MICROPLASTICS IN WASTEWATER AND BIOSOLIDS – WHAT IS THE BIG DEAL?

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Plastic pollution

- In 2017, 350 million tons of plastics were produced globally
- PET, HDPE, PVC, LDPE, PP, PS and PUR constitute 90% of plastic waste
- In Canada, 86% of plastics are landfilled, 9% are recycled, 4% are incinerated, and 1% end up in the environment
- Plastics remain in the environment from hundreds to thousands of years
- No incentive for plastics recycling - it is cheaper to produce plastics from raw materials
- Research and knowledge gaps in freshwater and terrestrial environments
- They are everywhere – including air!

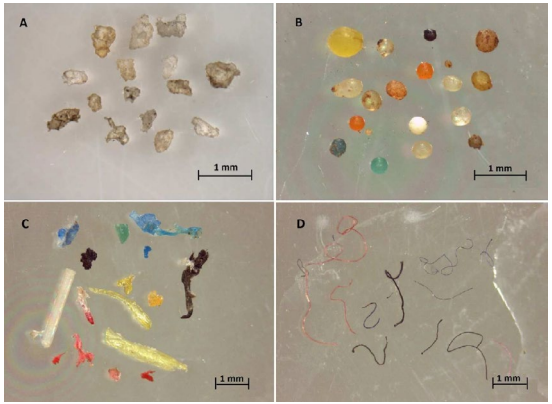
https://norwegianscitechnews.com

https://enlightngo.org

Plastics in water

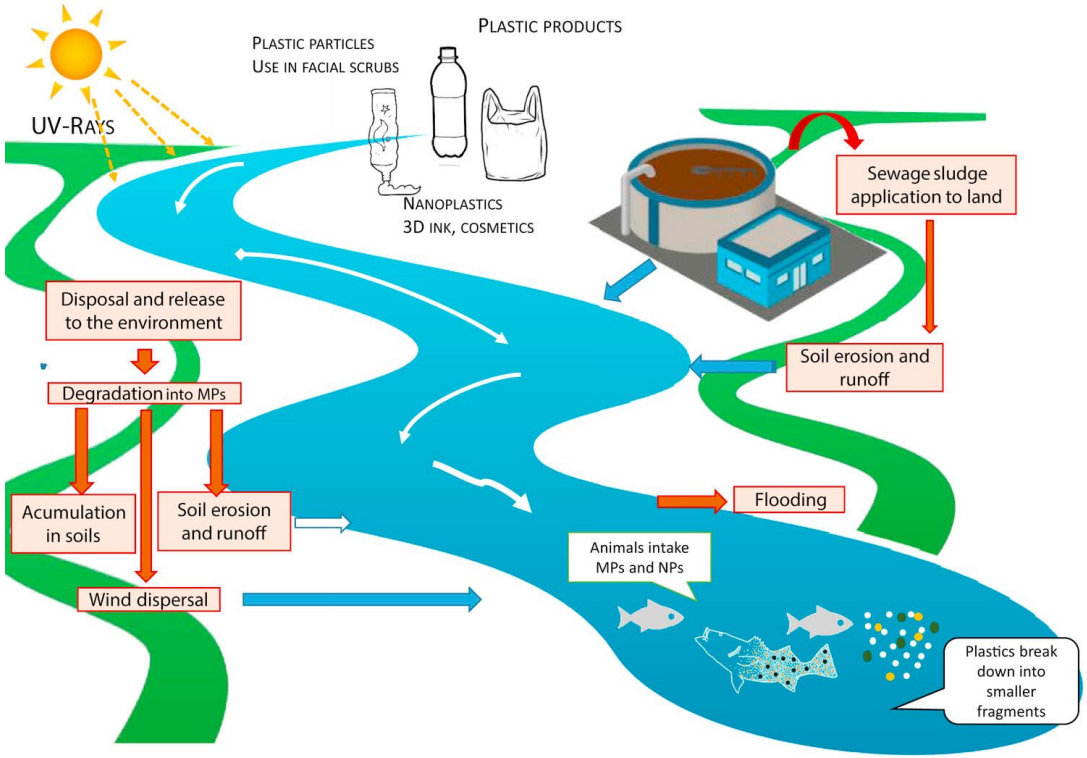
- Plastics can be grouped by their size as macroplastics (>25 mm), mesoplastics (5–25 mm), microplastics (<5 mm) and nanoplastics (<0.1 m)
- Microplastics come from primary and secondary sources
- Microplastics can be fibers, fragments, spheres, pellets, films, and foams
- Rate of degradation is very slow and affected by abiotic (i.e., light, temperature, shear) and biotic (i.e., enzymes, microorganisms)
- Degradation rate is closely related to polymer chemistry, structure, morphology, and physical and mechanical behaviour

https://www.nationalgeographic.org



Talvitie et al., Water Research, 2017, 123:401-407

Microplastic sources



- Plastic waste litter
- Wastewater effluents
- Combined sewer overflows
- Biosolids application
- Stormwater
- Agricultural plastics
- Industrial/commercial sources
- Deposition of airborne microplastics

Pico et al. (2019), TrAC Trends in Analytical Chemistry, 113, 409-425.

