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Bio-based flocculants for efficient and sustainable dewatering of microalgae

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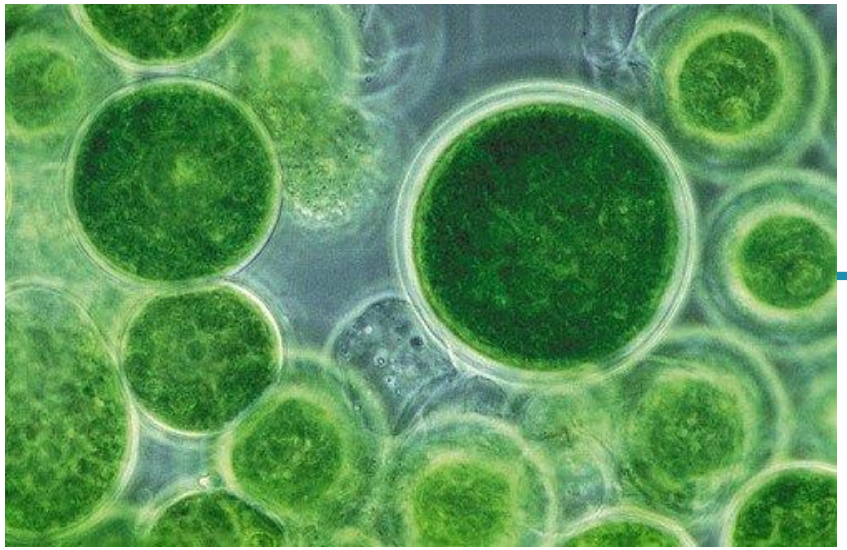
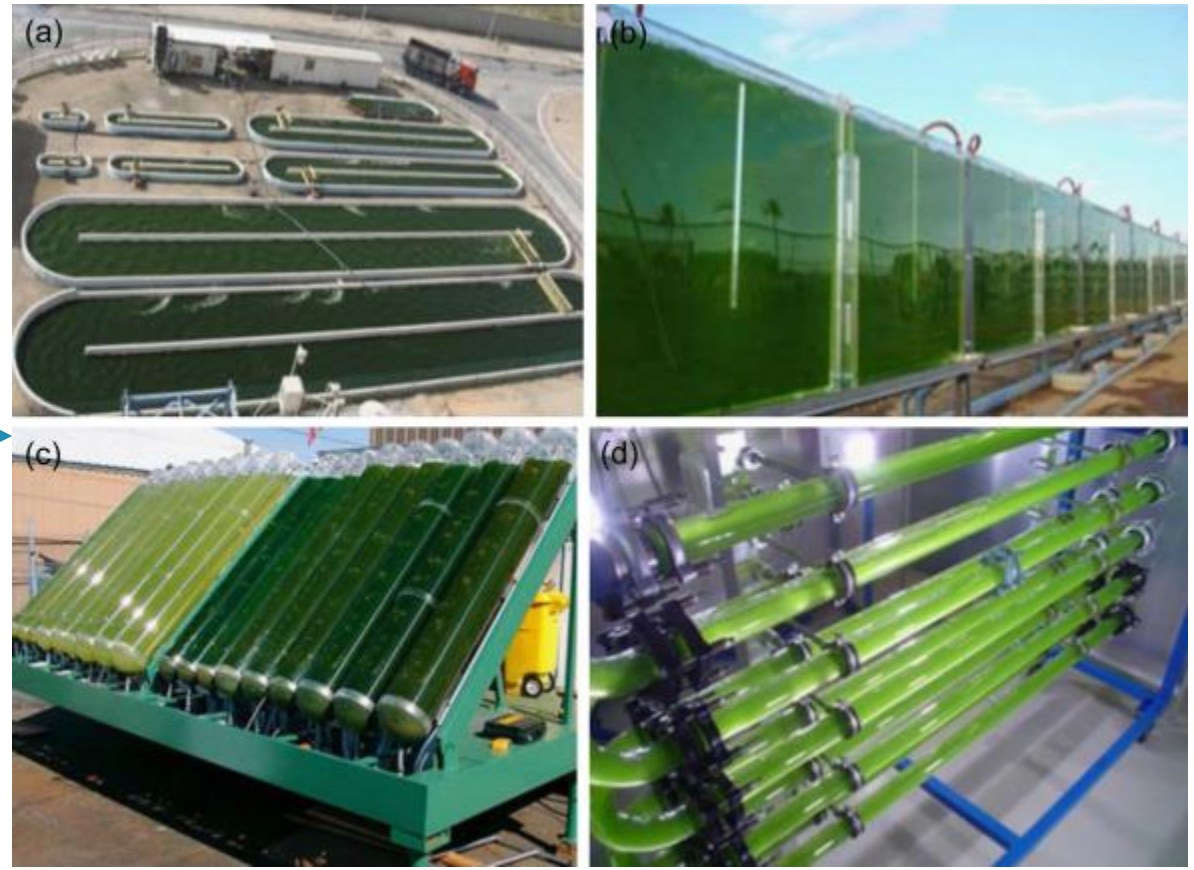
Introduction

Microalgae





[1] Halder, P.; Azad, A. K. Chapter 7 - Recent Trends and Challenges of Algal Biofuel Conversion Technologies. In *Woodhead Publishing Series in Energy*; Azad, A. K., Rasul, M. B. T.-A. B., Eds.; Woodhead Publishing, 2019; pp 167–179.

