MICROPLASTIC FILTRATION: ECO-FRIENDLY SOLUTIONS FOR WATER PURIFICATION

Feb 12th, 2025

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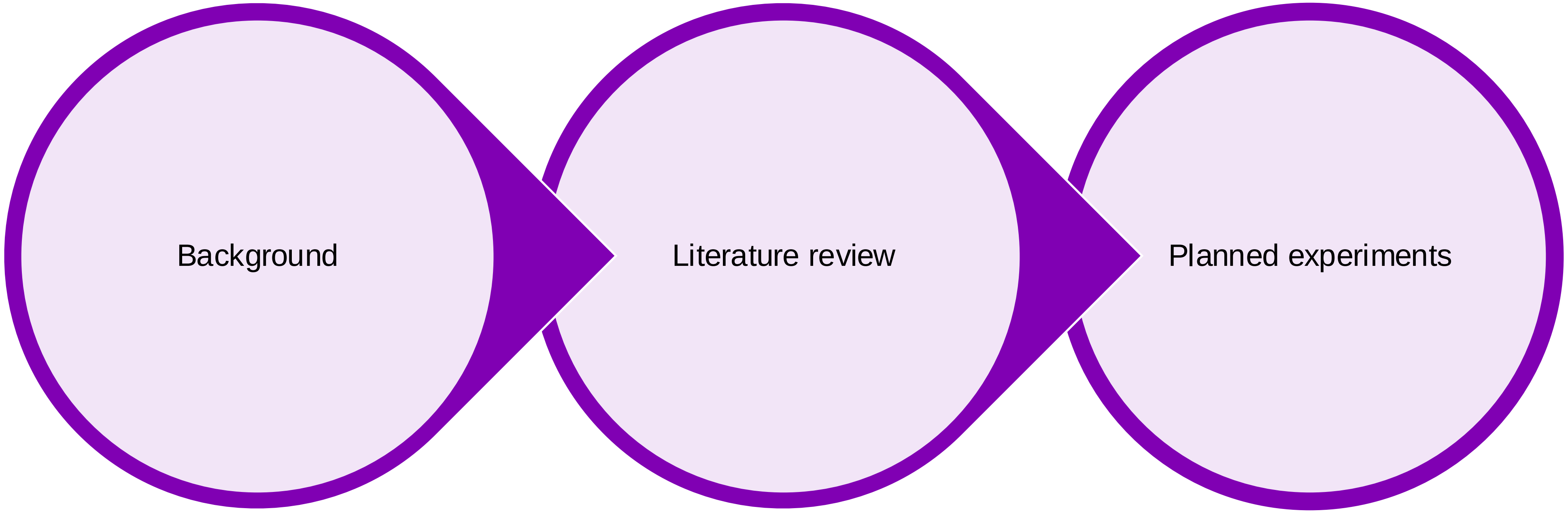
Sections



Background: Microplastic Pollution

- Microplastics are so small and often escape water treatment.
- Contain harmful chemicals → pollution
  - Polyethylene PE
  - polypropylene PP
  - polystyrene PS
  - polyvinyl chloride PVC
  - polyethylene terephthalate PET
- The goal is to make a cellulose-based filter to remove microplastics

