Ozone Nanobubble Technology for the Removal of Microbial and Chemical Contaminants in Water Supply Systems

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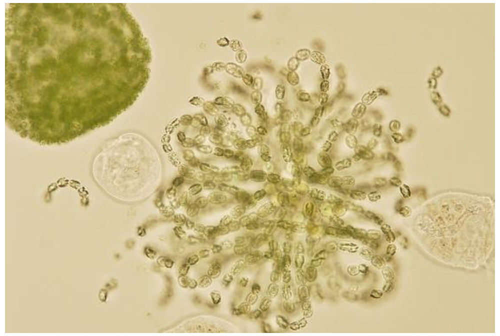
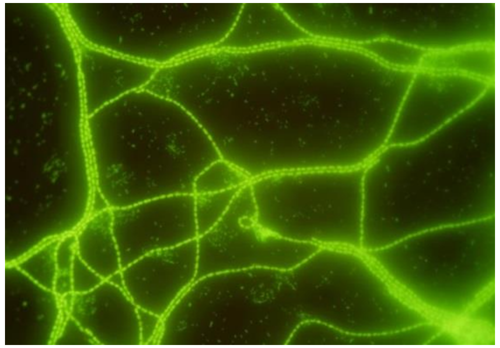
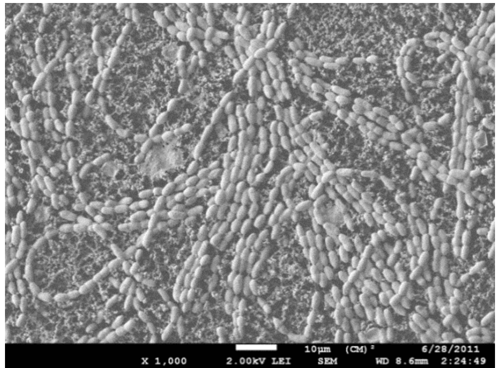
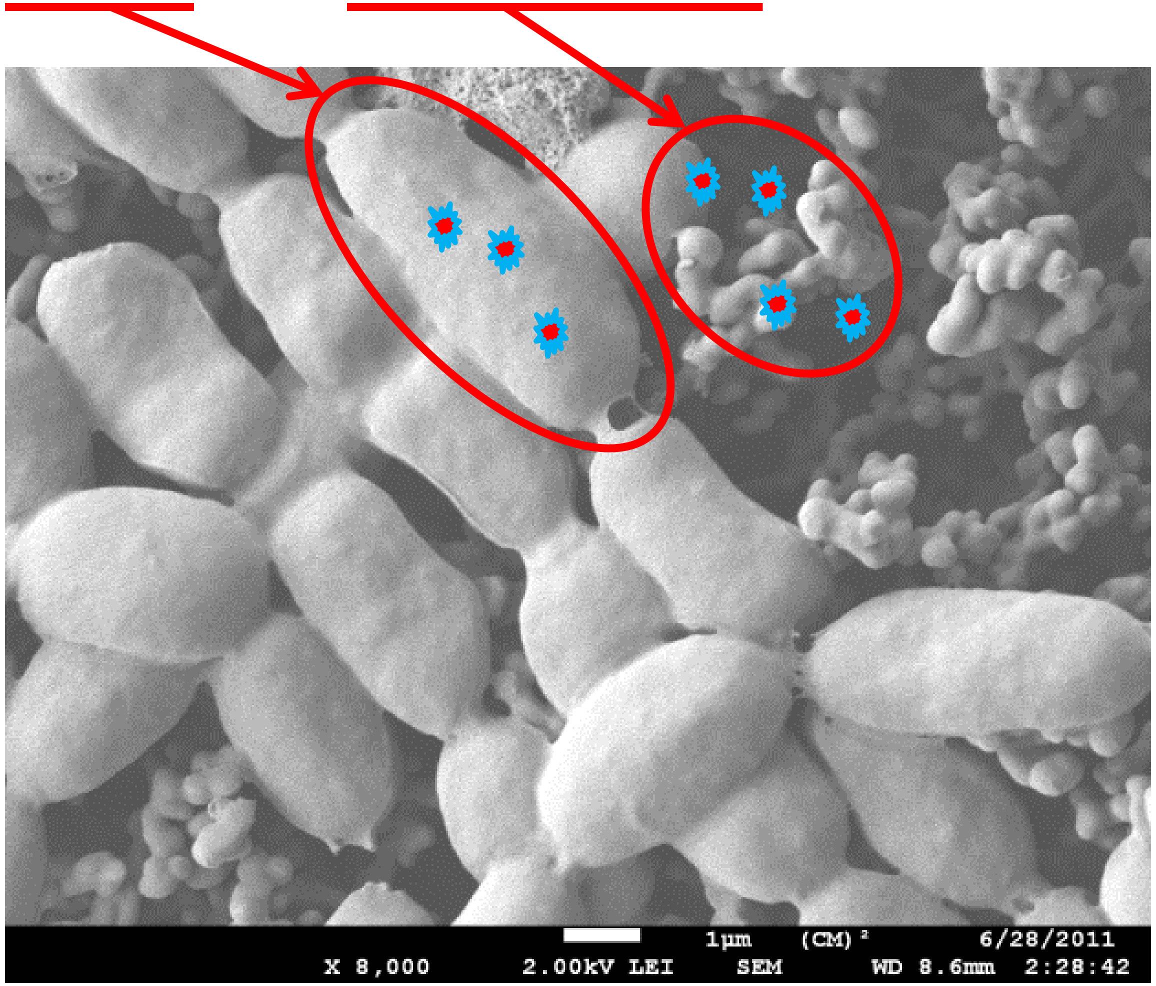






Cell identification/integrity & release

Intra- and extracellular compounds



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Toxic and nuisance blooms are within our water supply systems:

Factsheet

Research

List of Potentially Toxic Cyanobacteria

Water Research AUSTRALIA

List of Potentially Toxic Cyanobacteria

Cyanobacteria (also known as blue-green algae) pose a significant health hazard in public water supplies and recreational water bodies. Risk assessment is based on species identification and potential for toxin production. Thus, correct identification and reporting of toxic species is vital to stakeholders. Currently there is no uniform agreed list of species recognised as being potentially toxic within Australian waters; in fact, a recent survey found a large disparity in the respective lists maintained by accredited laboratories as to which species they consider as being potentially toxic. This fact sheet provides an up-to-date list of toxic species for all stakeholders.

What Has Changed?

Taxonomic revisions (name and classification changes) regularly occur which can make tracking toxigenic species over time difficult. Often industry professionals only become aware of these changes via their own literature search or acquire 'third hand' from others in the industry. Further, there has been an increasing awareness and identification of benthic toxic cyanobacteria, with several new records described from Australia. The current NHMRC Drinking Water Guidelines (2018) are only revised periodically and do not reflect these developments. Further confusion also arises due to large geographical disparity in toxin production for some species. Strains of a species can be non-toxic or vary in their toxin content. For instance, there are species known to be toxic elsewhere (e.g. *Planktothrix agardhii* in Europe), which haven't been recorded to be toxic in Australia; and vice versa.

Clarification of 'Potentially Toxic'

Cyanobacteria breakthrough into flocculation system:

ELSEVIER
Water Research
Volume 152, 1 April 2019, Pages 96-105

Diagnosing water treatment critical control points for cyanobacterial removal: Exploring benefits of combined microscopy, next-generation sequencing, and cell integrity methods

Arash Zamyadi [a b c], Caitlin Romanis [d], Toby Mills [d], Brett Neilan [d], Florence Choo [b], Lucila A. Coral [b e], Deb Gale [f], Gayle Newcombe [g], Nick Crosbie [h], Richard Stuetz [a], Rita K. Henderson [b]

https://doi.org/10.1016/j.watres.2019.01.002

RESEARCH ARTICLE | MARCH 22 2021

Toxic cyanobacteria in water supply systems: data analysis to map global challenges and demonstrate the benefits of multi-barrier treatment approaches

Arash Zamyadi; Caitlin M. Glover; Attika Yasir; Richard Stuetz; Gayle Newcombe; Nicholas D. Crosbie; Tsair-Fuh Lin; Rita Henderson