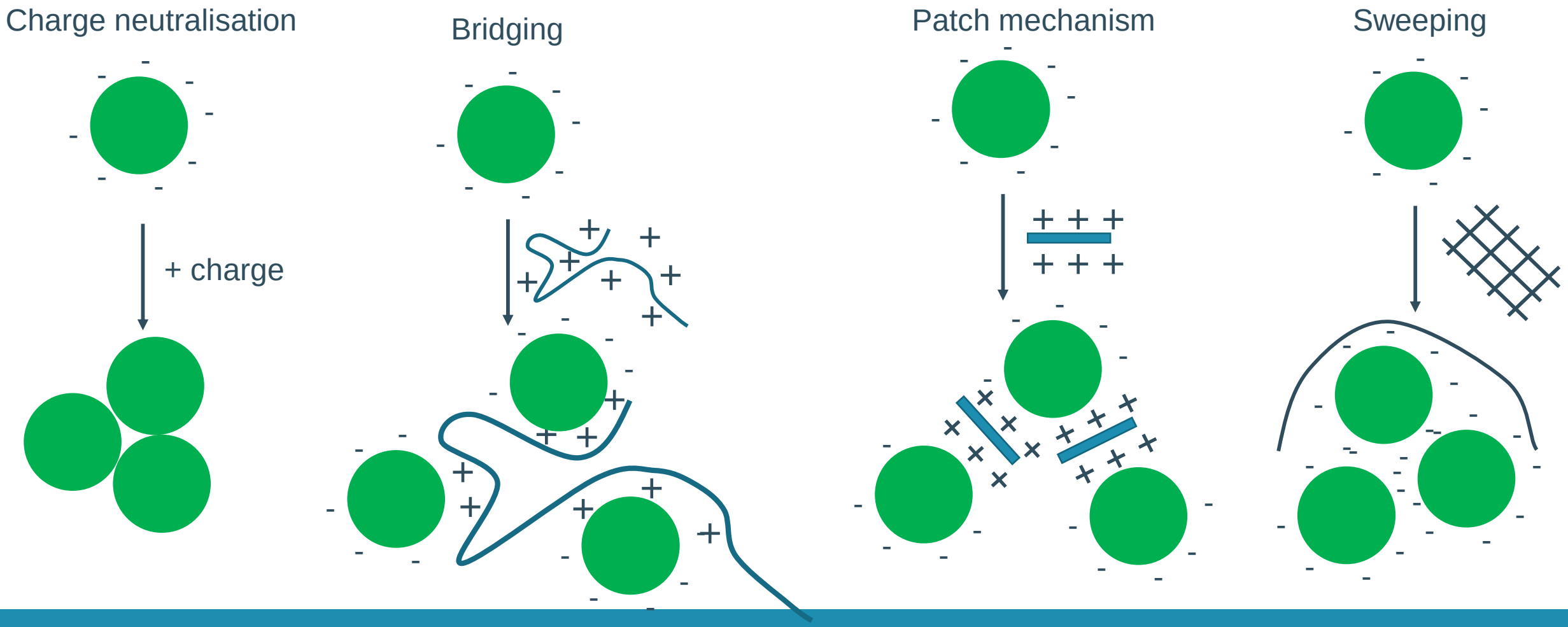
Microalgae

High costs

- Cultivation: Nutrients, water, CO_2-supply
- Biomass processing
- **Harvesting**
  - Small cell size
  - Low concentration
  - Cell-cell repulsion

centrifugation

Flocculation



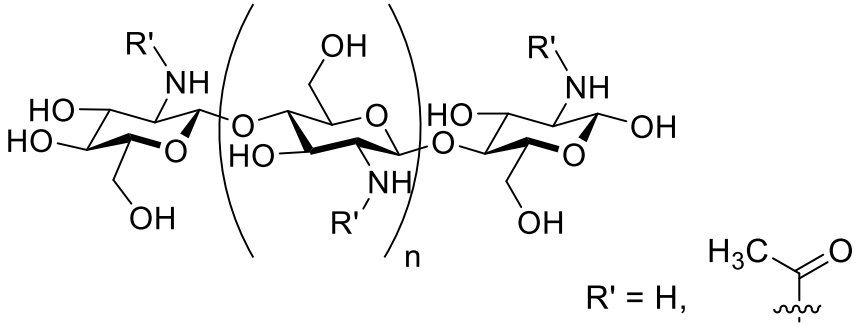
Flocculants

	Metal salts	Synthetic Polymers	Biopolymers
Applicability	+	+/-	+
Cost	+	+	+
Dose	-	+	+
Contamination	-	-	+
Mechanism	**Charge neutralisation or sweeping**	**Bridging**	**Bridging or patch or sweeping**