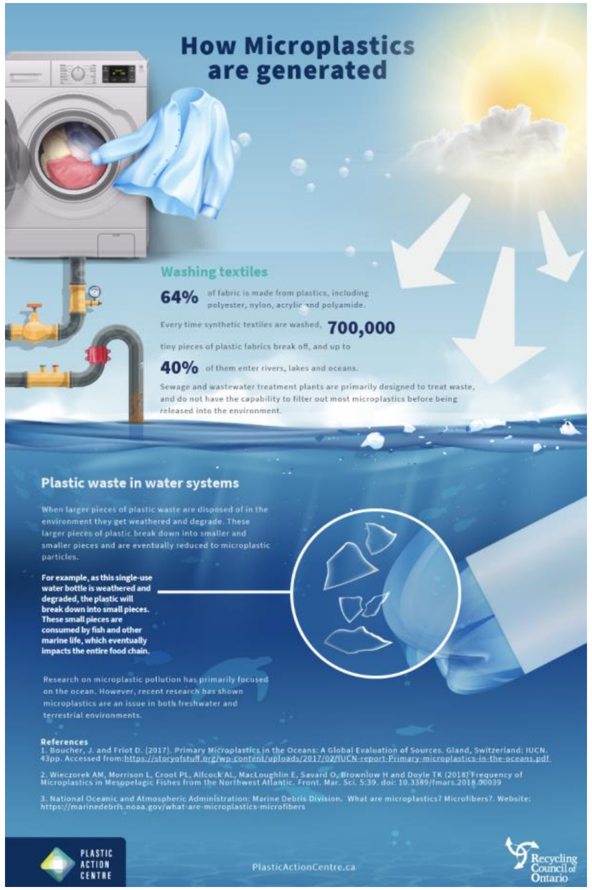
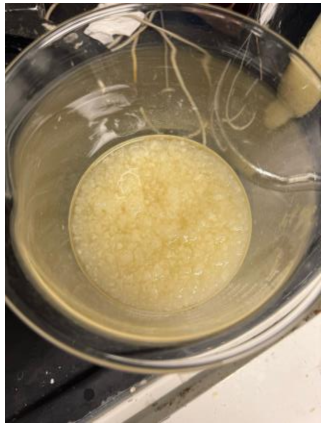


Fig 1: Microplastic Filtration Statistics

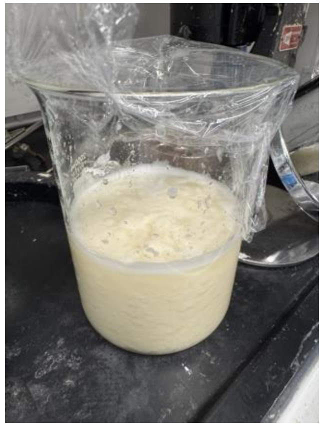
Reference: How plastics breakdown into microplastics

Reference: Microplastics in freshwaters and drinking water: Critical review and assessment of data quality

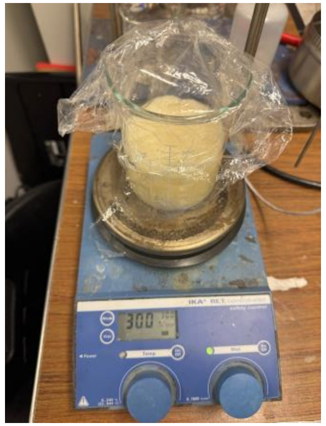
Background: Procedure of Foam Generation



1. Soak wood fiber so it swells.



2. Fiber beater to make smaller wood fibers



3. Add crosslinker or coating for mechanical strength

4. Add surfactant for foam generation

5. Blend and pour to mold

6. Final foam

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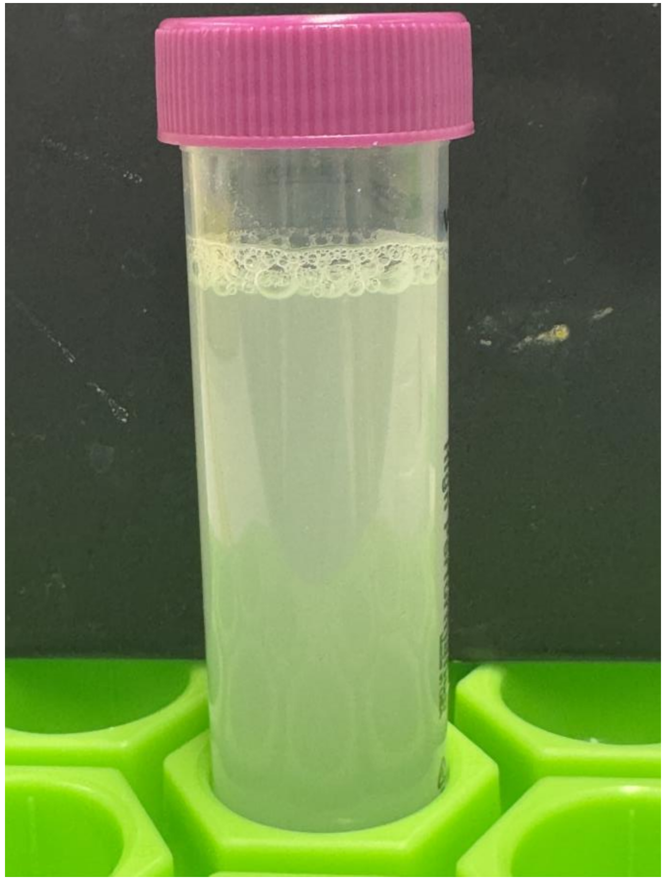
Background: Microplastic Filtration Setup