In the context of wastewater and biosolids treatment

Knowledge needs

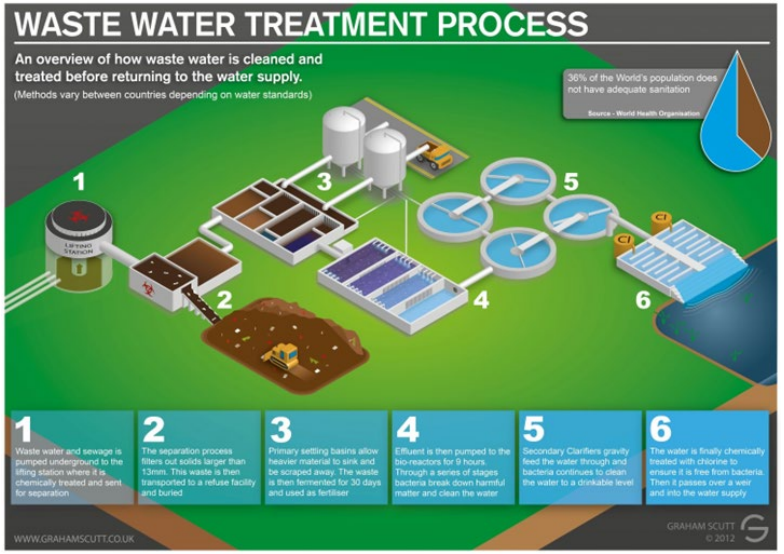
- ❑ Plastics size, shape, quantity, type
- ❑ Fate and transport
- ❑ Leaching additives
- ❑ Adsorption of chemicals
- ❑ Carrier for pathogens and genes
- ❑ Biofilm formation
- ❑ Inhibition mechanisms
- ❑ Impact on treatment technologies
- ❑ Environmental concerns
- ❑ Health concerns

Challenges

- ❑ Very challenging matrix
- ❑ No agreed sampling, quantification and identification methods
- ❑ Huge variance in reported results
- ❑ Lack of plant data and monitoring
- ❑ Small microplastics and microfibers
- ❑ Removal and monitoring technologies
- ❑ Regulatory landscape

Microplastics at wastewater treatment plants

- Wastewater treatment is a pathway for microplastics to the aquatic environment
- Reported MP concentrations: 0-30,000 particles/L in influent and 0-3,000 particles/L in effluent.
- Approx. 5%, 70%, 90% and 95% removal during preliminary, primary (physical), secondary (biological) and tertiary (advanced) treatment
- Larger MPs (> 5 mm) are removed during primary treatment and smaller MPs (<1 mm) during biological/chemical coagulation and flocculation
- Well-operated plants with physical, chemical and biological treatment processes can remove 99%
- Most microplastics end up in sludge and some microfibers remain in effluent



Effect of Treatment Technologies on Microplastics

- Quantities, size, shape and composition change throughout wastewater treatment
- Primary treatment (grit removal, primary clarifiers, skimmers) is the first barrier
- Activated sludge traps and removes remaining small (< 0.5 mm) microplastics
- Chemical disinfection and advanced oxidation increases the microplastic quantities through chemical degradation
- Filtration based treatment technologies (biofilters, ultrafiltration, sand filters, MBR) have shown the best performance
- Remaining microfibers in treated effluents is an issue
- Effluent end-of-pipe technologies are expensive and cost-benefit is questionable

Effect of Microplastics on Treatment Technologies

- Additives released from microplastics can damage cells and inhibit activities of key enzymes and genes
- Microplastics can catalyze the generation of intracellular reactive oxygen species
- Microplastics influence the microbial community and activity
- At low microplastics concentrations, improvements in aerobic/anaerobic biological treatment have also been observed
- Nanoplastics can penetrate the cell membrane and have been shown to be more toxic
- Type, size and surface charge
- Operational conditions play a role

Biosolids

- Up to 99% of microplastics in wastewater end up in sludge
- Reported MP concentrations: 1,500-24,000 particles/kg dry solids
- Approx 100 tons/year MP enter soil environment in Europe and North America
- The higher the biosolids application rates, the higher the microplastics counts in soil
- No feasible removal technologies from biosolids
- Microplastics have been shown to adversely affect plant growth and soil microbial pollution
- Contribution from biosolids to agricultural is approx. 1% of other microplastics sources