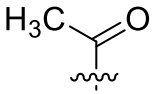
Chitosan-based flocculation

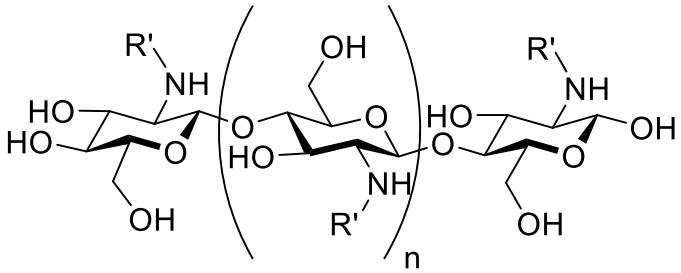
Chitosan

Hypholoma fasciculare - Gewone zwavelkop


R'
NH
HO
HO
O
OH
OH
O
HO
O
NH
R'
n
HO
O
R'
NH
OH
O
OH
H_3C
O
R' = H,

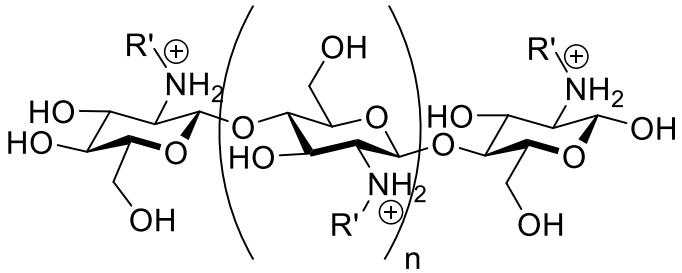
Chitosan

R' = H, 



Water insoluble

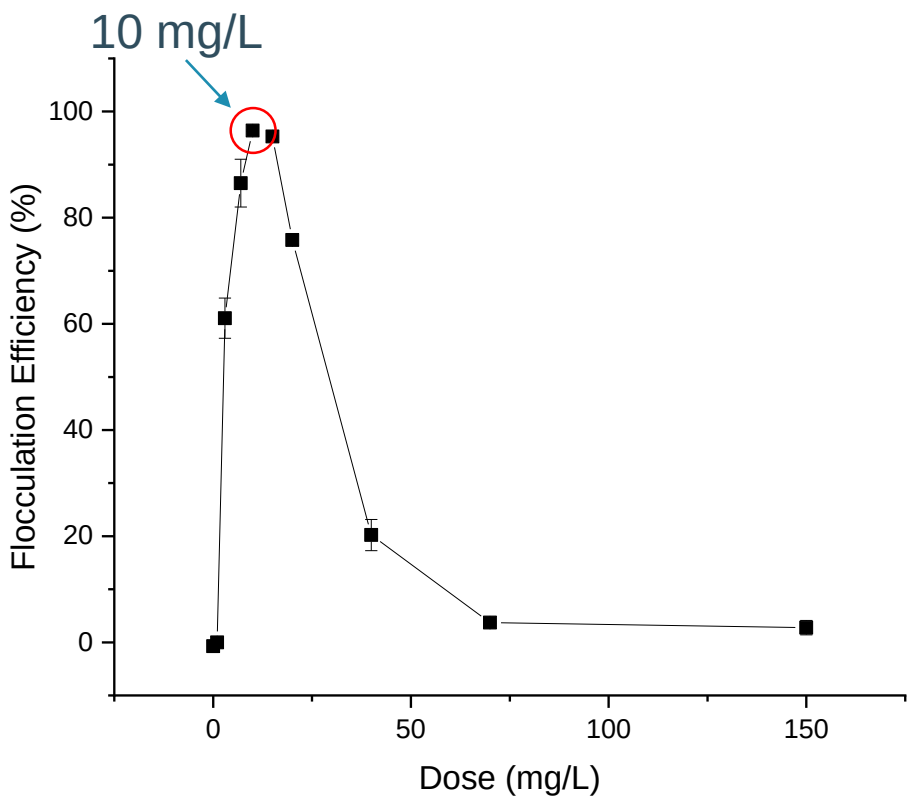
pH



Water soluble

Chitosan-based flocculation

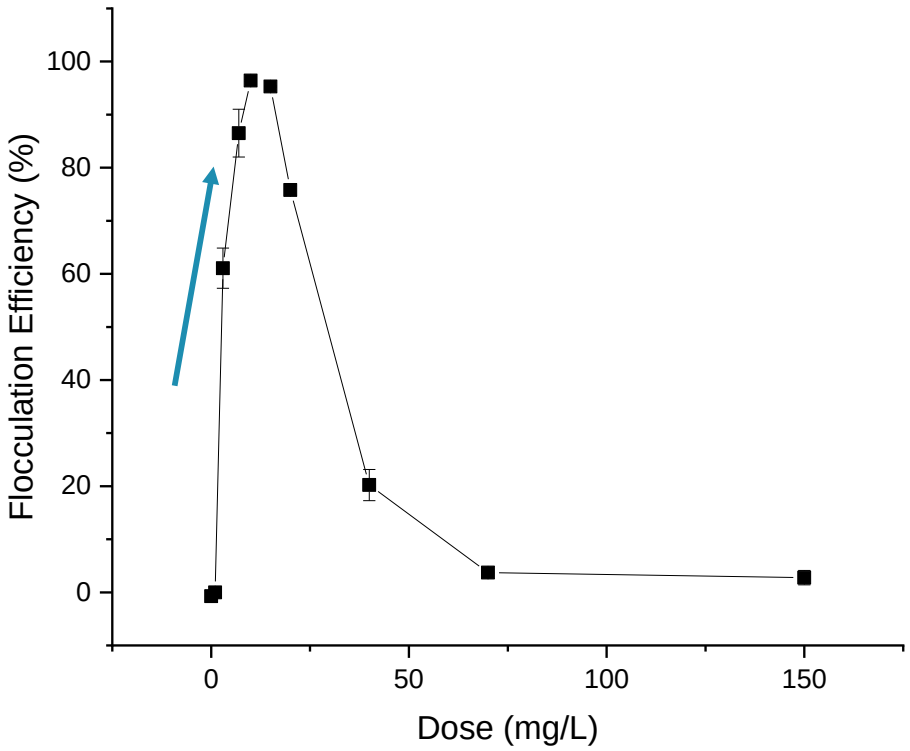
Fresh water microalgae

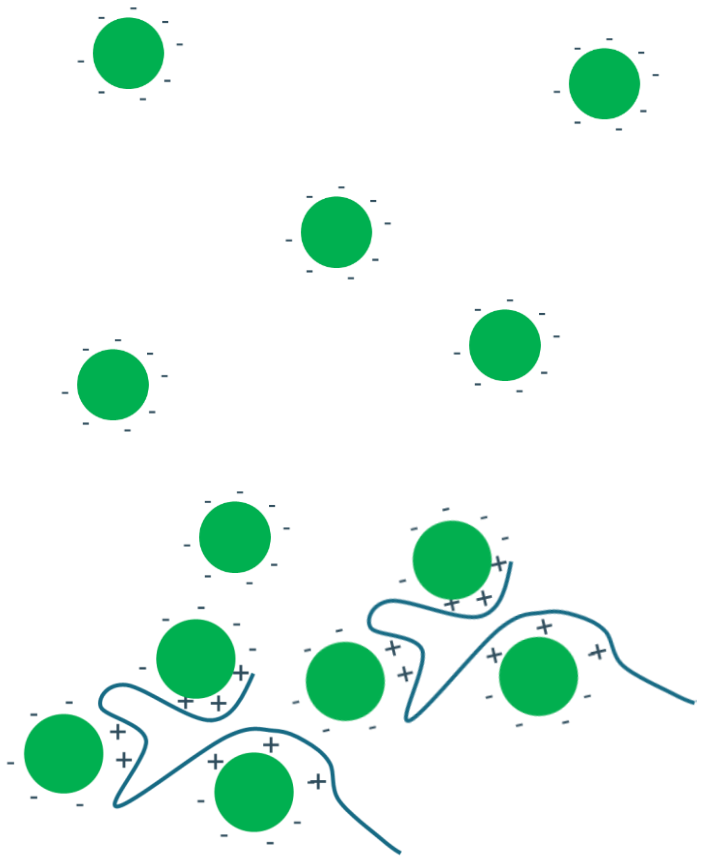


[2] Blockx, J.; Verfaillie, A.; Eyley, S.; Deschaume, O.; Bartic, C.; Muylaert, K.; Thielemans, W. Cationic Cellulose Nanocrystals for Flocculation of Microalgae: Effect of Degree of Substitution and Crystallinity. ACS Appl. Nano Mater. 2019, acsanm.9b00315

