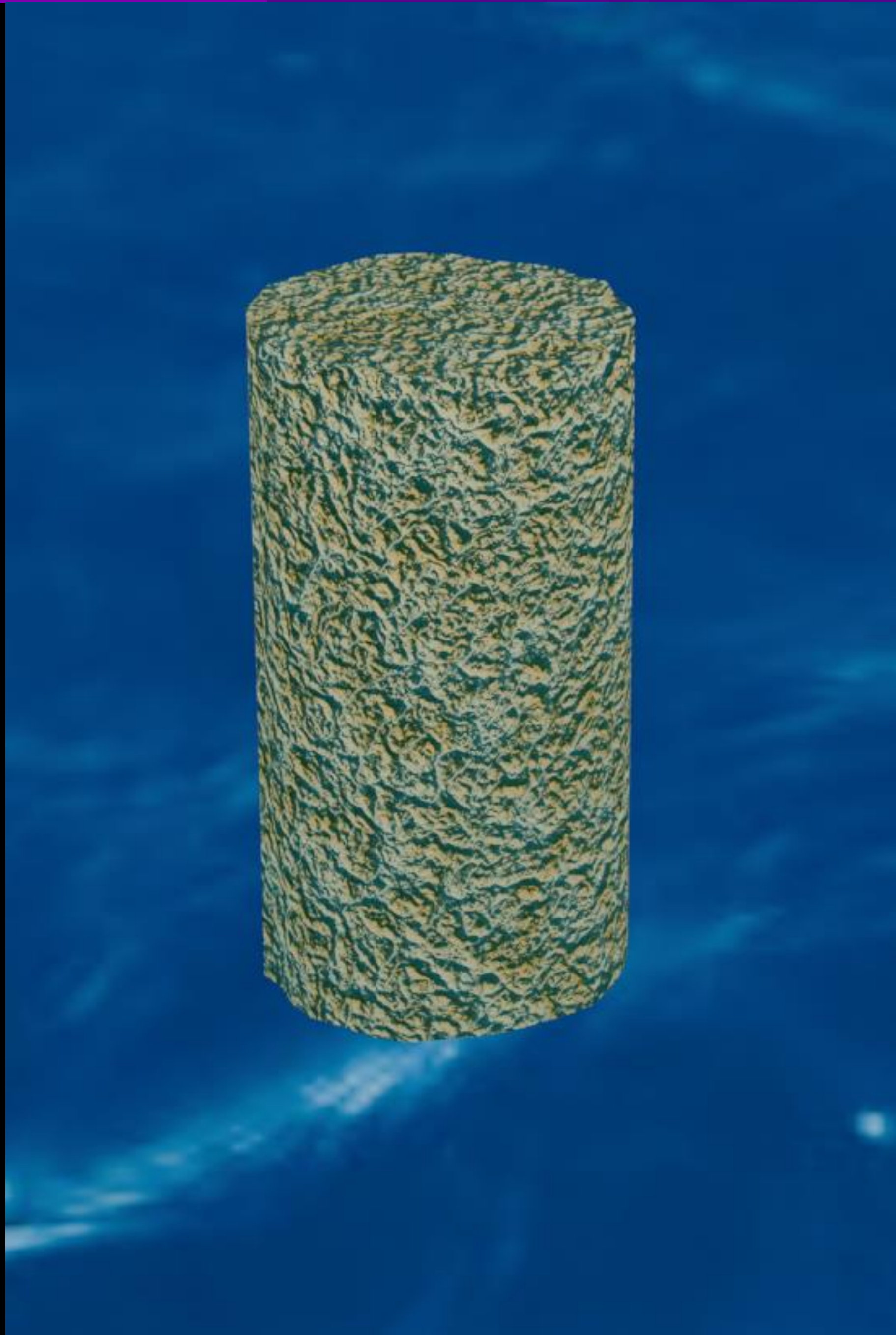
MICROPLASTIC FILTRATION: ECO-FRIENDLY SOLUTIONS FOR WATER PURIFICATION

April 16, 2025

Edlan So



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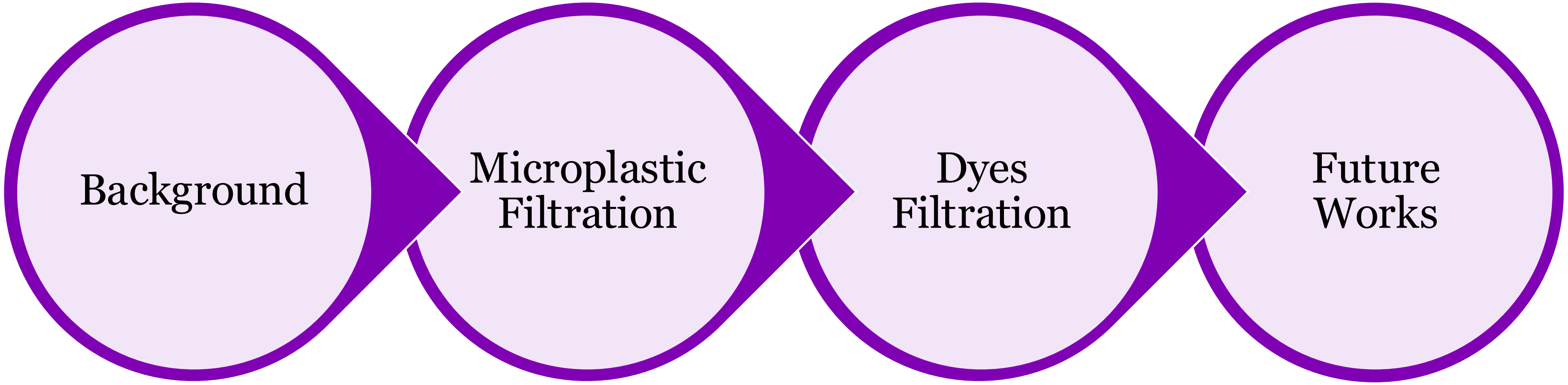
Sections


Background
Microplastic Filtration
Dyes Filtration
Future Works

BACKGROUND

Background: Microplastic Pollution

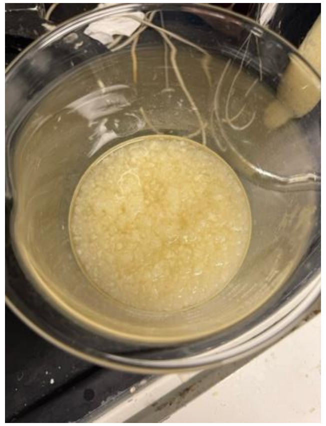
- Microplastics are so small and often escape water treatment.
- Contain harmful chemicals → pollution
  - Polyethylene PE
  - Polypropylene PP
  - Polystyrene PS
  - Polyvinyl chloride PVC
  - Polyethylene terephthalate PET
- The goal is to make a cellulose-based filter to remove microplastics

Fig 1: Microplastic Filtration Statistics

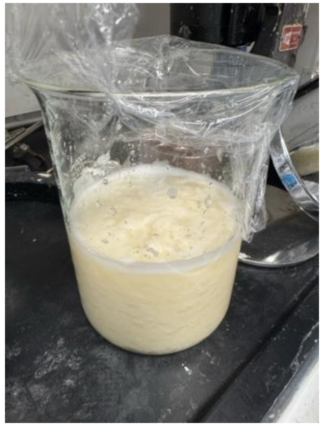
Reference: How plastics breakdown into microplastics

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

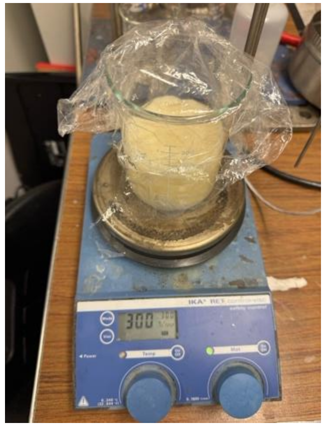
Background: Procedure of Foam Generation



