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Microplastic pollution in Onondaga and Skaneateles lakes in central New York

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Abstract

Microplastic (<5 mm) pollution is a globally recognized problem which varies regionally. Freshwater ecosystems have been vastly overlooked and under characterized for microplastics, including those in central New York. We provide the first measurements of suspected microplastic abundance and form in the surface waters of Onondaga Lake and its tributaries, as well as in the relatively pristine Skaneateles Lake. We found that samples from Onondaga Lake had higher concentrations than Skaneateles Lake, likely owing to more prevalent sources of plastic pollution from litter, wastewater effluent, combined sewer overflows (CSOs), and others. Our methodological development found that microplastic concentrations are highly influenced by sampling methodology, with lower concentrations but greater morphological diversity found in net samples compared to lower volume grab samples. Our findings indicate that microfiber pollution is the primary source of microplastics to these freshwater ecosystems. We also observed that, despite a ban on rinse-off cosmetics in 2015, samples from Onondaga Lake contained microbeads. Our work suggests the need for further improvements to policies addressing microplastic pollution in New York State and has important implications given the use of Skaneateles Lake as the primary drinking water source for the City of Syracuse.

Three Summary Points of Interest

- Sampling methodology is an important consideration in determining microplastic concentration, which can vary by orders of magnitude and collect vastly different morphologies.
- Surface water samples from Onondaga and Skaneateles lakes both contain suspected microplastics, with higher concentrations in Onondaga Lake, consistent with abundant and diverse microplastic sources from surrounding land use, wastewater effluent, combined sewer overflows, among others.
- Though not yet characterized by chemical analysis, the majority of suspected microplastics were microfibers, which is a large source of pollution emission into the environment, but not properly addressed by current plastic pollution policy.

Policy implication statement; products of interest and/or upcoming events

Following completion of remaining work, we plan to summarize findings for publication and distribution to interested local stakeholders.

Keywords: microplastic, freshwater, lakes, methods, central New York

Introduction

Microplastic (<5 mm) pollution is a globally recognized problem brought about by the production and mismanagement of plastic materials. Plastic pollution has resulted in widespread observations of microplastics in marine (Cole et al. 2011), freshwater (Eerkes-Medrano, Thompson, and Aldridge 2015), and terrestrial environments (Horton et al. 2017). Until recently, the majority of research on microplastics has focused on marine ecosystems, with particular focus on areas such as the Great Pacific Garbage Patch. However, freshwater microplastics not only act as a conduit for microplastic transport to the ocean, but also freshwaters have the potential to act as a sink for microplastics (Hoellein and Rochman n.d.). Therefore, it is important to advance understanding of microplastics in freshwater ecosystems.

Microplastics are a ubiquitous pollutant that pose unique challenges to environmental health and the scientific research community. Microplastics can negatively impact ecosystem health by affecting the growth, reproduction, and overall fitness of aquatic organisms (Horton et al. 2017). In addition, microplastics can act as vectors for a variety of persistent pollutants, acting as a “cocktail of contaminants” (Rochman 2015). Freshwater ecosystems present unique cases to observe and study plastic pollution because of differences among watersheds, owing to variation in sources and cycling of plastic within a given location and pathways of plastic supply to lakes. However, microplastics present a challenge for the scientific community due to the variability in methodologies employed, making it difficult to compare results across studies. Therefore, it is important to evaluate differences in microplastic abundance among sampling methodologies.

Compared to marine microplastic research, freshwaters are understudied with respect to microplastic pollution. This pattern is especially evident for regional characterization of microplastics. In this research we characterized the abundance, distribution, and potential sources of microplastics in the surface waters of Onondaga and Skaneateles lakes. Onondaga Lake is a historically polluted lake adjacent to the City of Syracuse, NY. Over the past decade, this lake has experienced remarkable improvements in water quality. However, Onondaga Lake receives 20% of its water from the Metropolitan Syracuse Wastewater Treatment Plant (Metro), is impacted by combined sewer overflows, and its watershed includes considerable urban land use, all of which are potential avenues for microplastic supply. In contrast to Onondaga Lake, Skaneateles Lake is a relatively pristine source of drinking water for the City of

Syracuse and is unfiltered prior to distribution (as a result of a filtration avoidance agreement).

