NWWC 2024
Winnipeg, Manitoba
November 3rd - 6th, 2024

The Recovery of Curdlan from Aerobic Granular Sludge Wastewater Treatment Systems

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"Wastewater treatment plants should be viewed as water resource recovery facilities."

- World Bank

Source: https://edukite.org/course/water-and-sanitation-infrastructure-in-developing-countries/

Wastewater treatment and circular economy

The fundamental purpose of wastewater treatment is to remove pollutants.

- Organic matter (BOD, COD)
- Suspended solids
- Pathogenic microorganisms
- Nutrients (N & P)
- Toxic substances (heavy metals, organic compounds, etc)

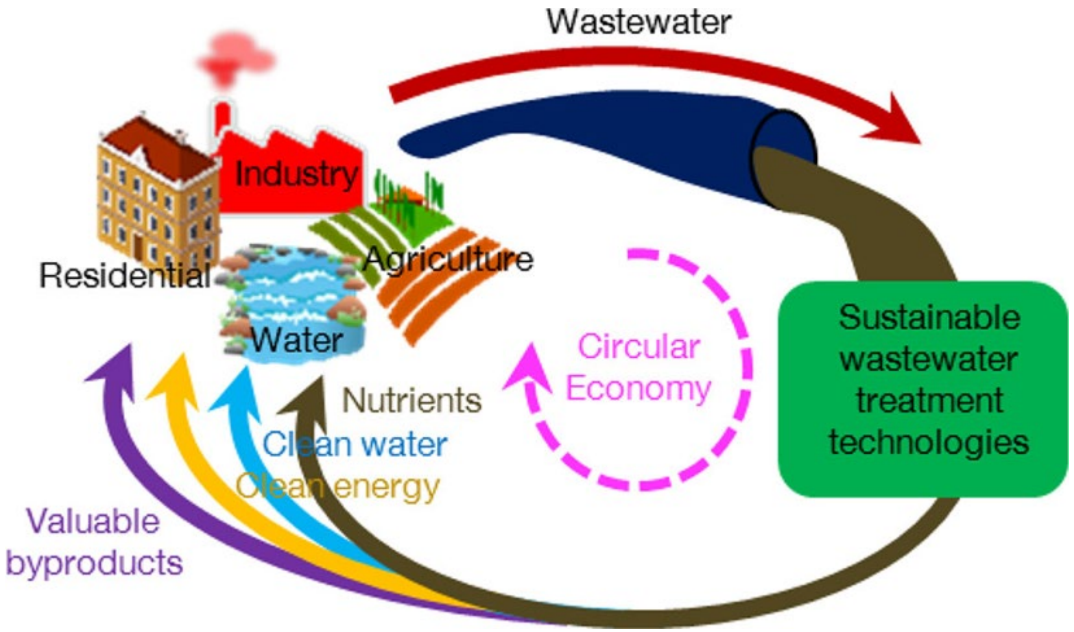


Fig 1: Graphical illustration of circular economy in wastewater sector

Source: Clean Water | Gift Catalogue | World Vision Canada

Waste-to-wealth concept

Wastewater = water + ~~pollutants~~ (resources)

The common technology for wastewater treatment has been is the **Convectional Activated Sludge (CAS) Process**.

Aerobic granular sludge (AGS)

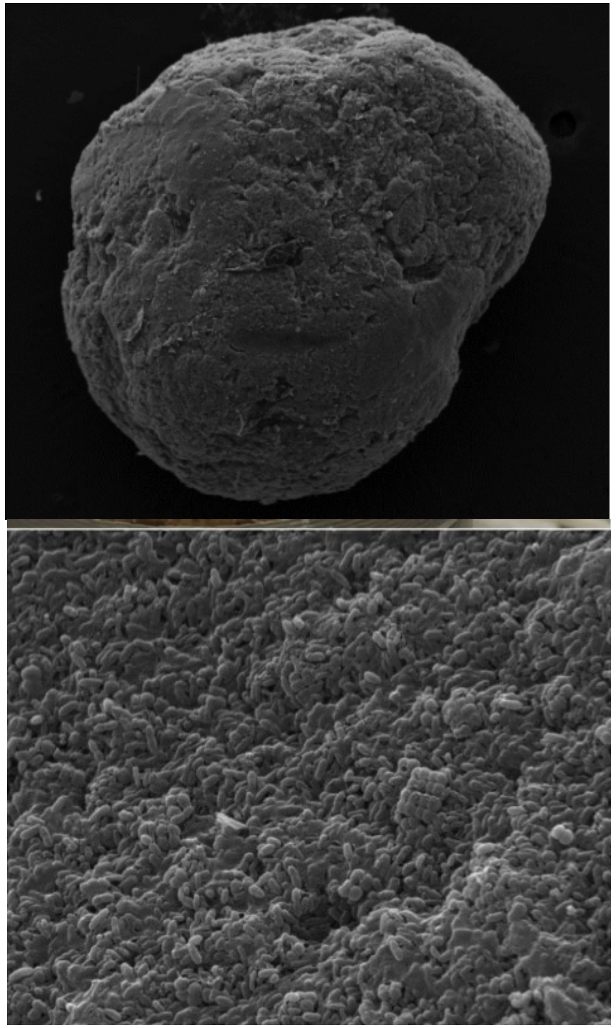


Fig 2: SEM images of AGS

Aerobic granules - aggregates of microbial origin, which do not coagulate under reduced hydrodynamic shear, and which subsequently settle significantly faster than activated sludge

- True microbial biomass
- Minimum particle diameter ~ 0.2 mm
- AGS SVI_5 is comparable to SVI_{30} of typical activated sludge

SVI_5

Iorhemen, O.T., Zaghloul, M.S., Hamza, R.A., Tay, J.H. (2020). ***J. Environ. Chem. Eng.*****, 8(2): 103681.**

Extracellular Polymeric Substance (EPS) in the Granule Matrix

- The aerobic granule structure exhibits high EPS content
- EPS is a naturally occurring biopolymer - both renewable & biodegradable
- EPS forms a hydrogel matrix as a dense network that contributes to the strength and stability of granules
- High EPS content of AGS offers a great opportunity to recover valuable resources from waste aerobic granules

Conventional treatment and AGS treatment

Compared to CAS, AGS offers:

- Outstanding settleability
  - **SVI = 30 – 50 mL/g**
  - **Settling velocity = AGS - *35 m/h; CAS <10m/h***
- Diverse microbial community
- High removal efficiency for both carbon & nutrients
- High biomass retention – **MLSS 8,000 – 15,000 mg/L**
- Ability to withstand high organic loading
- Small footprint requirement – ***Up to 75% footprint reduction***
- Saves energy – ***up to 50%***
- Tolerance to toxicity

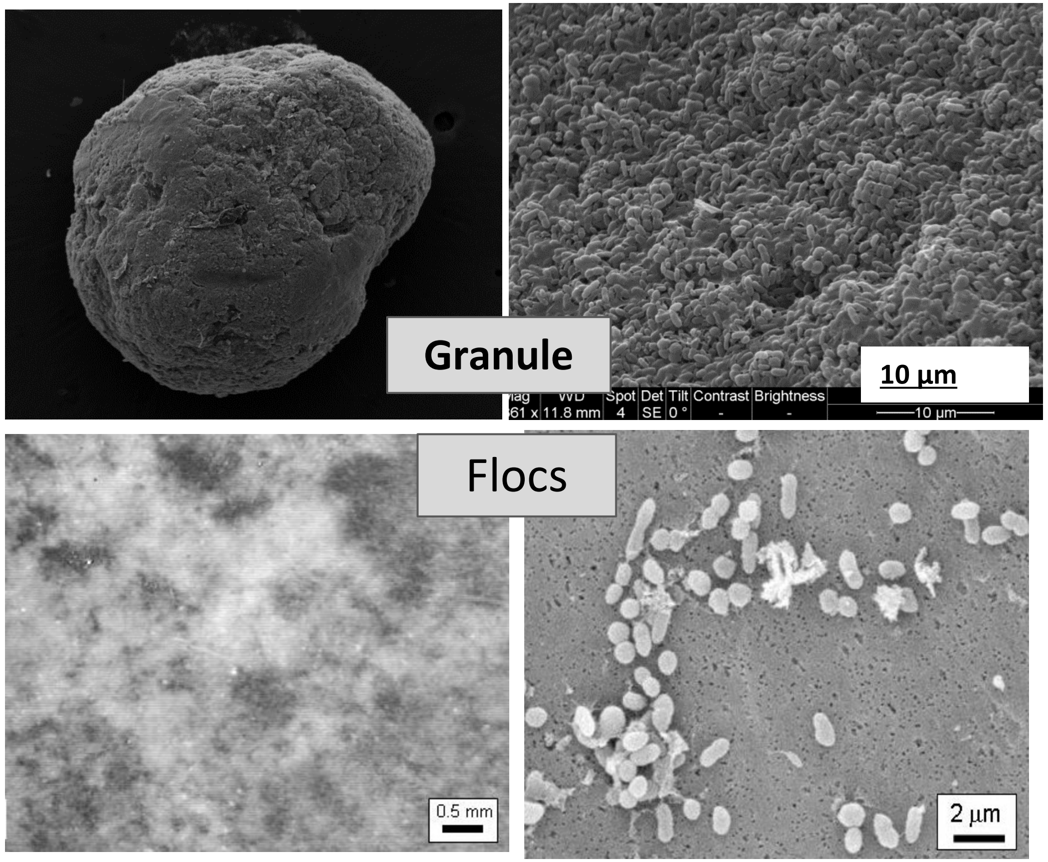


Fig 3: SEM images of AGS and CAS

Iorhemen, O.T., Zaghloul, M.S., Hamza, R.A., Tay, J.H. (2020). *J. Environ. Chem. Eng.*, 8(2): 103681.

Resource recovery from AGS

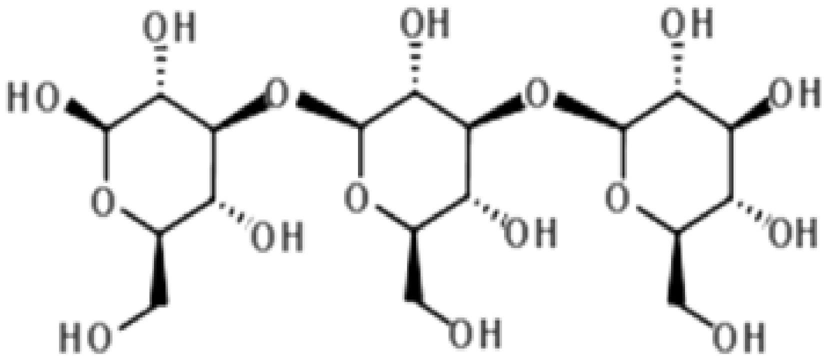
- ❑ Phosphorus
- ❑ Alginate-like exopolysaccharides (ALE)
- ❑ Polyhydroxyalkanoates (PHAs)
- ❑ Tryptophan

❖ **Recently, curdlan has been identified in the aerobic granule matrix.**

Source: https://www.thesourcemagazine.org/ostaras-circular-approach-to-phosphorus-recovery/

Curdlan

- Water-insoluble
- Linear exopolysaccharide
- Consists of glucosyl residues interconnected by β-1,3 glycosidic bonds.
- Produced by bacteria such as *Agrobacterium* sp., *Pseudomonas* sp., *Bacillus* sp.
- Thermal stability (80 - 100˚C)
- Water-holding capacity



Chemical structure of curdlan

Source: https://veerone.com/product/curdlan-gum/parameter

Industrial applications

❑**Food industry**

- *thickening agent or fat-mimic substitute*
- *Water holding capacity for meat processing (ham and sausages)*
- *Texture modifier in dairy and noodles*

❑**Pharmaceutical industry**

- *Antitumor activity*
- *Antiviral effect*
- *Prebiotic function*

https://www.idbs.com/2018/06/the-future-of-biologics-drug-development-is-today/
https://oft.organo.co.jp/english/product/curdlan_cd/

Industrial application

❖**Cosmetic industry**

- *Moisturizing*
- *Incense agents*
- *Chemosensor preparation*

❖**Engineering applications**

- *Grouting agent in soils*
- *Adsorbent for contaminated soil remediation*
- *Superplasticizer in concrete mixtures*

https://www.e3s-conferences.org/articles/e3sconf/pdf/2023/26/e3sconf_uesf2023_01032.pdf

Current issues and research prospects

Approval of US Food and Drug Administration for curdlan use in the food industry – 2005

Rise in demand for curdlan both in North America and Europe *(Yuan et al., 2021; Zhai et al., 2017*).