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

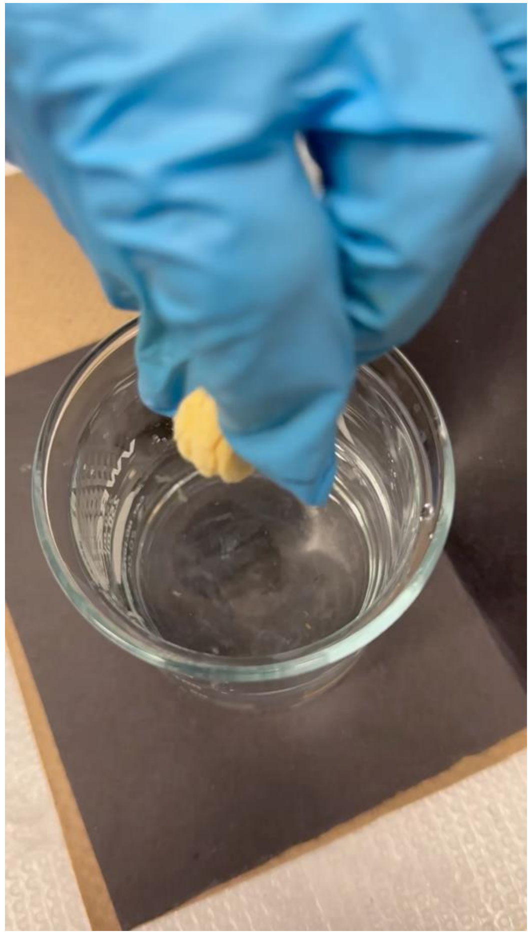
5. Blend and pour to mold

6. Freeze for a night to produce final foam

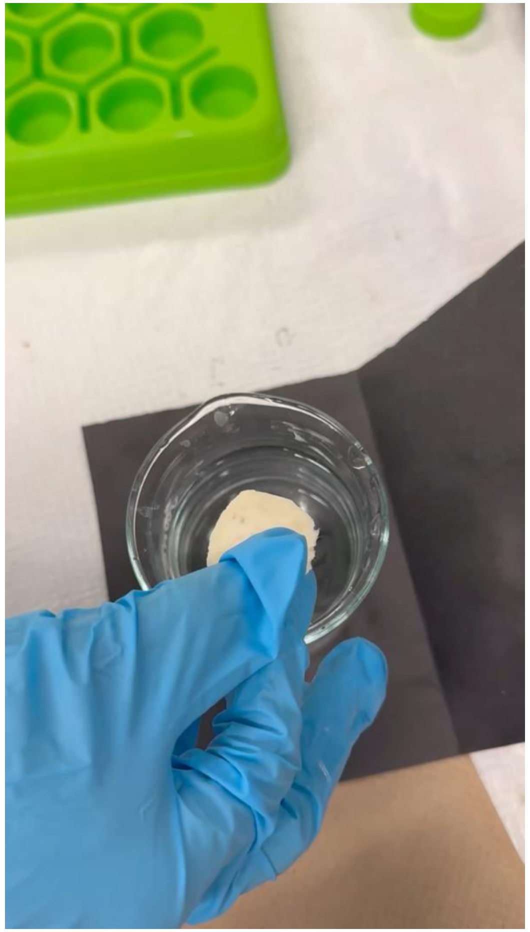
Background: Importance of Polyethylenimine (PEI)

- PEI is a wet strength agent → increase mechanical strength
- PEI (cationic polymer) → coated onto cellulose foam (negative)
- PEI is relatively expensive

With PEI:



Without PEI:



Reference: Polymeric Wet-Strength Agents in the Paper Industry: An Overview of Mechanisms and Current Challenges

Background: Modifications

- Typical foam composition
  - 4g of 1% Tween 80 (Foaming Agent) (non-toxic and biodegradable)
  - 20g of 1% PEI (Wet Strength Agent)
  - 200g of 3% soaked wood fiber
- Filters are modified by different types of formulation:
  - CNC modifiers (eg. 5.0g of 4% CNC)
  - Different amounts or concentration of PEI variations (eg. 10.0g of 1% PEI / 2g of 10% PEI…)

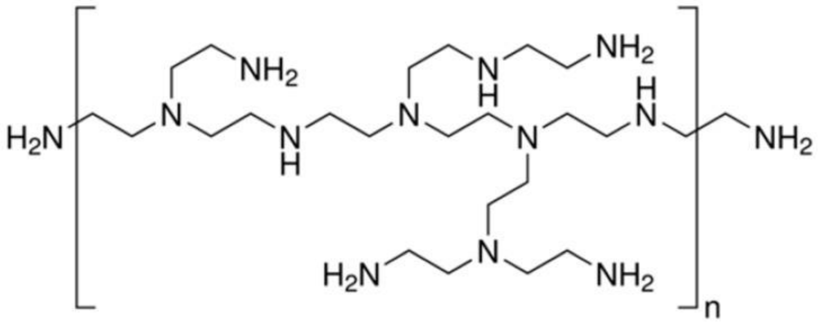


Fig 3: PEI compound

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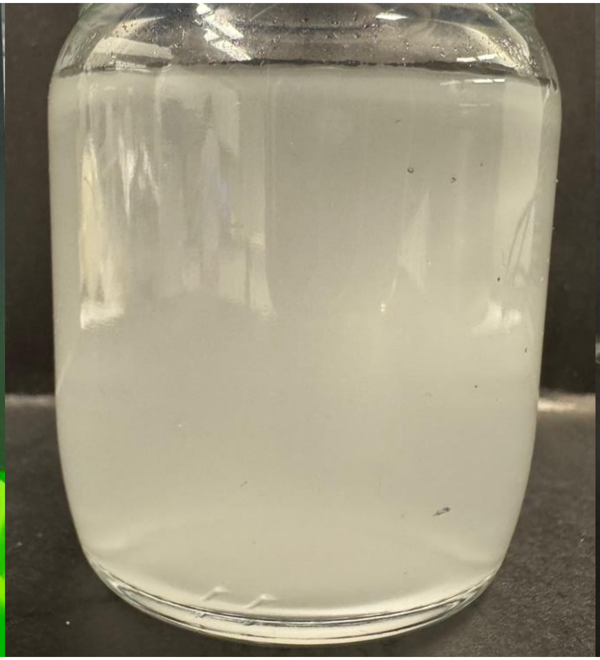
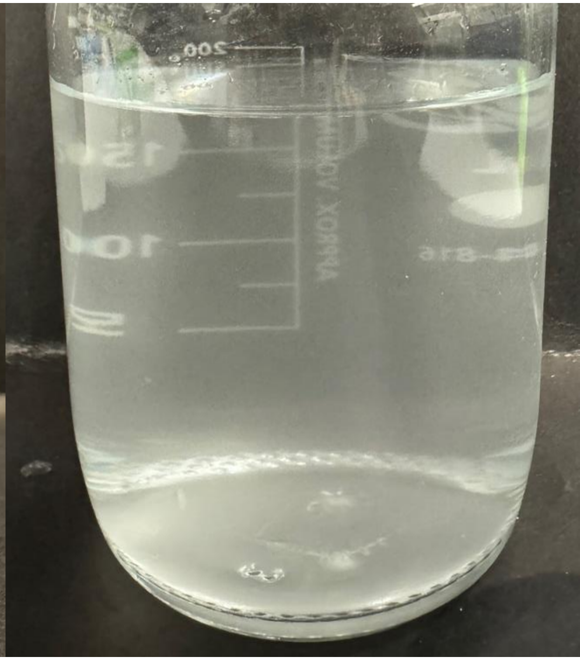
Background: Microplastic Filtration Setup

- Created solutions of **polyethylene (PE)** in 2 types of surfactants and 1 type of chaotropic ion
  - SDBS (anionic)
  - CTAB (cationic)
  - Urea
- After we make 3 types of dispersed solutions, we can test filtration using the particle counter.