Microplastics in biosolids

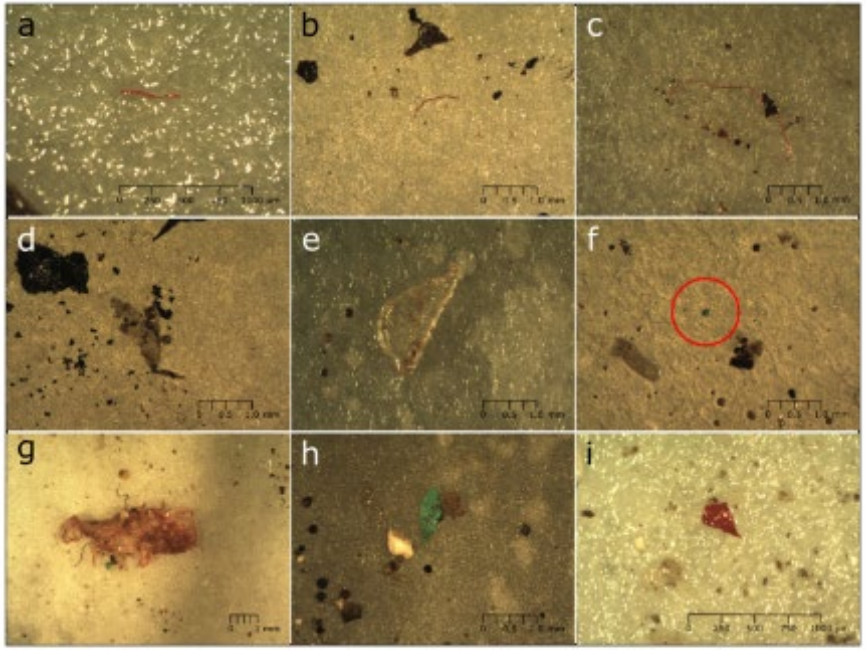
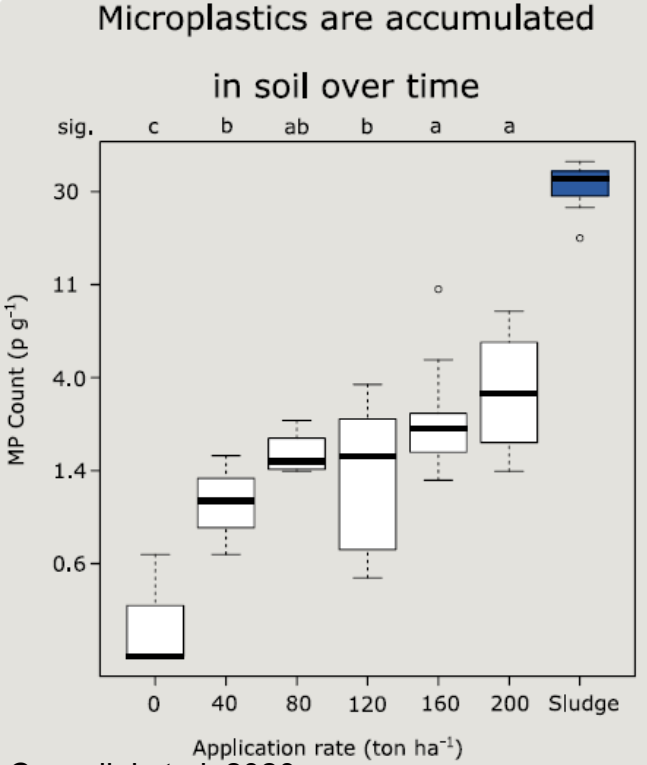


Fig. 7 Example images of the microplastics observed. Fibers (a, b, c), films (d, e), pellets (f), and fragments (g, h, i).



