Persistence of cyanobacteria and microalgae in drinking water treatment plants across Eastern Australia

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Acknowledgement

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- Honour student team

Items for today

1. **Background – nuisance microalgae and cyanobacteria**
2. **Project '***Advanced diagnostics and treatment strategies to mitigate algal growth and accumulation within drinking water treatment plants***'**
3. **Algal community analysis across unit operations in drinking water treatment plants**
4. **Key highlights**
5. **Next steps**

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Nuisance algae and cyanobacteria

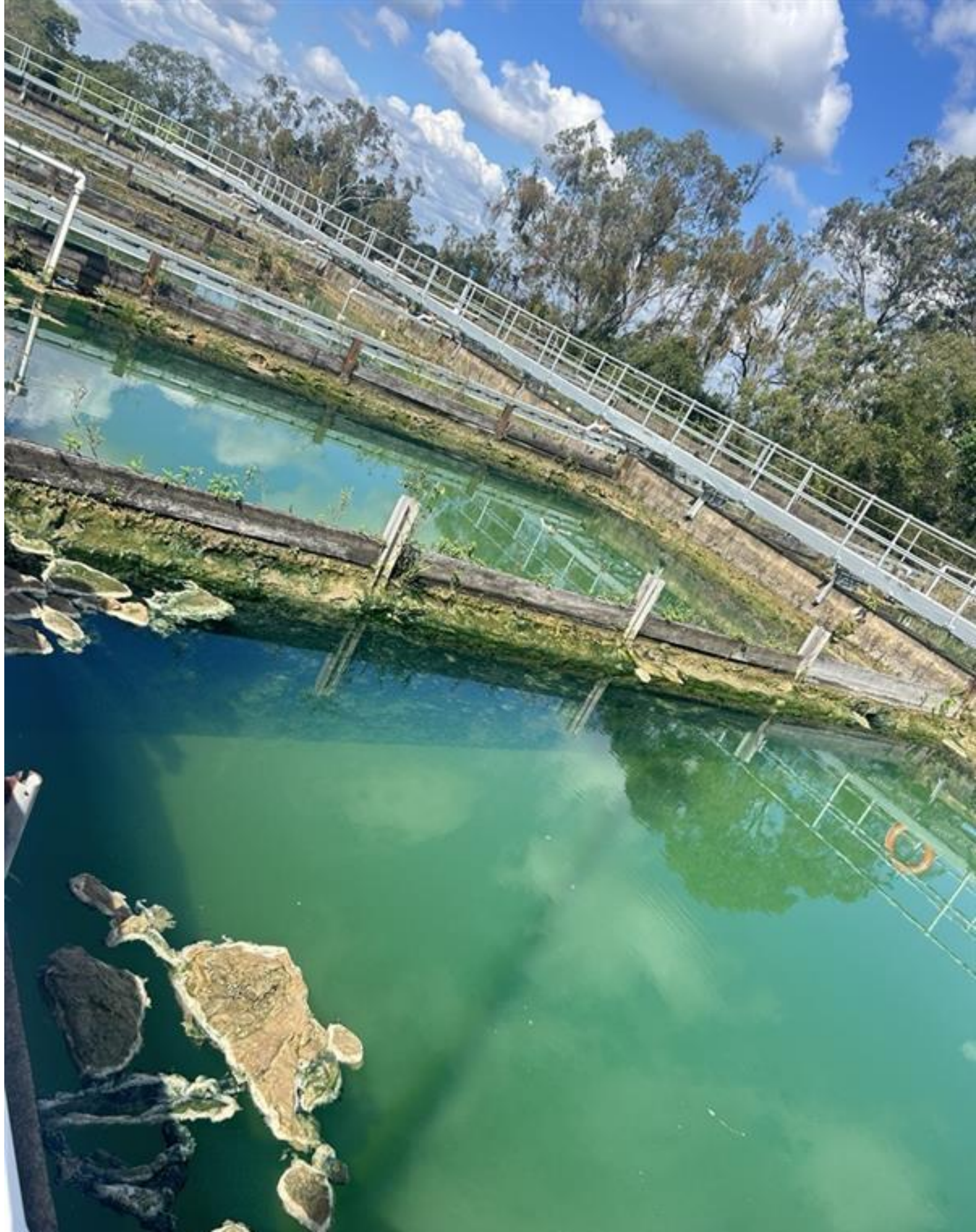
- Toxins
  - Taste & Odour
    - Disinfection by-products (DBPs)



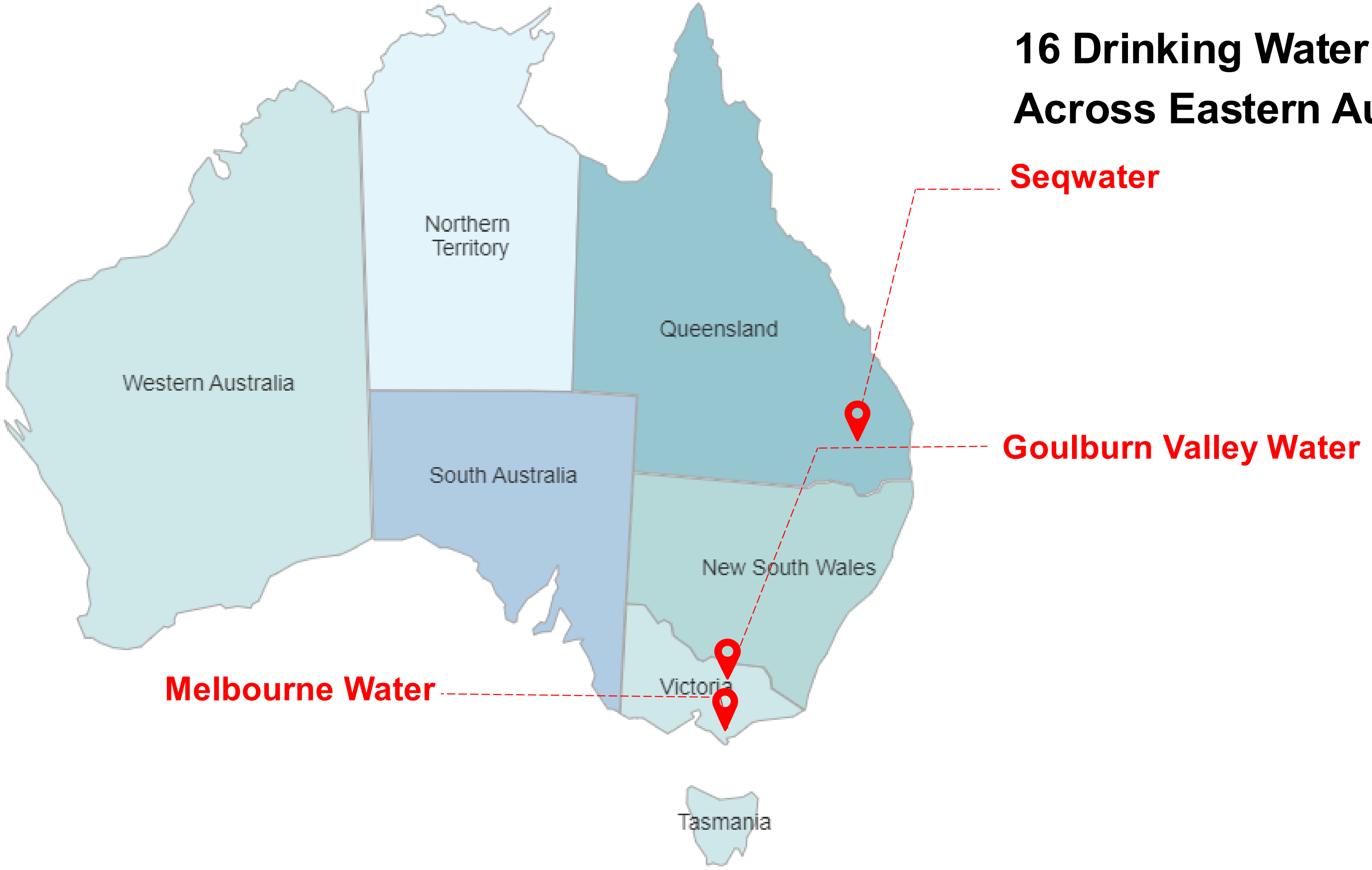
1. Background

2. Project

‘Advanced diagnostics and treatment strategies to mitigate algal growth and accumulation within drinking water treatment plants’