PE with water itself (not dispersed at all)



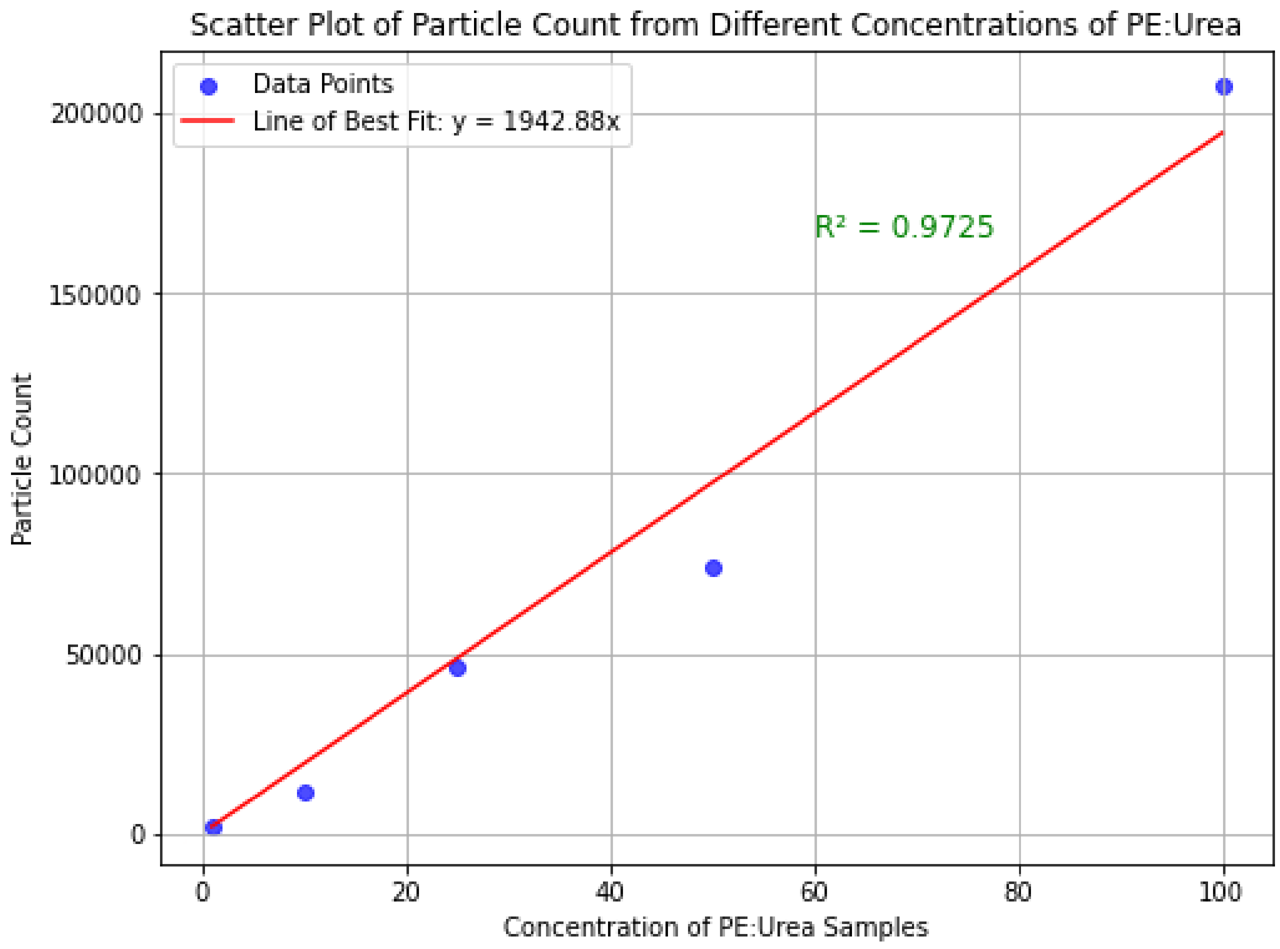
PE with a surfactant (fully dispersed)



PE with urea (fully dispersed)