Onondaga and Skaneateles lakes represent important ecosystems and resources for central New York. To characterize regional sources and variations in microplastic pollution between these two lakes, this work had specific aims to:

1. Determine the influence of sampling methodology (grab, bucket, or net) on microplastic abundance and form;
2. Characterize the spatial and temporal variability of microplastic concentrations in the surface waters of Onondaga and Skaneateles lakes; and
3. Evaluate potential sources of microplastic based on multiple lines of evidence.

Results & Discussion

Microplastic Sampling Methods

Microplastic samples were collected by either grab (~1 L), bucket (19.5 – 39 L), or net (160,000 – 370,000 L), which were sieved at or after collection through a mesh size 20 μm , 355 μm , and 300 μm , respectively (**Figure 1**). Sampling methodology had a large impact on microplastic abundance measurements. Our grab samples consistently had the highest concentrations but were the most sensitive to blank correction due to their low counts. Compared to bucket and net samples, grab samples had the least morphological diversity, collecting only fibers and films. Fibers were the dominant microplastic morphology in all sample types.

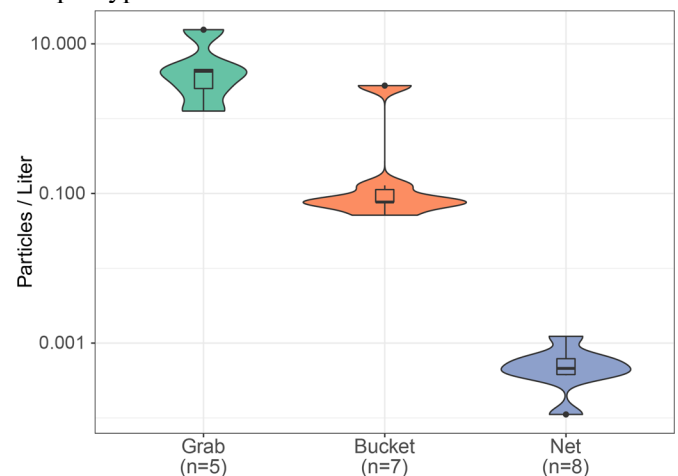


Figure 1: A violin plot showing the distribution of suspected microplastic concentrations among sample types for surface water samples obtained in 2019 and 2020.

A potential explanation for these differences is the mesh size used in bucket and net collections, which

could exclude smaller fibers and films. Since we have yet to chemically confirm the fibers and films from our grab samples, it is also possible that grab samples are more likely to contain particles that are visually mistaken as microplastics.

We also found that bucket samples had the most variation based on sampling location. For example, two of our samples collected from the inner harbor of Onondaga Lake had a 2 order of magnitude difference in concentration between one side of the harbor, which had more visible debris, than the other. This spatial variability stresses the importance of sample location when using grab or bucket sampling. Since grab and bucket samples are more spatially limited than net samples, they are less precise in characterizing the concentration of larger bodies of water. However, grab and bucket samples present a more affordable and less time-consuming method for microplastic sampling.

Prior work comparing sampling methods found similar patterns between grab and net sampling. Barrows et al. (2017) collected net tows with accompanying grab samples (1 L), finding that nets tend to underestimate smaller size fractions. Green et al. (2018) used a variety of net sampling techniques in conjunction with grab samples, finding that microplastic concentrations in net sample were 3 to 4 orders of magnitude less than grab samples (1 L). Their grab samples underestimated fragments and films compared to net samples.

We plan to continue characterizing remaining samples and conducting measurements of a sub-sample of particles to obtain particle size distributions. This analysis will allow us to draw conclusions on whether smaller size fractions are omitted from bucket and net sampling. Our comparisons are limited by spatial and temporal variability across our sample types. Since sampling by each method was not conducted at the same time, differences between sampling techniques may also reflect temporal variability at a given location.