Chitosan-based flocculation

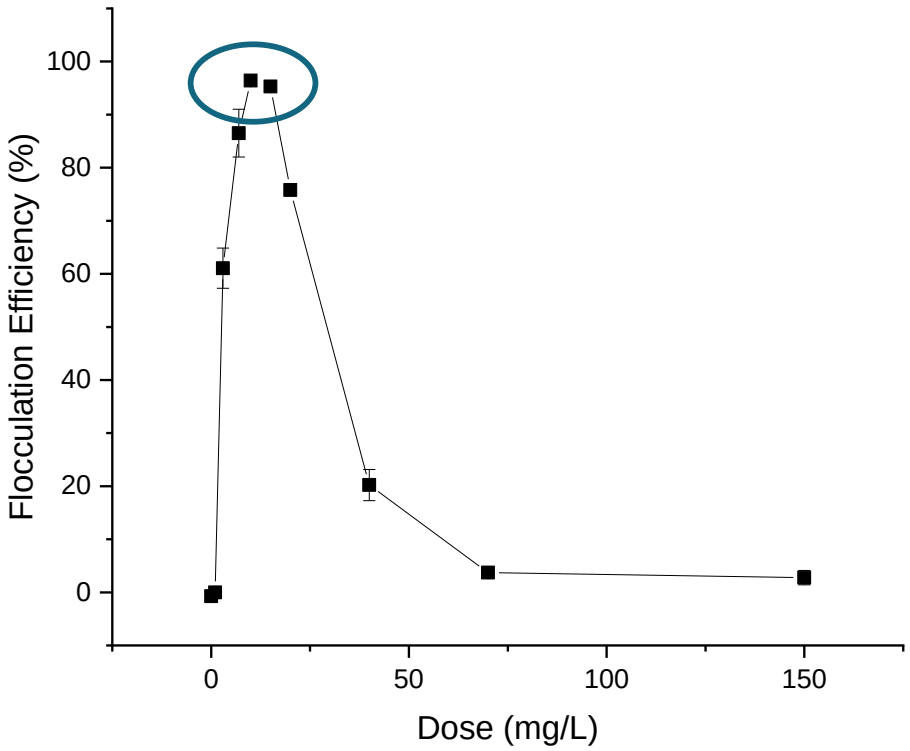
Fresh water microalgae

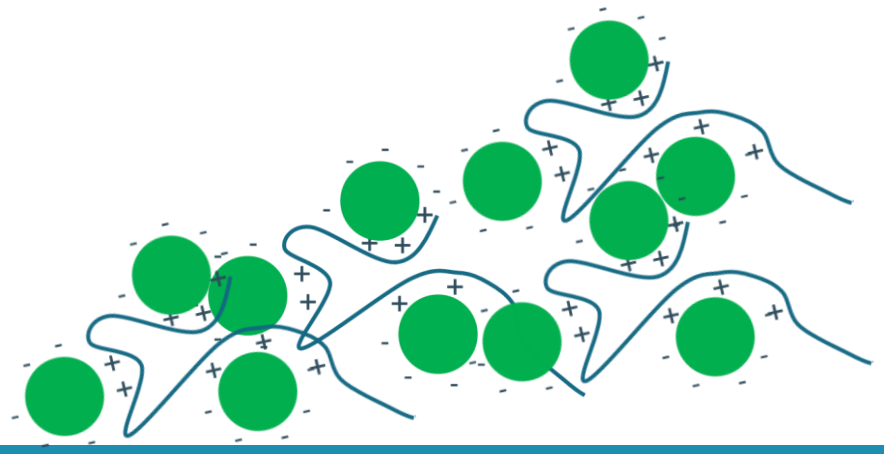




Chitosan-based flocculation

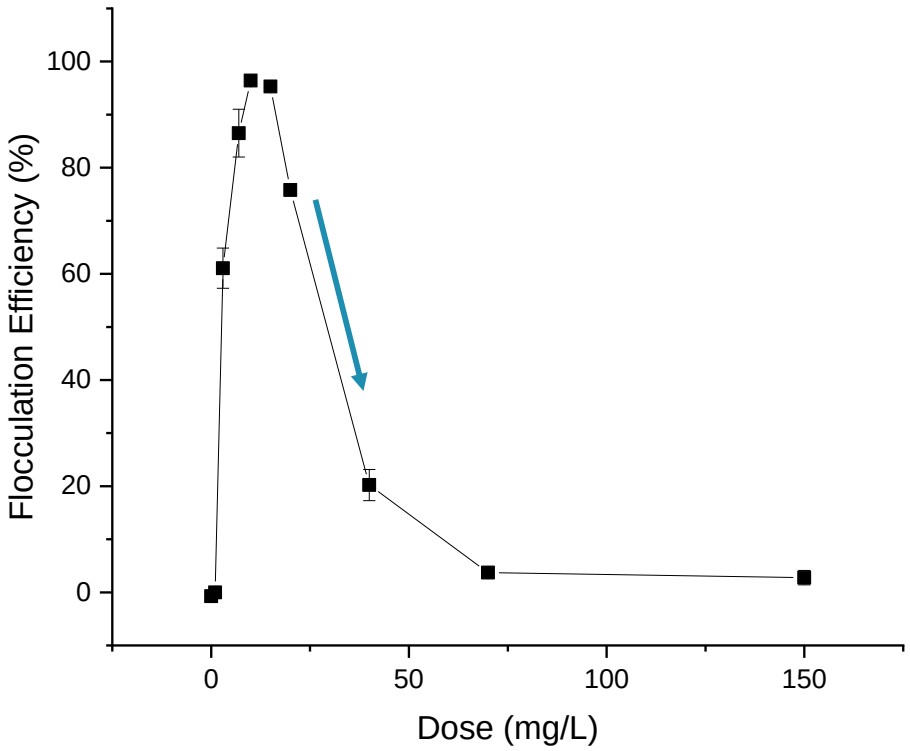
Fresh water microalgae

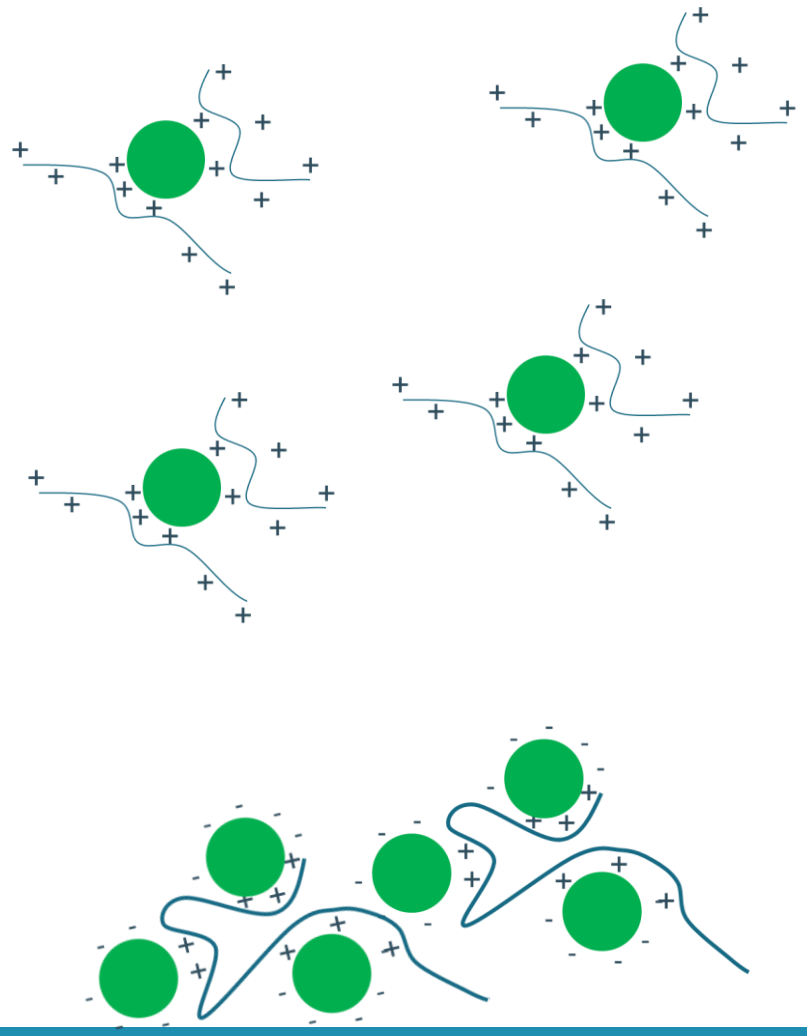




Chitosan-based flocculation

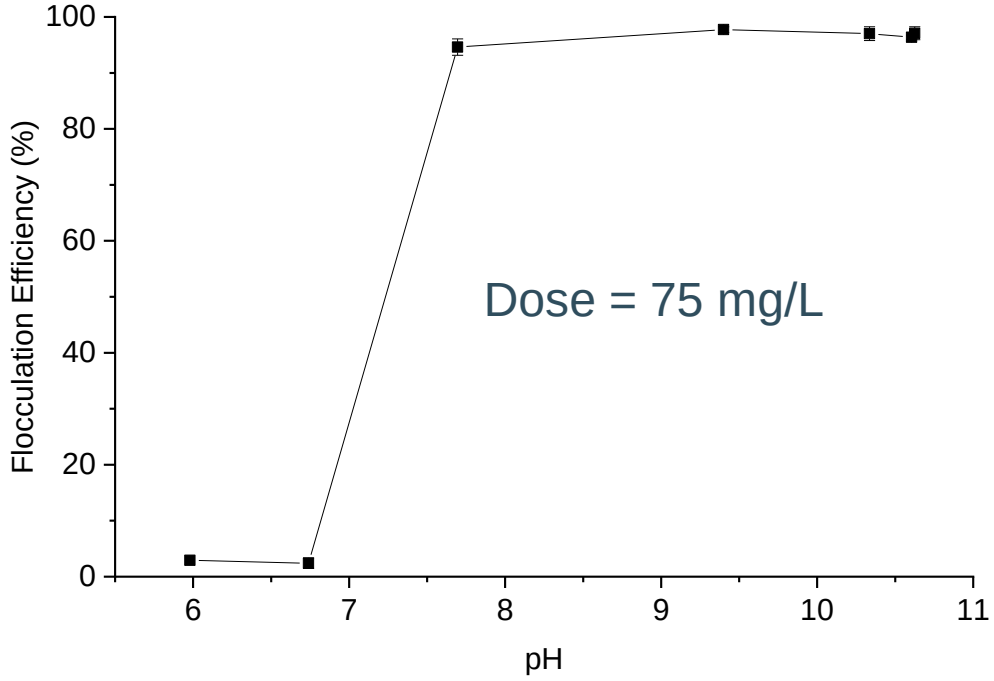
Fresh water microalgae