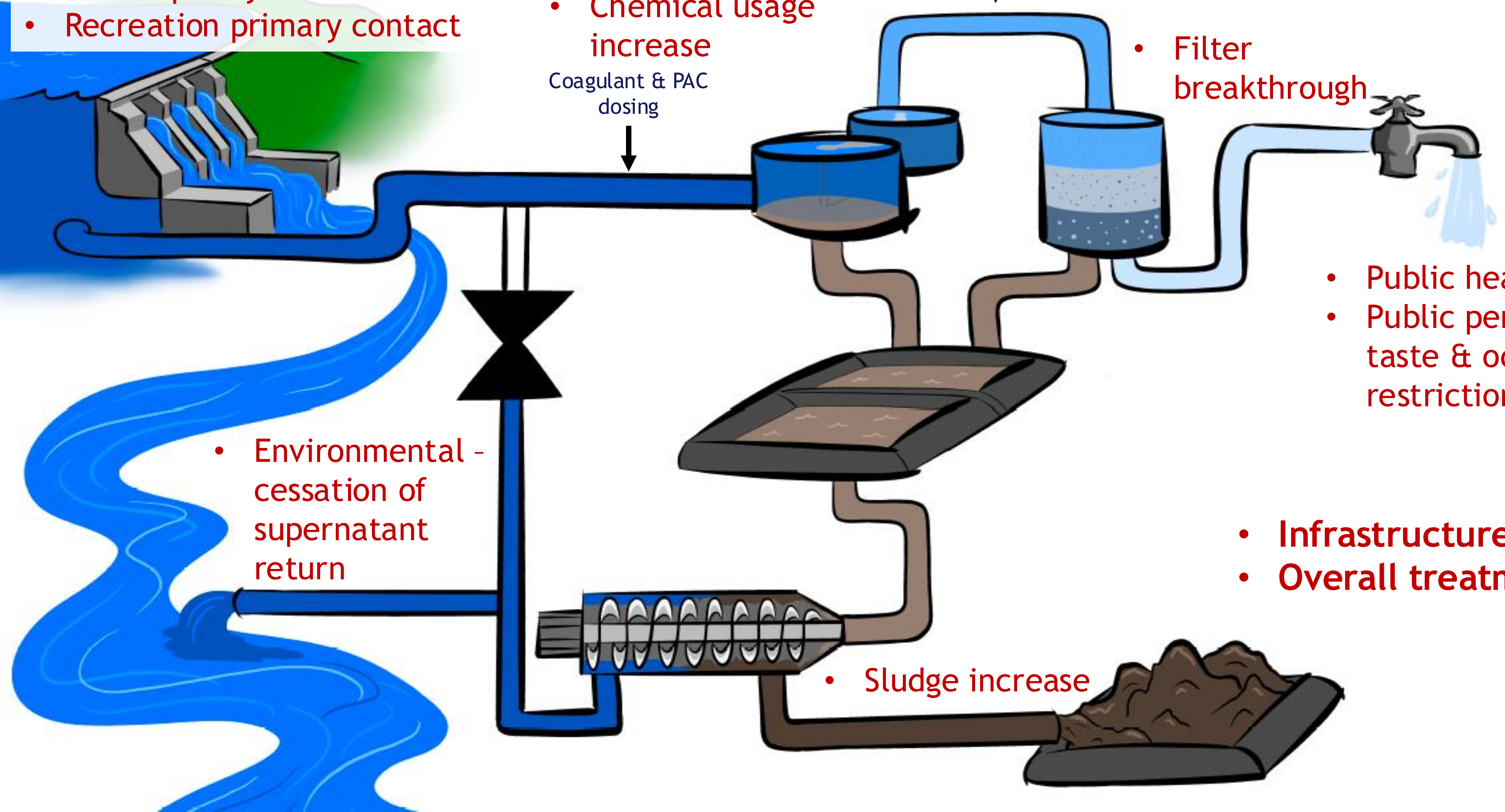
https://doi.org/10.2166/h2oj.2021.067

What's the impact?

Impact on the entire supply system!

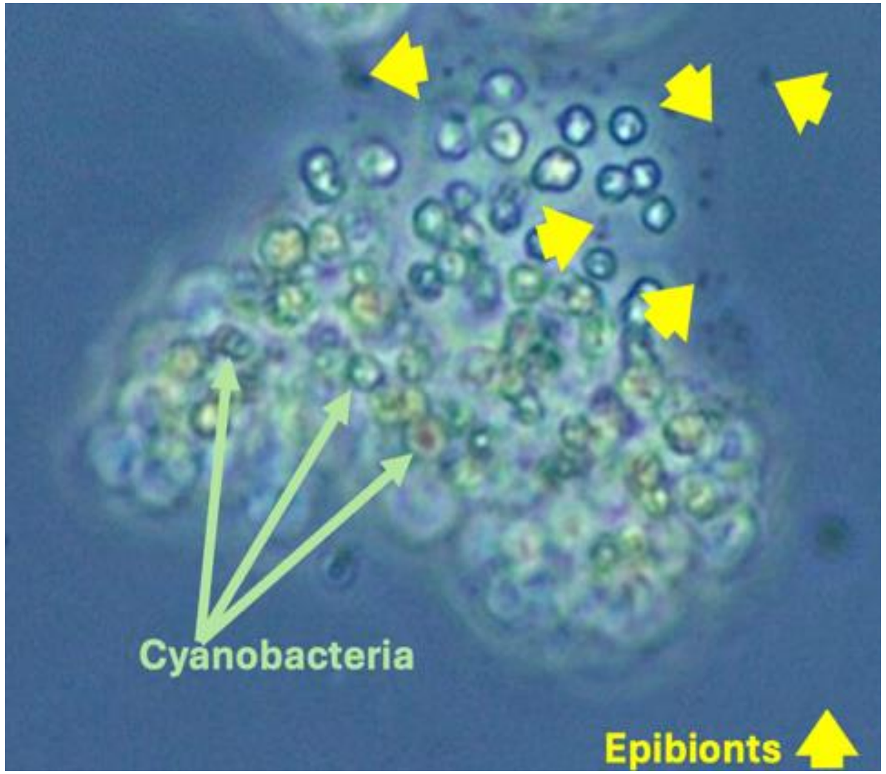
- Cyanobacteria increase
- Water quality decline
- Recreation primary contact

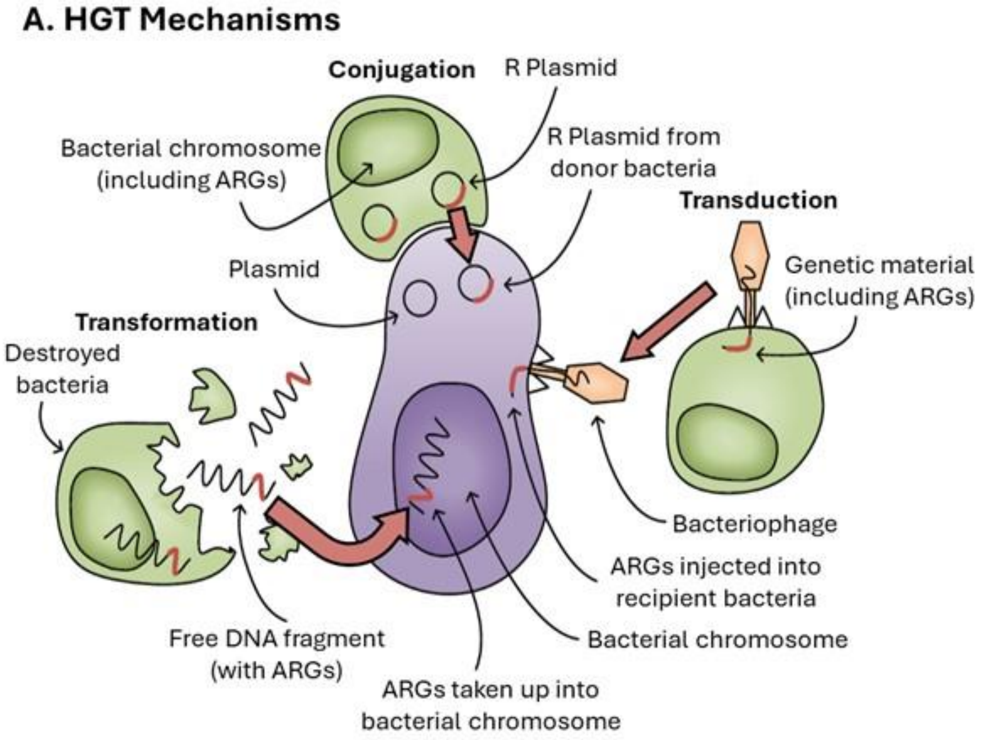
- Chemical usage increase



- Disinfection by-product increase
- Filter breakthrough
- Public health – toxins
- Public perception – taste & odours, water restrictions
- Environmental – cessation of supernatant return
- Sludge increase
- **Infrastructure strain**
- **Overall treatment costs**

__In recycling treated wastewater:__ The entire bloom ecosystem including cellular epibiont, associated microbial and chemical contaminants are of concern, beyond toxins and T&O issues:





Develop scalable approaches for treatment in manufactured water
Hydrogen peroxide for source and ozone as AOP!

Maybe we can stop or control the breakthroughs?
But what options do we have?

