Novel operating strategies for sustainable treatment of regional community wastewater using high rate algal ponds

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Wastewater treatment systems

- Highly engineered
- Energy intensive
- Need expert technical support to operate and maintain
- Challenge for regional, rural and remote communities

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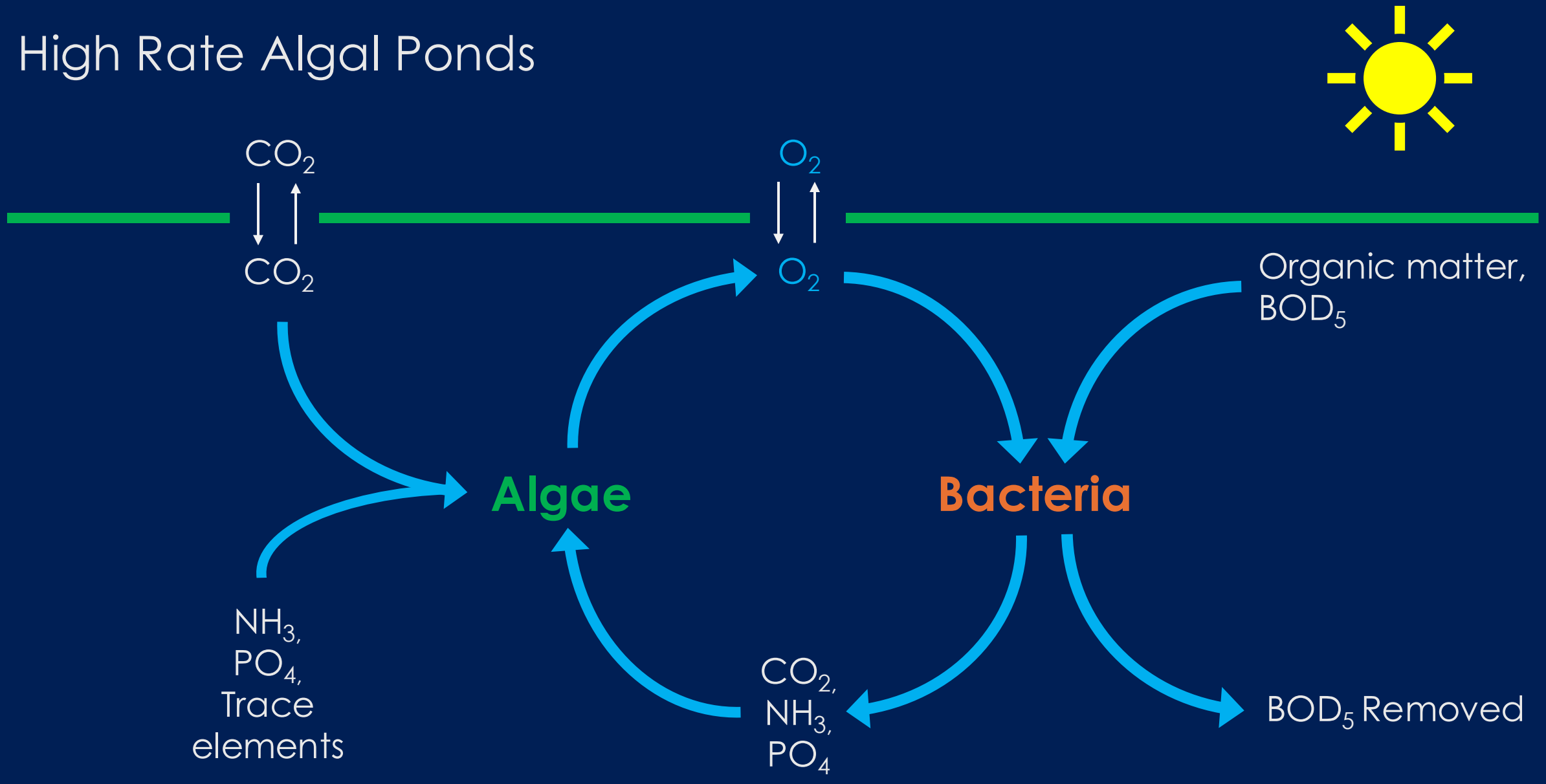
High Rate Algal Ponds