Spatial and Temporal Variability in Microplastic Concentrations

Sample concentrations from Onondaga and Skaneateles lakes may be a function of both time and location of collection (**Figure 2**). Samples collected in October 2019 had higher microplastic concentrations compared to those collected from August – October 2020 for both Onondaga and Skaneateles lakes. We hypothesize that this difference may be due to the dry conditions experienced in 2020, which would decrease inputs of street litter and effluent into nearby bodies of water. Another potential influencing factor may be

changes in human behavior during the COVID-19 pandemic, which could have reduced street litter if people were less likely to leave their homes.

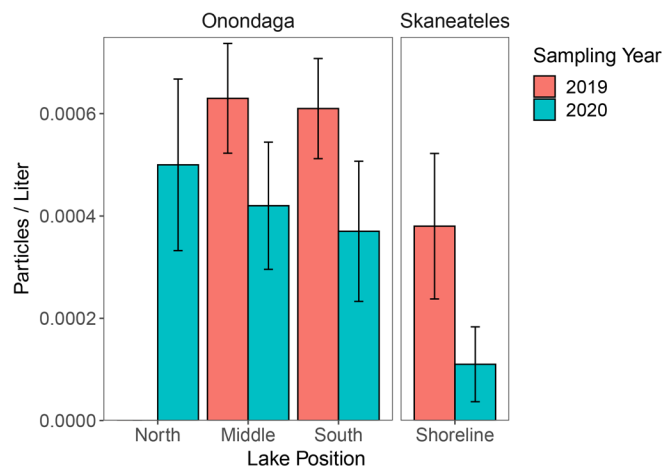


Figure 2: Suspected microplastic concentrations (particles/liter) from Onondaga and Skaneateles lakes collected using a 300 µm net. Error bars represent +/- equipment blank values. When an equipment blank was not available, an average of equipment blanks was used.

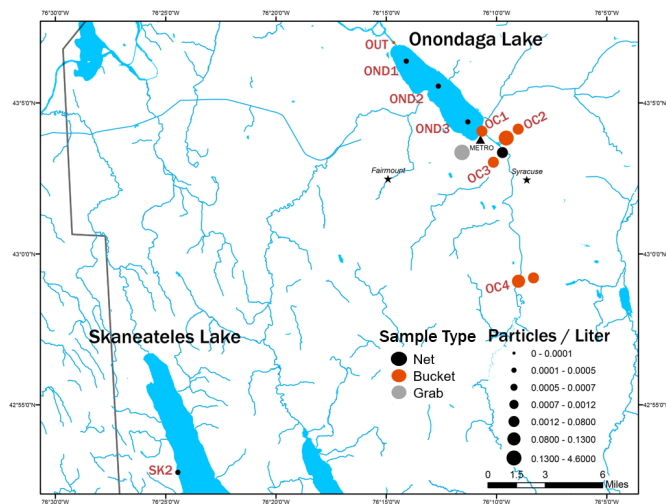


Figure 3: Suspected microplastic concentrations from samples collected in 2020. Bucket samples were collected in June and net samples in August – October. The Metro grab sample shown is the value obtained from our 2019 sample, since we were unable to sample in 2020 due to the pandemic.

Samples collected from Skaneateles Lake were characterized by lower concentrations of suspected microplastics than Onondaga Lake. This pattern is consistent with the abundance and diversity of plastic pollution sources to Onondaga Lake from the urbanized watershed, Metro effluent, combined sewer overflows, and other sources. However, due to limitations of boat access we were only able to sample the Northern portion of Skaneateles Lake (**Figure 3**). Moreover, unlike our

Onondaga Lake samples, Skaneateles samples were trawled along the shoreline, rather than across the middle of the lake.