- Created solutions of polyethylene (PE) in 3 types of surfactants.
  - SDBS (anionic)
  - CTAB (cationic)
  - Tween 80 (neutral)
- After we put 3 types of solutions, we can test filtration using the particle counter.

Microplastic filtration

PE with water itself
(not dispersed at all)



PE with a surfactant
(fully dispersed)

Background: Modifications

- Filters are made up of several components:
  - Wood Fiber (slightly negative)
  - Crosslinker:
    - PEI/GPTMS (Crosslinker) (cationic)
    - PEI coating (cationic)
    - Citric Acid Crosslinker (anionic)
  - Surfactant:
    - CNC – Quab-342 (cationic)
    - Tween 80 (neutral)
    - TTAB (cationic)
    - SDS (anionic)
- General expectation is that filters made with cationic crosslinkers can absorb negatively coated PE and filters made with anionic crosslinkers can absorb positively coated PE.

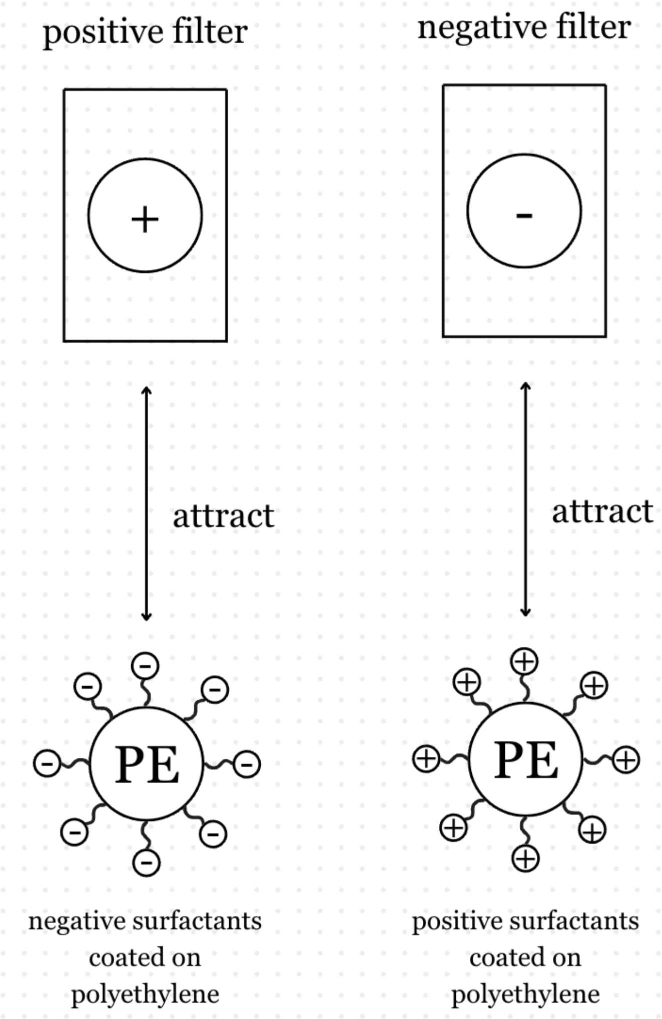


Fig 3: Schematic diagram

Background: Previous Co-op Students Data

Formulations	SDBS (anionic) coated polyethylene filtration efficiency	Tween 80 (neutral) coated polyethylene filtration efficiency	CTAB (cationic) polyethylene filtration efficiency
Wood fiber + citric acid + TTAB	97.9%	98.7%	96.7%
Wood fiber + Tween 80 (NO crosslinker)	99.9%	99.9%	99.9%
Wood fiber + TTAB (NO crosslinker)	99.9%	99.9%	99.9%
Wood fiber + SDS (NO crosslinker)	99.9%	99.9%	99.9%
Wood fiber + PEI (crosslinked) + GPTMS + SDS	56.7%	15.8%	40.1%
Wood fiber + PEI (crosslinked) + GPTMS + CNC-Quab-342	99.0%	35.0%	60%

Background: Previous Data on PEI coating

Formulations	SDBS (anionic) coated polyethylene filtration efficiency	Tween 80 (neutral) coated polyethylene filtration efficiency	CTAB (cationic) polyethylene filtration efficiency
1g PEI	92.5%	97.0%	97.5%
2.5g PEI	77.8%	45.1%	70.0%
5g PEI	34.6%	11.0%	46.1%

note: all formulations have wood fiber, SDS and varying amount of 20w/t% PEI coating

Background: Goals

- We built a filter from cellulose to remove microplastics with different components
- Study the behavior of the different systems to determine underlying filtration mechanisms
- Optimize filter properties such as foam density
    - Surfactant type and amount
    - Amount of coating or crosslinker