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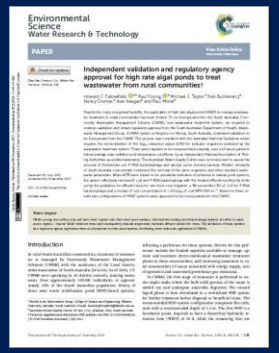
High Rate Algal Ponds

















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High Rate Algal Ponds

Microalgae biosolids difficult to remove

- Flocculation
- Dissolved air flotation/filtration
- Sedimentation – plate separators

Need to improve effluent quality for higher value reuse

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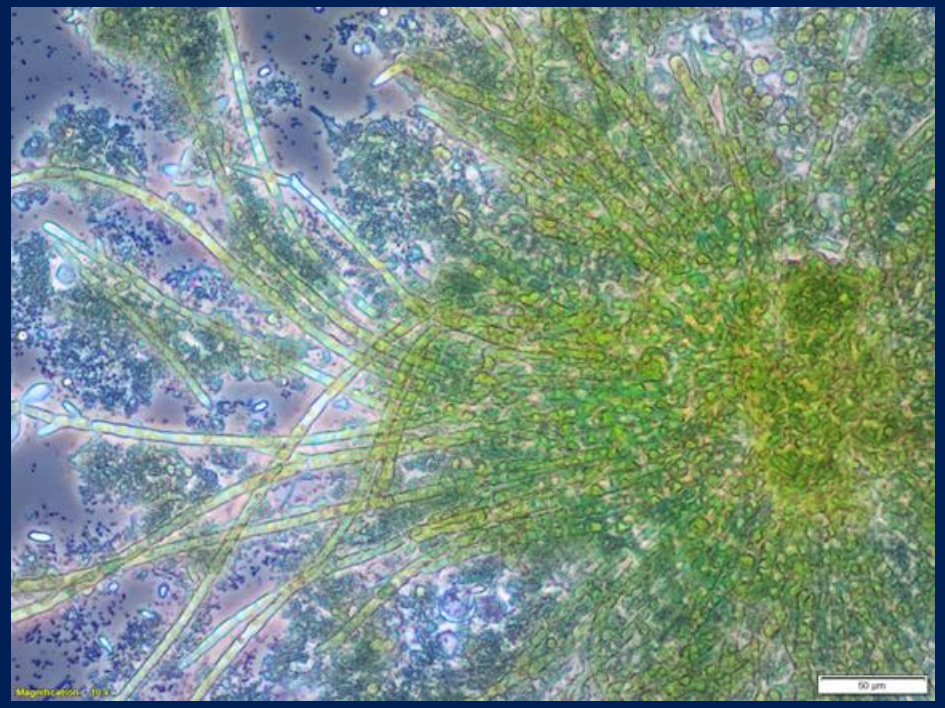

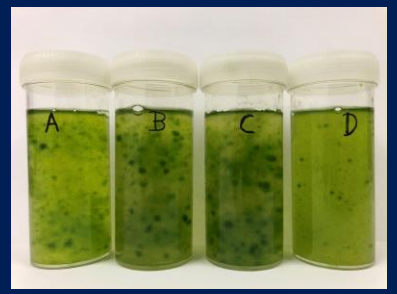

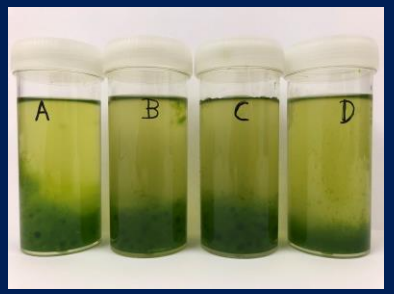

Novel operating strategies

Selectively enrich larger, denser algal-bacterial communities – biofilm like associations:

- Filamentous algae
- Photogranules

By operating HRAPs as sequencing batch reactors (SBRs)

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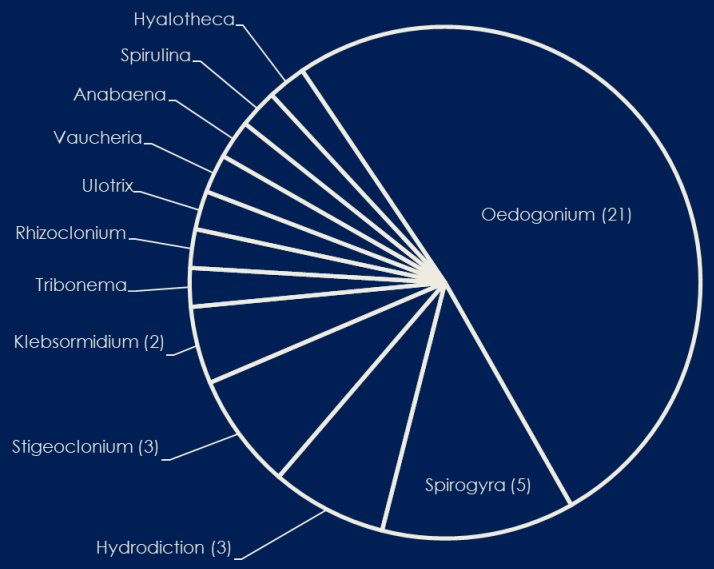
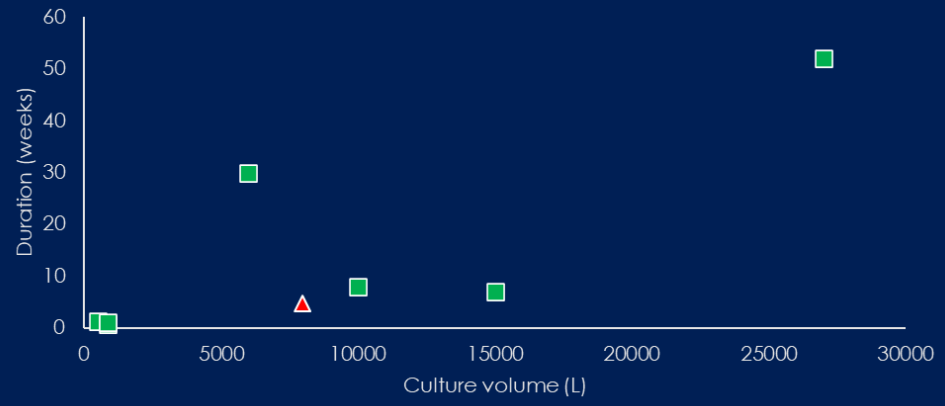
Filamentous algae wastewater treatment – status

PhD candidate Felipe Sabatte

- Review of 28 relevant studies
- Municipal wastewater and *Oedogonium spp*. were most used
- Most of the studies short time & small laboratory scale
- Used wastewaters with a high degree of pretreatment
- More studies focused on biomass productivity than treatment performance
- Recommended translational research - lab to outdoor systems at scale to further adoption this technology.
- Avoid use of filamentous algal inoculants