We anticipated that microplastic concentrations in Onondaga Lake would be highest in the southmost portion of the lake, closer to the Metro effluent and Onondaga Creek which drains through urban Syracuse and receives a number of CSOs. However, concentrations were relatively consistent or lower in the southern portion of the lake (**Figure 2**). We are interested in investigating this pattern further in the context of lake depth profile sampling. If inflowing effluent from Metro has greater density than lake water, our surface water samples may have not collected associated microplastics from effluent. Our collections could also be influenced by the density of the microplastic particles themselves, which will be further revealed upon chemical characterization in the coming months.

Potential Sources of Microplastic

Previous work found that the majority of floatables or floating macroplastic entering Onondaga Lake from combined sewer overflows (CSOs) was derived from street litter (ARCADIS 2013). However, there are many other potential sources of microplastic in the Onondaga and Skaneateles lake watersheds.

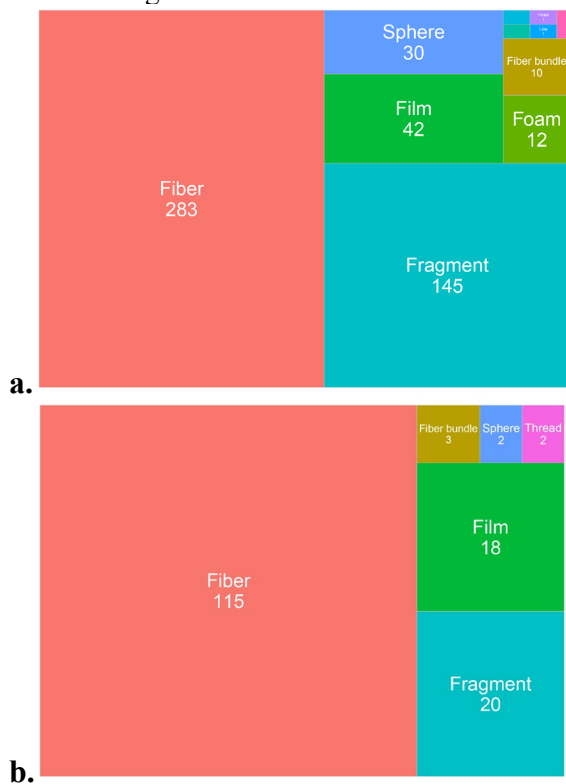


Figure 4: Tree maps showing the abundance of suspected microplastic morphologies from net and grab samples collected from a) Onondaga

Lake (5 net samples, 2 grab samples) and b) Skaneateles Lake (2 net samples, 2 grab samples).

Our current data on plastic particle morphology is limited by the number of processed samples. However, we have found that both net and grab samples collected from either lake had different morphological make-up, owing to potentially different sources (**Figure 4**). Both lakes had a large fraction of their suspected microplastics as fibers, which could be sourced from laundering of clothing and wastewater effluent or air transport of fibers (De Falco et al. 2020). These observations are limited by our lack of chemical characterization, as some of these fibers may be natural or semi-synthetic fibers, which are not plastic but are still derived from anthropogenic sources.

Compared to Skaneateles Lake, Onondaga Lake samples were characterized by more non-fibrous morphologies (**Figure 4**). Onondaga Lake samples contained more colorful spheres, consistent with microbeads (Eriksen et al. 2013) which could come from abrasives, personal care products, or cleaning products not removed during wastewater treatment.

Based on our current data, it is difficult to determine the most prevalent source of microplastic. We plan to continue to process and characterize plastic particles from water collections to narrow down contributions from different sources. However, it is exceedingly difficult to do so given the diversity of sources and pathways for microplastics.

Policy Implications

This work has implications for local policy focused on reducing sources of plastic pollution to improve both human and environmental health. These are the first results finding suspected microplastic contamination in Skaneateles Lake, which is the source of unfiltered drinking water for the City of Syracuse. It would benefit New York to follow California’s example in defining and planning the regulation of microplastics in drinking water (California Water Boards 2020).