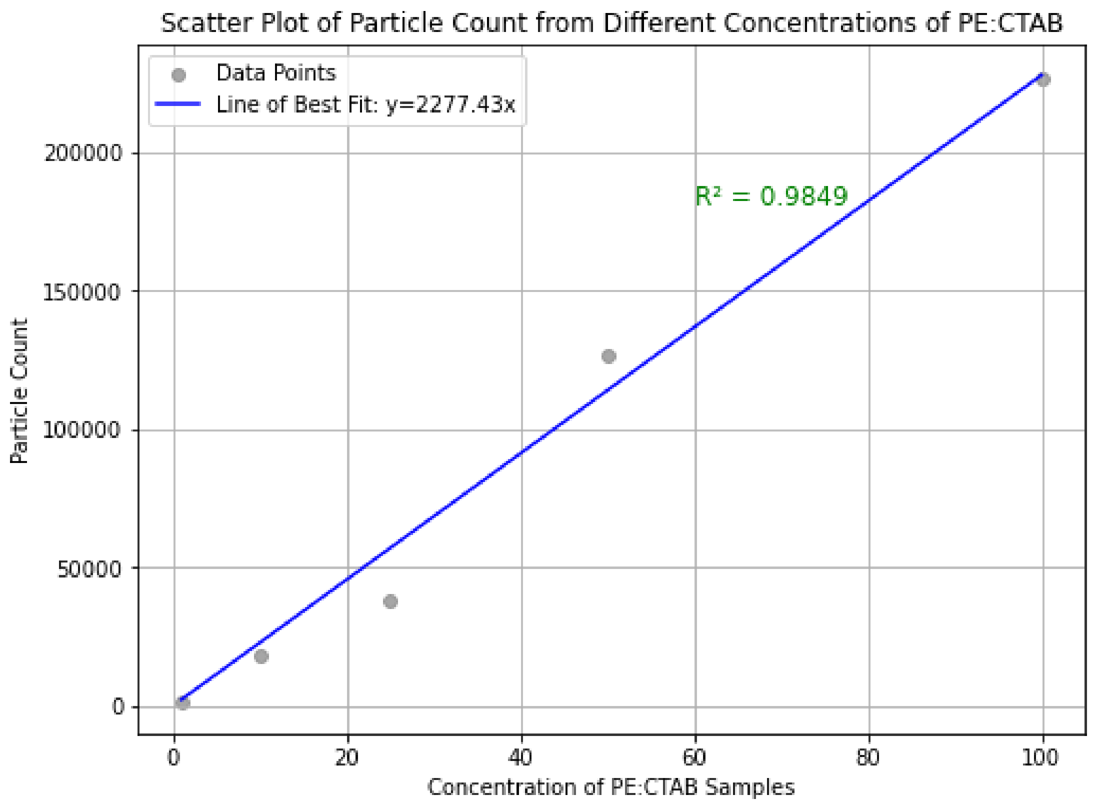
MICROPLASTIC FILTRATION

Microplastic Dispersion: Calibration Curve of PE: Urea

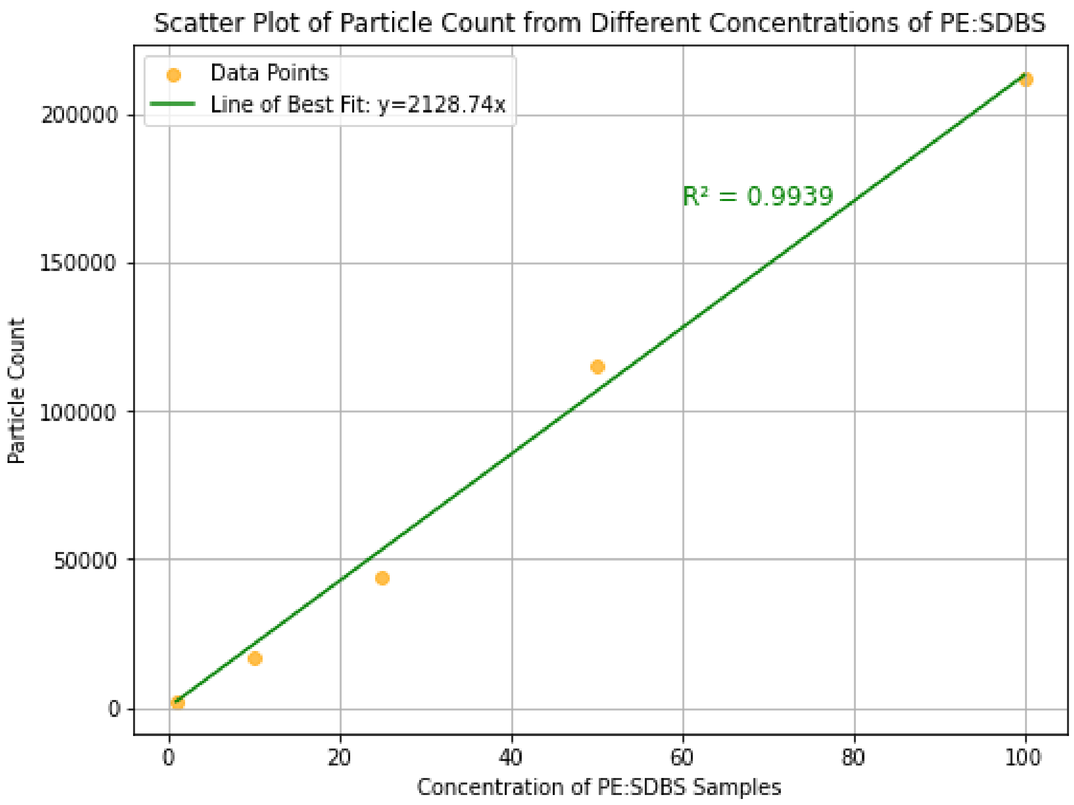


Stock solution:
60mg of PE +
1g of urea in
100mL 1% NaCl

Microplastic Dispersion: Calibration Curve of PE: Surfactants



Stock solution: 800mg of PE + 16mg of CTAB in 100mL 1% NaCl



Stock solution: 800mg of PE + 16mg of SDBS in 100mL 1% NaCl

Microplastic Dispersion: Removal Efficiency

- 300 mg/L microplastic solutions are filtered through the wood fibers
- Removal efficiency is obtained by fitting particle count of the filtrate into the best fit
- Find the filtrate concentration by using $y = mx$, where y is particle count, and x is concentration
- $\frac{\boldsymbol{Original\ Concentration - Filtrate\ Concentration}}{\boldsymbol{Original\ Concentration}} \times \mathbf{100\%}$

Left: Water
Middle: Filtrate
Right: MP solution

Microplastic Dispersion: Normal Foam Removal

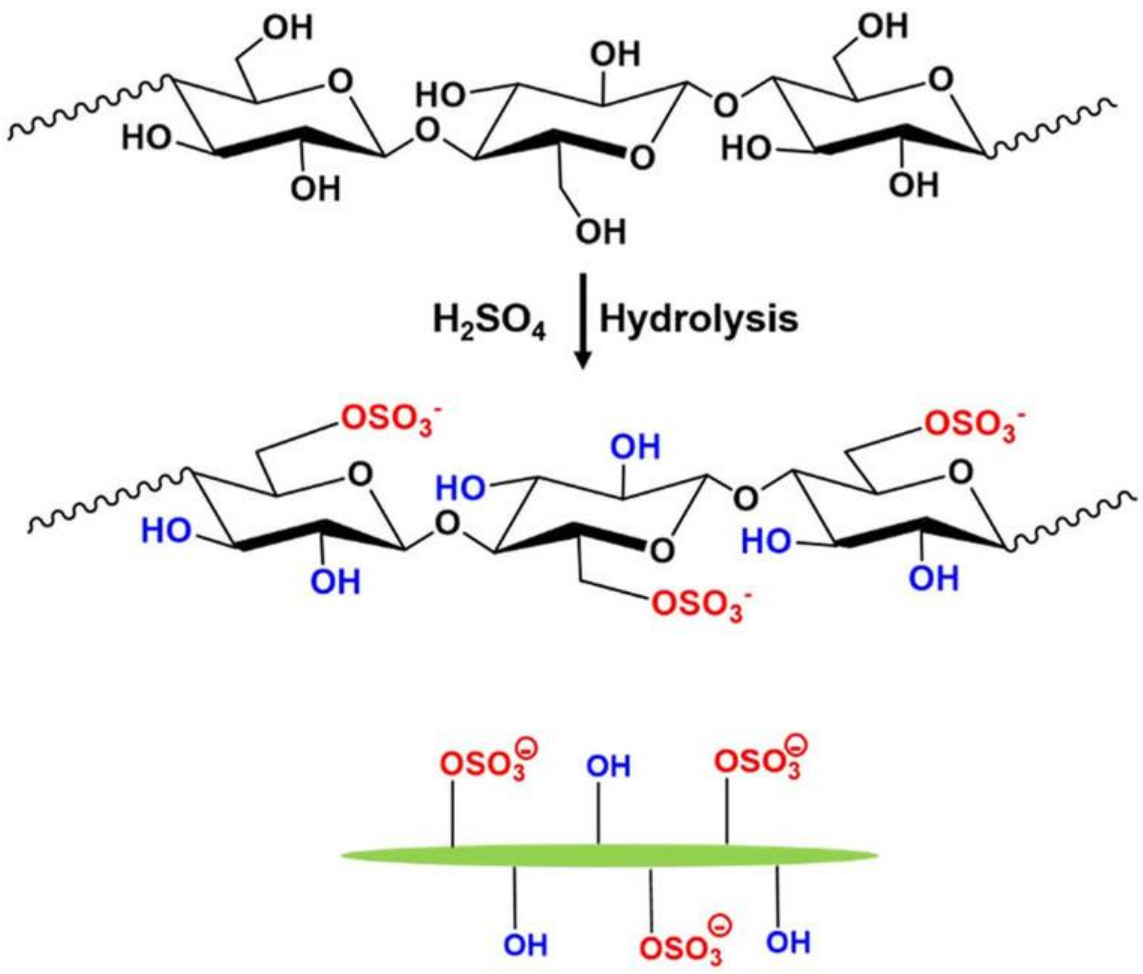
- Using 4.0g of 1% Tween 80 + 20g of 1% PEI

*20mL of 300 mg/L MP solution is filtered

Trials	PE: CTAB Flow Time (s)	PE: CTAB Removal Efficiency	PE: SDBS Flow Time (s)	PE: SDBS Removal Efficiency	PE: Urea Flow Time (s)	PE: Urea Removal Efficiency
1	43.94	99.89%	42.17	99.95%	29.30	97.34%
2	56.43	99.90%	58.96	99.98%	35.27	98.88%
3	34.29	99.32%	44.47	99.98%	40.22	99.02%
Average	44.89	99.70%	48.53	99.97%	34.93	98.41%

Microplastic Dispersion: CNC Modified Foam Removal

- Potential improvement: Incorporate with cellulose nanocrystals
- Nano-scale adsorbents have higher surface area
  - Better removal efficiency



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Microplastic Dispersion: CNC Modified Foam Removal