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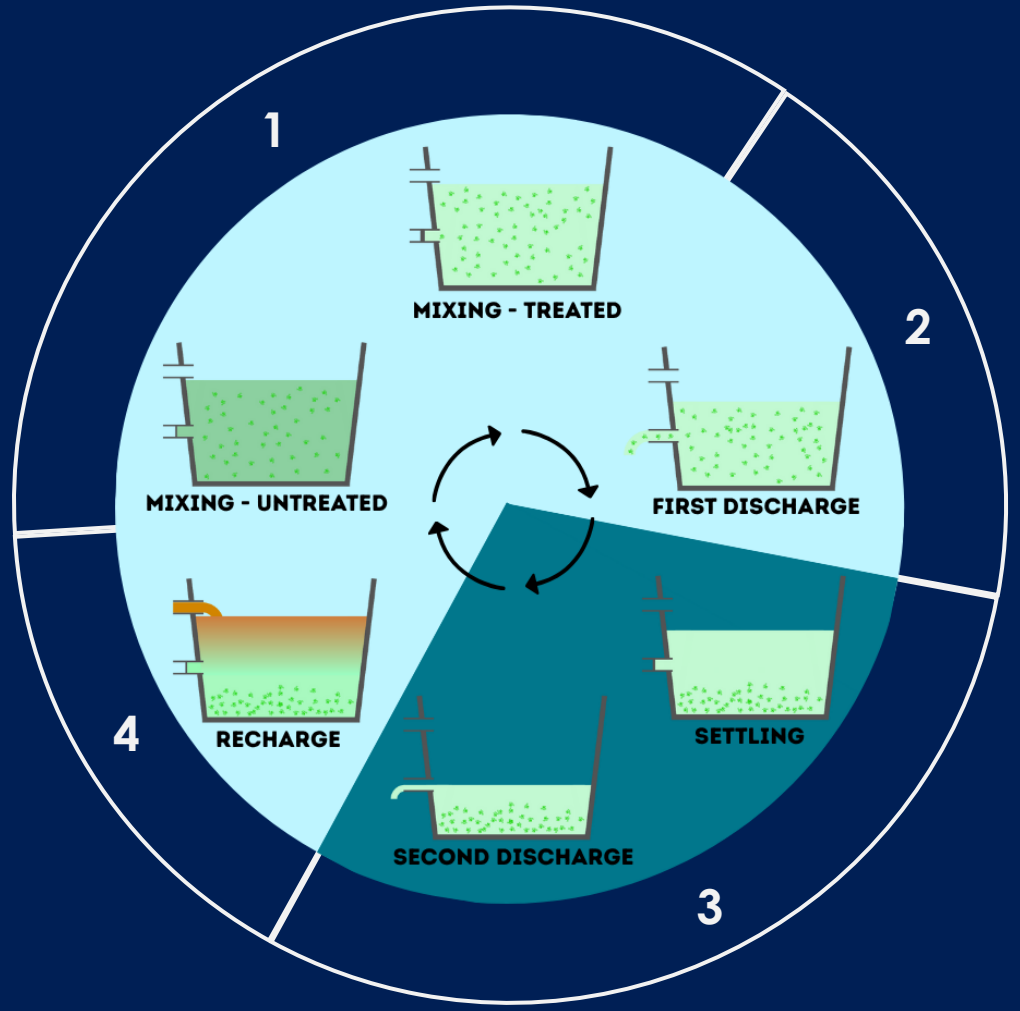
HRAP-SBR operation to enrich filamentous algae



1. Daytime mixing – reaction phase
2. First discharge while mixing – control of solids retention time (STR)
3. Nighttime discharge of settled supernatant – balancing volume for hydraulic retention time (HRT)
4. Influent feed