Current global market value – over 102 billion USD *(Bali, 2024) Cognitive Market Research*

This research could contribute to the curdlan market

Curdlan from wastewater

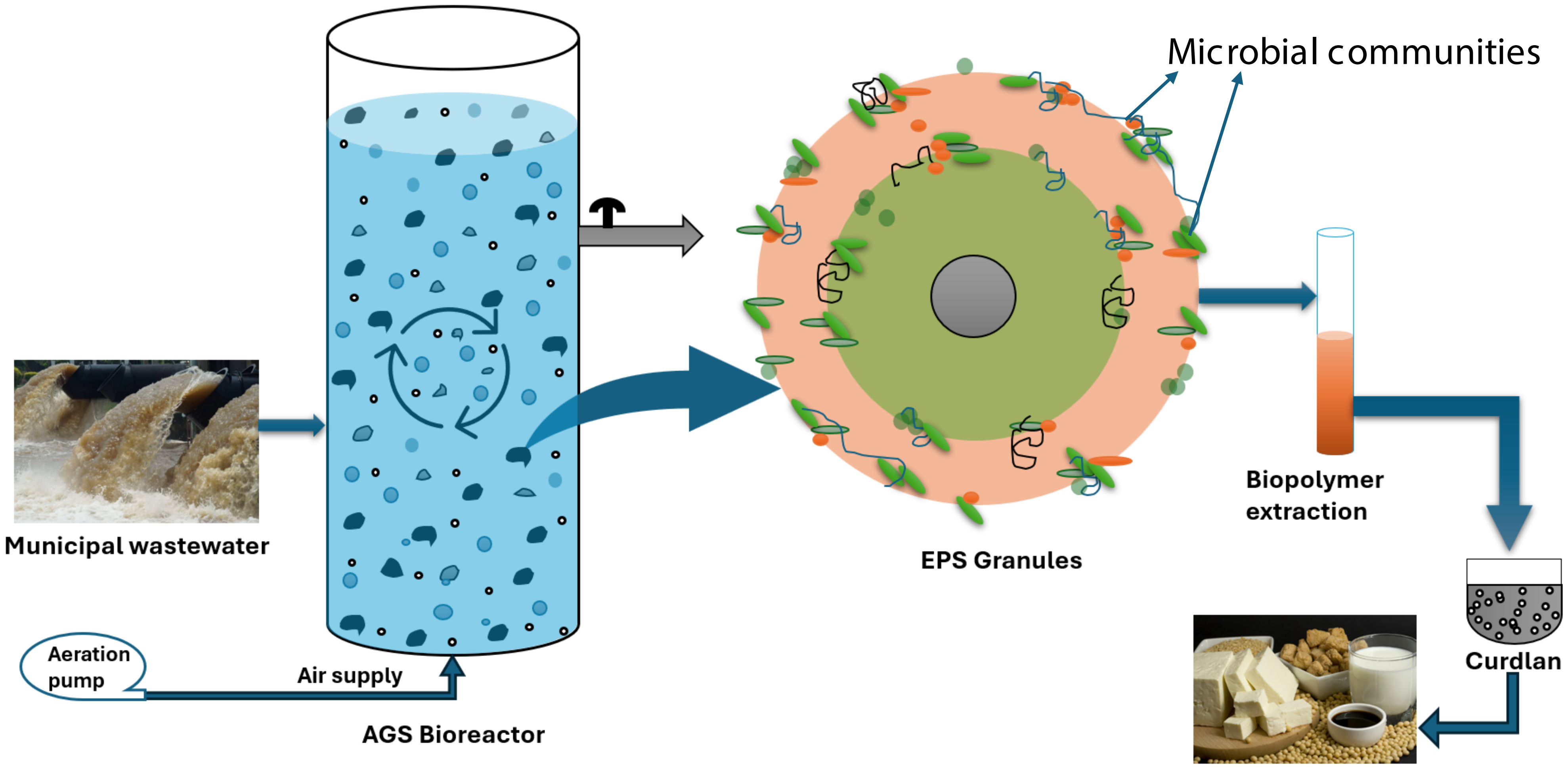
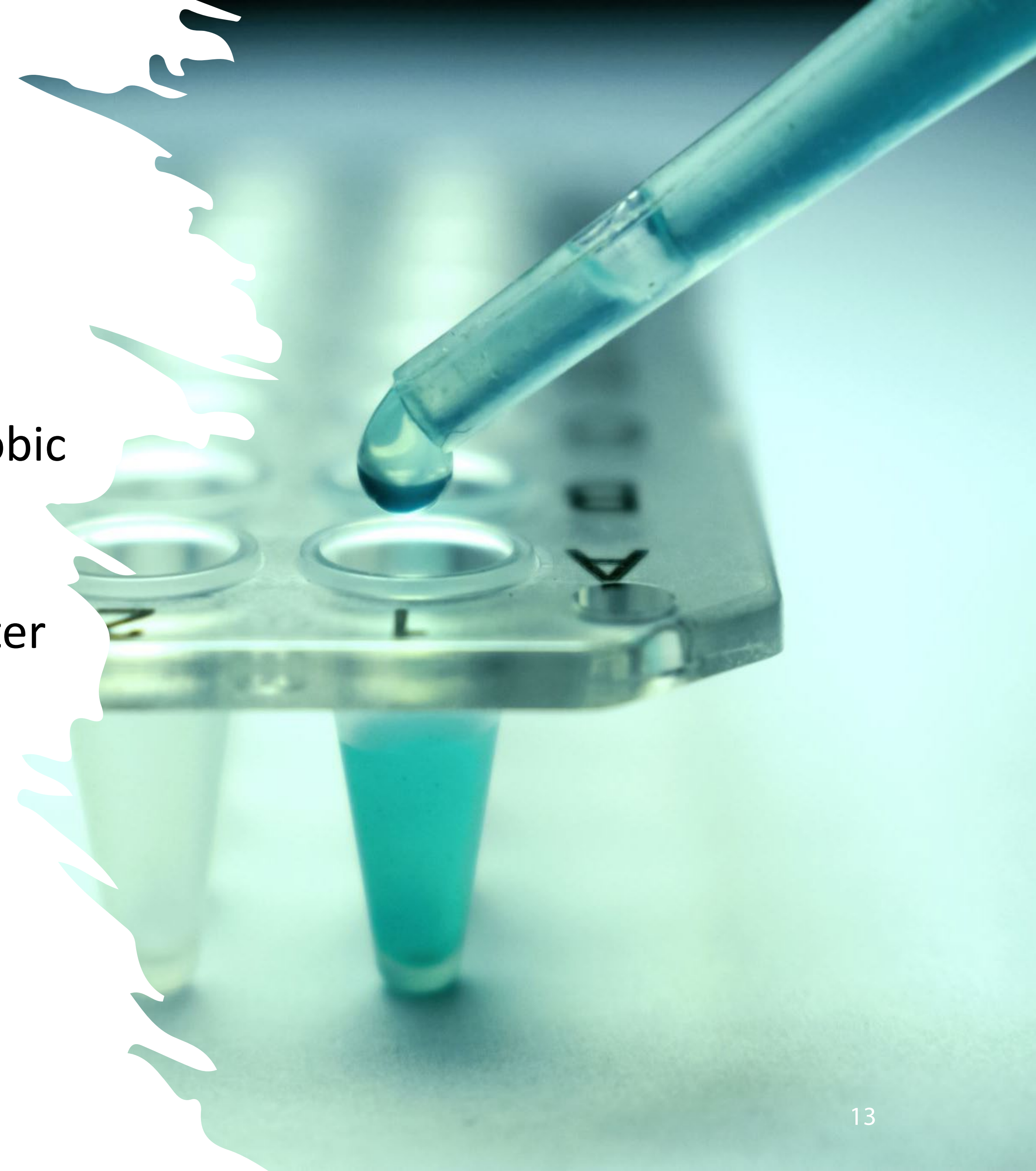