Literature Review: Filtration Mechanism

- Methods:
  - Physically remove bacteria from water
  - Altering membrane surfaces by covalent linkage
  - Polyelectrolyte adsorption
  - Layer-by-layer (LbL) Modification

Reference: Cellulose-based water purification using paper filters modified with polyelectrolyte multilayers to remove bacteria from water through electrostatic interactions

Literature Review: Structure of Adsorbents (Wood)

Adsorbents	Structure
Raw wood	- Dense and compact structure - Less visible hollow spaces
$NaClO_2$-Delignified Wood	- Noticeable removal of lignin - Clearer and more open lumen structures - Cell walls appear thinner and smoother
Na_2SO_3-Delignified Wood	- Similar to $NaClO_2$ but may show more structural damage - Lumen and fiber networks are more exposed, but some fibril structures may remain
DES-Delignified Wood	- More extensive lignin removal compared to other methods - Larger microfibrils and cellulose-rich regions

Reference: Cellulose nanofiber-coated delignified wood as an efficient filter for microplastic removal

Literature Review: Other Adsorbents

Adsorbents	Features
Cellulose-Based Adsorbents	- Utilize abundant hydroxyl groups for heavy metal ion removal. - Enhance adsorption capacity for improved efficiency.
Nanocellulose Hybrid Adsorbents	- Includes CNCs and CNFs, derived from natural cellulose. - Combine nanocellulose with other components for enhanced heavy metal ion removal, leveraging high surface area and tunable chemistry. - Dye Removal Using Nanocellulose Materials: Effective against anionic (eg. methyl orange) and cationic (eg. methylene blue).

Reference: Cellulose-Based Materials for Water Remediation: Adsorption, Catalysis, and Antifouling

Literature Review: Foam Generation

Global Mechanism	Sub-Mechanism	Examples
Physical foaming	Mechanical foaming	Bubbling, sparging, foam generation in porous media, wave breaking, shaking, rotor–stator mixers, kitchen blender, double syringe technique
	Phase transition	Champagne, beer, extrusion, cream dispenser, shaving foam
Chemical foaming	Chemical reaction	Fizzy drink tablets, baking powder, polyurethane foaming
	Electro-chemical reaction	Micro-flotation
Biological foaming	Yeast	Baking