Uniquely provides independent control of SRT and HRT

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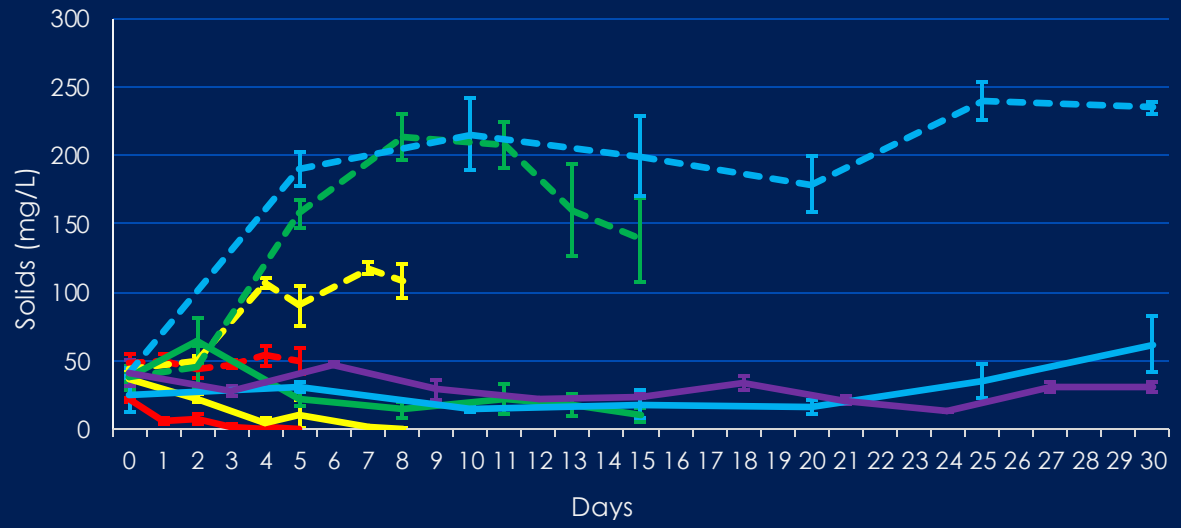
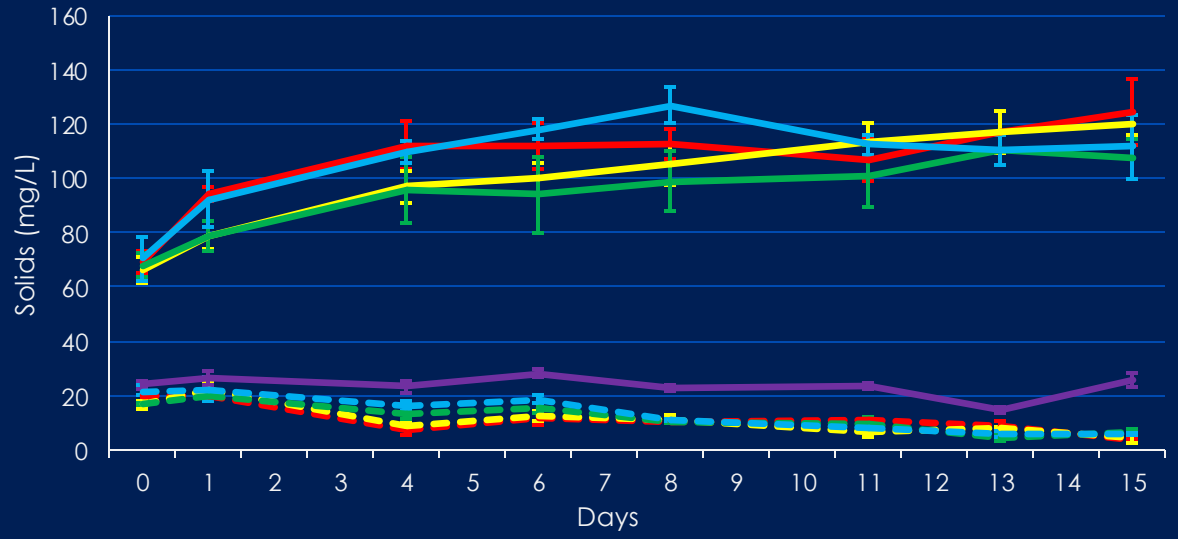
Proof of HRAP-SBR concept – maintenance of filamentous algal population