Corradini et al, 2020

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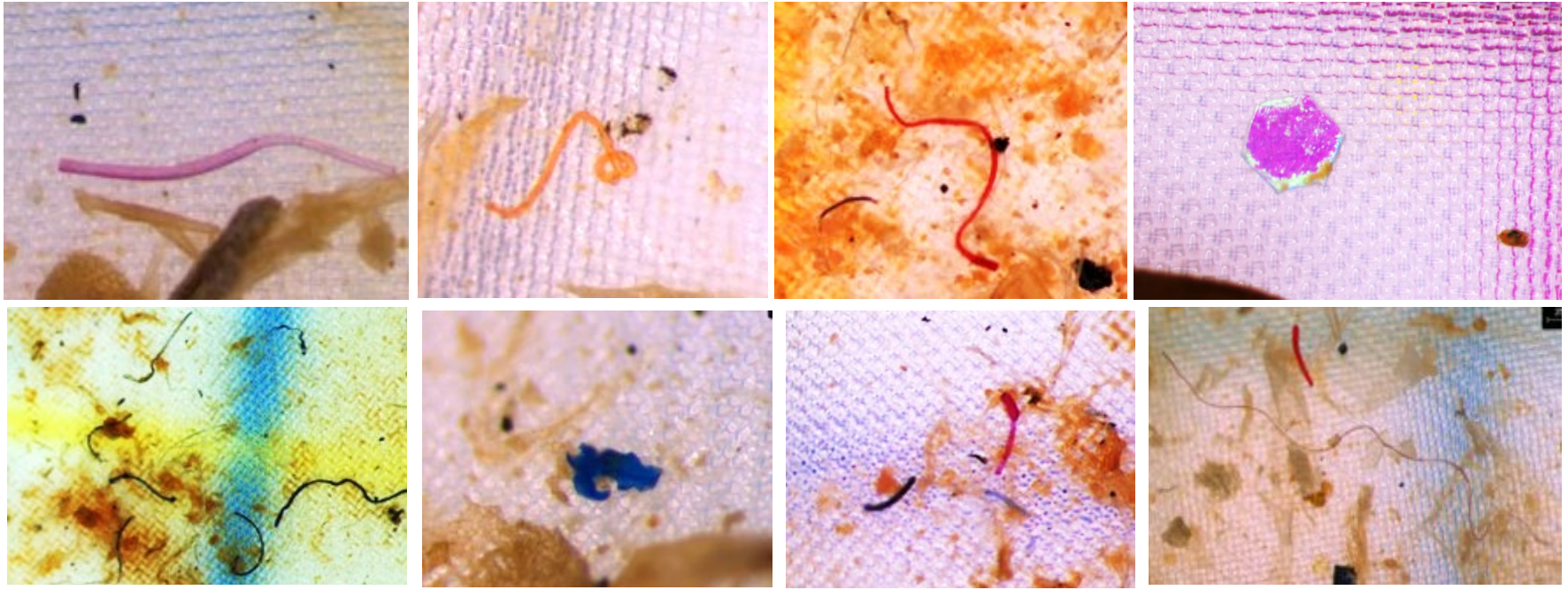
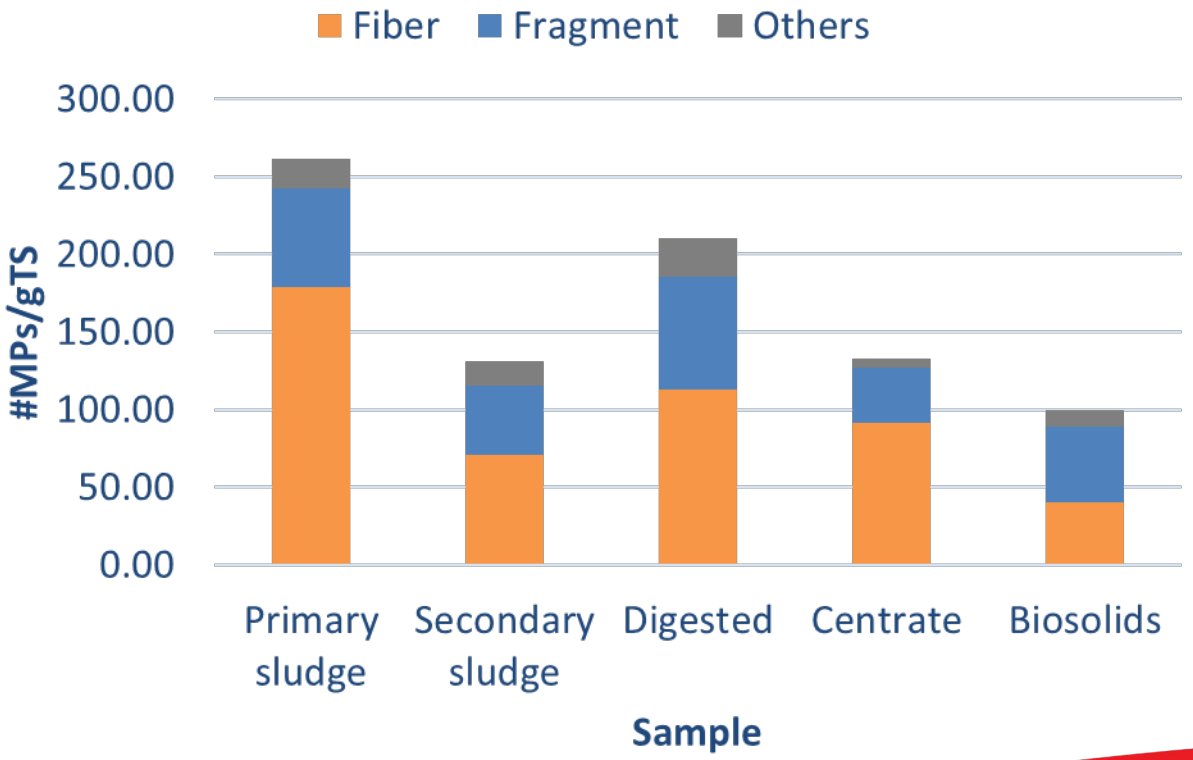
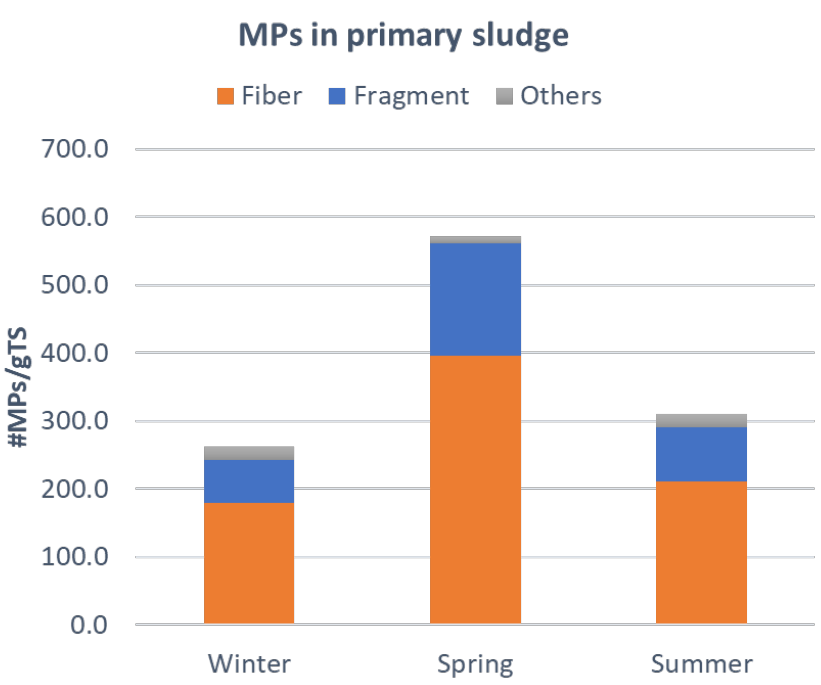
Results from our research group