“In-plant algae project” – started from 2024



16 Drinking Water Treatment Plants Across Eastern Australia

1. WTP1 >> Media filtration
2. WTP2 >> Media filtration
3. WTP3 >> Ozonation
4. WTP4 >> Media filtration
5. WTP5 >> Media filtration
6. WTP6 >> DAFF

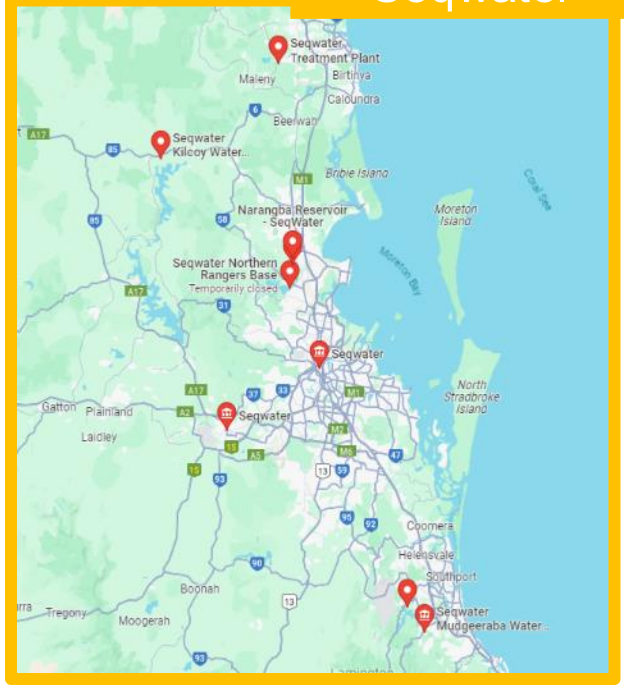
7. WTP7 >> DAFF
8. WTP8 >> DAFF
9. WTP9 >> Microfiltration
10. WTP10 >> Package plant
11. WTP11 >> DAFF
12. WTP12 >> Solid contact clarifier
13. WTP13 >> Media filtration

14. WTP14 >> DAFF
15. WTP15 >> Media filtration
16. WTP16 >> Media filtration

Historical data

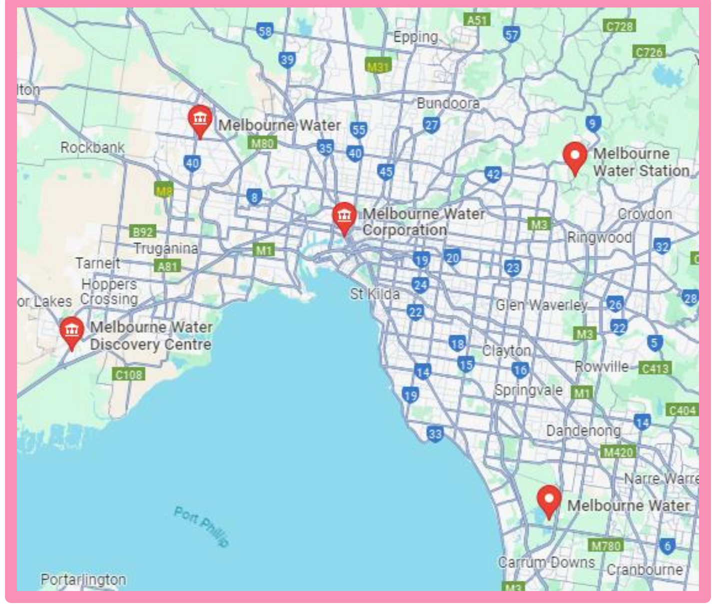
- **Algal data, water quality data, operating conditions, hydrodynamic conditions**

Seqwater



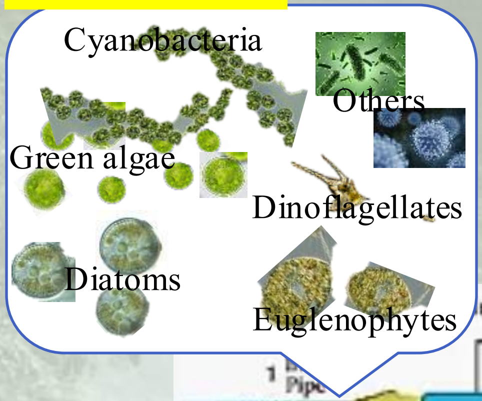
Goulburn Valley Water

Melbourne Water



Project overview

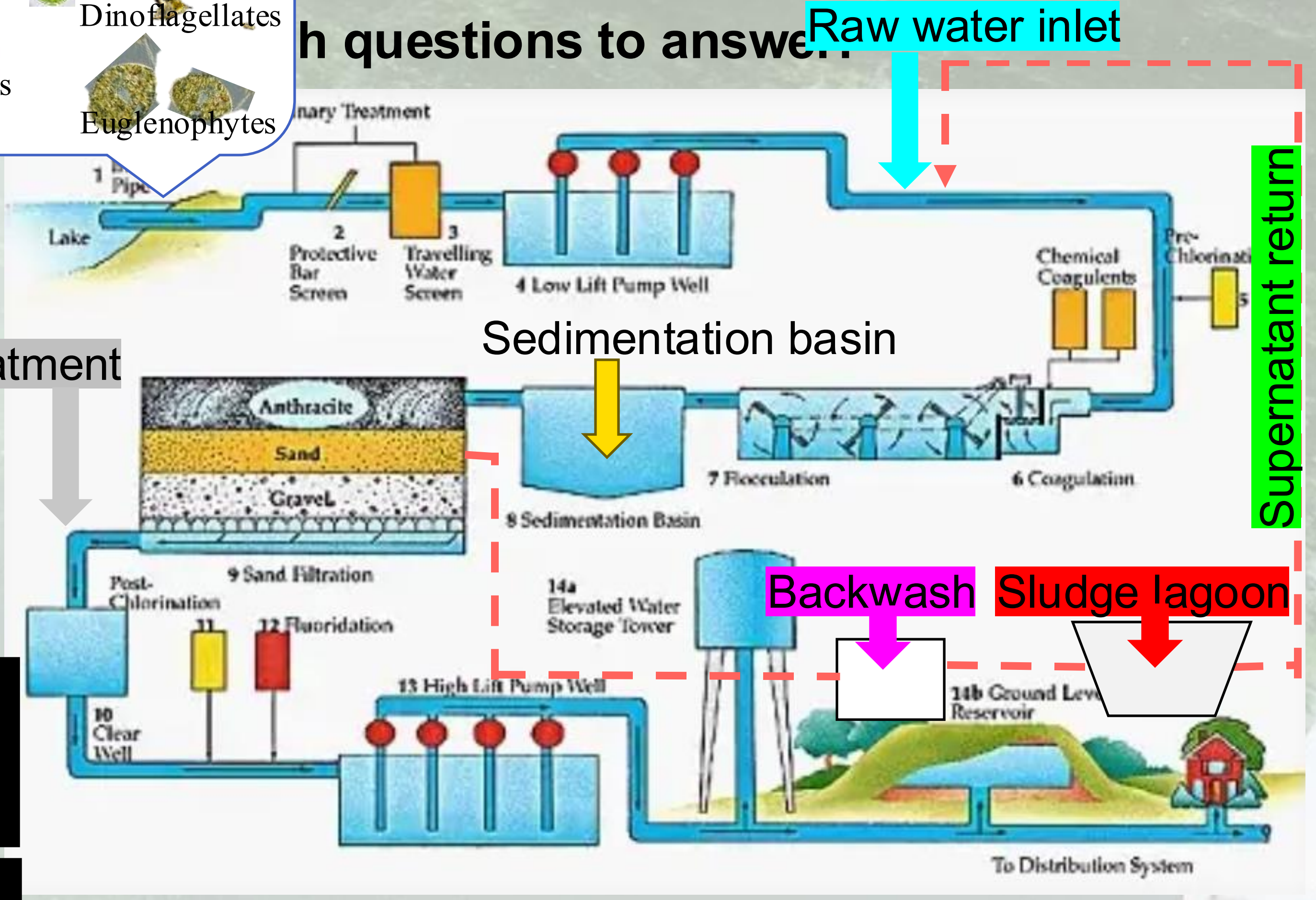
1 Algal/cyanobacterial community changes within DWTP



Aim:

The project aims to develop a robust prevention, control, and monitoring framework to mitigate the risks associated with the proliferation of nuisance and harmful algae and cyanobacteria <u>within</u> DWTPs.

h questions to answe



2 Proactive solution: Can any pre-treatment operation and hydrodynamics be re-engineered to minimise risks?

3 Reactive solution: most appropriate treatment method when build-up happens within DWTPs; do we need any changes to the treatment technologies?