HRAP
HRT: 1.6 2.5 5 10



HRAP
SRT: 5 d
HRT: 1.6 2.5 5 10

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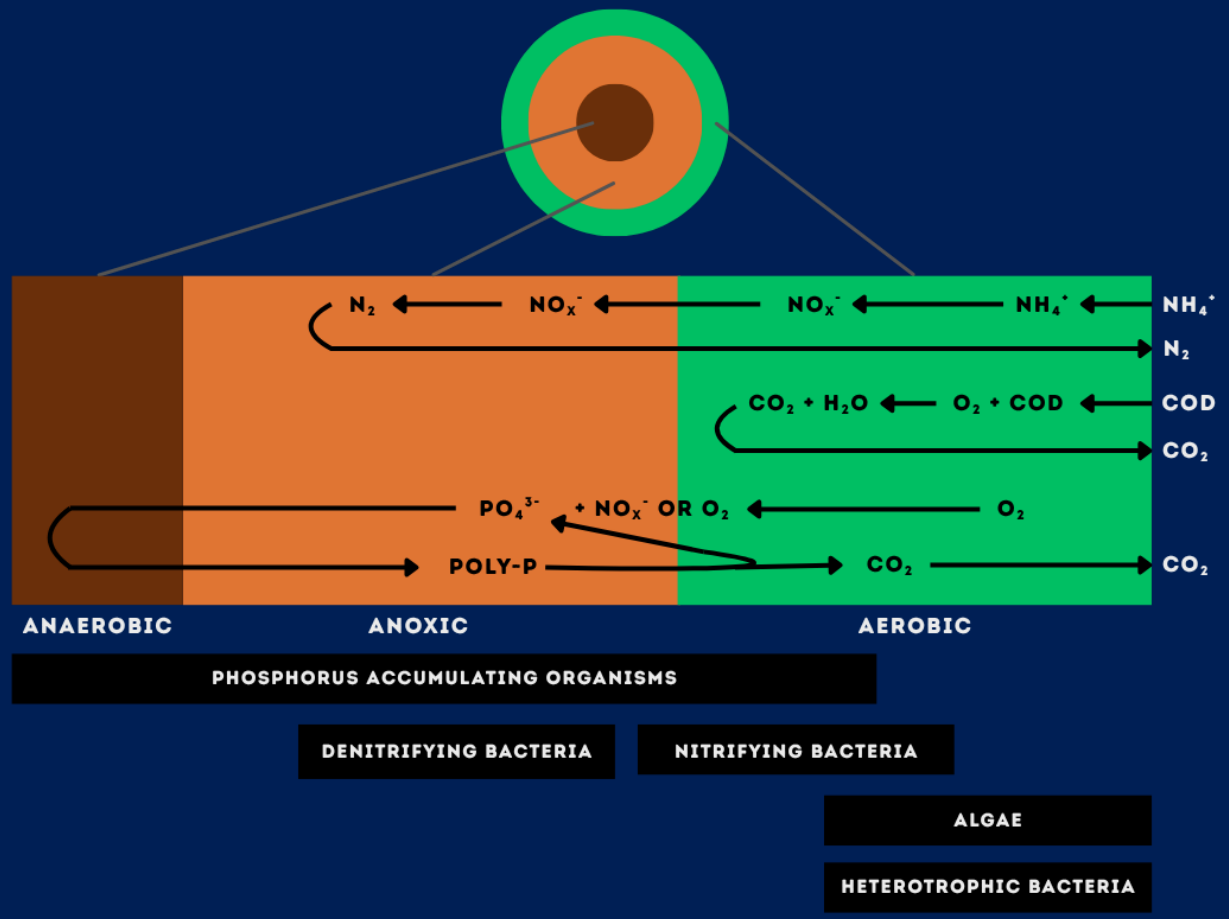
Photogranules

PhD candidate Sam Buterworth

Phosphorus accumulating organisms (PAOs)

- Volatile fatty acids used by PAOs anaerobically to produce and store polyhydroxyalkanoate (PHA)
- During the anaerobic growth of PAOs release EPS – encouraging photogranule formation
- In aerobic conditions PHA, metabolized for the assimilation of phosphate



Sam Butterworth, Felipe Sabatte, Harriet Whiley, Enzo Palombo, Melissa H. Brown, Ryan Cheng, Ben Van Den Akker and Howard Fallowfield (2025) Operating high-rate algal ponds as sequencing batch reactors: A novel approach to enhanced wastewater treatment. *Environmental Science: Water Research & Technology (In Review)*