- Using **4% CNC** + 4.0g of 1% Tween 80 + 20g of 1% PEI

*20mL of 300 mg/L MP solution is filtered

Trials	PE: Urea filtering through **4% CNC** Foam Flow Time(s)	PE: Urea filtering through **4% CNC** Foam Removal Efficiency	PE: Urea filtering through **Normal** Foam Flow Time (s)	PE: Urea filtering through **Normal** Foam Removal Efficiency
1	25.92	99.44%	29.30	97.34%
2	29.13	99.79%	35.27	98.88%
3	33.48	99.24%	40.22	99.02%
Average	29.51	99.49%	34.93	98.41%

Microplastic Dispersion: Varied PEI Foam Removal

- Using **different concentration of PEI** + 4.0g of 1% Tween 80

*20mL of 300 mg/L MP solution is filtered

Trials	PE: Urea filtering through **1% PEI** Foam Flow Time (s)	PE: Urea filtering through **1% PEI** Foam Removal Efficiency	PE: Urea filtering through **5% PEI** Foam Flow Time (s)	PE: Urea filtering through **5% PEI** Foam Removal Efficiency	PE: Urea filtering through **10% PEI** Foam Flow Time (s)	PE: Urea filtering through **10% PEI** Foam Removal Efficiency
1	29.30	97.34%	19.57	98.00%	43.67	99.89%
2	35.27	98.88%	20.37	90.09%	22.15	99.51%
3	40.22	99.02%	17.68	98.44%	30.42	99.61%
Average	34.93	98.41%	19.21	95.51%	32.08	99.67%

DYE FILTRATION

Dye Filtration: Why Dye Filtration?

- It better suits dynamic removal efficiency test over time
- Each component in the foam underlines the removal efficiency behavior
  - Cellulose + CNC can remove cationic dyes
  - PEI can remove anionic dyes

Dyes Filtration: Introduction

- Methylene blue is positive; methyl orange is negative
- CNC is anionic; PEI is cationic
- More CNC can adsorb more methylene blue, and more PEI can adsorb more methyl orange
  - Normal Foam Removal
  - CNC Modified Foam Removal
  - Varied PEI Foam Removal

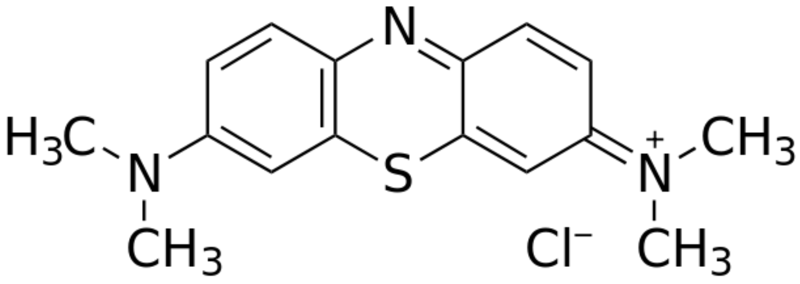


Figure: Methylene Blue

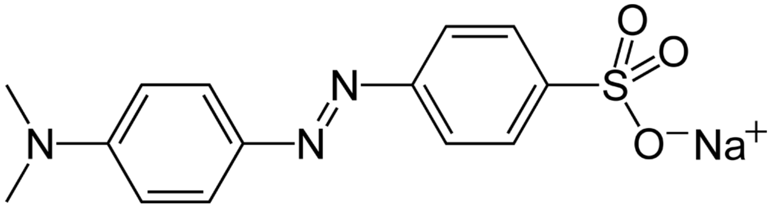
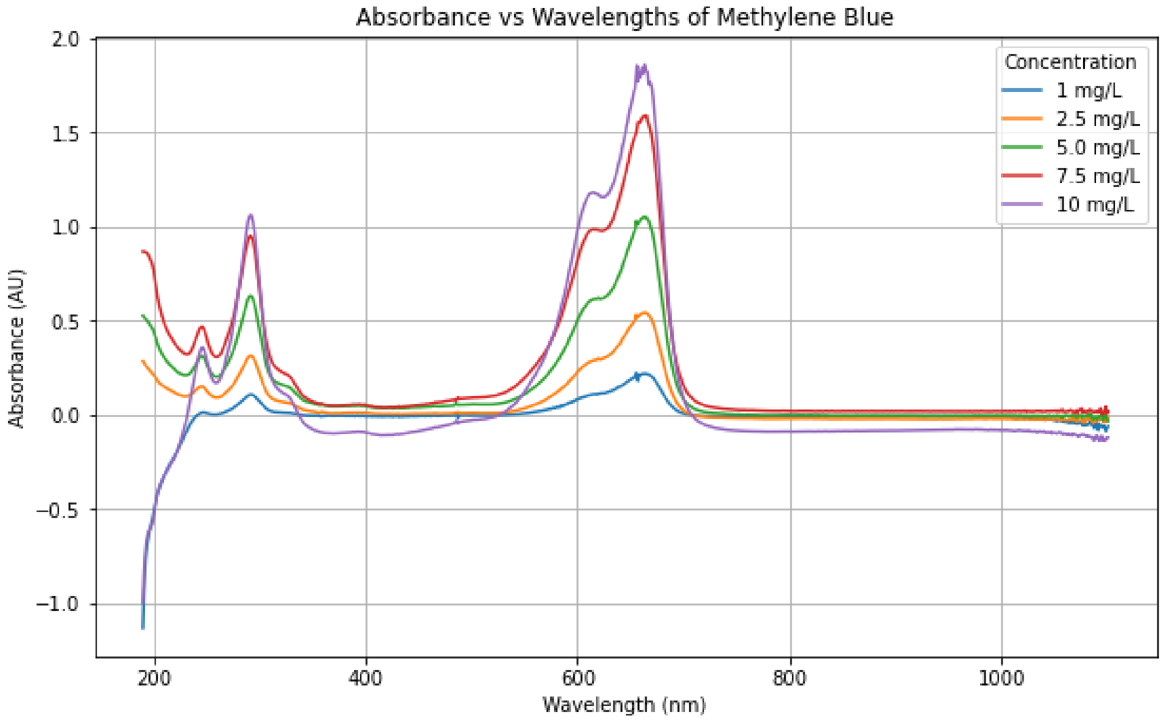
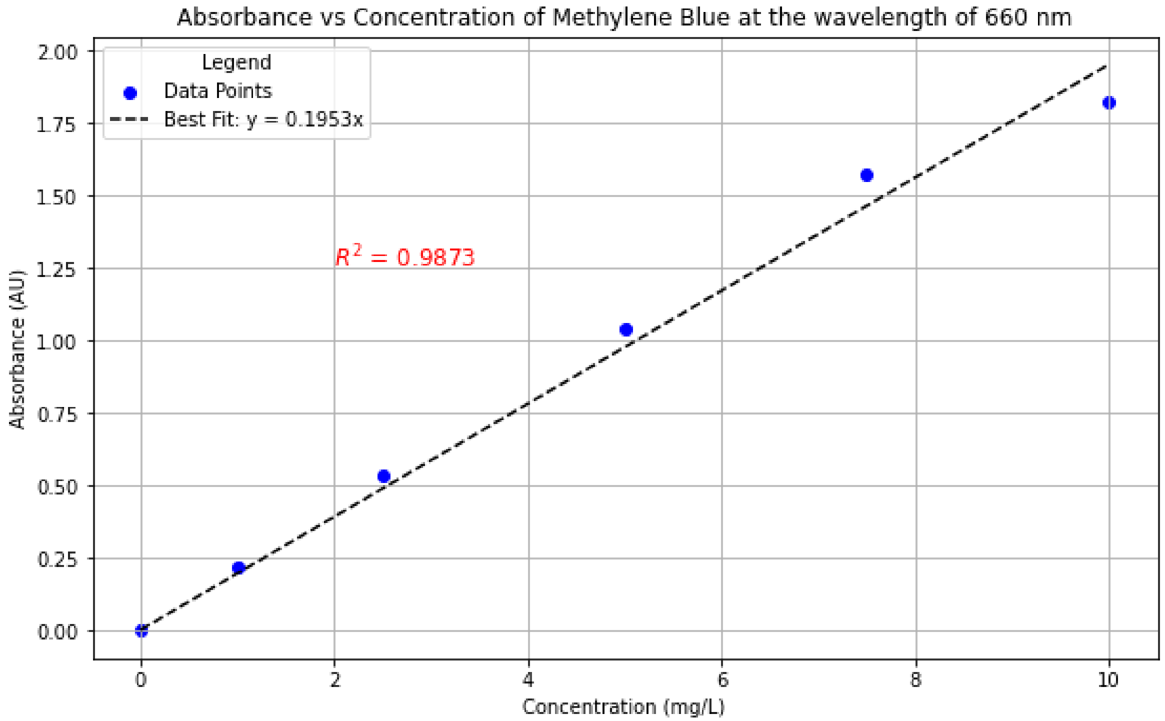