Fig 4: Graphical illustration of resource recovery from wastewater.

Research objective

To optimize the biosynthesis of curdlan in aerobic granule matrix, while maintaining efficient wastewater treatment in AGS-based wastewater treatment systems.



Experimental set-up

Fig 5a: Bioreactor during aeration phase

Fig 5b: Bioreactor during settling phase

Aerobic granules development

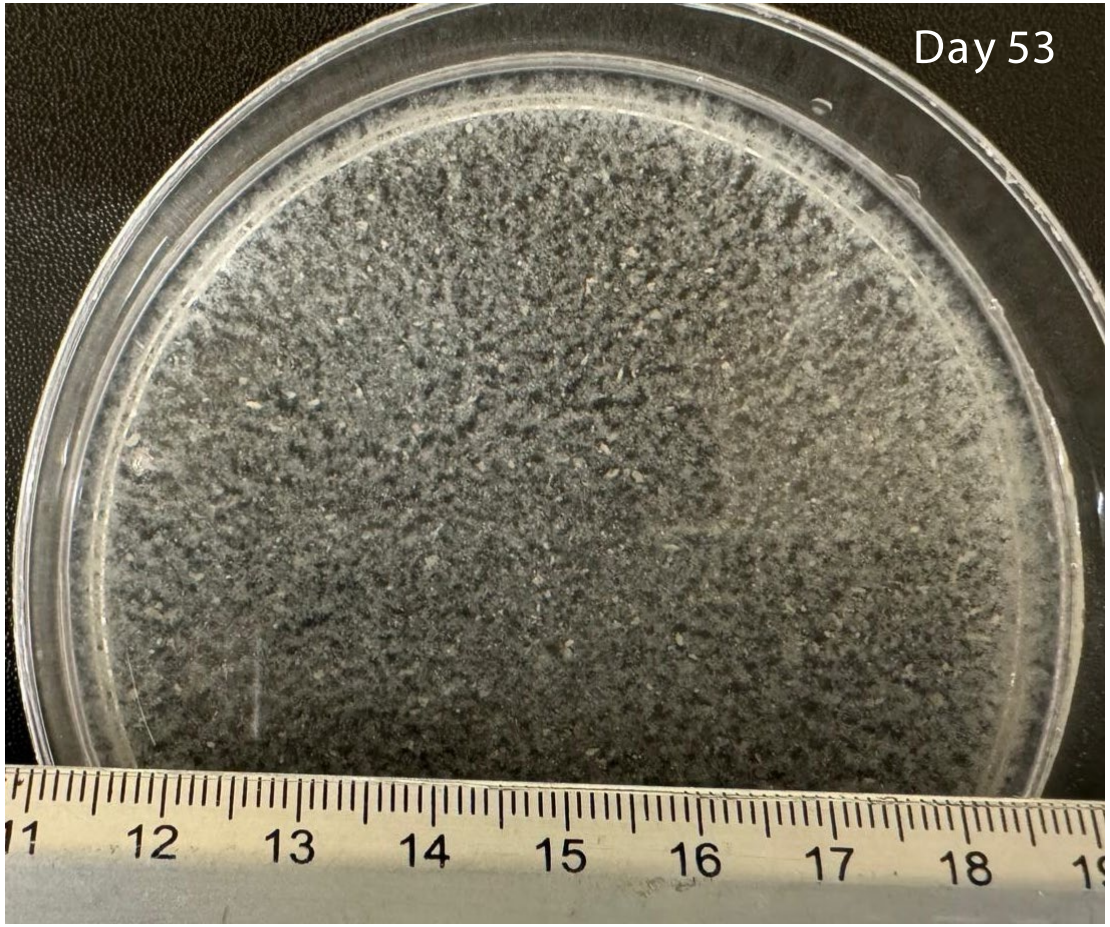


Fig 6a: Image of early stage of aerobic granules development.