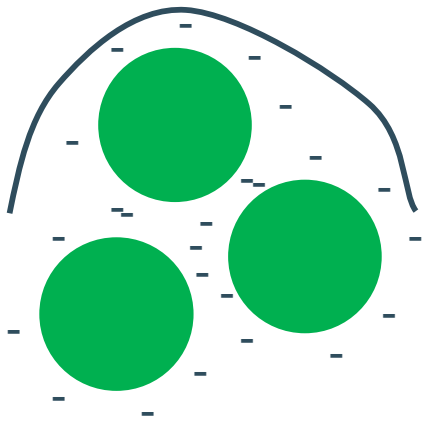




Chitosan-based flocculation

Marine microalgae



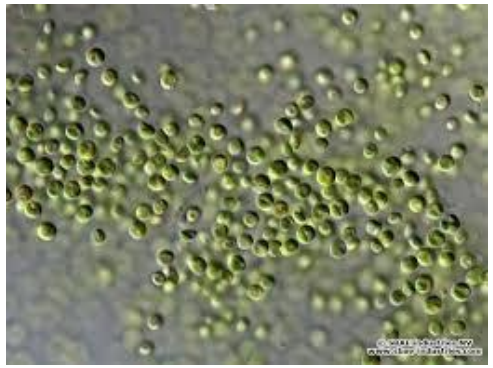


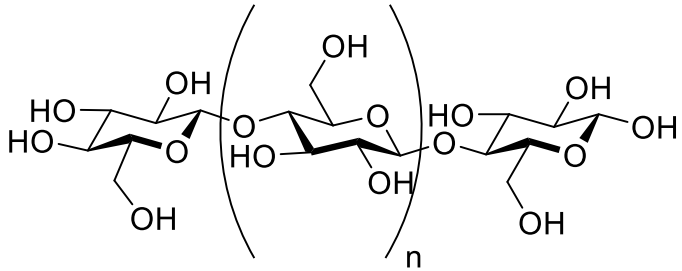
Sweeping mechanism

[2] Blockx, J.; Verfaillie, A.; Thielemans, W.; Muylaert, K. Unravelling the Mechanism of Chitosan-Driven Flocculation of Microalgae in Seawater as a Function of PH. ACS Sustain. Chem. Eng. 2018, 6 (9), 11273–11279