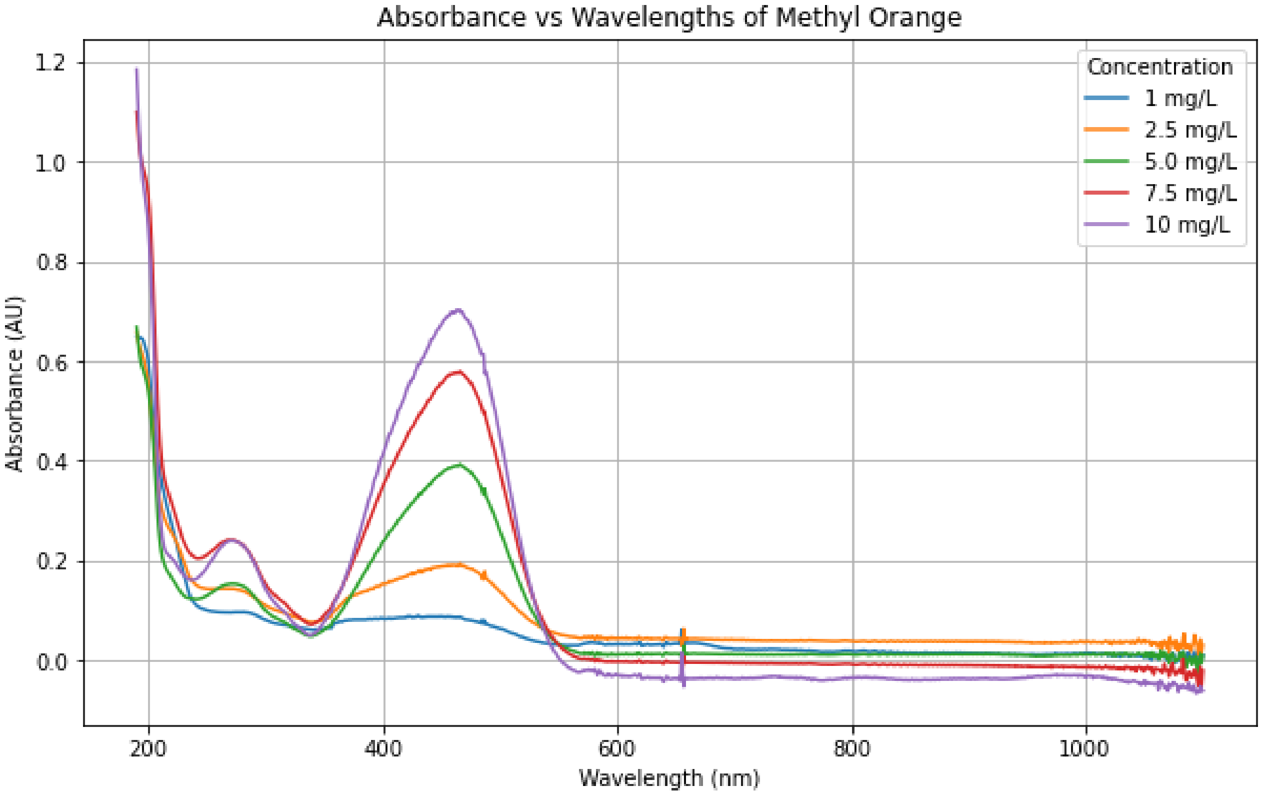
Figure: Methyl Orange

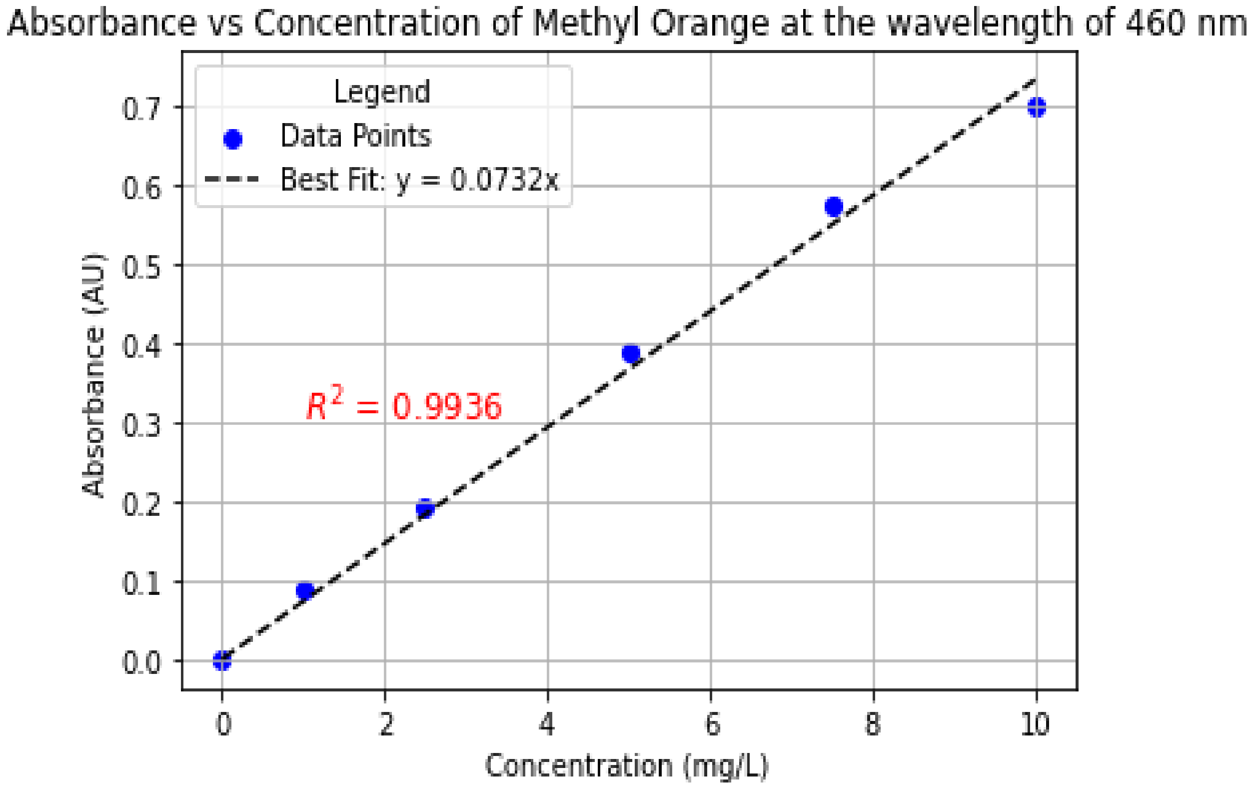
Dyes Filtration: Absorbance vs Concentration of Methylene Blue