REVIEW ARTICLE | OCTOBER 14 2025

Critical review of oxidant application and scalability for managing toxic *Microcystis* blooms in wastewater stabilisation ponds

Ortal Raikhlin; Nicholas Crosbie; Bojan Tamburic; Xiaoran Chu; Rita Henderson; Brandon Winfrey; Michael Burch; Arash Zamyadi

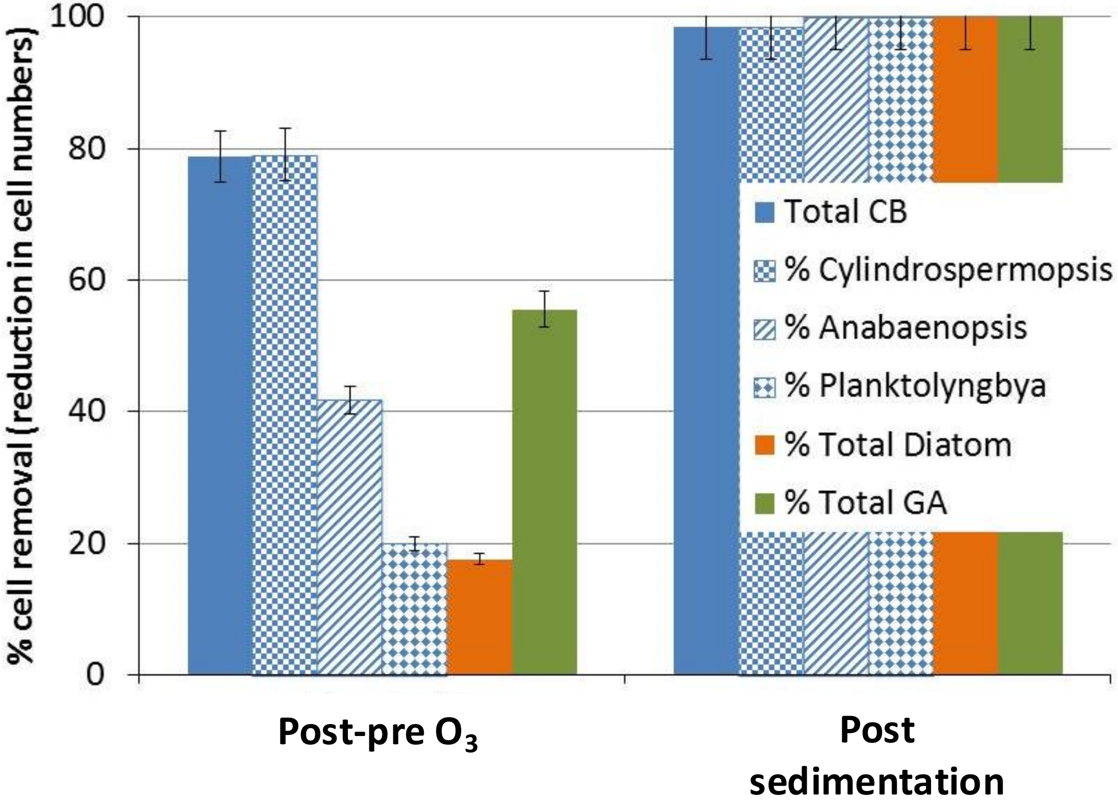
https://doi.org/10.2166/wqrj.2025.052

Oxidation using 5mg/L O_3 :

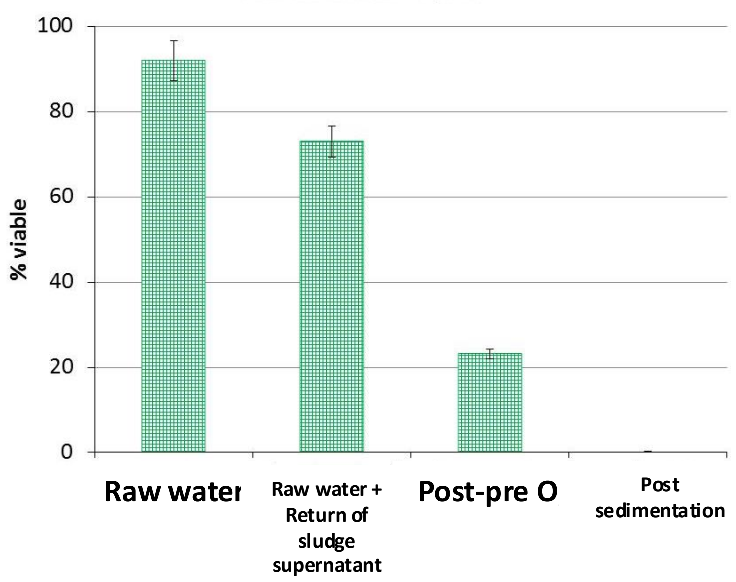
O_3 works but expensive at high dose, and challenging to diffuse

A. Zamyadi, C. Romanis, T. Mills, B. Neilan, F. Choo, L. Coral, D. Gale, G. Newcombe, N. Crosbie, R. Stuetz, R. Henderson (2019) Diagnosing water treatment critical control points for cyanobacterial removal: Exploring benefits of combined microscopy, next-generation sequencing, and cell integrity methods. ***Water Research***, 152, 96-105.

https://doi.org/10.1016/j.watres.2019.01.002



High removal rate & the remaining were damaged cells



Geosmin (ng/L) :

15.9	15.1	8.7	7.6	BDL	BDL	BDL
Raw water	Return of sludge recovery supernatant	Post pre-ozonation	Surface of sedimentation tank	Filtered water	Post interozonation and BAC	Finished water

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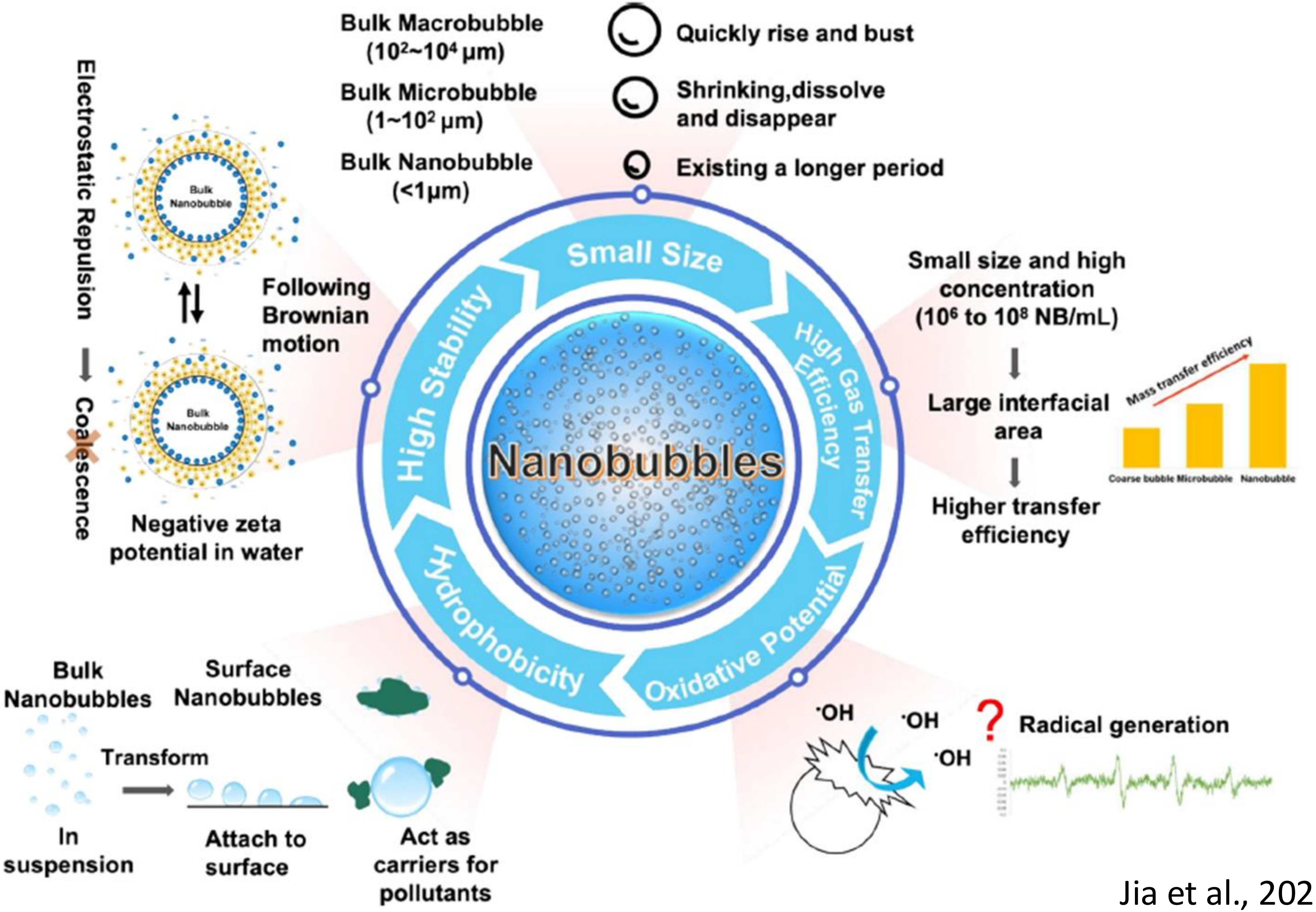
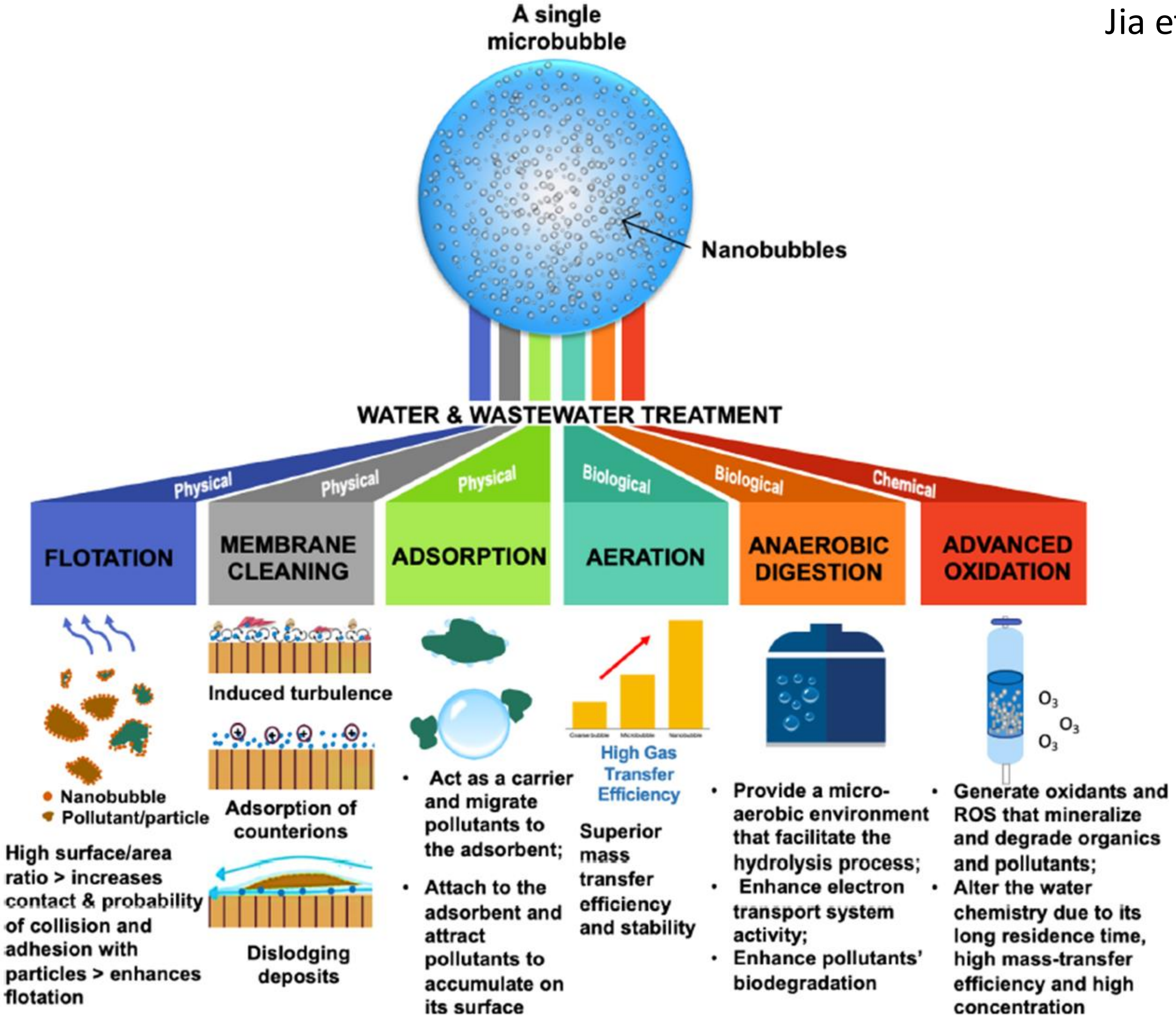
Scalable approaches for algal treatment in manufactured water: **Nanobubble**