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Photogranules - status

- Initially formed by mixing activated sludge (80%) with algal culture (17%) + aeration (*Purba et al.*, 2021)

- Aeration shown not to be necessary – photosynthetic DO sufficient (*Ansary et al., 2019*)

- Aerobic granular sludge (AGS) + algae/photogranules improved treatment performance (*Sales et al., 2022, Zhang et al., 2022*)

- Shallow laboratory-sale HRAPs (60L) comprising an unidentified algal species from a WWTP inoculated with activated sludge produced compact granules with good settleability (*dos Santos Neto et al., 2023*)

- Shown that HRAPs can form aggregates either from inoculum such as activated sludge or from pre-formed granules like AGS or microalgae-bacteria granules (MBG) fragments (*Pham et al., 2025*)

Research Objective

To use photogranules formed *in situ*, under natural conditions in HRAP-SBRs to treat wastewater.

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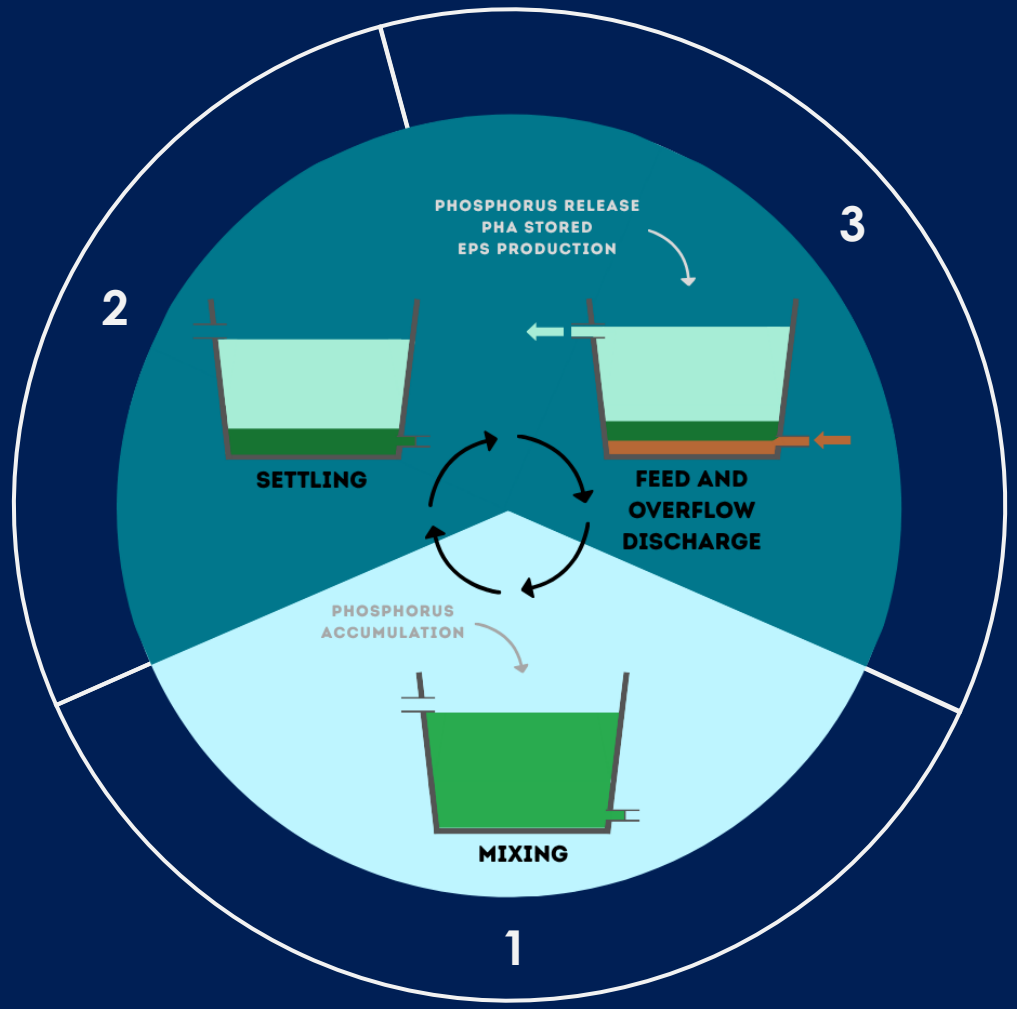
HRAP-SBR operation for photogranule production