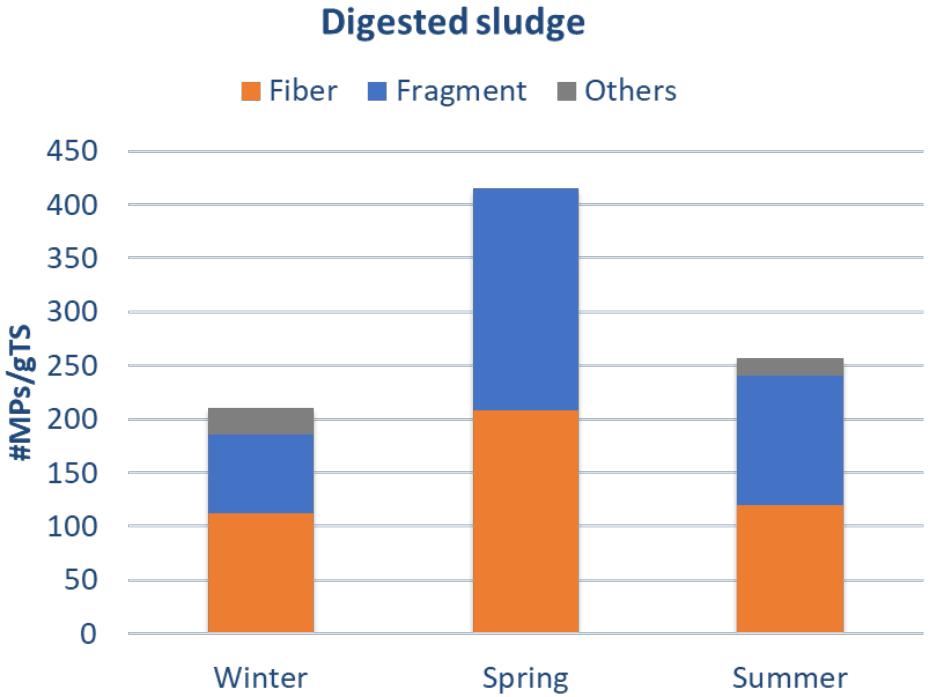


Microplastics quantities and types in different sludges



Seasonal distribution of microplastics





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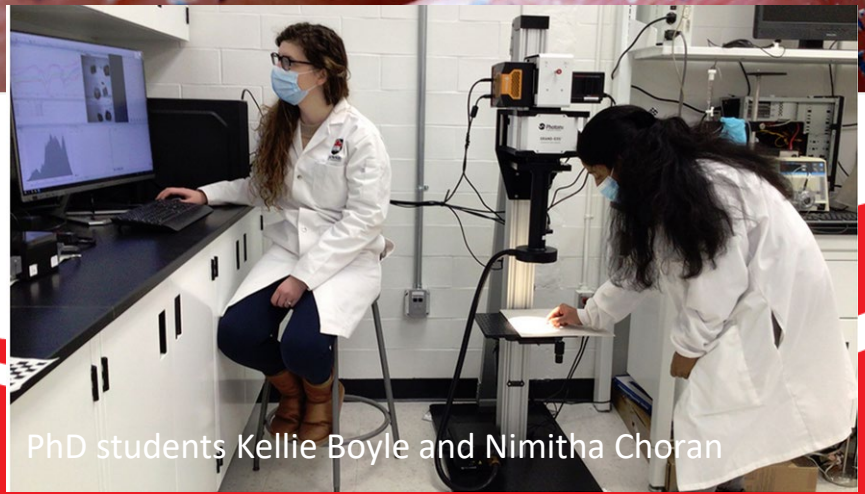
Validating and Testing New Microplastics Technologies

Funded by $250,000 grant from Environment and Climate Change Canada's Zero Plastic Waste Funding Initiative, Global Water Institute researchers are working with a trio of companies to test and validate their technologies.

