Plastics Pollution in the Laurentian Great Lakes

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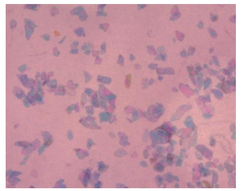
Scope

Plastic debris are pervasive and persistent pollutants in the world's aquatic environments, with significant economic, ecological, human health, and aesthetic impacts. We are exploring the feasibility of using spectroscopic techniques to detect plastic debris in rivers, lakes, beaches and sediments, while also using existing data sets to help characterize and map the distribution of plastic debris in the Great Lakes. Our research aims to advance the identification, tracking, mapping, and reporting of plastic debris in the Great Lakes to support public awareness, industries at risk, regulation of plastic waste disposal and treatment, and to expedite cleanup efforts. Our recent publication (Driedger et al., 2015) provides the first comprehensive review of plastic pollution research in the Great Lakes.

Background



Microscopic Plastic Debris

- Size (diameter): < 0.333 mm
- Sources: fibers from synthetic fabrics, breakdown of larger plastics
- Due to size and buoyancy, microscopic plastics are not retained by wastewater treatment plants
- Impacts: transport of toxins including POPs and heavy metals, accumulation in the food chain, transfer of toxins from plastic to wildlife (via ingestion)

Microplastic Debris

- Size (diameter): 0.33 mm – 5 mm
- Sources: microbeads in personal care products, pre-production pellets (nurdles), breakdown of larger plastics
- Impacts: transport of toxins including POPs and heavy metals, accumulation in the food chain, transfer of toxins from plastic to wildlife (via ingestion)

Macroplastic Debris

- Size (diameter): >5 mm
- Sources: litter from beach-goers, fishing materials (e.g. nets, line), stormwater discharge, human littering, illegal offshore dumping, loss during shipping
- Impacts: wildlife entanglement and ingestion, transport of toxins including POPs and heavy metals, transport of invasive species, reduced tourism activity, shipping and fishing vessel damage, reduced fishing catch, beach and harbor cleaning costs

Cost of Combating Plastics Pollution in the Great Lakes

Stickel et al. (2012) estimated that $13 per resident annually is spent on the following activities:

- Beach and waterway cleanups
- Street sweeping
- Installation of storm-water capture devices
- Storm drain cleaning and maintenance
- Manual cleanup of litter
- Public anti-littering campaigns

By extrapolation, given that the Great Lakes region houses 36 million people within 50 km of its shoreline, we estimate that the direct cost of combating plastic pollution in the Great Lakes is:

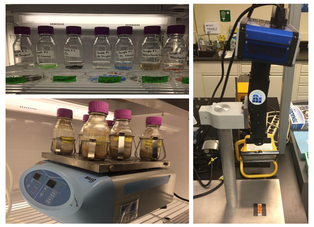
US $468,000,000

Spectral Identification

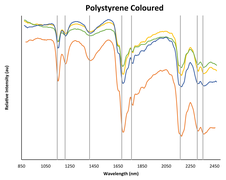
We conducted a feasibility study on the use of near infrared reflectance (NIR) and Raman spectroscopy for detecting plastic debris in aquatic environments. In collaboration with P&P Optica, a spectrometer manufacturer in Waterloo, we conducted two experiments to determine the effects of mechanical weathering and biofilm growth on the NIR and Raman spectra of plastic debris. The experiments intend to simulate the fate of plastic debris in lake environments. The results obtained so far indicate little changes in the diagnostic spectral characteristics of the plastics upon mechanical weathering and colonization by microorganisms. The intensities of the NIR spectra for the debris covered by biofilms, however, are attenuated relative to the naked plastic surfaces. Raman spectroscopy may help overcome this limitation of NIR.

Weathering Experiment

4 types of plastic (PET, PVC, PS, and PC) were exposed to light, sand, and shaking in an environmental chamber (simulating a beach environment) for 472 days.



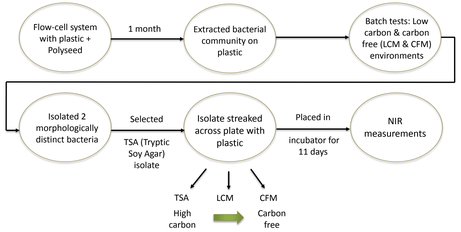
NIR spectrometer (right) used to collect spectra of the weathered plastics (left)

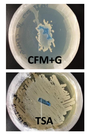


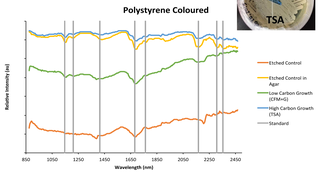
NIR spectra of weathered plastic debris: preliminary results show minimal changes in the spectral features of weathered plastics when compared with the initial, unweathered plastics.