Dyes Filtration: Absorbance vs Concentration of Methyl Orange





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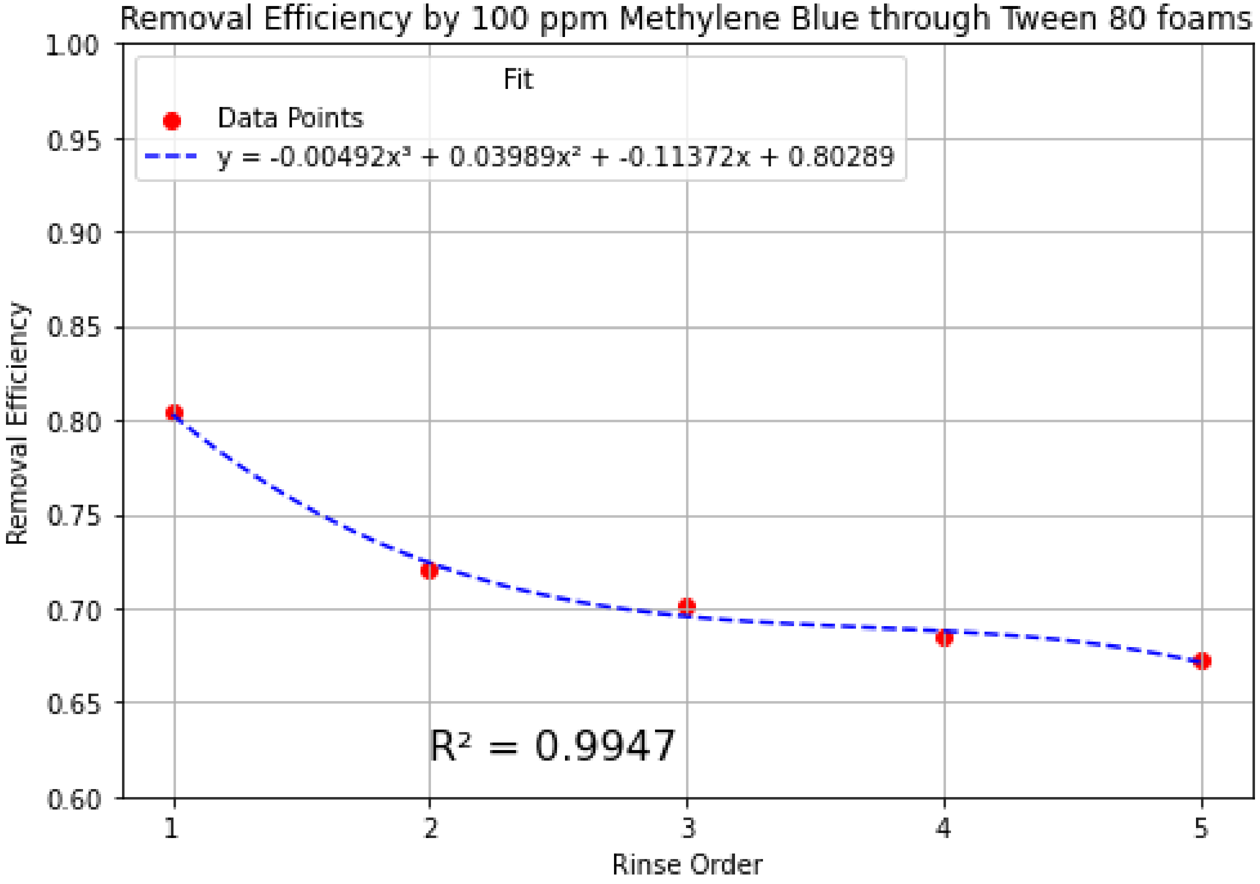
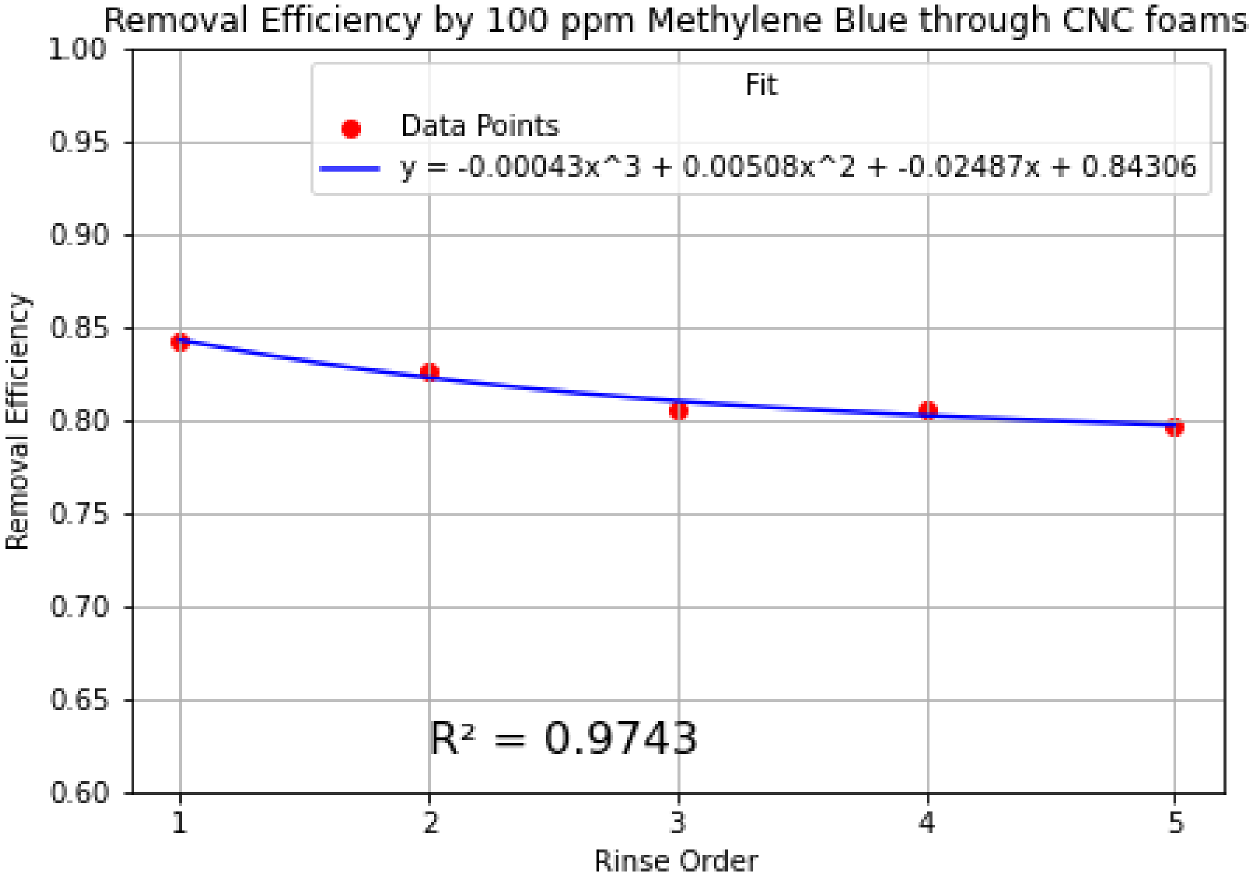
Dyes Filtration: Methylene Blue Removal Efficiency