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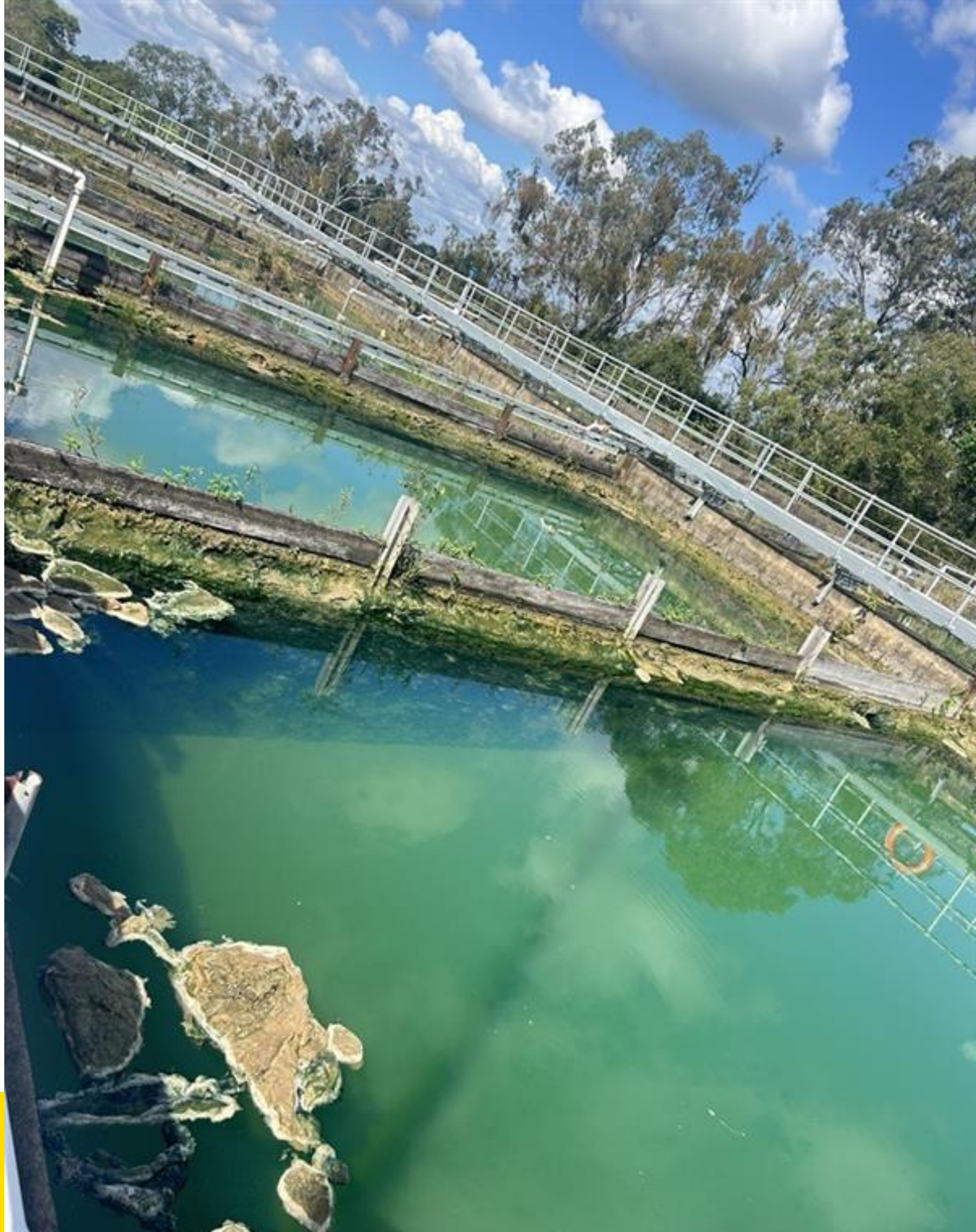
3. Algal community analysis

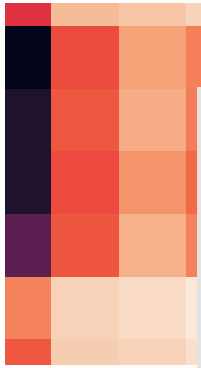
across unit operations in drinking water treatment plants



Data processing

❶ Algal hierarchy harmonisation

- Different plants reported algal data at varying taxonomic levels (e.g., *family*, *genus*, *species*).
- Data cleaned and standardized to a consistent taxonomic hierarchy
- Normalisation applied across all plants to ensure comparability.

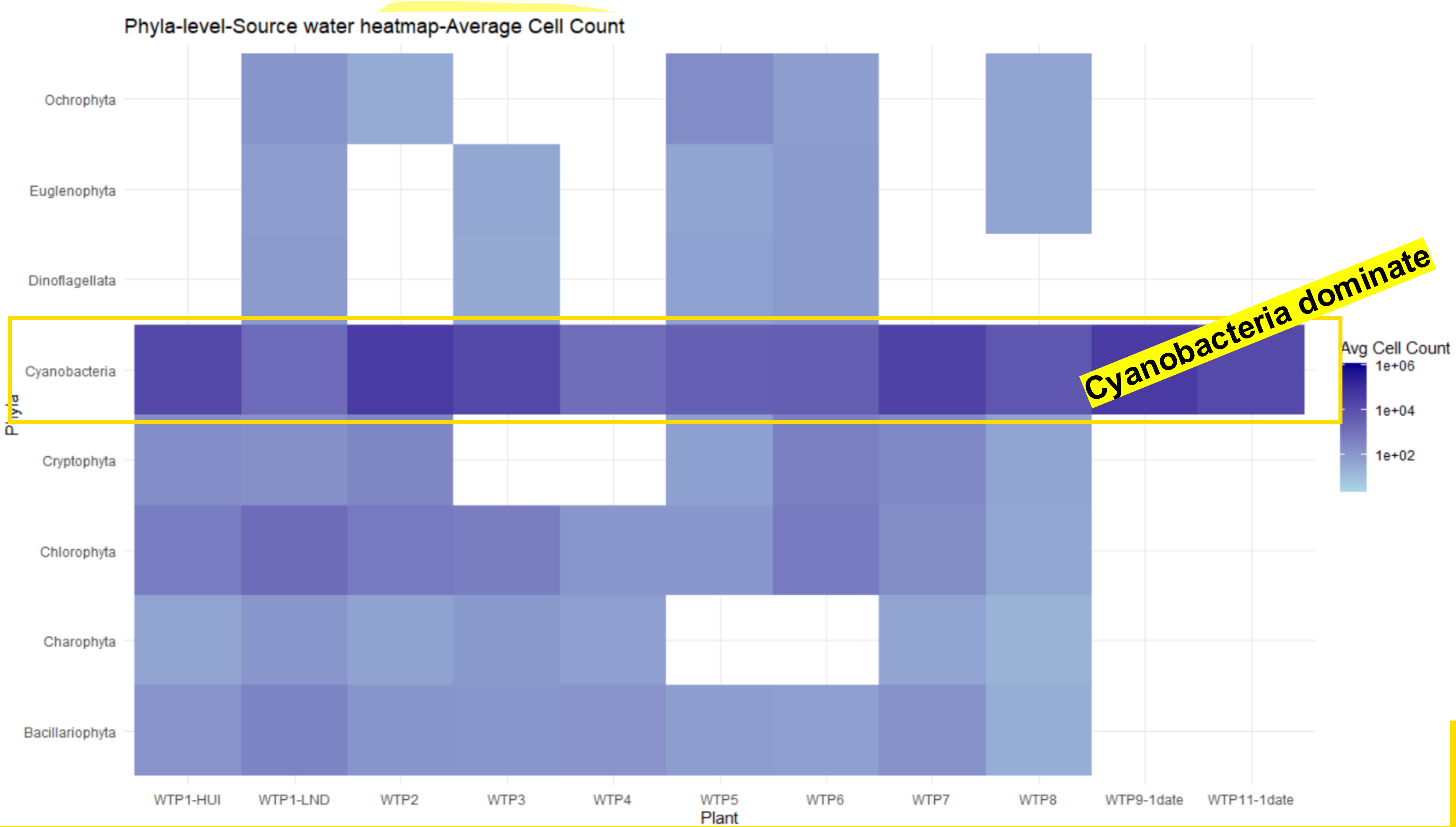


❷ Taxonomic profiling and heatmap

- Each plant had different numbers of algal community samples and time spans.
- For each plant, R programming was used:
  - *Determine frequency of detection for all genera.*
  - *Select the top 20 most frequently recorded genera.*
  - *Filter these genera and compute their averaged cell counts across the full dataset for that plant.*
- Heatmap colour intensity represents the avg. cell count (gradient scale)
- Genus level: Top 20
- Family and Phylum level: all