Microplastics Pollution and Your Health: Using Technology to Find a Growing Environmental Threat

View story



PhD students Kellie Boyle and Nimitha Choran

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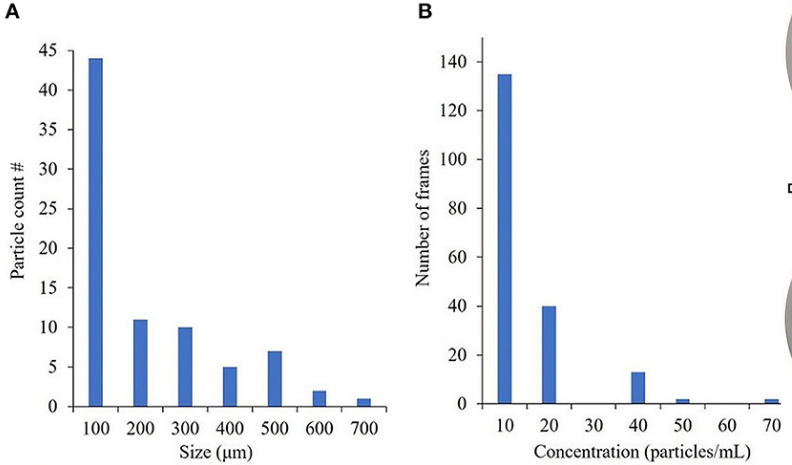
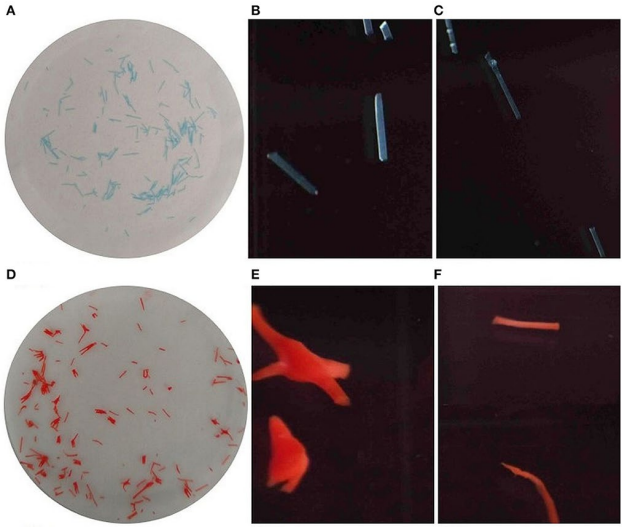
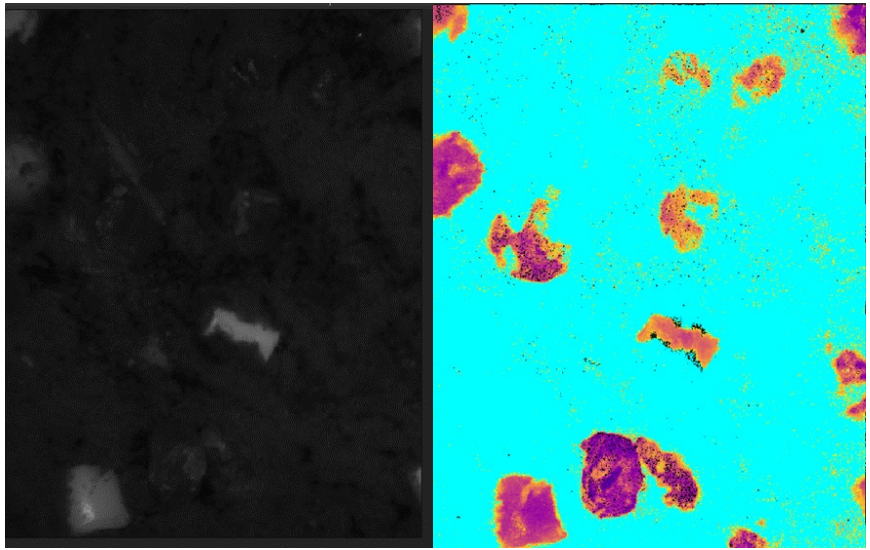
Microflow imaging for MP quantification in water and wastewater

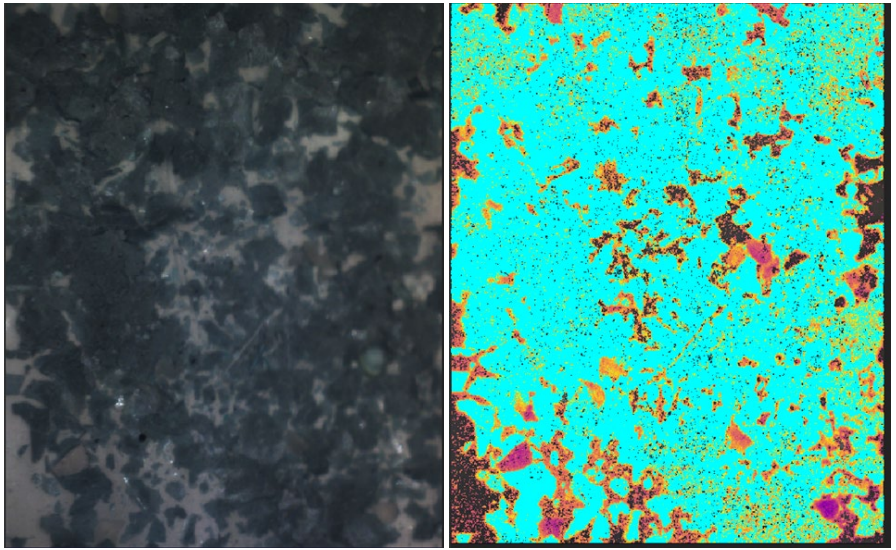
(A) Flow cell (B) flow tube





Visualization and identification of microplastics in biosolids – hyperspectral imaging





