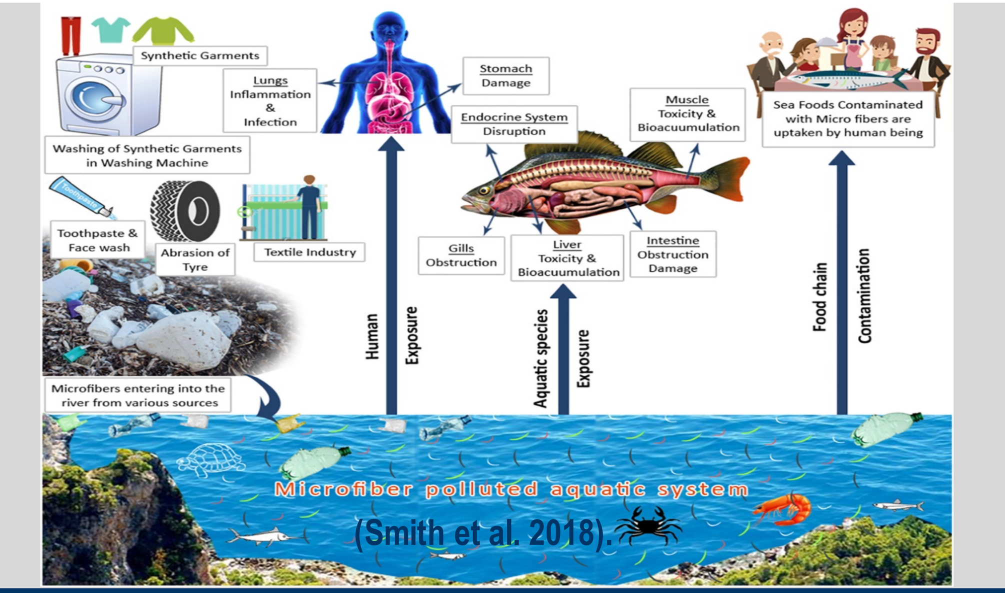
Conservation Implications and Recommendations

- Microplastics in consumer products are not completely captured in typical WWTP processing→ plant upgrades recommended
- Synthetic fibers are ubiquitous and may pose a greater threat than microbeads. Origins of microfibers are in laundering and atmospheric fallout.
- Human microplastic consumption from mussels is minimal when compared to microplastics in household dust. Mussels range from 123-4620 microplastics particles per capita, where as household dust ranges from 13,731-68,415 microplastic particles per capita (Dris *et al.*, 2016).

→ Assembly Bill 3279 in CA proposes a label for any clothing comprised of more than 50% polyester and Bill 341 in CT proposes any synthetic clothing be labeled such to increase consumer awareness.

→ Hartline *et al.* (2017) concluded that top-load washing machines emit 7x's more microfibers than front-loading washing machines.

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



(Smith et al. 2018)

Acknowledgements

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