Jia et al., 2023

Jia et al., 2023

Scalable approaches for algal treatment in manufactured water: **Nanobubble**



Scalable approaches for algal/cyanobacterial treatment in manufactured water
Ozone nanobubble oxidation

New Results

Exploring use of ozone nanobubbles for removal of cyanobacteria and co-occurring antimicrobial resistance genes in water supply and reuse systems

Ushalini Saththiyananthan, Calum J Walsh, Steven Newham, Mark Putmann, Daniel Flanagan, Karen Rouse, Filippo Nelli, Elnaz Karamati Niaragh, Louise M Judd, Karolina Mercoulia, Torsten Seemann, Ming Su, Min Yang, Linda Blackall, Benjamin Howden, Eric Wert, Arash Zamyadi

doi: https://doi.org/10.1101/2025.10.15.682302

https://doi.org/10.1101/2025.10.15.682302

bioRxiv
THE PREPRINT SERVER FOR BIOLOGY



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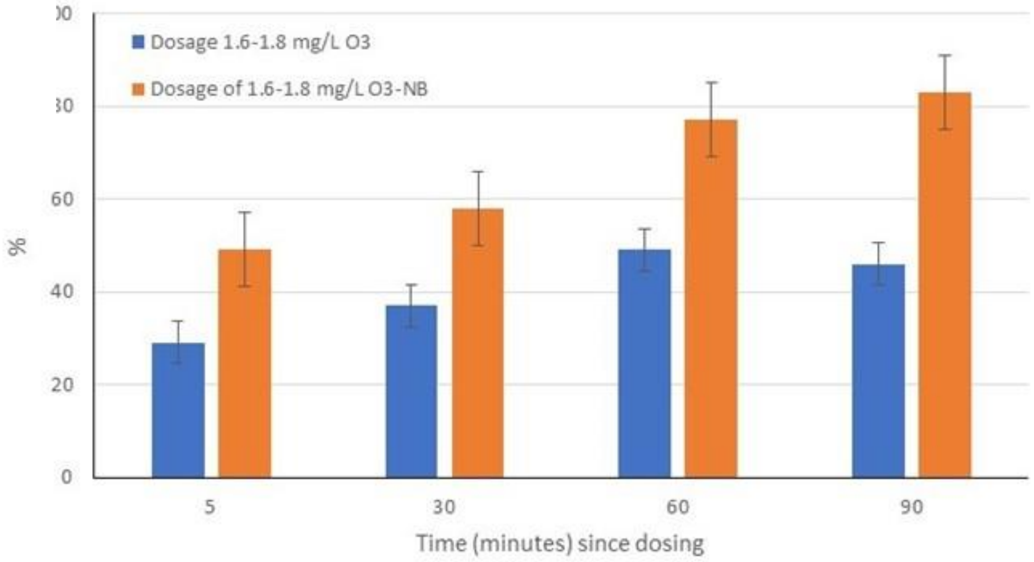
In drinking water reservoir

In Class C recycled water

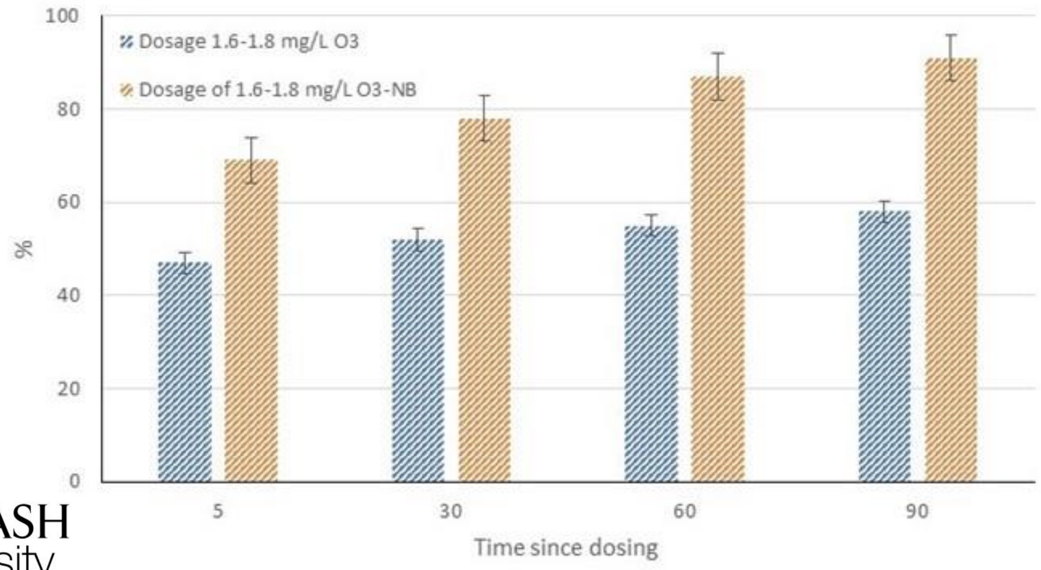
In lagoon-based wastewater treatment

In the studied drinking water reservoir:

Reduction in total cyanobacterial cell numbers

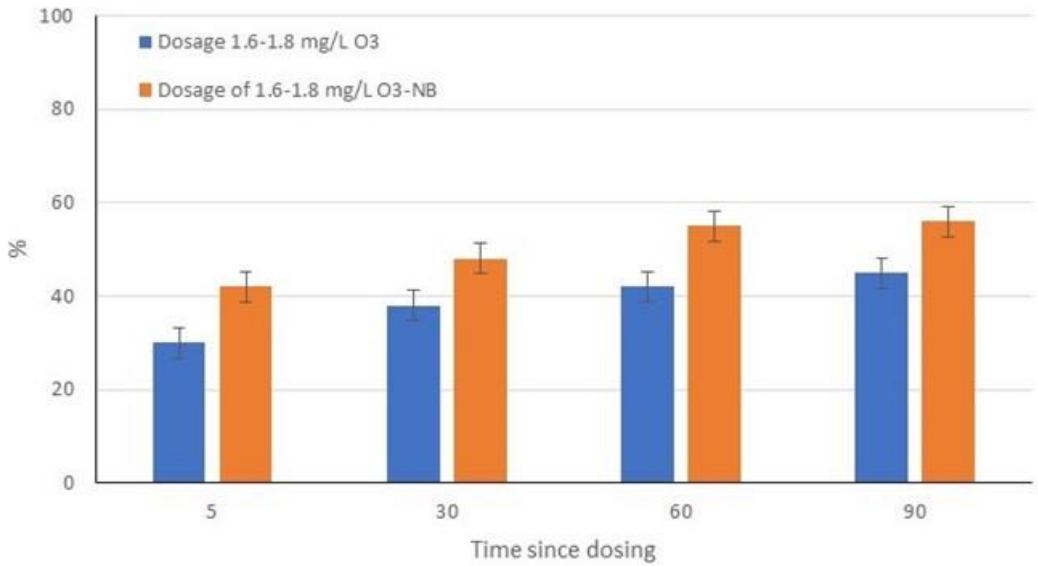


Reduction in total cyanobacterial cell viability

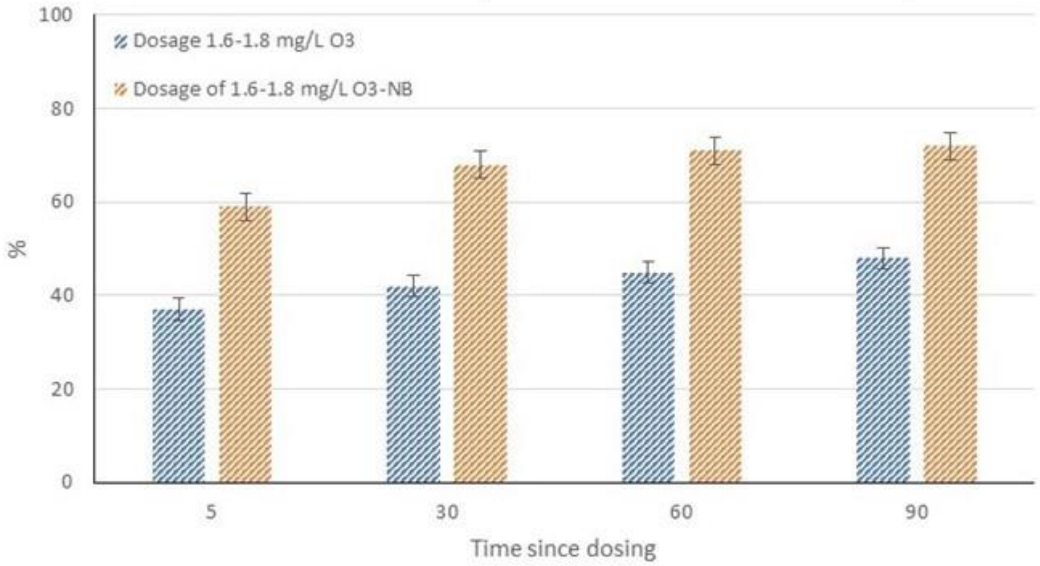


In the Class C recycled water:

Reduction in total cyanobacterial cell numbers



Reduction in total cyanobacterial cell viability



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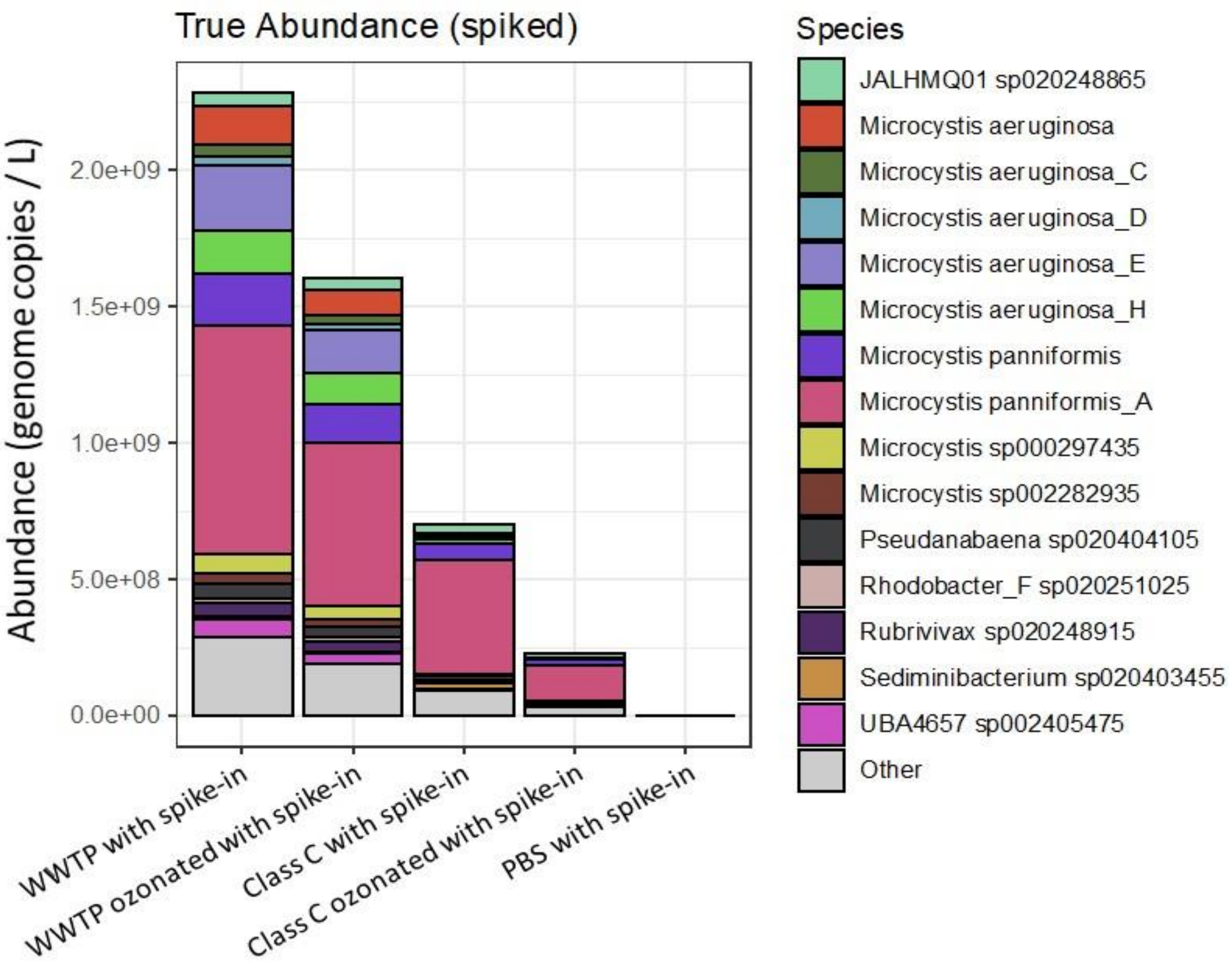
Scalable approaches for algal/cyanobacterial treatment in manufactured water
Ozone nanobubble oxidation

Absolute abundance of cyanobacterial strains in WWTP-post-aeration and Class-C recycled water with and without ozone nanobubble oxidation (90 minutes of contact).

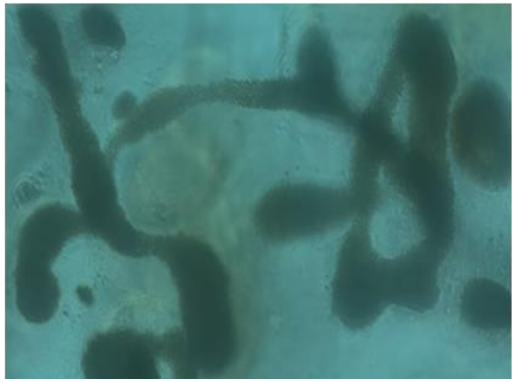


ARGs were analysed pre and post ozone nanobubble application:
https://doi.org/10.1101/2025.10.15.682302

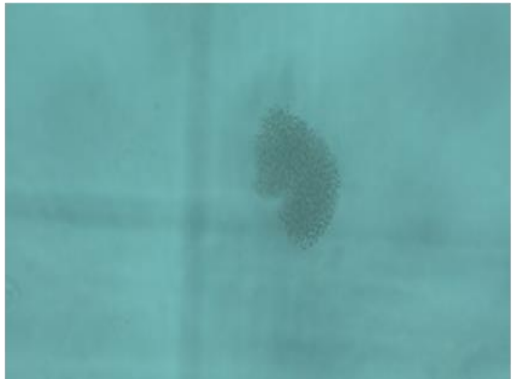
Scalable approaches for algal/cyanobacterial treatment in manufactured water