Effect of treatment chemicals on microfibers and microfilms

Before Treatment

After Treatment

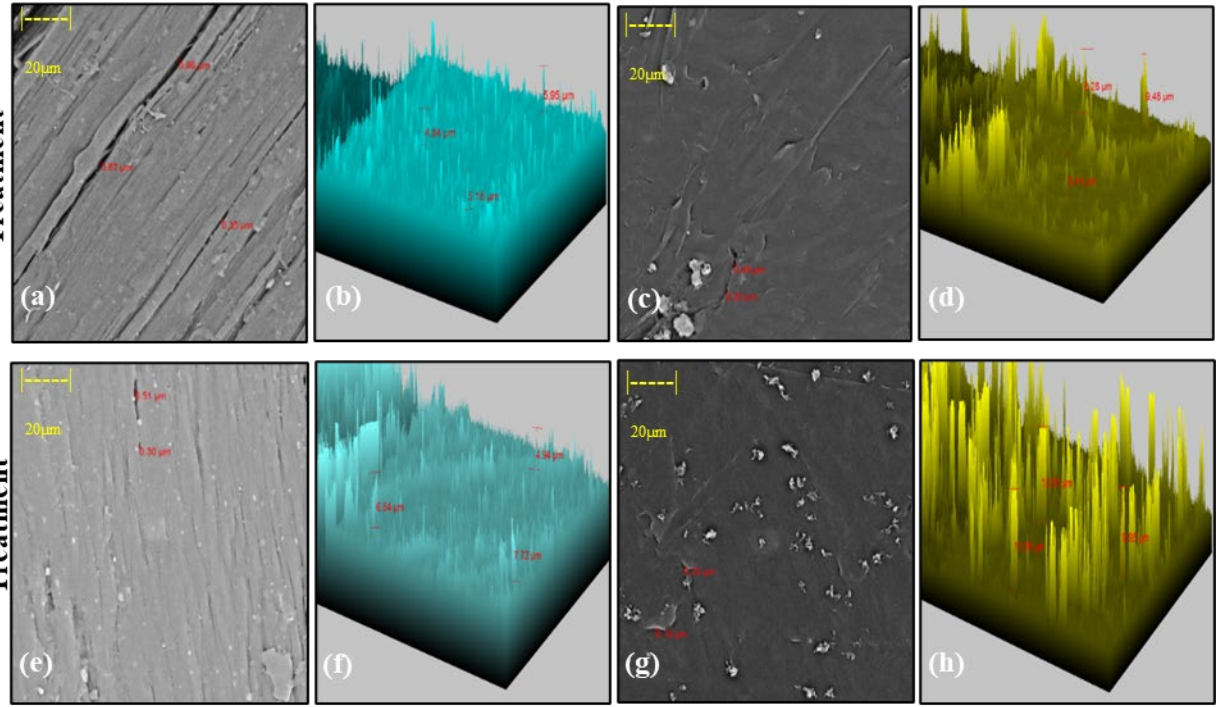


Figure: (a) SEM image of untreated MFs at 20µm, (b) 3-D structure of untreated MFs, (c) SEM image of untreated MPFs at20µm, (b) 3-D structure of untreated MPFs, (e) SEM image of NaOCl treated MFs at 20µm, (f) 3-D structure of treated MFs, (g) SEM image of NaOCl treated MPFs at 20 µm, (h) 3-D structure of NaOCl treated MPFs.

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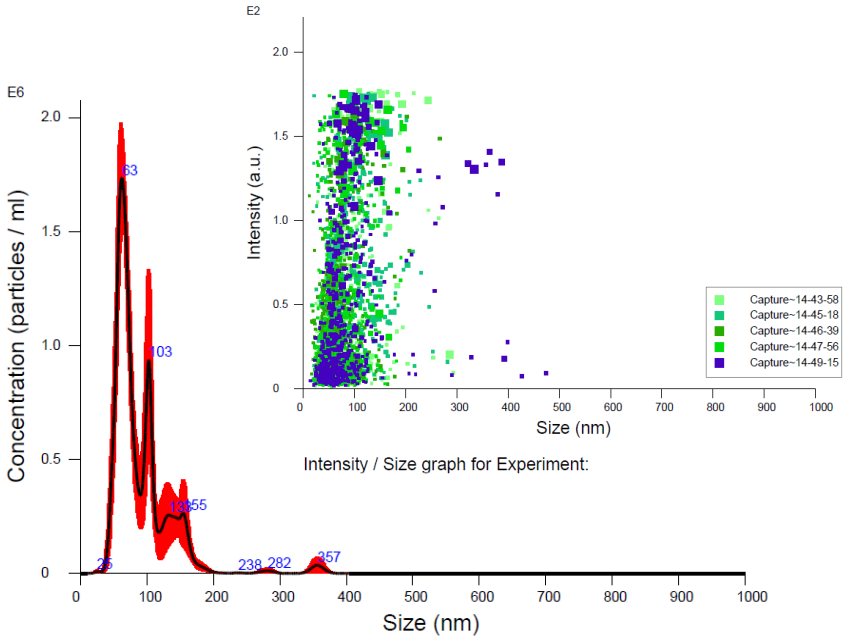
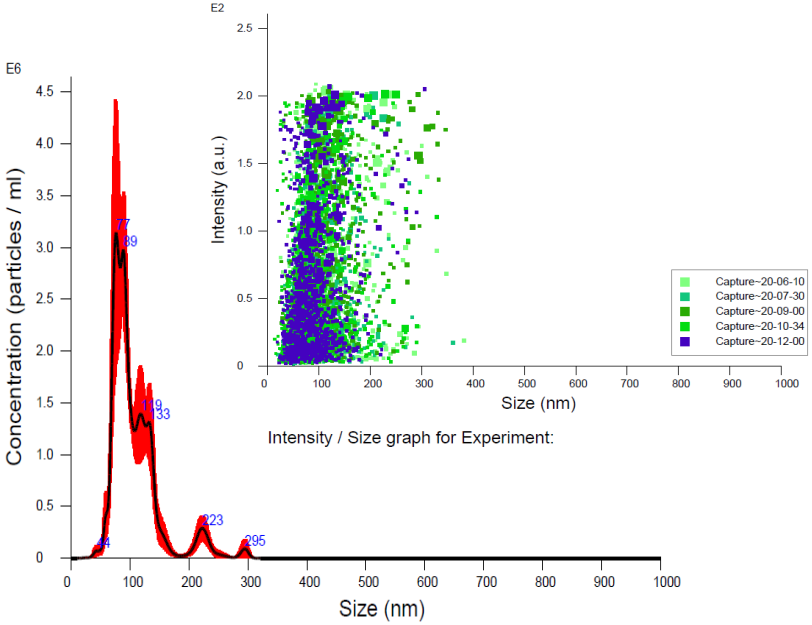
Nanoplastics are released during treatment