Though New York has recently implemented a ban on plastic bags, we found that the majority of microplastic was not films consistent with the breakdown of grocery bags, but fibers from laundering or air transport. Compared to grocery bags, fibers are a more difficult source to control. There is currently no definitive benefit to substituting plastic fiber clothing for natural fibers, which are also prevalent in the environment (Athey et al. 2020). However, legislative efforts to reduce microfiber shedding from clothing into the air or during

laundering, as well as improving microfiber removal from the laundering and wastewater treatment process could prove beneficial in curbing this source of pollution (Napper, Barrett, and Thompson 2020; De Falco et al. 2020).

Despite the monumental effort to reduce macroplastic inputs into Onondaga Lake via floatable control technologies, street sweeping, and green infrastructure, we still found a total of 243 potential microplastic fragments. It is important to better characterize local sources of larger pieces of plastic, which can form microplastic over time. This characterization could be in the form of community efforts and citizen science to both clean-up and survey areas within each watershed. Litter surveys would not only engage the local community in the scientific process and plastic pollution reduction, but also give meaningful spatial data on the distribution of litter.

We also found evidence of potential microbead contamination of Onondaga lake despite a ban on microbeads in rinse-off cosmetics in 2015 via the Microbead-Free Waters Act (House Energy and Commerce Committee 2015). These findings could indicate that microbeads are still circulating in freshwater systems since the ban in 2015. Since the legislation does not ban the use of microbeads in other products aside from rinse-off cosmetics, it is likely that other sources of microbeads are making their way into the environment.

Methods

Surface water samples were collected using three methods depending on location and accessibility. We assessed the variation among sampling methods by using three different methods to collect surface water microplastics. Lake samples were collected using a 300 µm net, with additional 1 L grab samples at the start, beginning, and end of each tow (Barrows et al. 2017). Tributary and outlet samples were taken as 1 L grab samples, volume-reduced bucket samples, or as net samples, as location allowed. Volume-reduced bucket samples were obtained using a stainless-steel bucket with a natural fiber rope. Bucket samples were field sieved through either a 355 µm or 106 µm sieve into a separate bucket to determine approximate volume sampled. Each sample was stored in pre-rinsed glass mason jars with stainless steel lids. Due to delays in sample processing, only the results of the 355 µm bucket samples are presented here.

In the laboratory, all samples were catalogued and re-labeled to lower bias when processing and counting. Samples with high amounts of visible debris,

such as leaves, sticks, and other detritus, were sieved through a stack of four sieves: 4.75 mm, 1 mm, 355 µm, and 20 µm, while low debris samples were sieved through the 20 µm sieve to reduce sample loss, contamination, and processing time. Samples from each size fraction were processed using a wet peroxide oxidation method (Masura et al. 2015) with minor modifications. After noticeable deformation of plastic particles using this method, we lowered the processing temperature to 30°C (Munno et al. 2018). Additionally, some samples required re-processing across multiple days and eventually formed an iron precipitate coating on particles due to the solution becoming overly alkaline. To combat precipitate formation, hydrogen peroxide additions were coupled with Fe(II) solution additions. Any precipitates that formed were dissolved in the samples using additions of oxalic acid. Following digestion, sample fractions were vacuum filtered onto gridded 0.45 µm mixed cellulose ester filters.

Filtered samples were examined at the Syracuse Biomaterial Institute using a stereomicroscope. We developed a visual microplastic identification and decision tree (**Figure 5**) based on previous work (Liboiron 2017; Conkle et al. 2019; Free et al. 2014; GESAMP 2019; Lusher et al. 2017; Marine & Environmental Research Institute 2015; Norén 2007; Rochman et al. 2019; Sedlak et al. 2017; Wagner et al. 2014; Zhou et al. 2020).