Step Process	Features
One-step process (limited)	Generates the bubbles → final foam with a well-defined gas fraction
Two-step process	Loose bubbles are generated → compacted to give the final foam (eg. gravity / pressure-driven drainage of the liquid)
	Creates a coarse foam containing large bubbles → broken into smaller bubbles to create the final foam

Reference: The Science of Foaming

Literature Review: Adsorption Isotherm

Models	Situation
Langmuir Isotherm Model	When adsorption occurs on a homogenous surface, with a finite number of identical adsorption sites, and no lateral interactions. Suitable for single-layer adsorption. Common in gas adsorption and material surface studies.
Sips isotherm model	When the surface has both heterogeneity and a finite adsorption capacity. Applicable for porous materials or systems transitioning between Langmuir and Freundlich behavior.
Multilayer physisorption isotherms	When studying physical adsorption involving van der Waals forces on heterogeneous surfaces, or when analyzing multiple adsorption layers (e.g., BET theory for gas adsorption in porous solids)

- For monolayer adsorption: **Langmuir**
- For heterogeneous or multilayer adsorption: **Sips**
- For pore size and energy distribution studies: **BET (multilayer physisorption)**

Reference: Insights into the modeling of adsorption isotherm systems

Planned Experiments: Demonstration of Foams

dense wood fiber → non-uniform

not dense wood fiber → uniform

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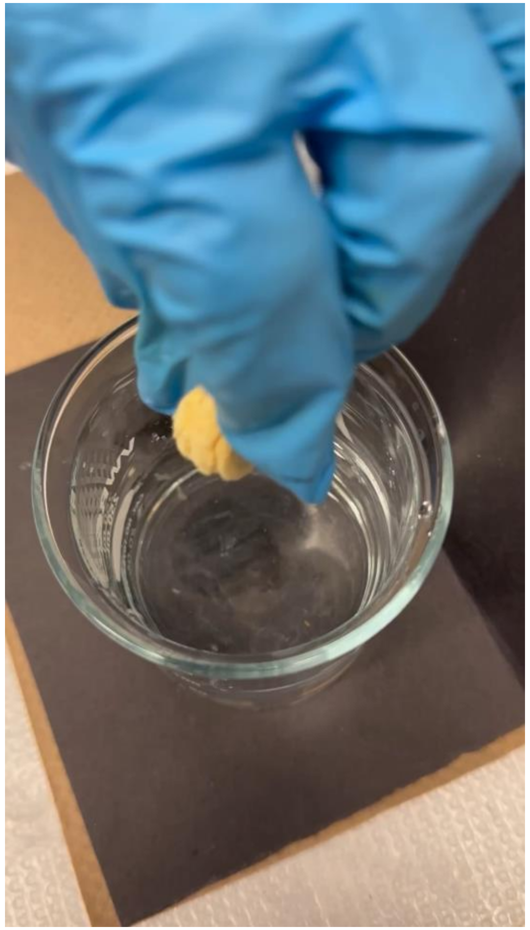
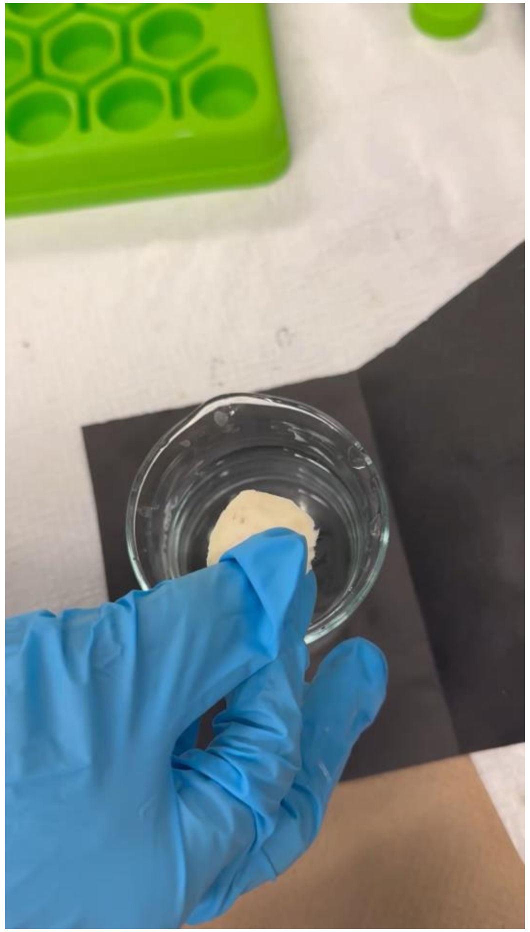
Planned Experiments: Importance of PEI