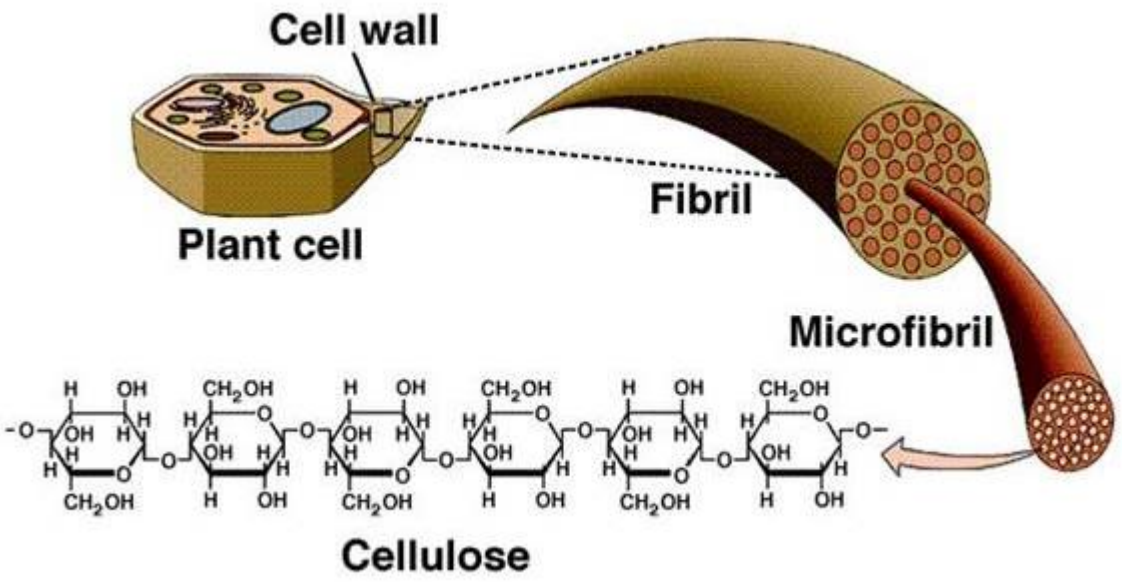
Nanocellulose-based flocculation

Cellulose

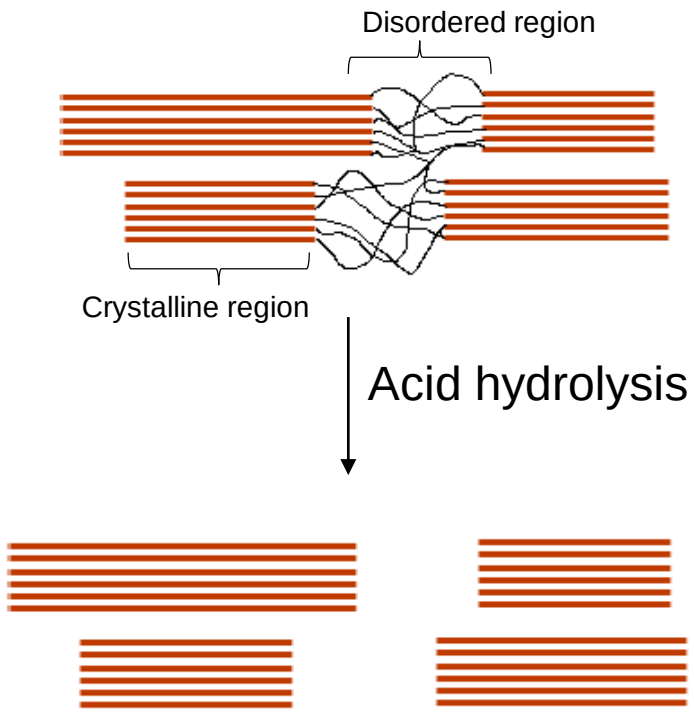




Cellulose nanocrystals



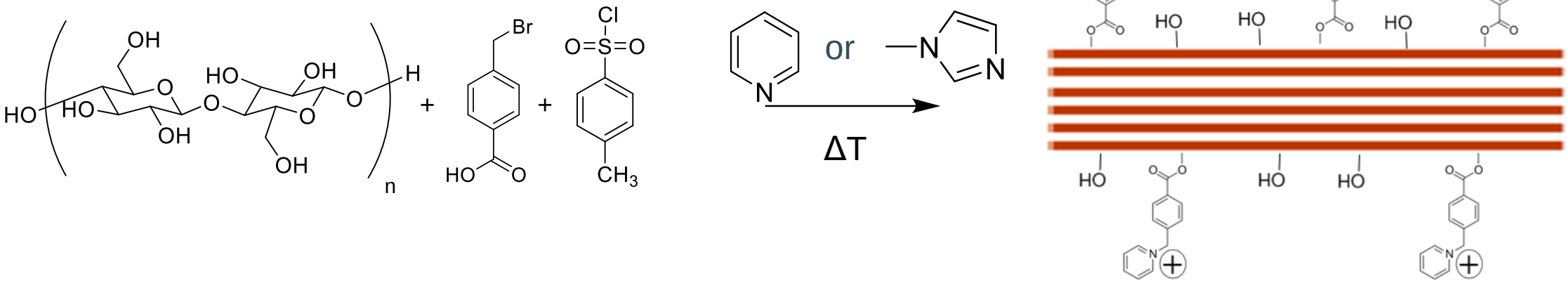
Randy Moore, Dennis Clark and Darrell Vodopich, Botany Visual Resource library © 1998 The McGraw-Hill Companies, Inc. All rights reserved.