Algal community

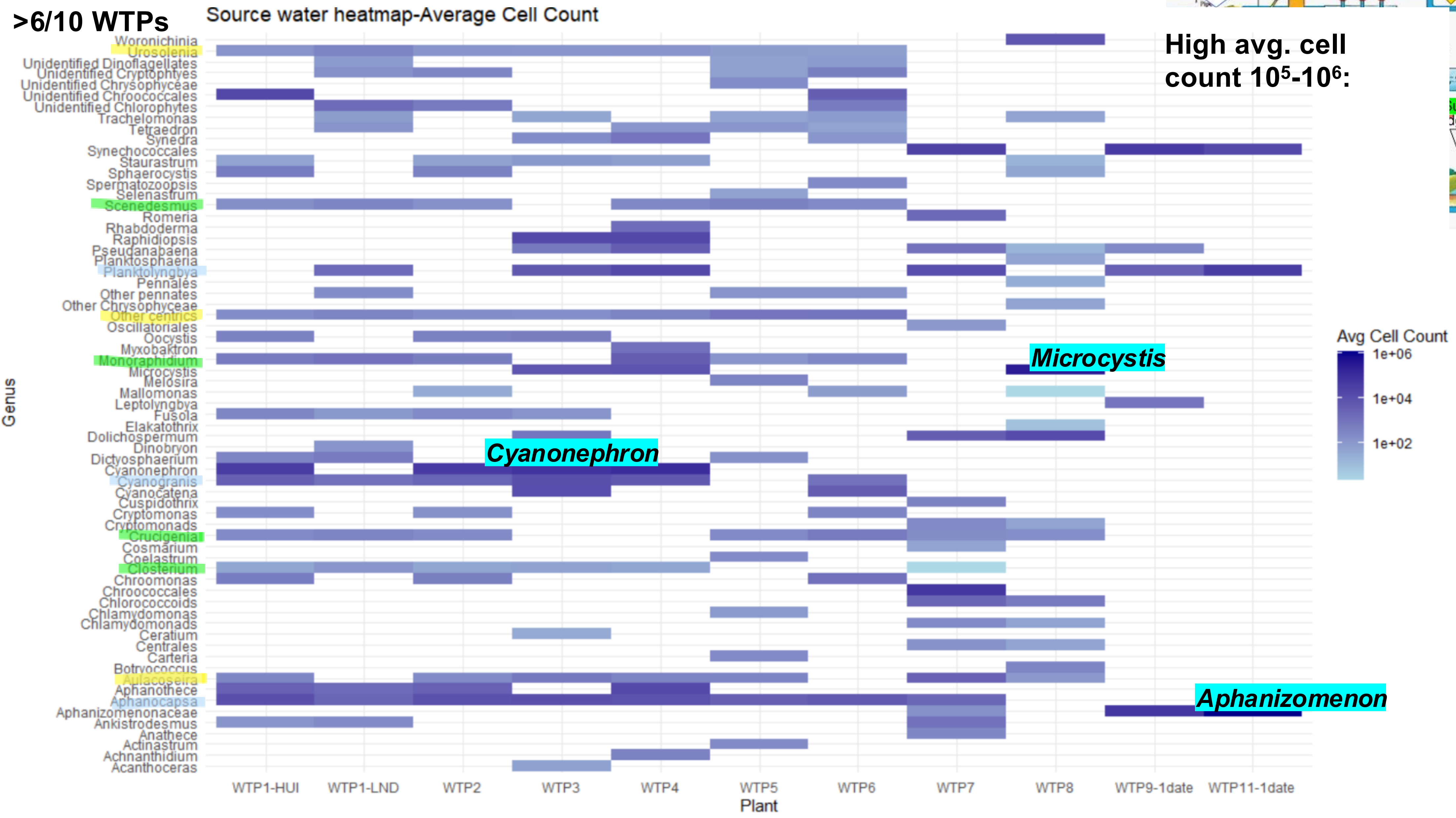
- Source water 10 WTPs - Phylum level

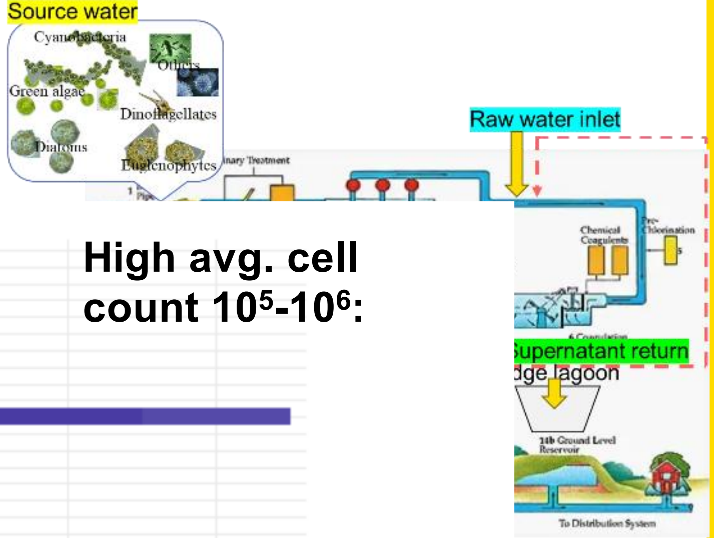


Algal community

- Source water 10 WTPs - Genus level

>6/10 WTPs

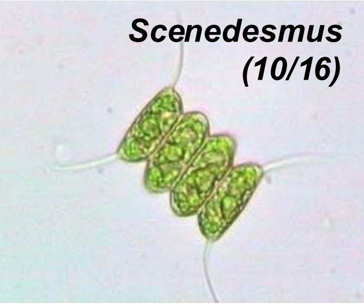


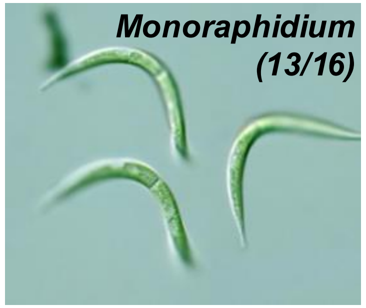


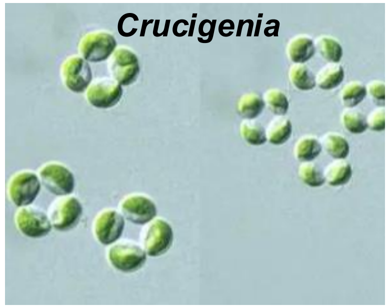
High avg. cell count 10^5-10^6:

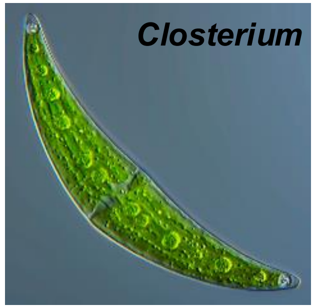
Frequent detected genera in Source water (>6/10 plants)