1. Daytime mixing – reaction phase
2. Cessation of mixing – settling
3. Influent feed to settled solids and overflow discharge

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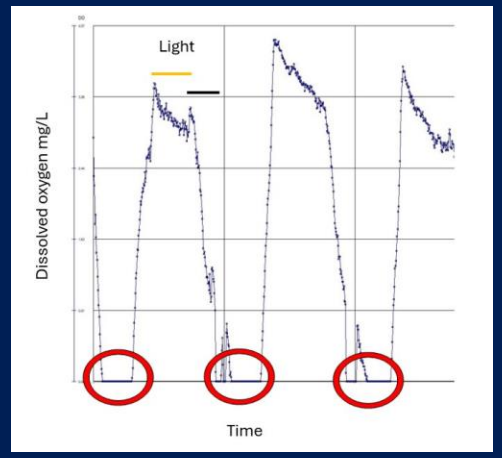
Photogranules



Inlet: 1704 mg BOD_5/L

Effluent: 198 mg BOD_5/L

Removal: 88.4%

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Conclusions

HRAP-SBR operation offers independent control of SRT and HRT

Filamentous algae
- Proof of concept HRAP-SBR maintains a filamentous population
- Wastewater treatment equivalent to HRAP
- Readily settleable solids

Photogranules
- Can be developed in HRAP-SBRs
- Readily settleable solids
- Preliminary results suggest BOD removal = HRAPs

Future research – Angaston pilot plant

- Transportable
- Pond built in sections for on-site assembly
- Paddlewheel pieces each <50 kg for manual handling & assembly
- Self-contained operation

Angaston pilot plant

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Angaston pilot plant

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Thank you

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References

1. L. D. A. Purba, A. Yuzir, A. Zamyadi, M. H. A. Halim, E. D. Zeca and N. Abdullah, Cultivation of aerobic granular sludge by modification of seeding condition, *Desalination and Water Treatment*, 2021, 223, 280-289. A.

2. A. Ansari, A. S. Abouhend and C. Park, Effects of seeding density on photogranulation and the start-up of the oxygenic photogranule process for aeration-free wastewater treatment, *Algal Research*, 2019, 40, 101495.

3. M. Sales, T. Marinho, I. C. Marinho, S. Gavazza, M. T. Kato, B. S. Magnus and L. Florencio, Start-up strategies to develop aerobic granular sludge and photogranules in sequential batch reactors, *Science of The Total Environment*, 2022, 828, 154402.

4. B. Zhang, W. Li, L. Wu, W. Shi and P. N. L. Lens, Rapid start-up of photo-granule process in a photo-sequencing batch reactor under low aeration conditions: Effect of inoculum AGS size, *Science of The Total Environment*, 2022, 820, 153204.

5. M.-D.-T. Pham, X.-T. Bui, T.-K.-Q. Vo, T.-S. Dao, L.-T. Le, T.-D.-H. Vo, K.-P.-H. Huynh, T.-B. Nguyen, C. Lin and C. Visvanathan, Microalgae − bacteria based wastewater treatment systems: Granulation, influence factors and pollutants removal, *Bioresource Technology*, 2025, 418, 131973.

6. A. G. dos Santos Neto, M. Barragán-Trinidad, L. Florêncio and G. Buitrón, Strategy for the formation of microalgae-bacteria aggregates in high-rate algal ponds, *Environmental Technology*, 2023, 44, 1863-1876.

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