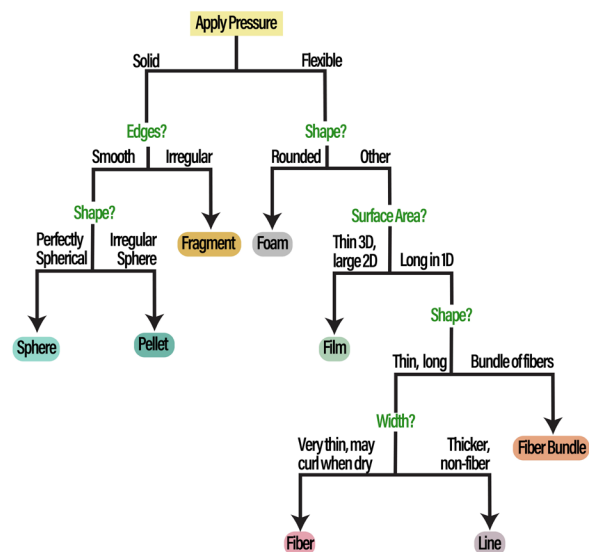


Figure 5: Decision tree protocol for morphology determination of microplastic particles, modified from GESAMP, 2019.

Suspected microplastics were picked from samples and characterized based on color and morphology (sphere, pellet, fragment, foam, film, fiber, fiber bundle, and line).

Further chemical characterization of a sub-sample of particles is in progress and will occur in the next few months.

Sample contamination is a large concern in the processing and sampling of microplastics. Sample processing was conducted in a class-1000 clean room or under a laboratory hood. To account for contamination sources, we periodically collected procedural, air, and equipment blanks. When conditions allowed, we also collected field blanks. All blanks, aside from equipment and procedural blanks, were collected by filling a pre-rinsed jar with DI water and leaving the jar out next to our area of processing. Procedural blanks were DI water which was processed as we would a sample. To further account for contamination, we used fibrous supplies (sponges, towels, lab coats) of one consistent color for all sample processing. Since all our fibers were a pink color, pink fibers were subtracted from all samples as contamination. Procedural blanks were subtracted based on color and morphology from all samples.

Outreach Comments

Our outreach activities included:

- Appearance in the Eagle Bulletin newspaper: “Bag ban hits home for local businesses” and the Daily Orange: “Syracuse retailers adjust to plastic bag ban” in March 2020.
- Appearance in the Newhouse Communications Center (NCC): “How’s the New York State Plastic Bag Ban Going?” in April 2020.
- A presentation and panel discussion at the Virtual Bio-Art Mixer in July 2020 to discuss this research in the context of the arts and other scientific disciplines.
- A virtual guest lecture in EAR 205: Water Sciences on plastic pollution and freshwater microplastics in October 2020.
- A live panel discussion on Sustainable Beauty Science hosted by The Eco Well on YouTube in November 2020.
- Organization of a Plastic & Waste Journal Club, to meet monthly in 2021, for plastic and waste professionals from different sectors.

We hope to participate in more outreach activities as the pandemic allows and our results are finalized.

Student Training

Over the course of this funding cycle, one graduate student and one undergraduate student were directly involved with the development and execution of

this project. Both students acquired experience in the field and laboratory during the project. Two other graduate students helped with sample collection.

Publications/Presentations

Markley, Laura, Driscoll, C., Costello Staniec, A., and Huth, E., Syracuse University. **Goldilocks and the Three Surface Water Sampling Methods.** Platform Presentation: MICRO2020 International Conference, November 2020, Virtual.

Markley, Laura, Driscoll, C., Costello Staniec, A., and Huth, E., Syracuse University. **Distribution and Potential Sources of Freshwater Microplastics in Onondaga and Skaneateles Lakes.** Platform Presentation: Society of Environmental Toxicology and Chemistry (SETAC) North America, November 2020, Virtual.

Mihai, F., Gündoğdu, S., Khan, F., Olivelli, A., Markley, L., and Emmerik, T. **“Plastic pollution in marine and freshwater environments: abundances, sources, and mitigation.”** *Emerging Contaminants in the Environment: Challenges and Sustainable Practices*, edited by Sarma, H., Dominguez, D., and Lee, W., Elsevier, USA. (In Review).

Additional final reports related to water resource research are available at <http://wri.cals.cornell.edu/news/research-reports>

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