- *Chlorophyta*

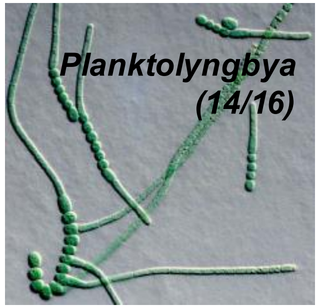


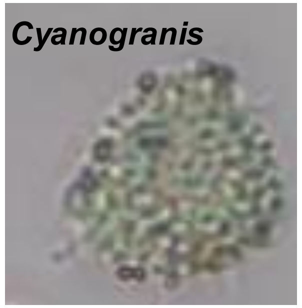






- *Cyanobacteria*

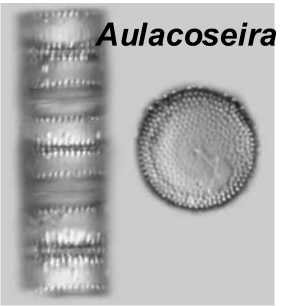




- *Bacillariophyta*

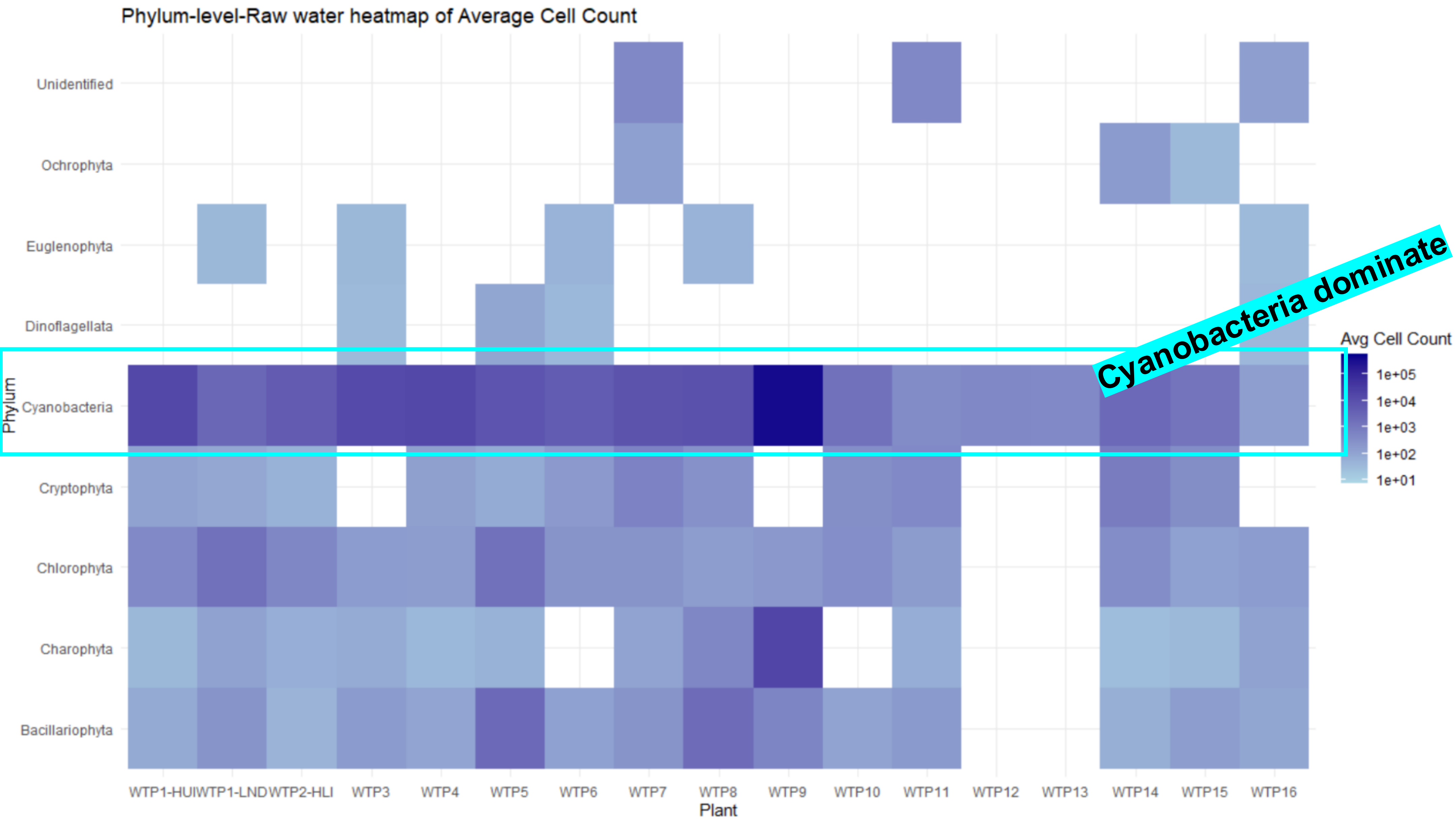
Urosolenia

Other Centrics



Algal community

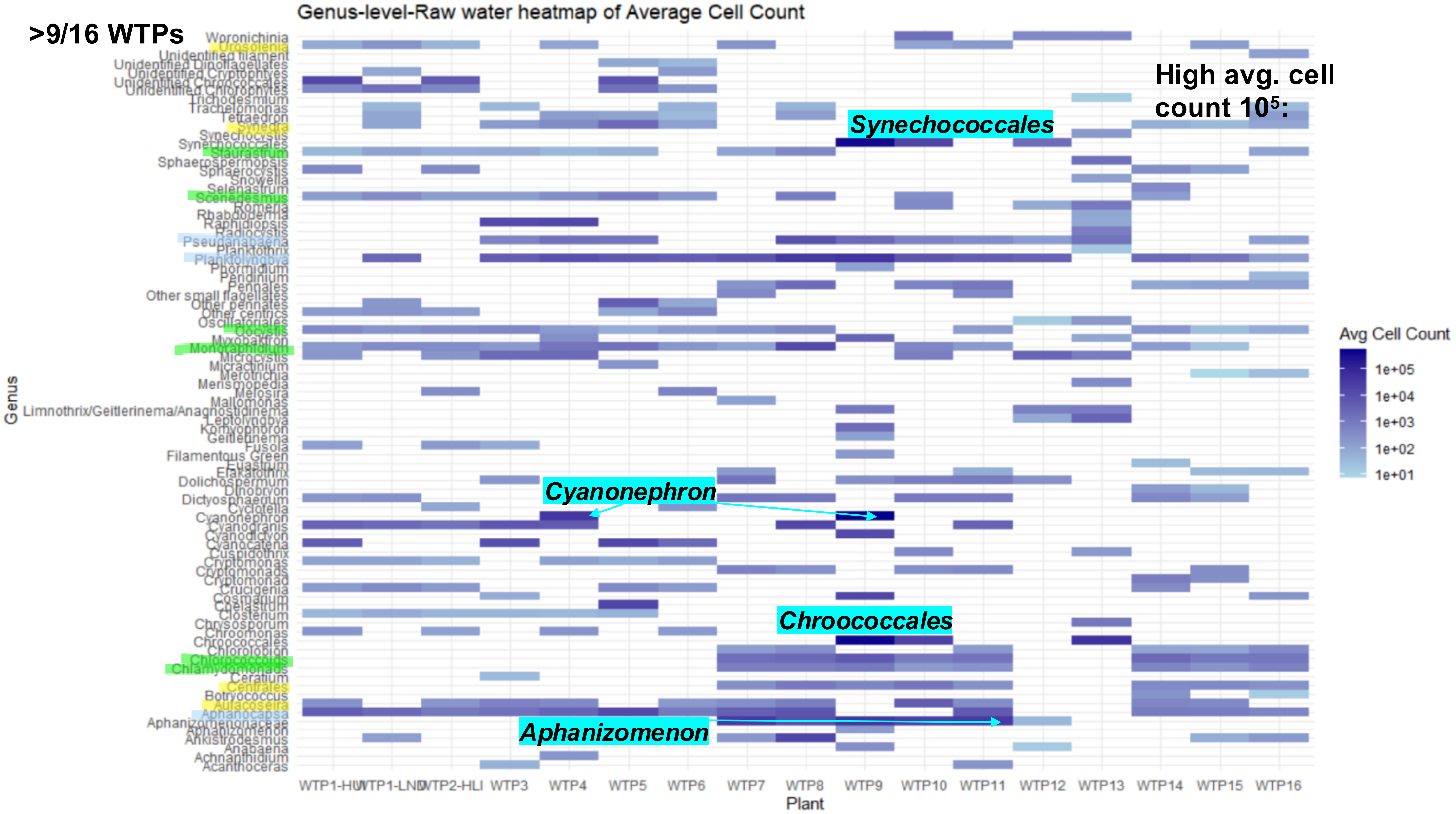
- Raw water 16 WTPs – Phylum level



Algal community

- Raw water 16 WTPs – Genus level

>9/16 WTPs

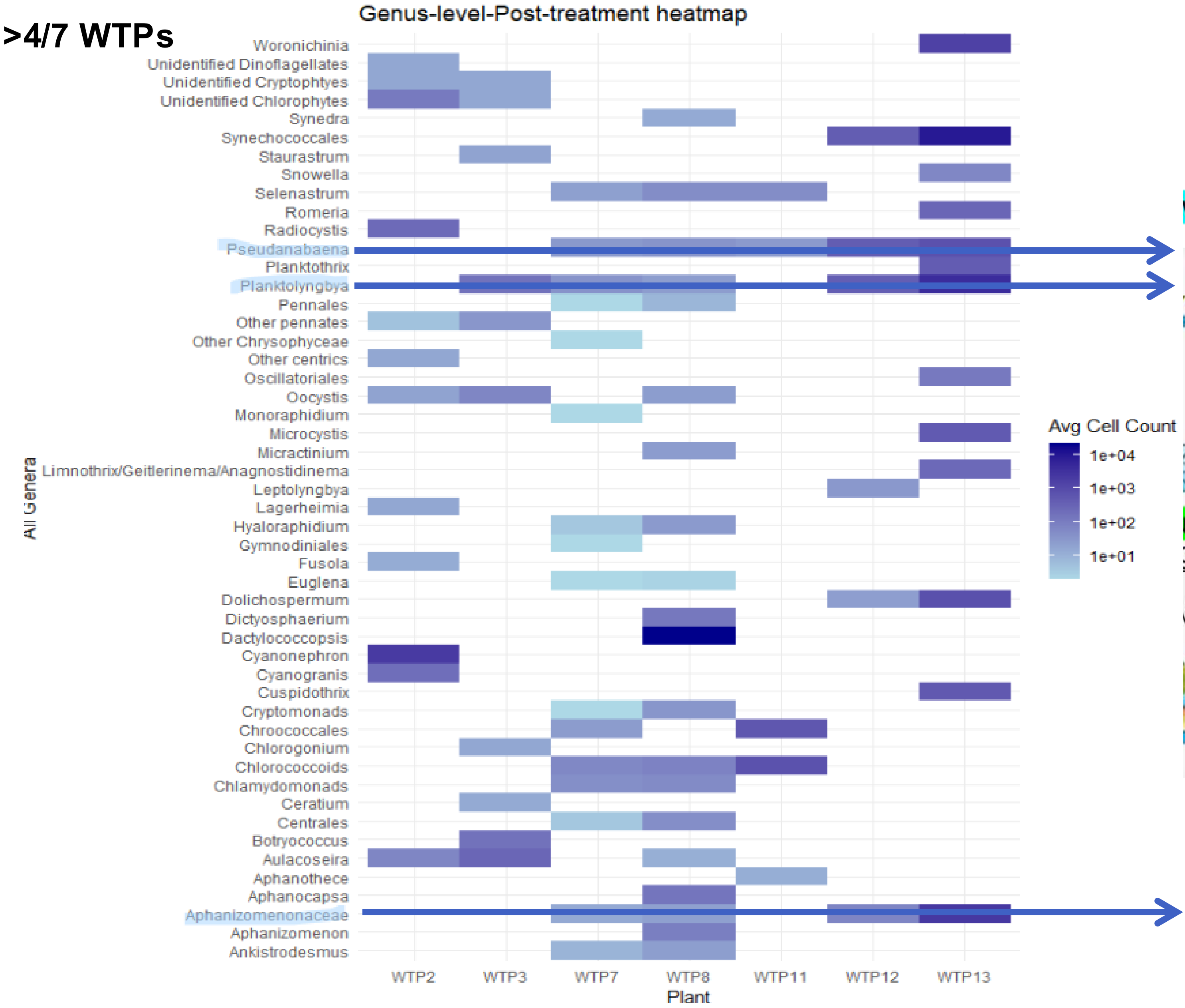


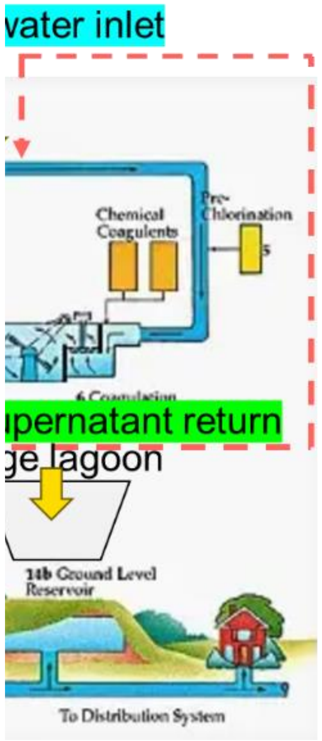
High avg. cell count 10^5:

Algal community results

- Post-treatment 7 WTPs – Genus level

>4/7 WTPs





Frequently reported cyanobacteria:

- *Pseudanabaena,*
- *Planktolyngbya,*
- *Aphanizomenon*

Frequently reported post-treatment cyanobacteria morphology:

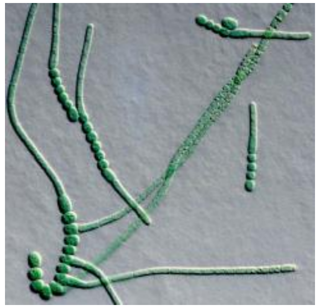
Filamentous | **Very thin** | ***Plant operations:***

Sand filtration
Dual gravity filtration
Dissolved air flotation

Pseudanabaena

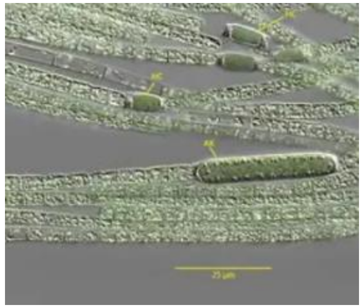
Narrow, usually <2um

Planktolyngbya



Delicate filaments with little mucilage

Aphanizomenon



Can form bundles, buoyant, flexible

Filamentous taxa may have a higher likelihood of bypass or passage through filtration system

- Weave through pore spaces
- Flex or bend (especially if long and “slimy”)
- Low adhesion/weaker flocculation
- Buoyancy/hydrodynamic/operational factors

Refs

- Xu, Hangzhou, et al. "Using sodium percarbonate to suppress vertically distributed filamentous cyanobacteria while maintaining the stability of microeukaryotic communities in drinking water reservoirs." *Water Research* 197 (2021): 117111
- Xu, Hangzhou, et al. "Advances and challenges in the technologies for cyanobacterial cells removal in drinking water treatment." *Chemosphere* 359 (2024): 142338.
- Kordahi, Michel A., George M. Ayoub, and Ramez M. Zayyat. "A critical review of current research on cyanobacterial cells and associated toxins in aquatic environments: Occurrence, impact, and treatment methods." *Journal of Environmental Chemical Engineering* 12.5 (2024): 113931.