Ozone nanobubble oxidation

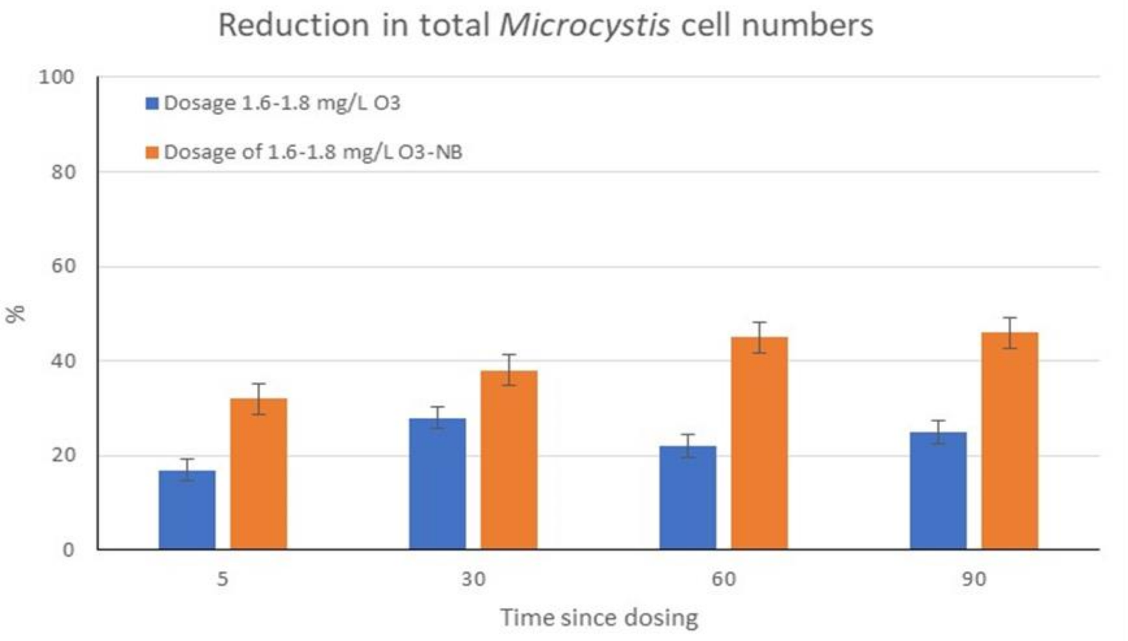
Comparative reduction of cyanobacteria cell numbers and total cell viability by conventional ozone and ozone nanobubbles in the lagoon-based wastewater treatment

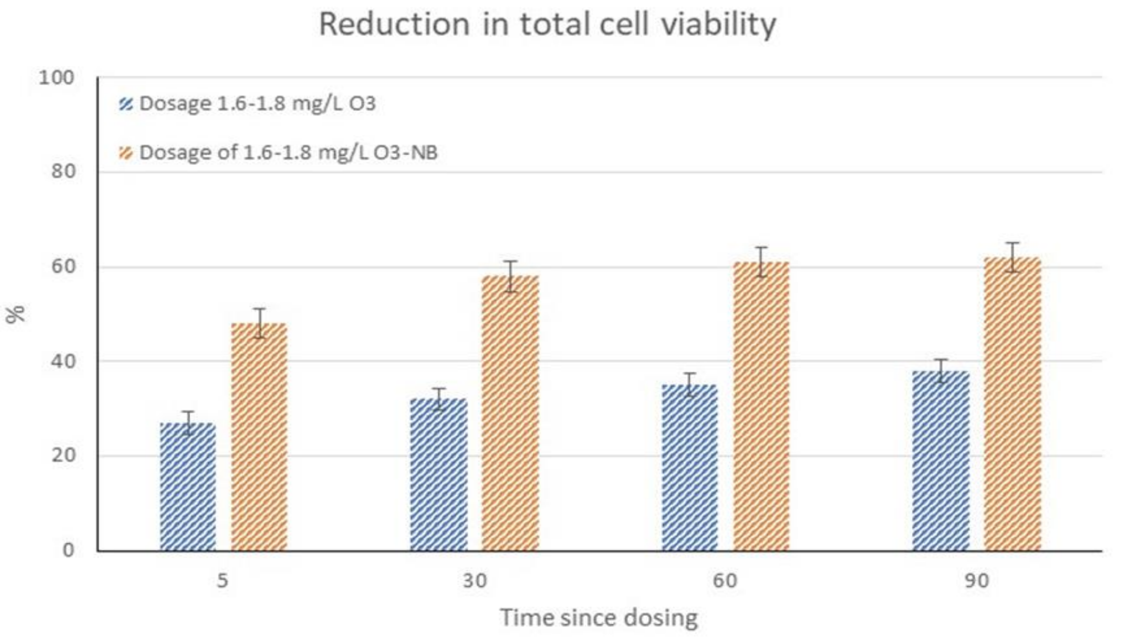


Pre-ozone nanobubble



Post-ozone nanobubble





Develop scalable approaches for treatment in manufactured water
Ozone nanobubble AOP

Oxidation efficient but high energy cost or OH&S risk; how can we improve this, maybe with an AI driven decision tool?

Step 1 - kinetics model:

Table 2 – Rate of cell lysis (k_{lysis} – $M^{-1}\ s^{-1}$) during ozonation of the studied bloom samples. R^2 values are presented in parenthesis.

Genera present at each bloom	Bloom event				Average and range per genus
	15 NTU 197,000 cells/mL	25 NTU 338,000 cells/mL	45 NTU 1,620,000 cells/mL	65 NTU 1,282,000 cells/mL	
Anabaena	0.30×10^2 ($R^2 = 0.93$)	0.51×10^2 ($R^2 = 0.97$)	1.74×10^2 ($R^2 = 0.97$)	1.66×10^2 ($R^2 = 0.98$)	$1.1 \pm 0.8 \times 10^2$
Aphanizomenon	2.17×10^2 ($R^2 = 0.94$)	0.60×10^2 ($R^2 = 0.95$)	0.43×10^2 ($R^2 = 0.98$)	0.71×10^2 ($R^2 = 0.96$)	$0.98 \pm 0.8 \times 10^2$
Microcystis	0.25×10^2 ($R^2 = 0.92$)	0.47×10^2 ($R^2 = 0.97$)	0.22×10^2 ($R^2 = 0.96$)	0.41×10^2 ($R^2 = 0.93$)	$0.34 \pm 0.1 \times 10^2$
Pseudanabaena	0.95×10^2 ($R^2 = 0.99$)	2.31×10^2 ($R^2 = 0.77$)	0.81×10^2 ($R^2 = 0.97$)	1.68×10^2 ($R^2 = 0.99$)	$1.44 \pm 0.7 \times 10^2$
Total counts	0.22×10^2 ($R^2 = 0.93$)	0.64×10^2 ($R^2 = 0.98$)	0.40×10^2 ($R^2 = 0.96$)	0.59×10^2 ($R^2 = 0.97$)	$0.46 \pm 0.2 \times 10^2$

WATER RESEARCH 73 (2015) 204–215

Available online at www.sciencedirect.com
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journal homepage: www.elsevier.com/locate/watres
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WATER RESEARCH

Fate of toxic cyanobacterial genera from natural bloom events during ozonation

CrossMark

Arash Zamyadi [a,*], Lucila A. Coral [a,1], Benoit Barbeau [a], Sarah Dorner [a], Flávio R. Lapolli [b], Michèle Prévost [a]

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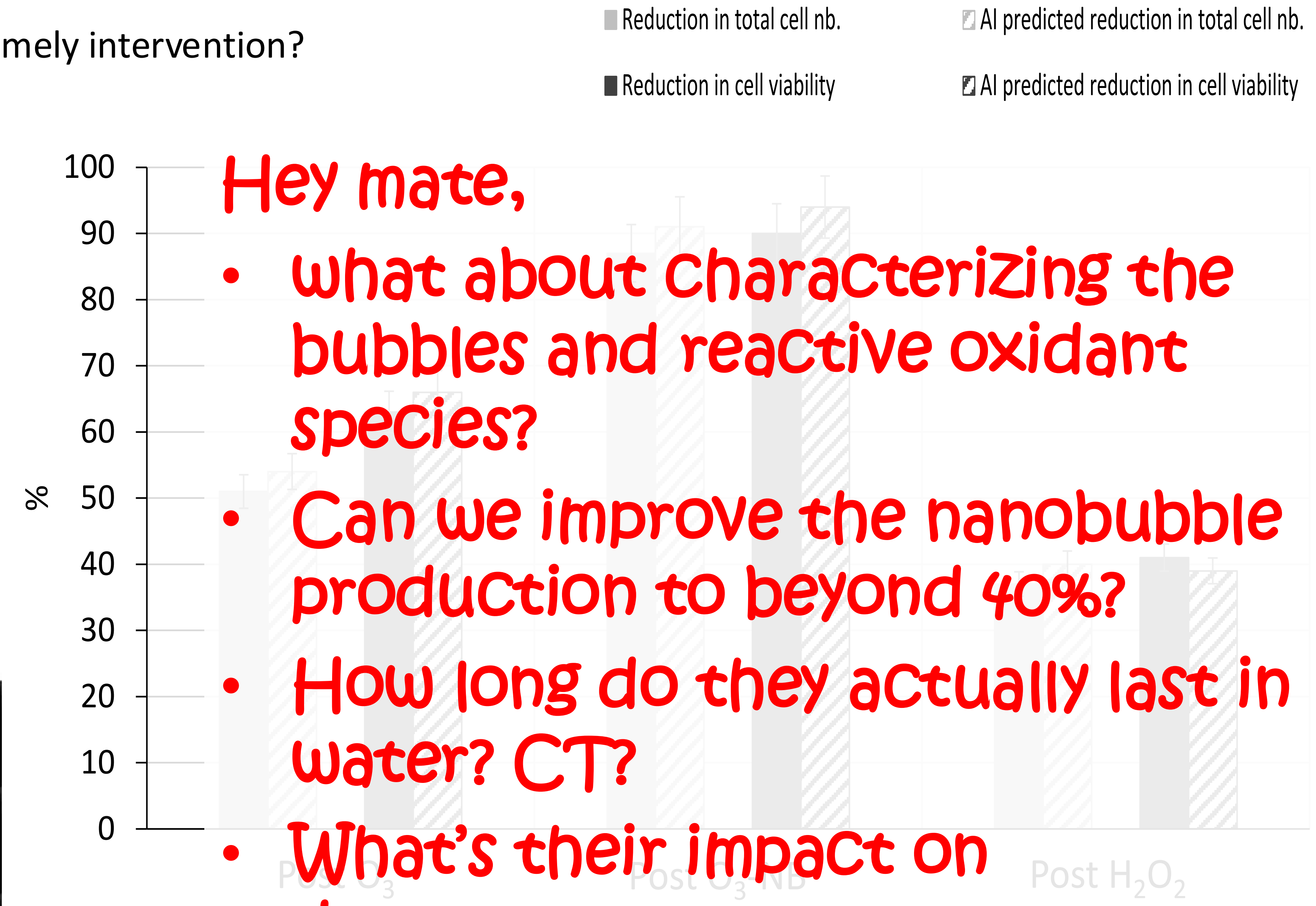
AI guided timely intervention?