Biofilm Experiment

A biofilm was grown on PS and PET. The flow chart (below) describes the method developed to grow the biofilm and prepare samples for NIR measurement.



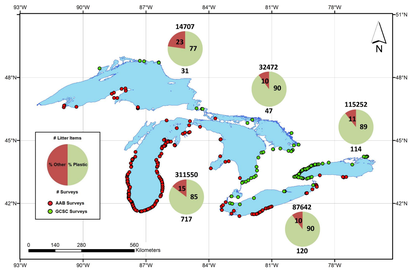




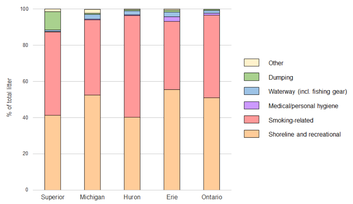
NIR spectra of weathered PS with biofilm: preliminary results show that the major spectral features are identifiable in PS for both high and low carbon environments, and in PET in a high carbon environment.

Shoreline Litter Analysis

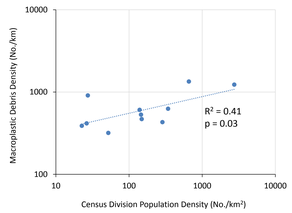
To date, few scientific articles have been published that include quantitative data describing the distribution of plastic debris on Great Lakes shorelines. Data characterizing the spatial and temporal distribution of plastic debris is important for developing waste reduction and management strategies. Volunteer-led beach cleanups provide a valuable, alternative source of data about shoreline plastics. We are using litter survey data generated during cleanups between 2008 and 2013 by volunteers of the Adopt-a-Beach (AAB) and Great Canadian Shoreline Cleanup (GCSC) programs to delineate the abundance, sources, and distribution of plastic debris on Great Lakes shorelines.



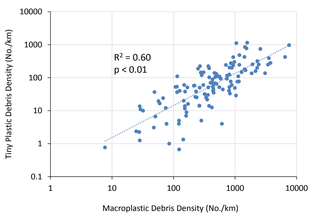
2012 AAB & GCSC data: Location of beach cleanups, number of surveys conducted, and the percentages of litter comprised of plastic in each Great Lake (Driedger et al., 2015).



2012 AAB & GCSC data: Percentages of litter items in the Great Lakes grouped according to activity. The most common individual litter items found on beaches include cigarette filters, plastic food wrappers, and plastic containers (Driedger et al., 2015).



2013 GCSC data: A significant positive correlation exists between mean macroplastic debris density and census division population.



2013 GCSC data: A significant positive correlation exists between macroplastic debris density and tiny plastic debris (< 2.5 cm in diameter) density.

Conclusions and Future Research

- NIR has the ideal spectral range for in situ identification of plastic debris. Due to significant attenuation in water, NIR sensing technology is most promising for plastics detection in filtered water samples and solid-phase samples (sediments, soils, beach sand). Raman suffers less from attenuation in water than NIR and will be used to develop in situ sensors for monitoring plastics within the water column.
- Weathering of plastics does not significantly alter their spectral features; current NIR spectral libraries are sufficient to identify weathered plastics. Biofilms diminish NIR spectral peaks but spectra can still be identified.
- Volunteer beach cleanups show that typically more than 80% of litter along the shorelines of the Great Lakes is comprised of plastics. Because intact or near-intact debris, such as cigarette filters and food related items, mostly represent in-situ litter, beach-goers appear to be a major source of plastic debris.
- Population density (and by extension, number of beach-goers) was found to be a significant driver of litter density on Great Lakes shorelines. The strong correlation between macroplastic and tiny plastic debris indicates their sources are likely related.
- Future research will include field deployment of NIR spectrometer, continued analysis of shoreline litter data, and application of Raman spectroscopy.

Contributors

Poster prepared by Alex Driedger

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References:

Driedger, A.G.J., Dürr, H.H., Mitchell, K., Van Cappellen, P., 2015. Plastic Debris in the Laurentian Great Lakes: A review. J. Great Lakes Res. 41, 9-19.

Stickel, B.H., Jahn, A., Kier, B., 2012. The cost to West Coast communities of dealing with trash, reducing marine debris. Kier Associates. Blue Lake, CA, USA ((21 pp.). http://www.epa.gov/region9/marine-debris/pdf/WestCoastCommsCost-MngMarineDebris.pdf).

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