- PEI helps increase the mechanical strength. It can rebound from water due to its property of elastic recovery as it returns to its original length.

With PEI:



Without PEI:



Planned Experiments: Filtration Mechanism of Microplastics

- Study the removal efficiency of increasing concentrations of 3 types of surfactants stabilize microplastics.
  - SDBS: polyethylene
  - Tween 80: polyethylene
  - CTAB: polyethylene
- Study the behavior for different systems
  - Tween 80 + PEI coating
  - Tween 80 + Citric acid
- Fit the removal efficiency data to different adsorption isotherm models

Planned Experiments: Filtration Mechanism of Dyes

- Removal efficiency test of 2 dyes
  - Methylene Blue (Cationic)
  - Methyl Orange (Anionic)
- Fit the removal efficiency data to different adsorption isotherm models

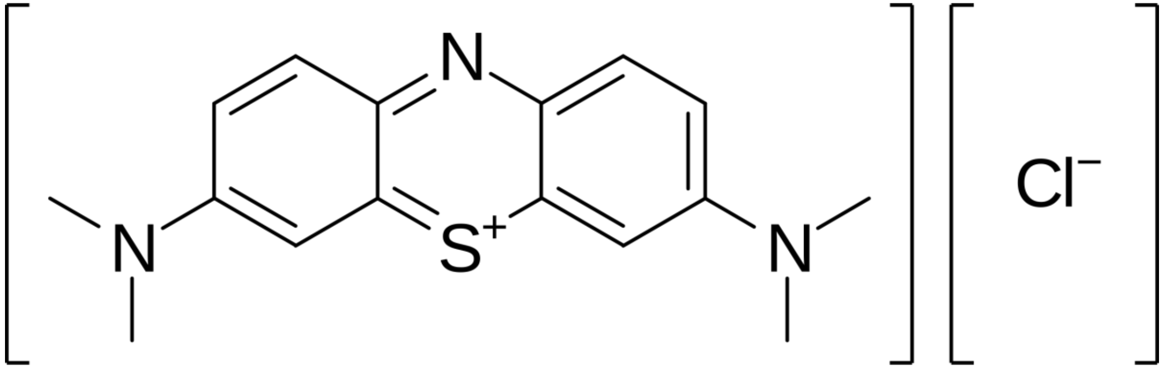


Figure: Methylene Blue

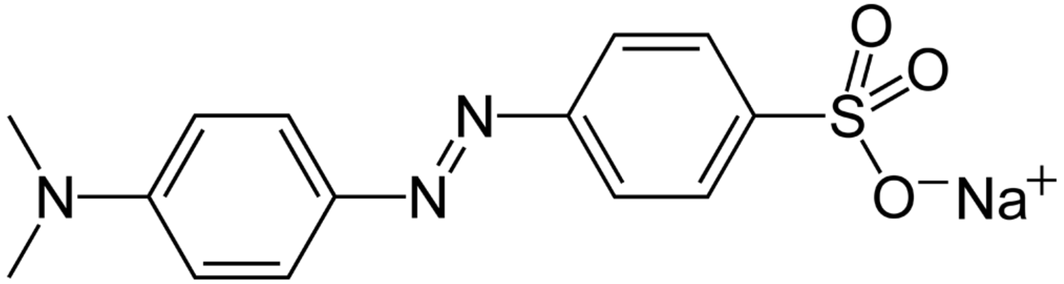


Figure: Methyl Orange

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