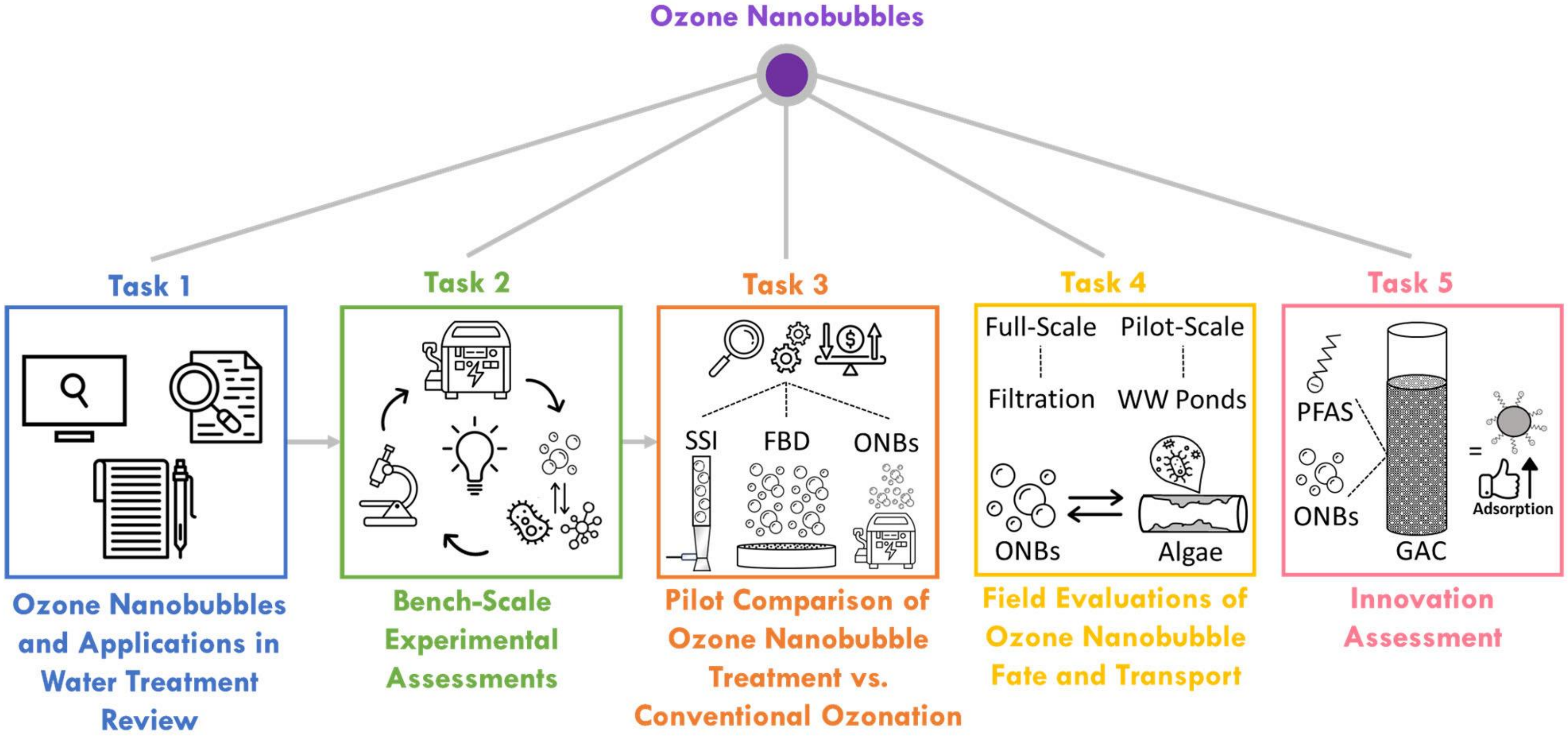
Step 2 - Use AI-based image segmentation and clustering tool to identify and count the cell, and then calculate the ozonation performance using the rates from Step 1, as a fast decision tool:



Hey mate,

- what about characterizing the bubbles and reactive oxidant species?
- Can we improve the nanobubble production to beyond 40%?
- How long do they actually last in water? CT?
- What's their impact on downstream processes?

Ozone Nanobubbles (NBs) Technologies for Water Treatment (2024-2027)



ARC – Discovery Project. Four Key Research Questions to address Knowledge Gaps in Cyanobacterial Oxidation

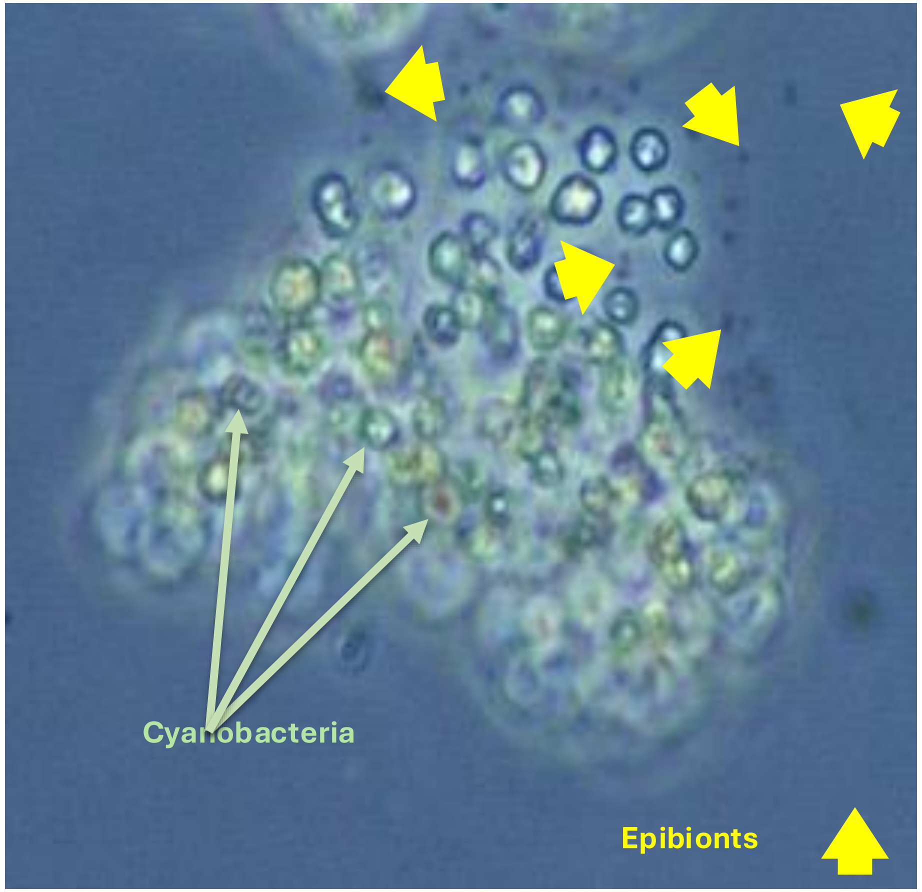
Australian Government
Australian Research Council
Doherty Institute
The University of Melbourne
Monash University

1. Metagenomics (MAGs) and Visualisation

- Cyanobacteria and epibionts
- rRNA targeted fluorescence *in situ* hybridization

2. Culturing

- Cyanobacteria and epibionts
- Metataxonomics
- Chemotaxis – epibiont to cyanobacteria
- Novel control strategies