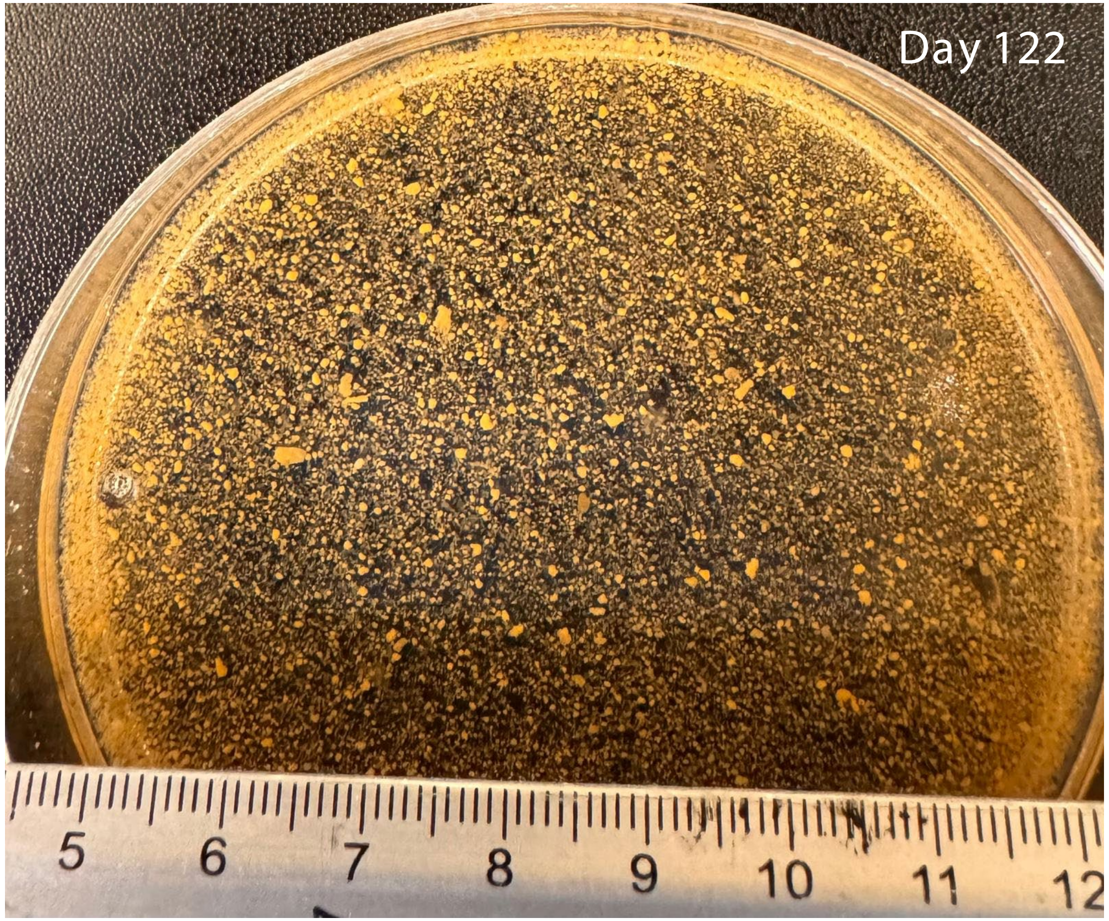


Fig 6b: Image of recent development stage of aerobic granules.

Experimental factors

| Runs – 9 | Factors – 3 | Levels – 3 |

- Carbon-to-Nitrogen ratio
- Feeding strategy
- Organic loading rate (OLR)