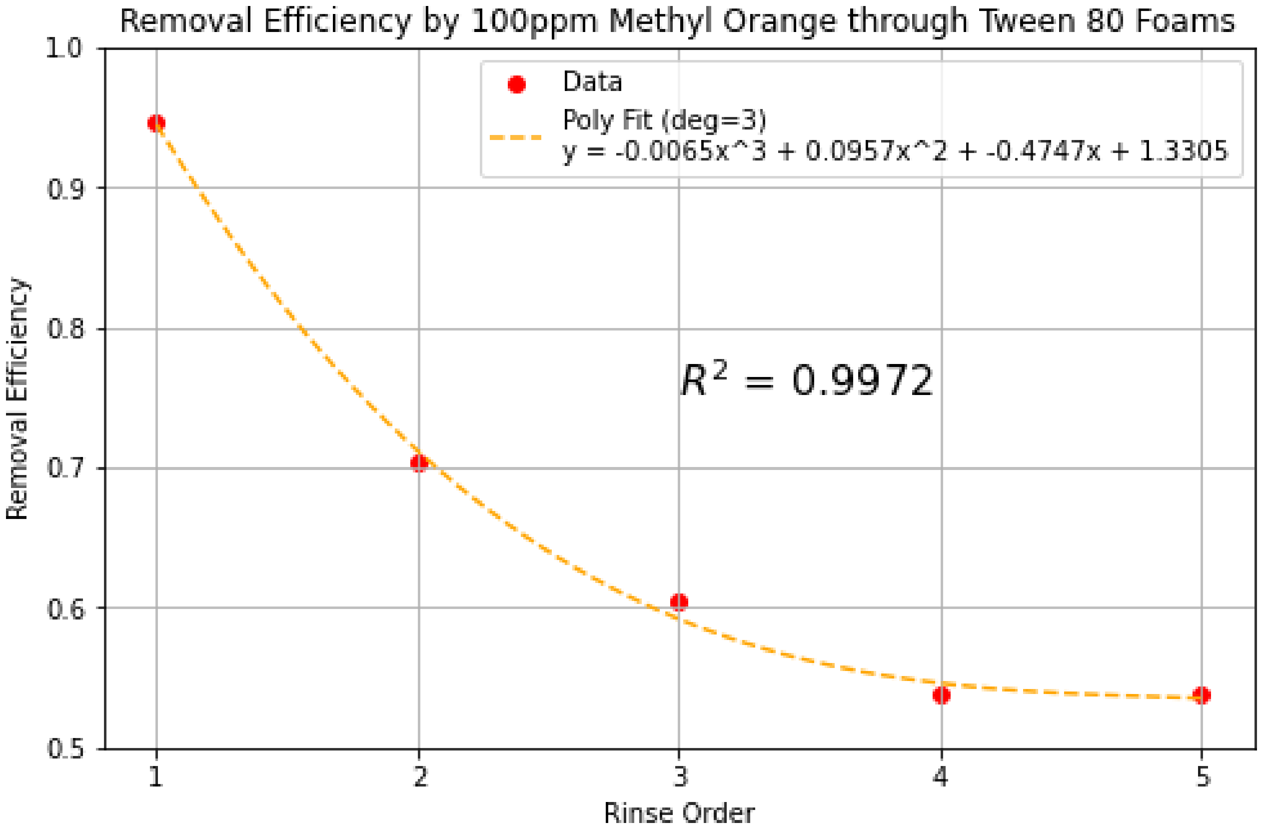
*Filter 5 sets of 6mL 100mg/L methylene blue through foams

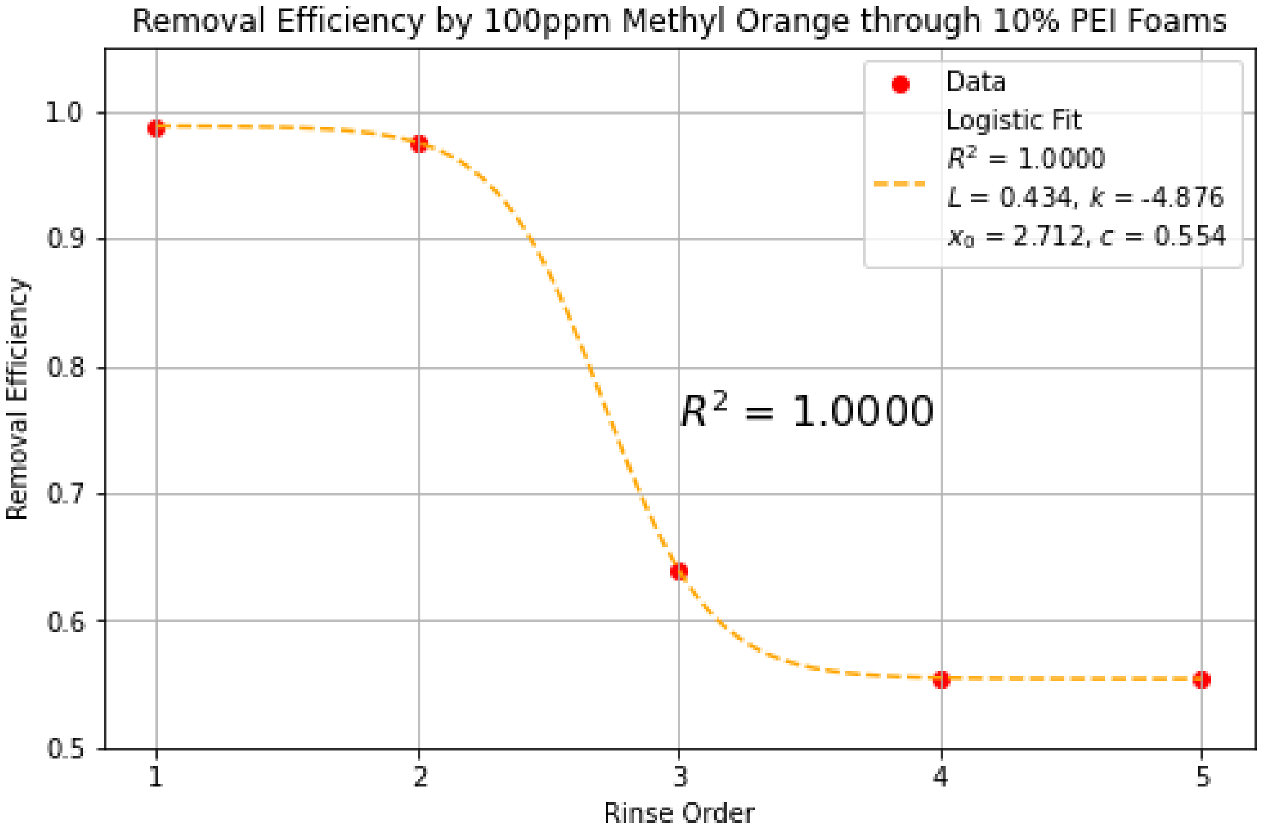




Dyes Filtration: Methyl Orange Removal Efficiency

*Filter 5 sets of 6mL 100mg/L methyl orange through foams





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Dyes Filtration: Explanations

- The foam with CNC (-) can filter more methylene blue (+) than the normal foam
- The foam with more PEI (+) can filter more methyl orange (-) than the normal foam
- Foams can filter methyl orange more efficiently than methylene blue
  - PEI inside the 10% PEI foam is dominant over CNC → can filter 98% of methyl orange
  - PEI inside the CNC foam is dominant over CNC → can filter 84% of methylene blue

FUTURE WORKS

Future Works

- Make fully dispersed PE: Tween 80 solution (neutral)
  - Plot the calibration curve that is similar to PE: Urea, PE: CTAB, and PE: SDBS
- Fit adsorption isotherm to the dye filtration data
- Measure the porosity using the moisture analyzer

Citations

Bajt, Oliver. “From Plastics to Microplastics and Organisms.” FEBS open bio, April 2021. https://pmc.ncbi.nlm.nih.gov/articles/PMC8016121/#:~:text=Sunlight%2C%20wind%2C%20and%20waves%20continuously,1%2C%202%2C%203%5D.

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