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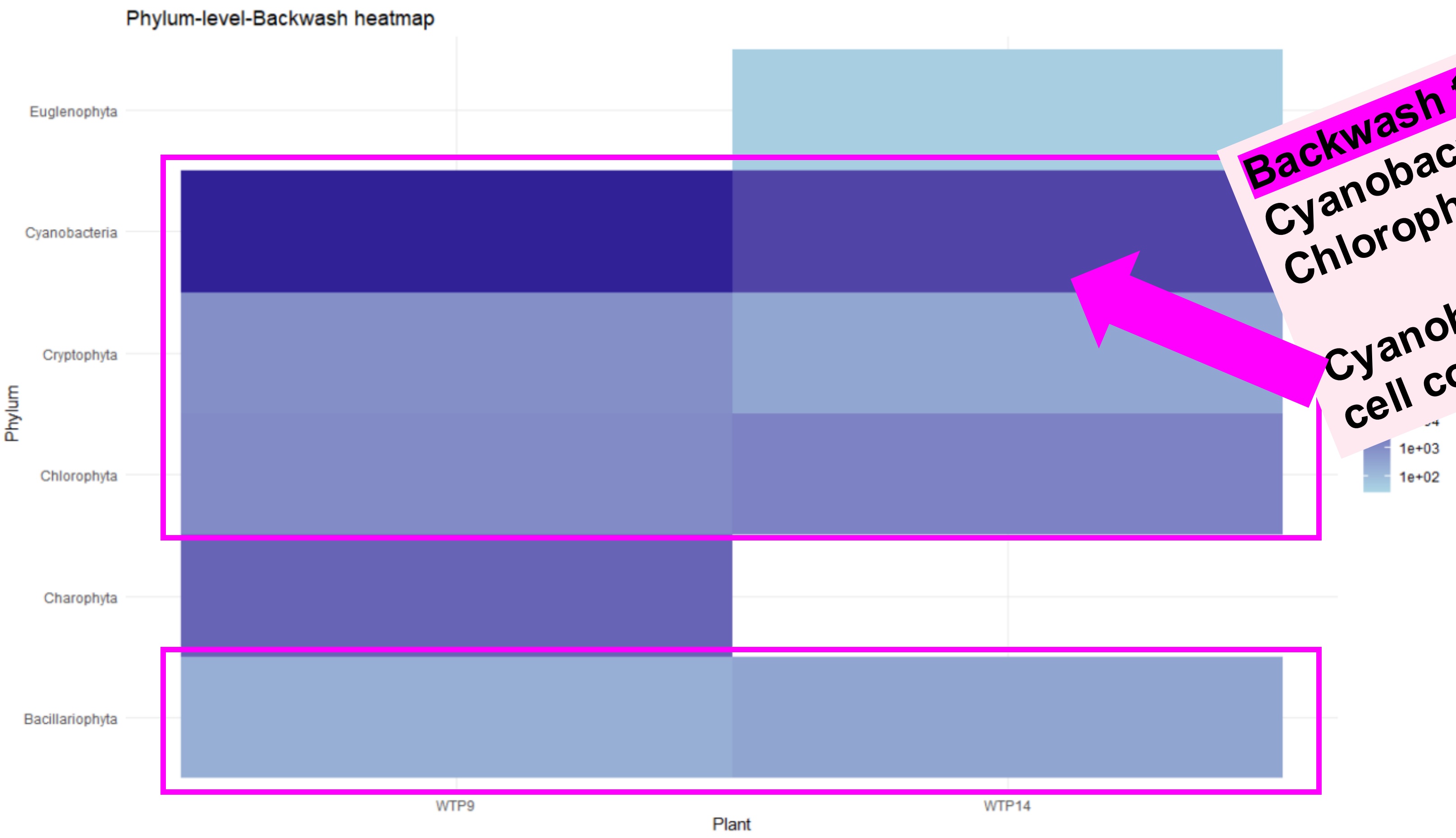
Algal community