AGS performance and biomass analysis

Biomass analysis – MLSS / MLVSS

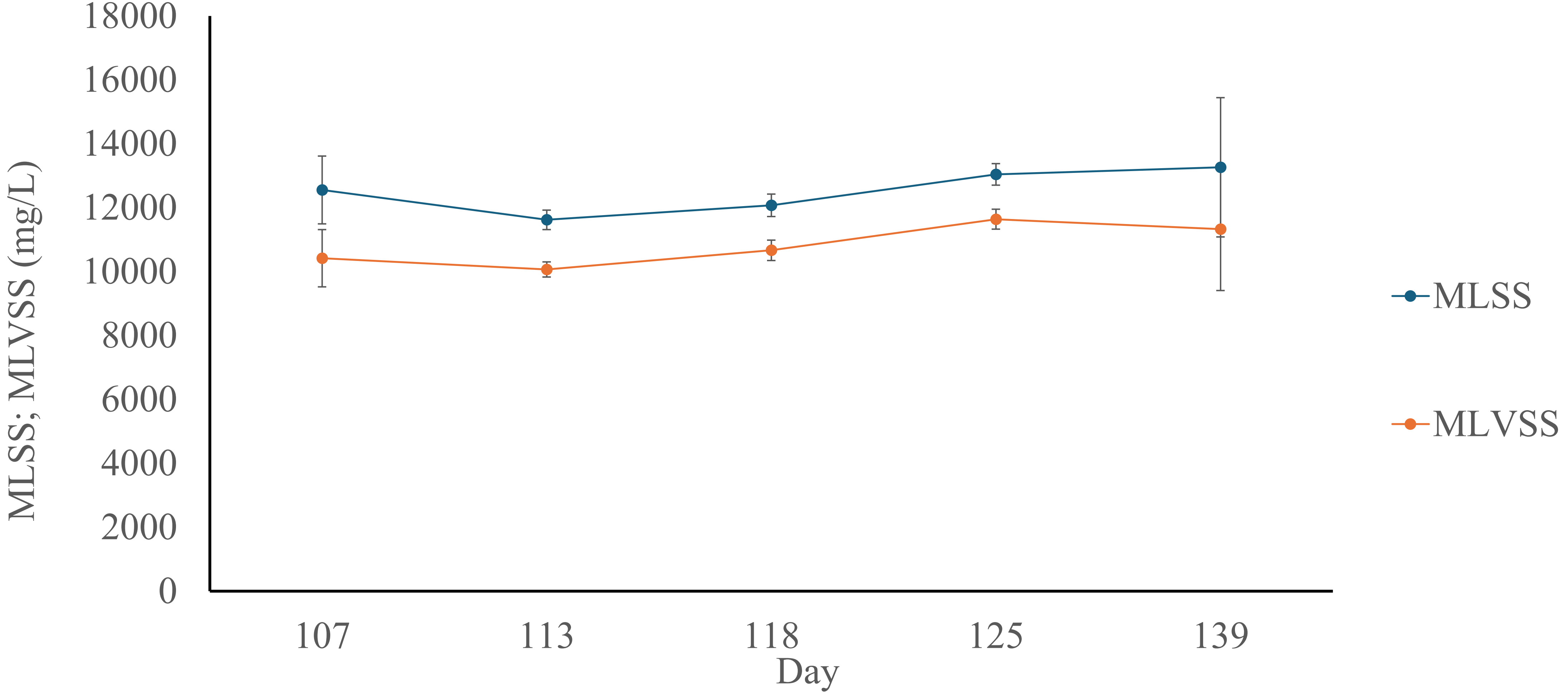


Fig 7: Bioreactor biomass concentration

Biomass - Settleability

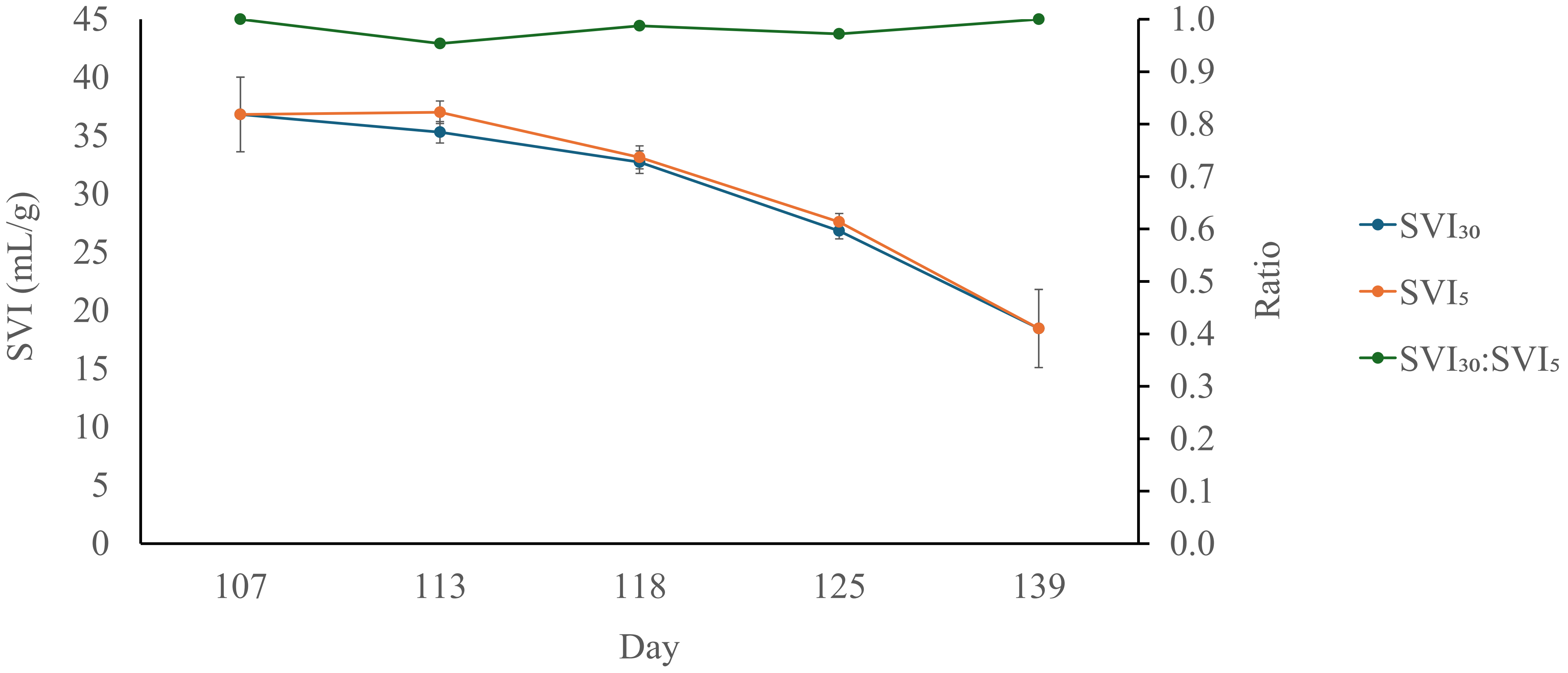


Fig 8 : Bioreactor biomass settleability

COD

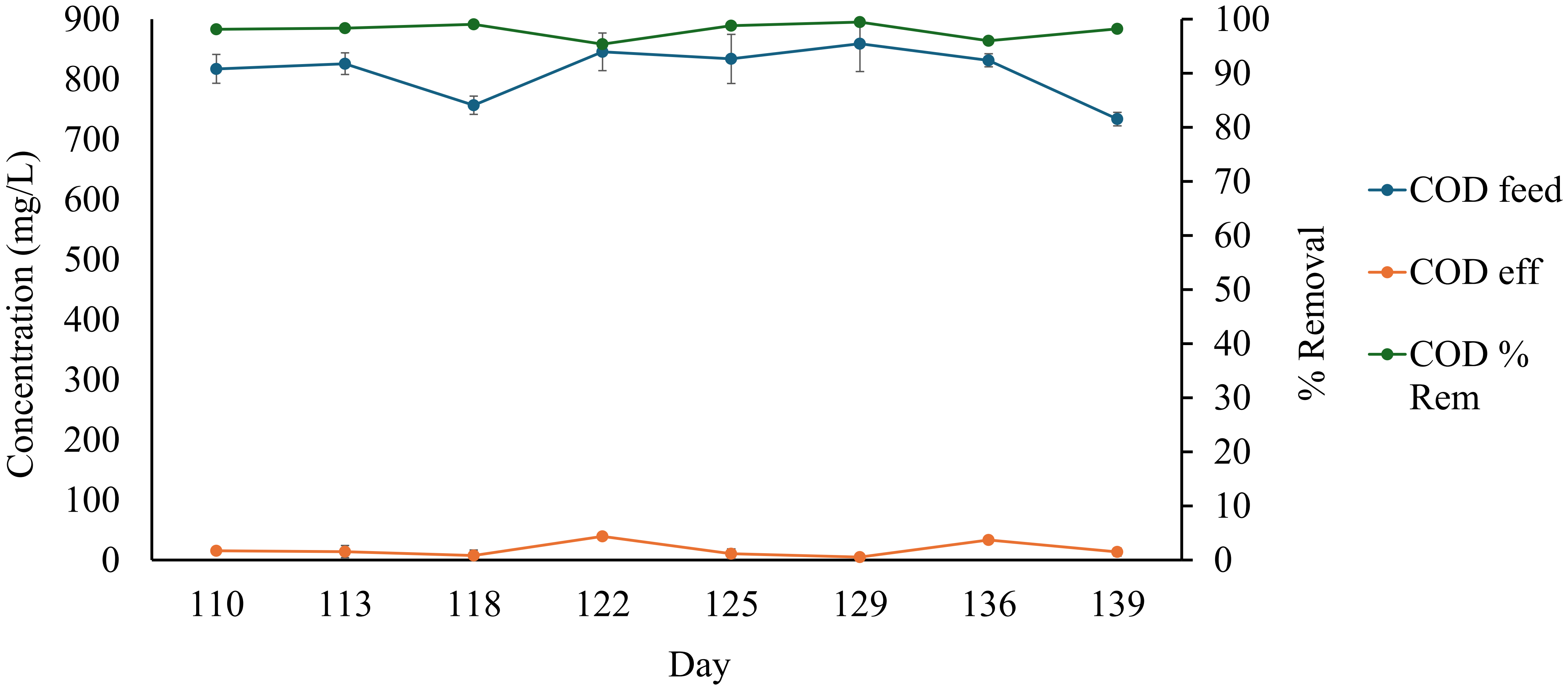


Fig 9: COD removal profile

Nitrogen

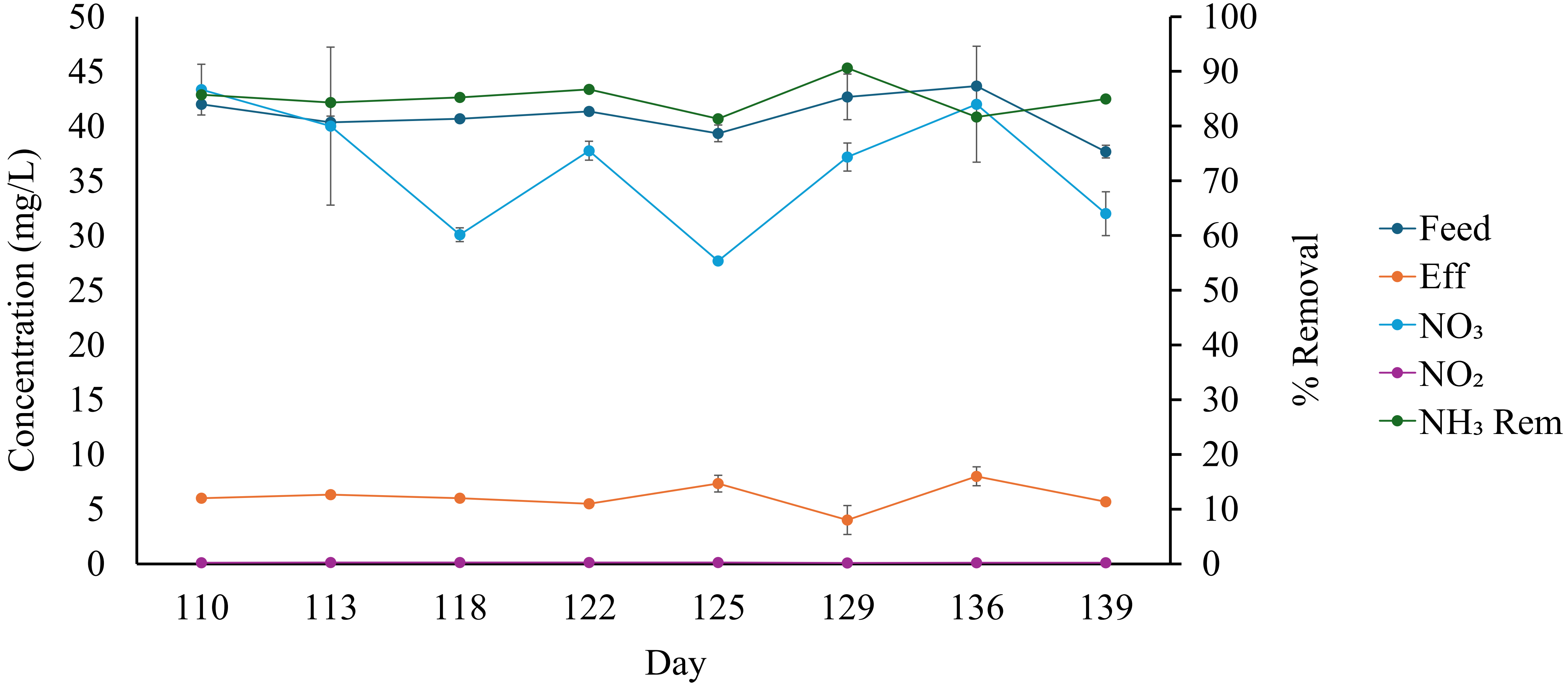


Fig 10: Nitrogen removal profile

Phosphorus