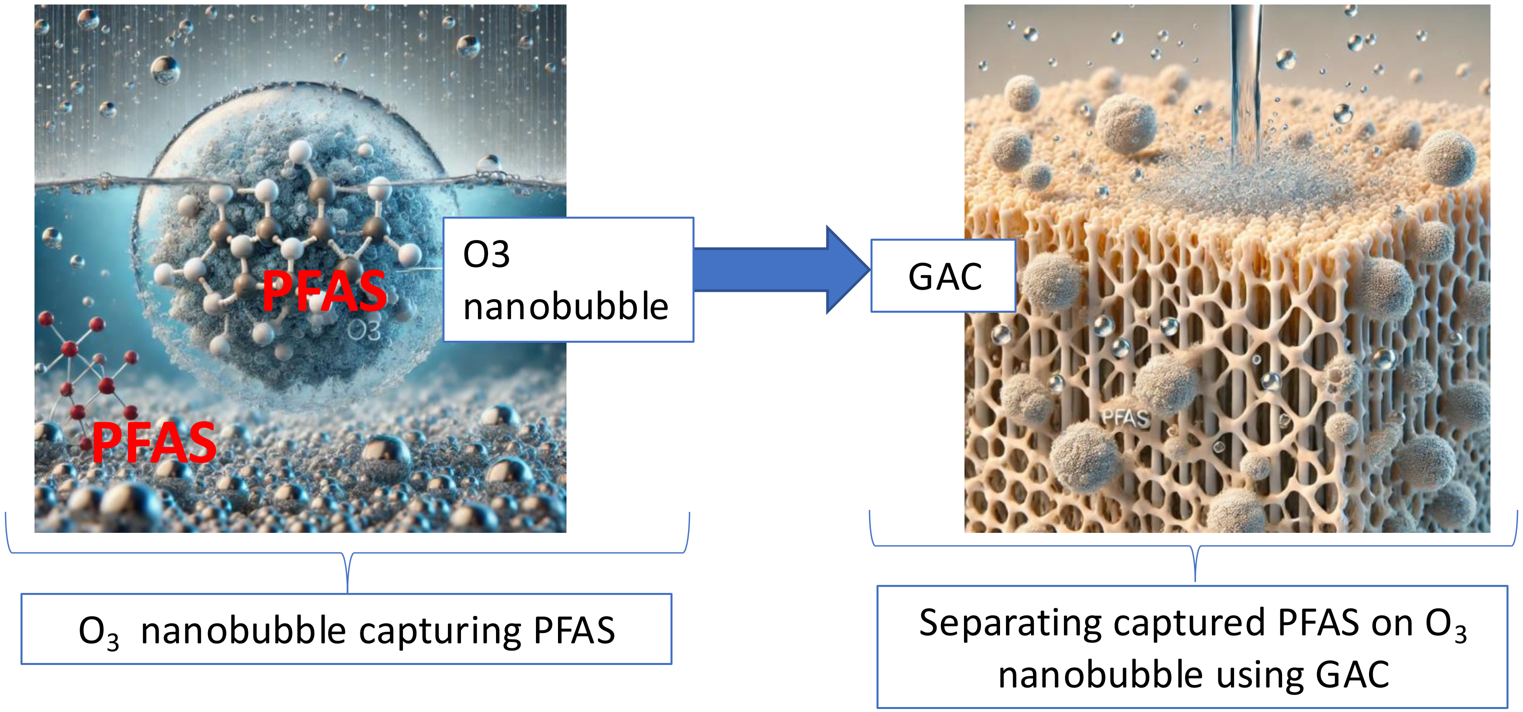
3. Antibiotic Resistance Genes (ARGs)

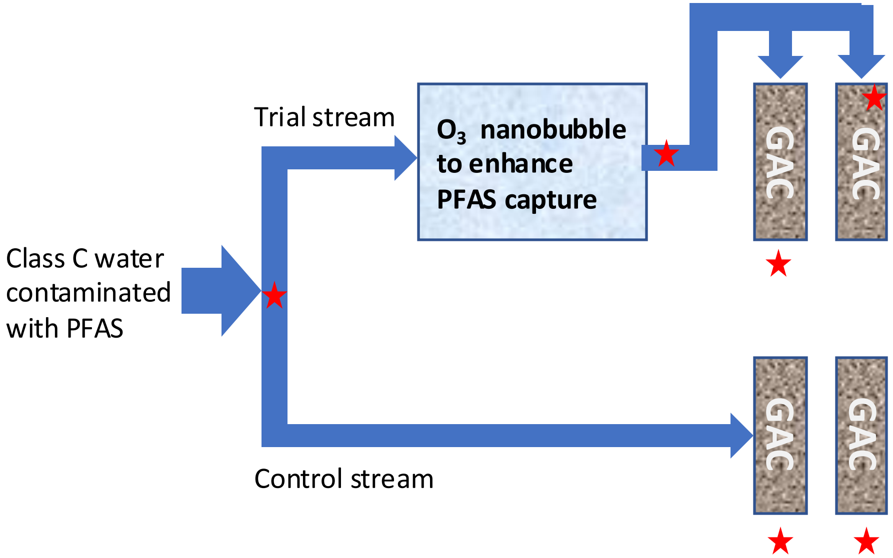
- Sequences from metagenome assembled genome
- ARGs in genomes/plasmids and in extracellular polymeric substances
- Implications

4. Novel Oxidation Treatment

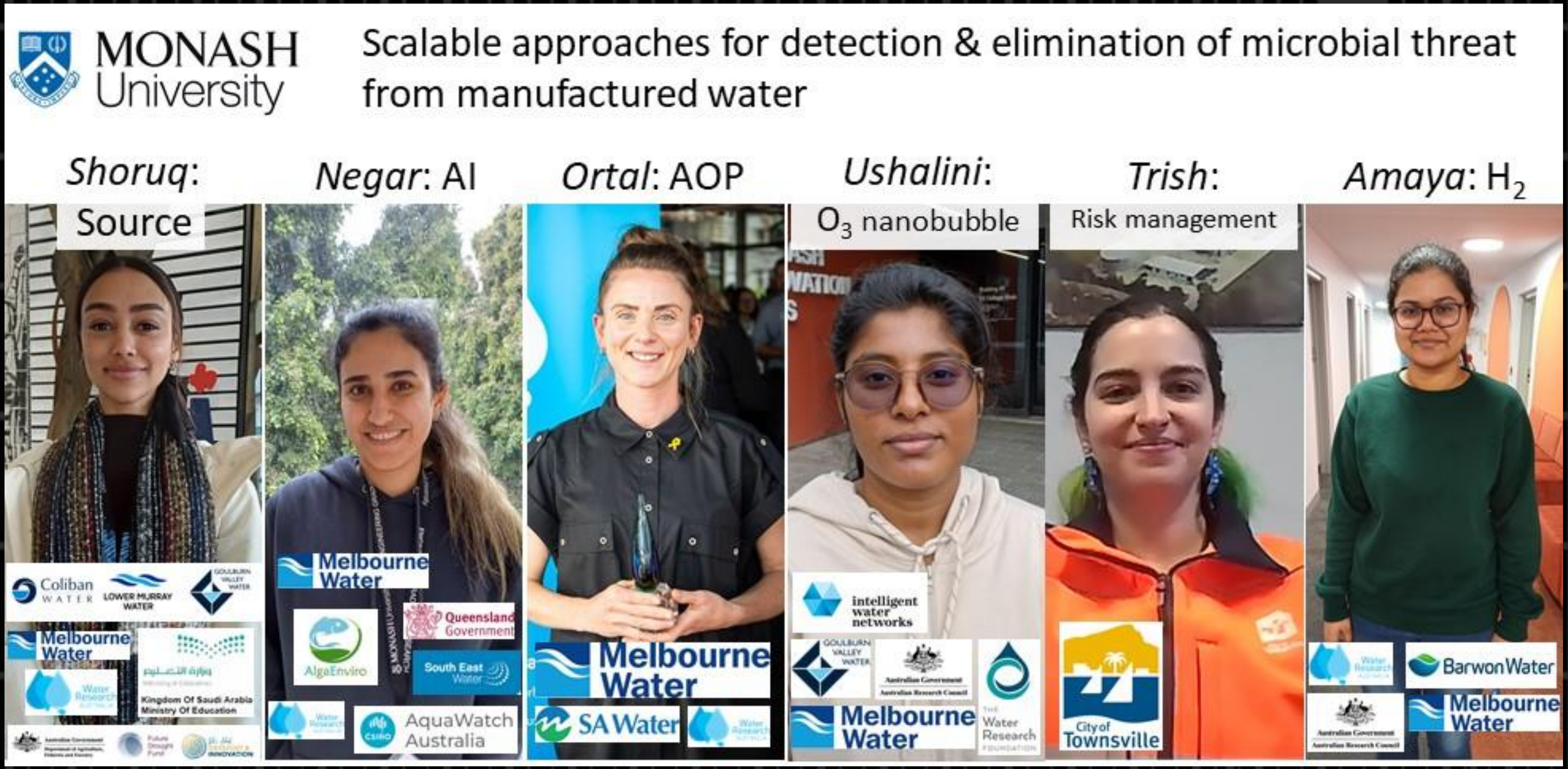
- Hydrogen peroxide and ozone nanobubble application
- New mechanistic model
- Impact on cyanoHAB ecosystem

Explore the use of ozone nanobubbles for enhanced PFAS removal from water on GAC





THANK YOU!



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