Individual cellulose nanocrystals

Modification of nanocellulose

- Nanocellulose modification



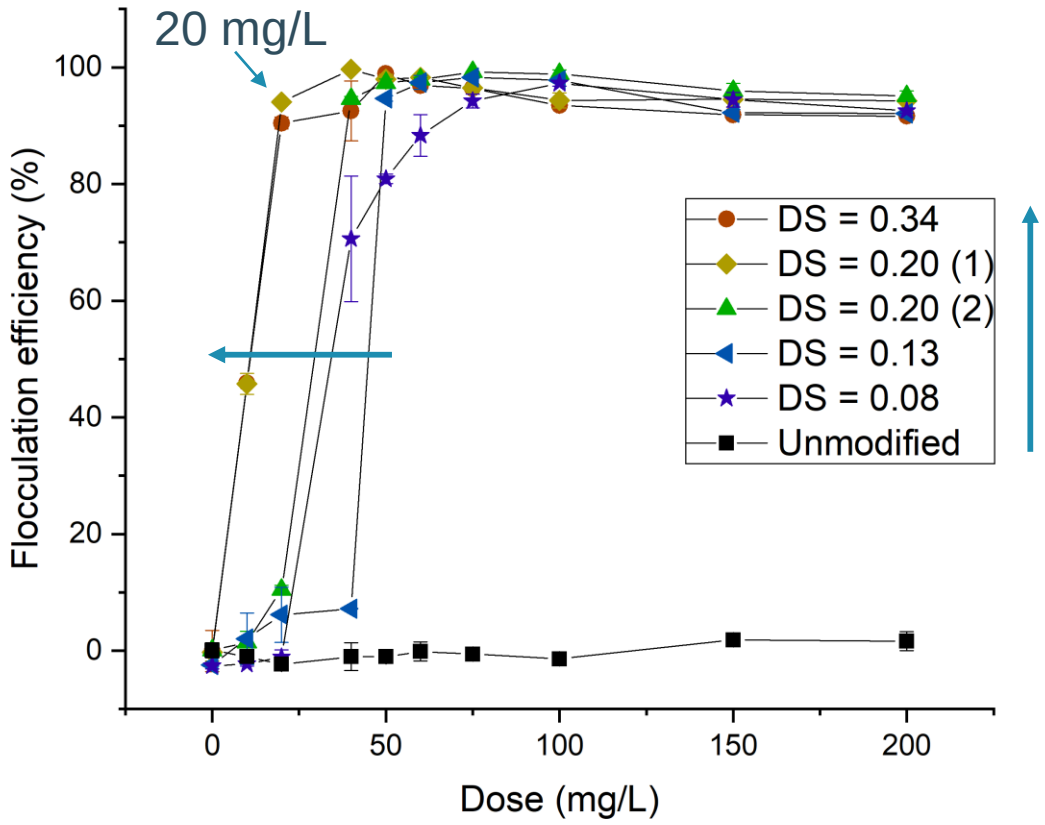
- Control over conditions
  - Temperature
  - Reaction time
  - Molar ratio reactants

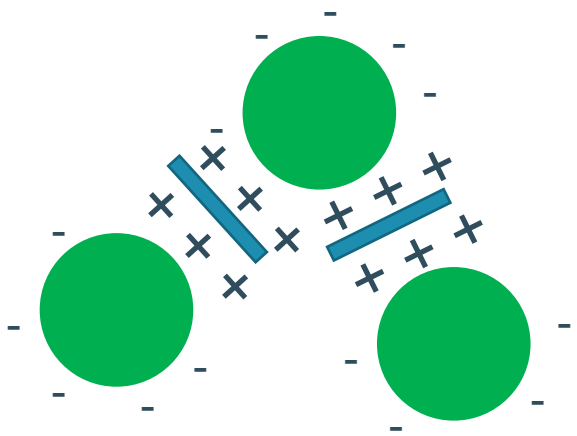
Control over degree of substitution (DS)

[2] Blockx, J.; Verfaillie, A.; Eyley, S.; Deschaume, O.; Bartic, C.; Muylaert, K.; Thielemans, W. Cationic Cellulose Nanocrystals for Flocculation of Microalgae: Effect of Degree of Substitution and Crystallinity. *ACS Appl. Nano Mater.* **2019**, acsanm.9b00315

Nanocellulose-based flocculation

Fresh water microalgae





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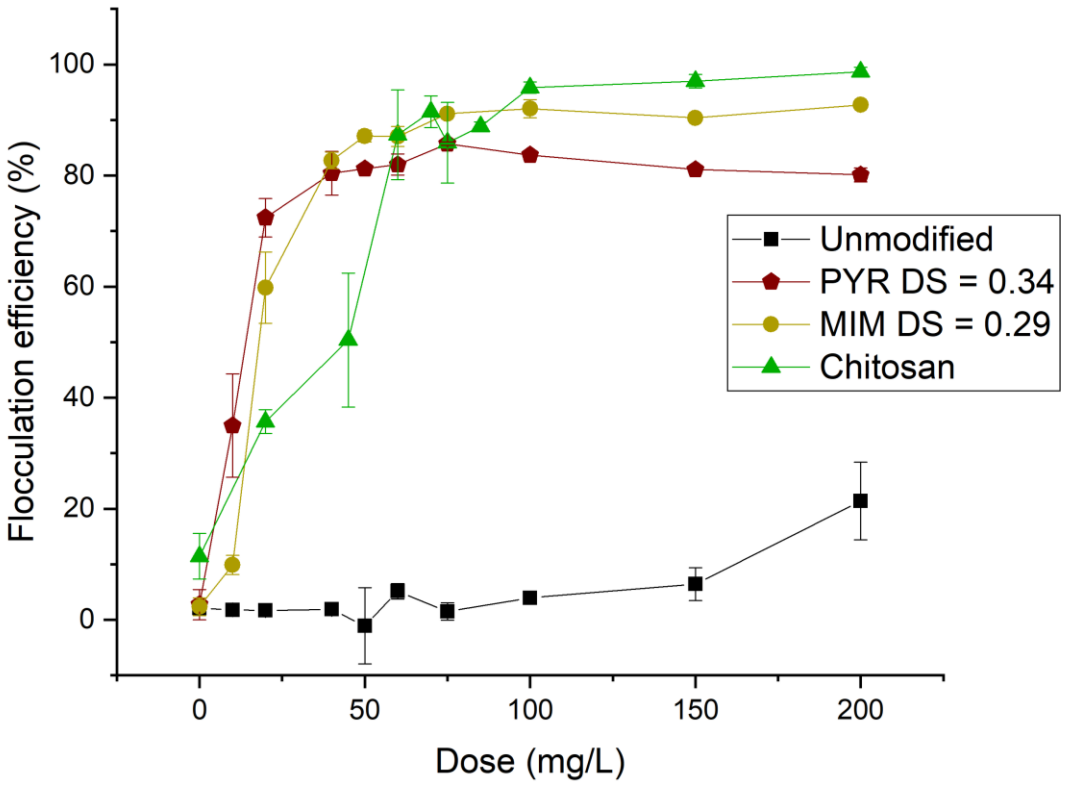
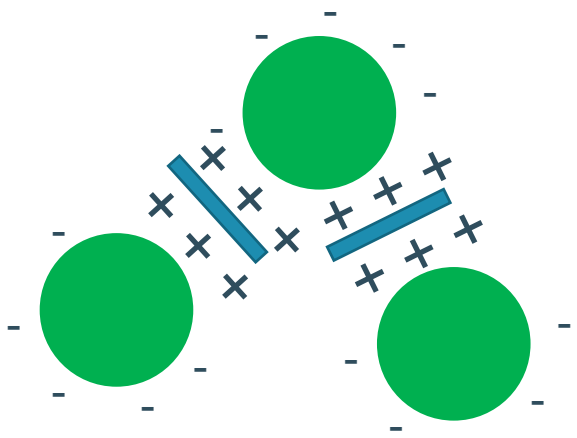
Nanocellulose-based flocculation