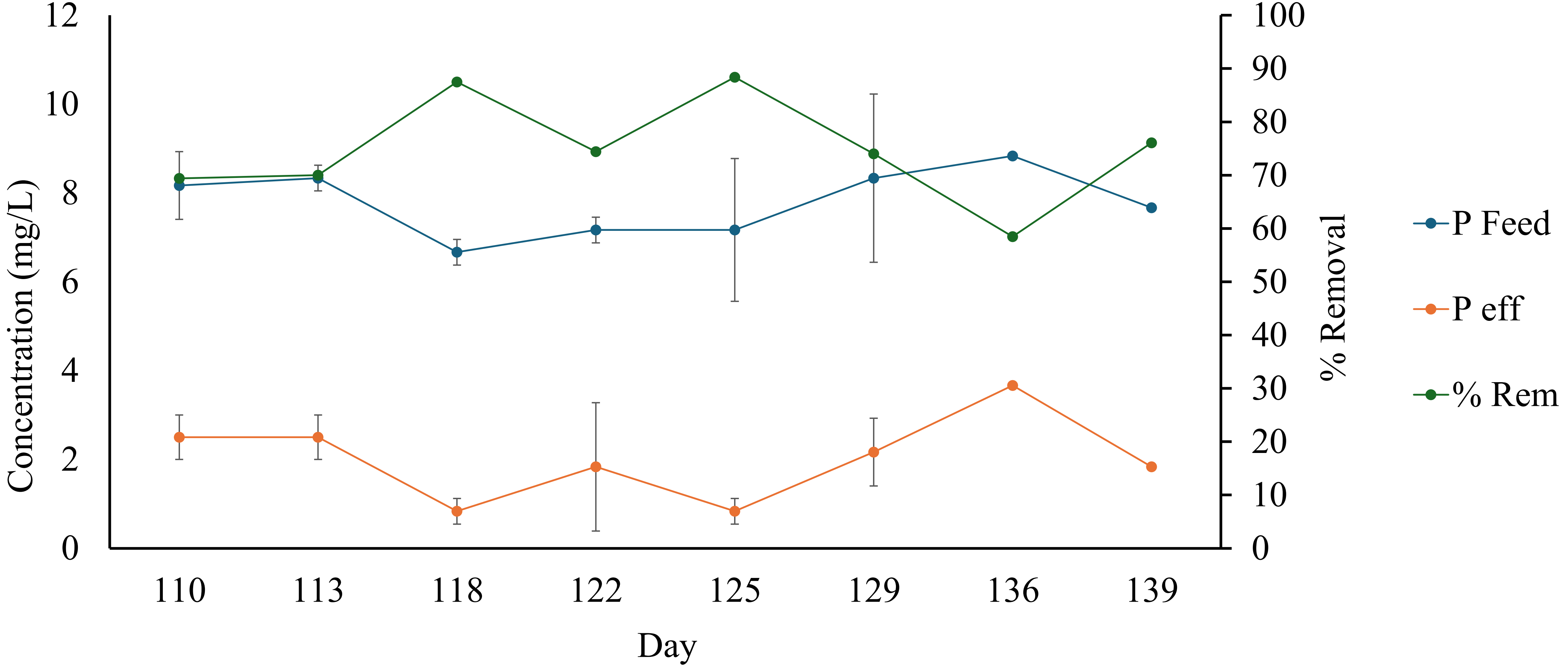


Fig 11: Phosphorus removal profile.

Curdlan from AGS

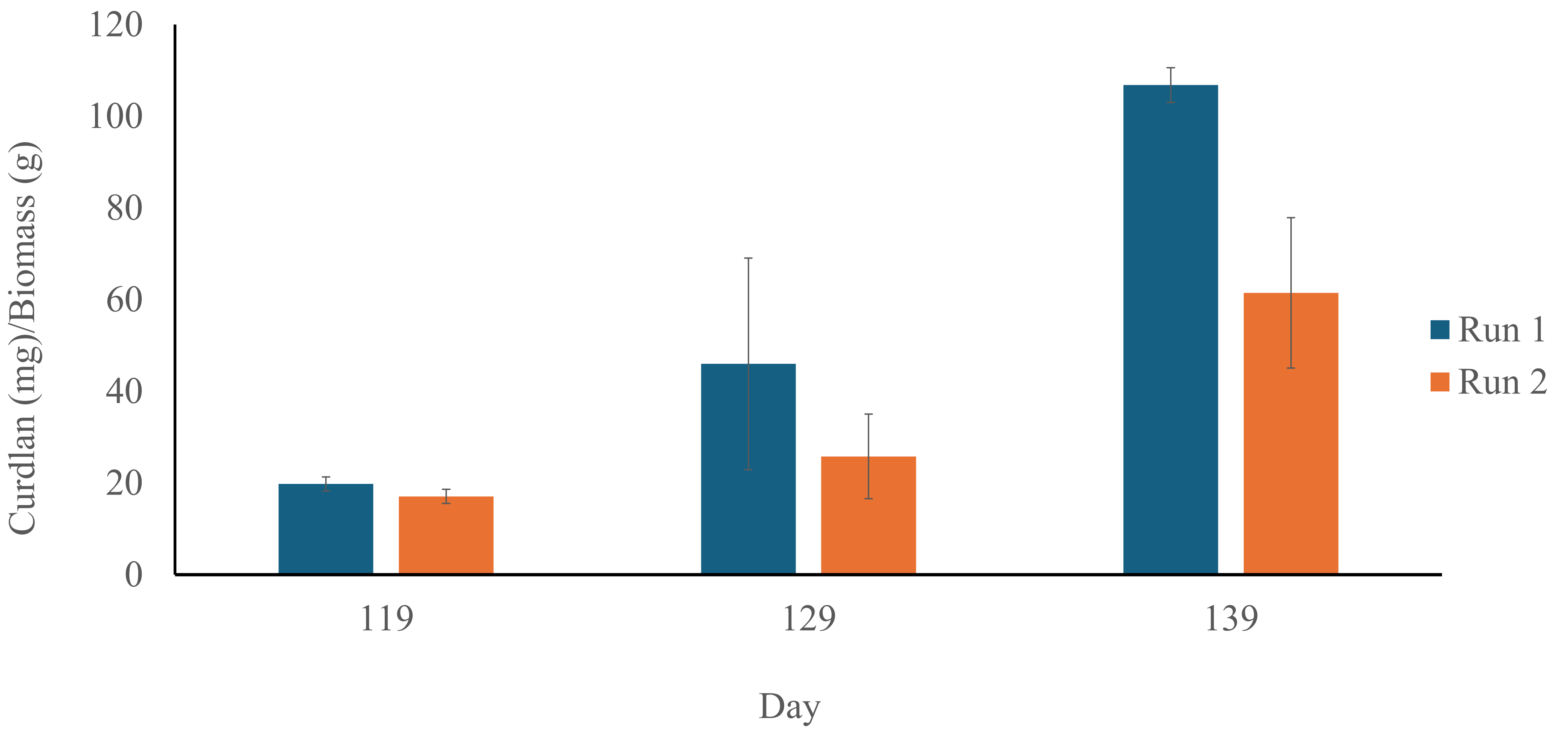


Fig 12: Curdlan recovered from aerobic granules

Curdlan from AGS

Fig 13a: Wet curdlan gel extract

Fig 13b: Dried curdlan gel extract

Conclusion

- Results from experimental runs 1 and 2 indicate that curdlan is biosynthesized in the aerobic granule matrix.

- Future experimental runs will provide further insight into optimizing curdlan biosynthesis from aerobic granule sludge.

- These findings further contribute to achieving biorefinery paradigm in wastewater treatment.

Acknowledgements

NSERC CRSNG

The Natural Sciences and Engineering Research Council of Canada

UNBC UNIVERSITY OF NORTHERN BRITISH COLUMBIA

Faculty of Science and Engineering

Thank you!

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