- Backwash tank, Sludge Lagoon, Supernatant return
- Phylum level

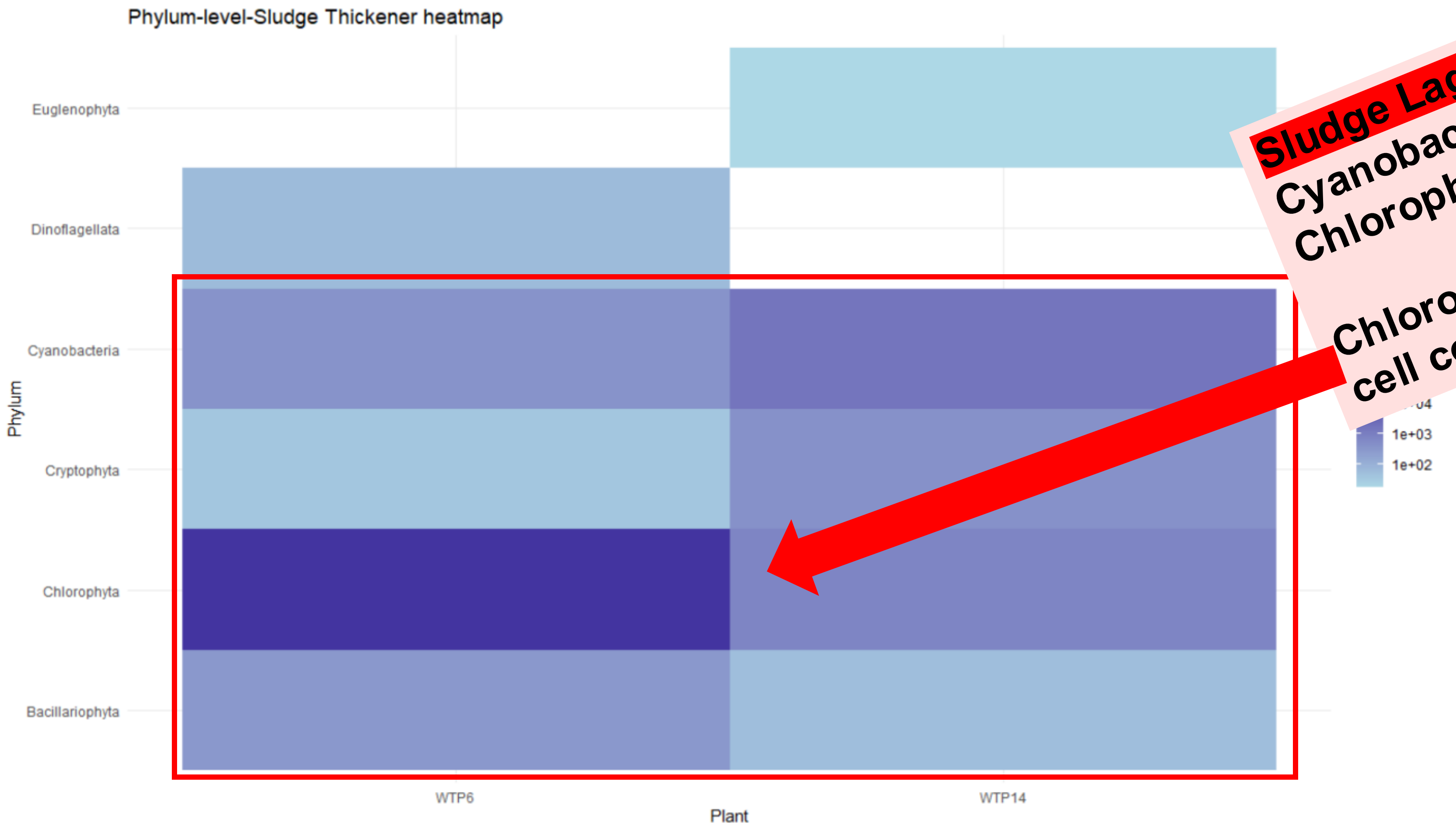


Backwash tank dominate:
Cyanobacteria, Cryptophyta, Chlorophyta, Bacillariophyta

Cyanobacteria have the highest avg. cell count

Algal community

- Backwash tank, Sludge Lagoon, Supernatant return
- Phylum level

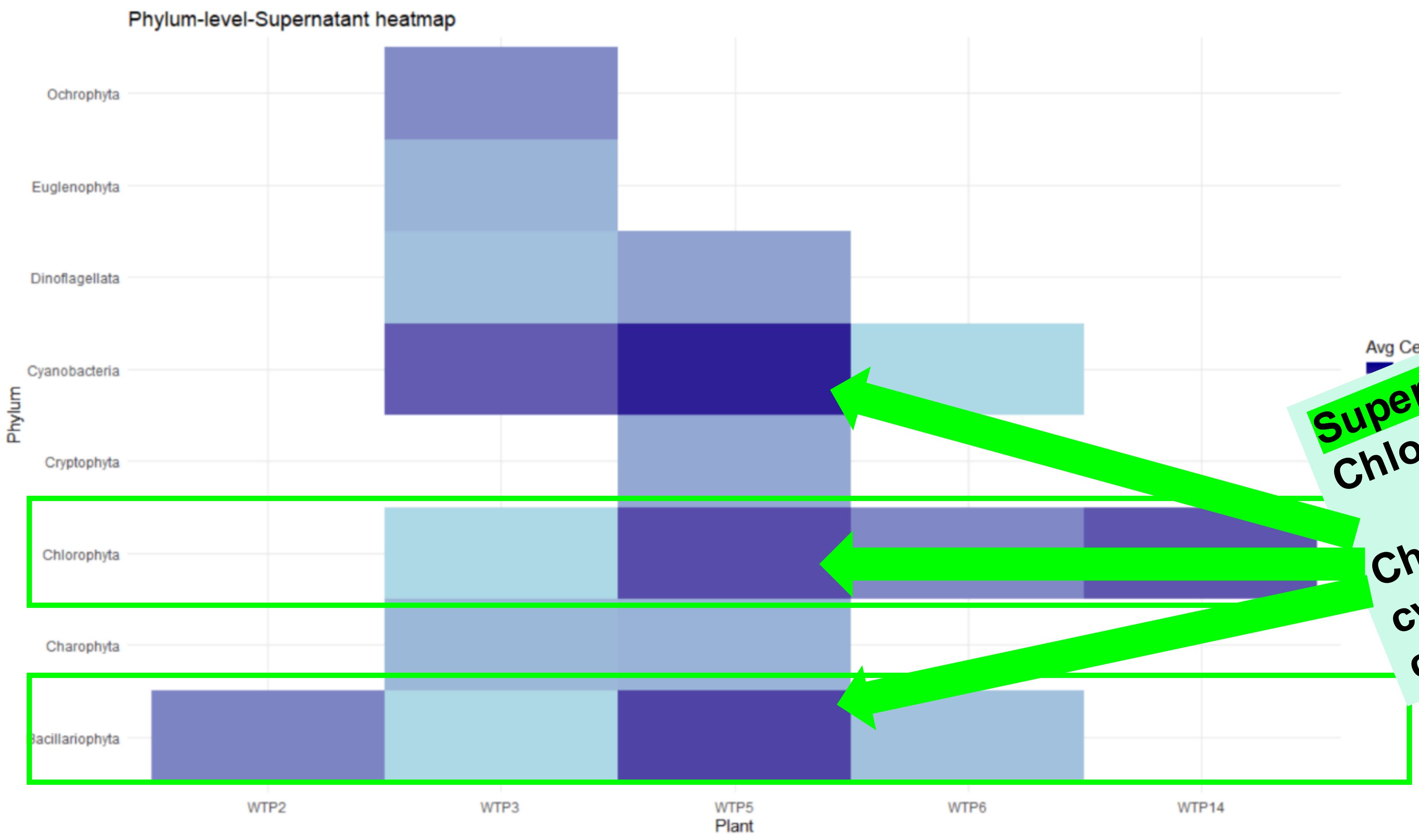


Sludge Lagoon dominate:
Cyanobacteria, Cryptophyta, Chlorophyta, Bacillariophyta

Chlorophyta have the highest avg. cell count

Algal community

- Backwash tank, Sludge Lagoon, Supernatant return
- Phylum level



Supernatant return dominate:
Chlorophyta, Bacillariophyta

Chlorophyta, Bacillariophyta and cyanobacteria all have high avg. cell count depending on plants.

4. Key highlights of algal community across WTPs

- **Source vs Raw water**
  - Cyanobacteria, Chlorophyta (green algae) and Bacillariophyta (diatoms) are all frequently recorded in Source and Raw water inlet.
  - Cyanobacteria have the highest avg. cell count in both Source and Raw water in despite of WTPs.

- **Post-treatment**
  - Thin and filamentous cyanobacteria (*Pseudanabaena, Planktolyngbya, Aphanizomenon*) frequently persisted after treatment. This might be attributed to their fine morphology, poor flocculation, and buoyancy.

- **Downstream processes: Backwash, Sludge Lagoon and Supernatant return**
  - Across downstream processes, Cyanobacteria, Chlorophyta, Cryptophyta and Bacillariophyta consistently dominate.
  - Cyanobacteria peak in backwash tanks, Chlorophyta in sludge lagoons, and both Chlorophyta and Bacillariophyta (with variable Cyanobacteria) in supernatant returns.
  - Recycling these water risks re-introducing biomass and organic matter.
  - Different plant design, e.g. retention time, backwash frequency, tank dimensions may have an impact on the community variations. -> Future work needed.

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5. Next steps

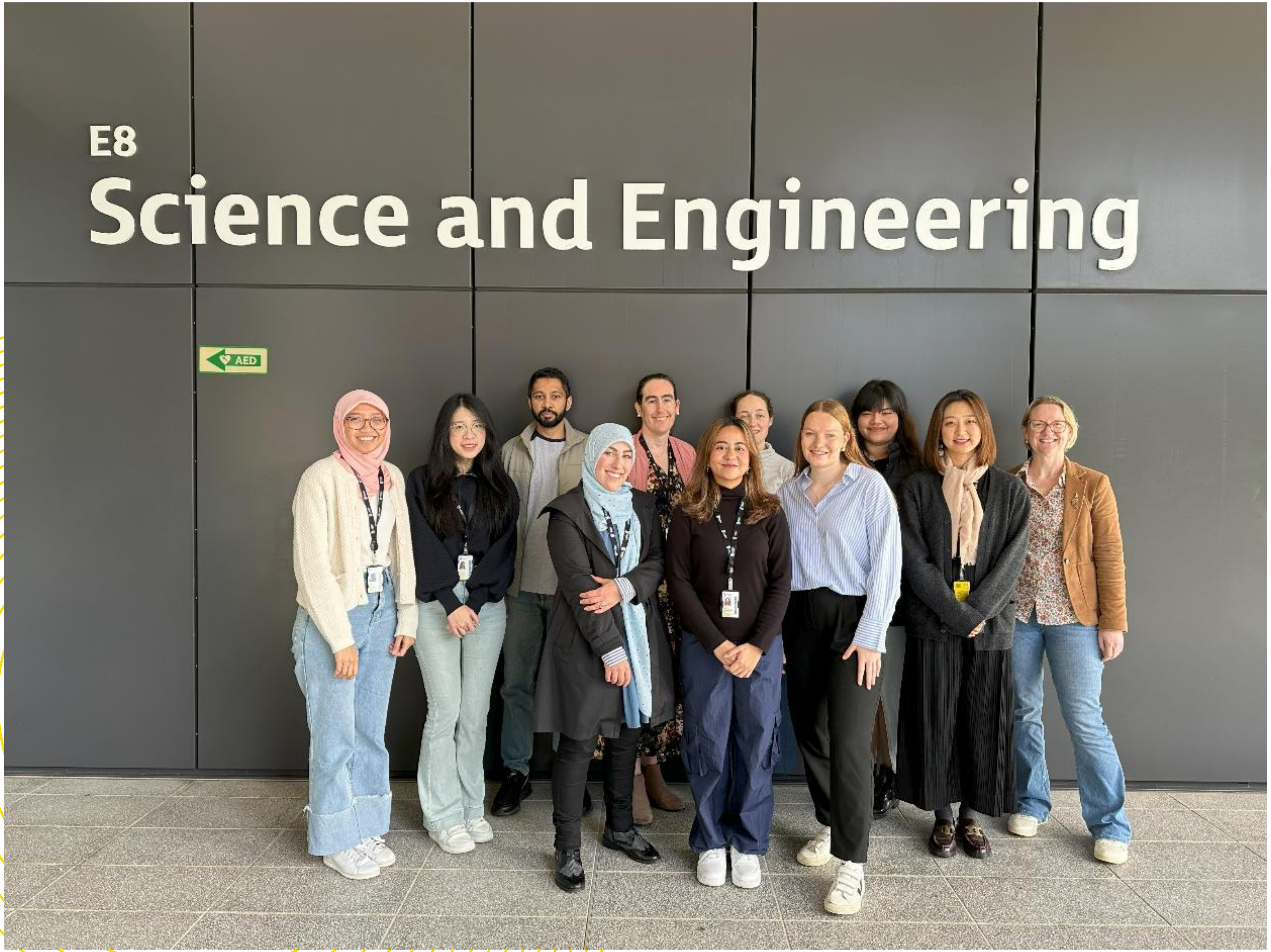
Statistical analysis: Apply multivariate approaches across multiple plants to identify key drivers of breakthrough patterns.

Expanded sampling program: conducting a detailed analysis of community changes within each WTP and correlation studies on community dynamics, selective removals, and operational conditions in the context of drinking water treatment

PhD laboratory work: Optimise pre- and post-treatment strategies under controlled conditions to test interventions and validate findings.

Overall project outcome: Based on the outcomes of these correlations, proposing both proactive and reactive engineering strategies to enhance the resilience of drinking water treatment plants against algal and cyanobacterial challenges.

Our research group



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Thank you for your attention

Questions?