MP spiked water samples – before mixing



MP spiked water samples – after mixing

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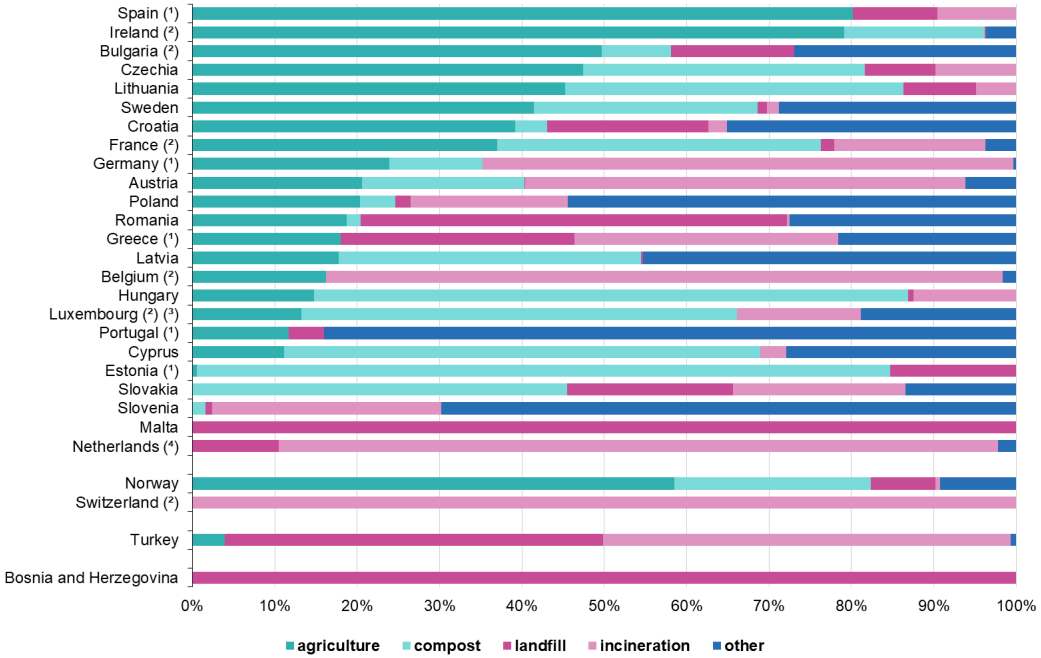
Regulatory developments in Europe

Disposal of sewage sludge from urban wastewater treatment by method of disposal, 2018
% of total



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Source control is the only effective and sustainable solution for plastic waste

Thank you!

Contact: banu.ormeci@carleton.ca

Methodology

Sample processing:

Quantification and Identification

Visual identification using Leica M165 C to isolate to presumed MPs[1] :

1. No visible cellular or organic structure
2. Colored particles have a homogeneous color
3. Plastic pieces are typically flexible and resistant to breaking from prodding

MPs were broadly classification into fibers, fragments and microbeads, along with colour

[1] Hidalgo-Ruz et al. (2012)

Collaboration with industrial partners

- Research and technology acceleration project funded through ECCC Zero Plastic Waste
- Carry out innovative research on the monitoring of microplastics in water systems and the removal of microplastics and microfibers from wastewater
- Research is geared towards the needs of Canadian technology providers so that research results can find immediate uptake
- We provide the know-how and technology support to our industrial partners to help them adopt/modify research results to their needs and products, facilitate pilot and full-scale testing for verification
- Assist them with finding new application sites (i.e., monitoring stations, treatment plants) through our networks