Marine microalgae





[4] Blockx, J.; Verfaillie, A.; Eyley, S.; Deschaume, O.; Bartic, C.; Muylaert, K.; Thielemans, W. Cationic Cellulose Nanocrystals for Flocculation of Microalgae: Effect of Degree of Substitution and Crystallinity. *ACS Appl. Nano Mater.* **2019**, acsanm.9b00315

Conclusions and work in progress

General conclusions

Chitosan

Fresh water microalgae

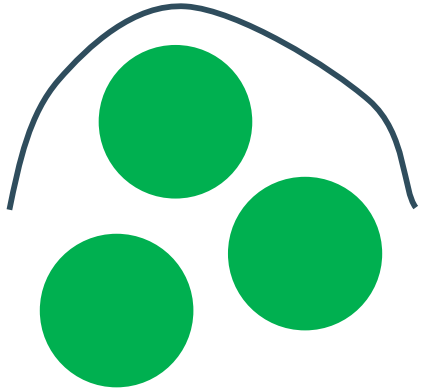
Marine microalgae

Low pH

High pH

- Mechanism with ‘biological interactions’
- Low dose required
- Restabilization

- Sweeping mechanism
- Higher dose required



General conclusions

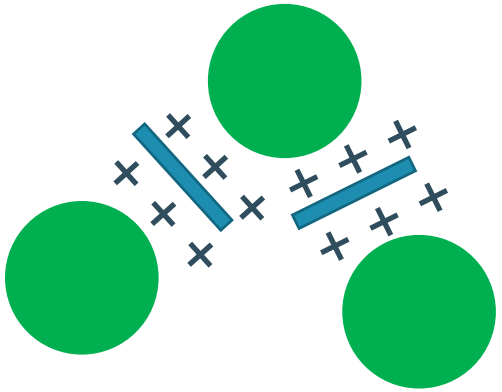
Cellulose nanocrystals

Fresh water microalgae

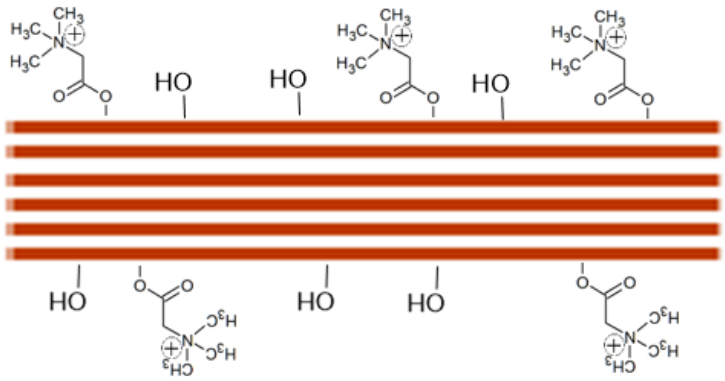
- Patch mechanism
- Low dose required
- Good control of reaction and flocculation

Marine microalgae

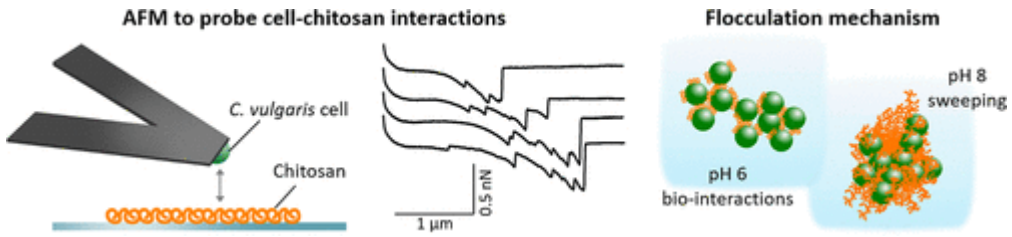
- Patch mechanism
- Low dose required
- Good control of reaction and flocculation



Work in progress



- Betaine modification of cellulose nanocrystals: bio-based graft



- Atomic Force Microscopy (AFM): a sensitive tool for analysis of flocculation properties

[5] Demir, I.; Blockx, J.; Dague, E.; Guiraud P.; Thielemans, W.; Muylaert, K.; Formosa-Dague C. Nanoscale evidences unravel microalgae flocculation mechanism induced by chitosan. ACS Appl. Bio Mater. 2020

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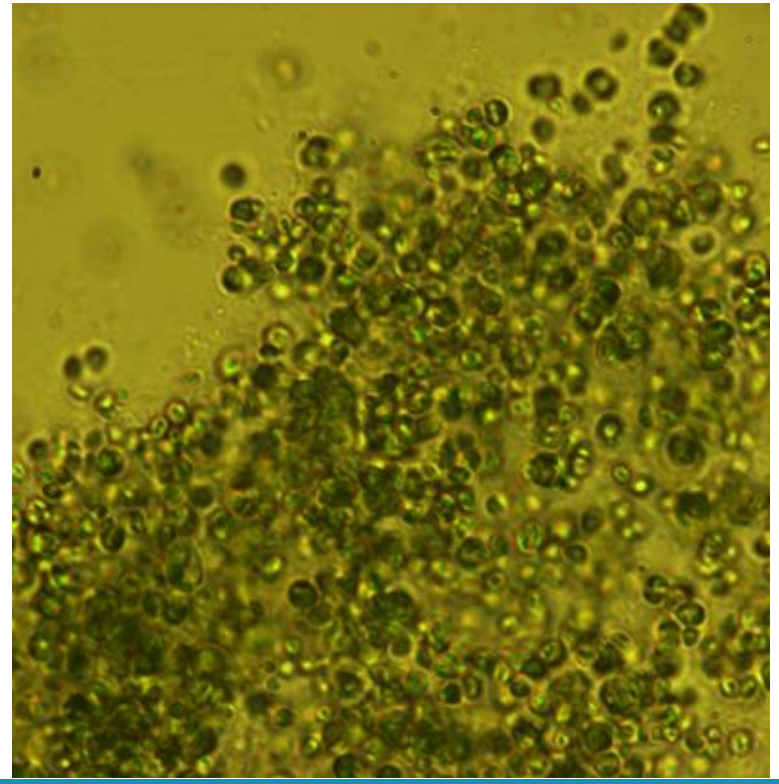
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