Ozone Nanobubble Disinfection for Algae in Freshwater and Brackish Water Systems

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Purpose

Research Question: How does the stability of NBs in fresh water and brackish water differ from that of macrobubbles? Are ozone NBs effective at controlling algae that blue-green algae and red tide?

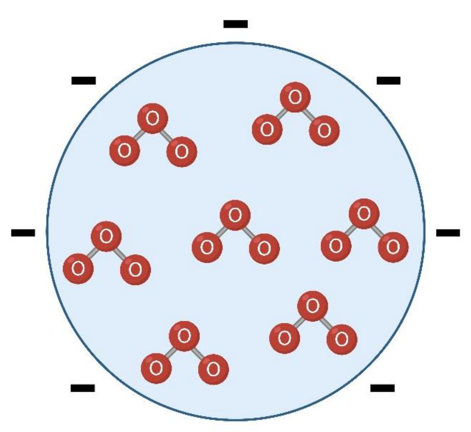
My research aims to investigate whether the differing chemical compositions of these water bodies influences ozone NB formation, stability, and their effectiveness in neutralizing these algae.

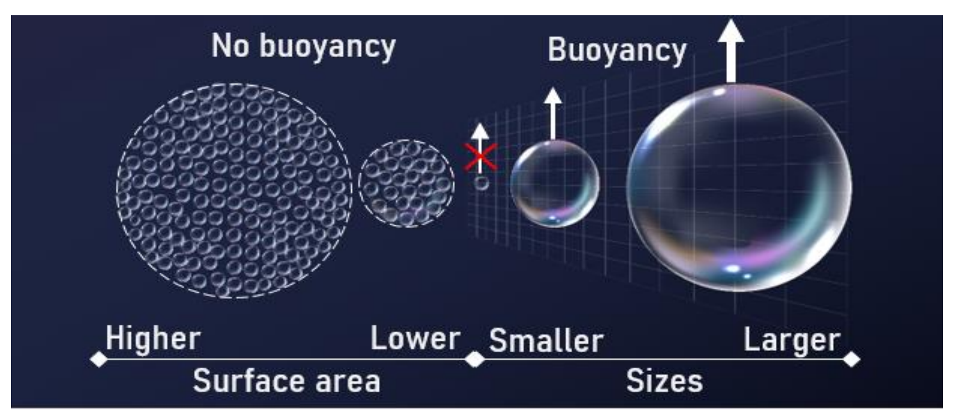
Background

Credit: Jesús Morón-López

Harmful algal blooms (**HABs**) occur when photosynthetic organisms rapidly grow into dense populations, often dominated by a single species. This study focuses on *Microcystis aeruginosa* (**blue-green algae**) and *Karenia brevis* (**red tide**) which both form HABs. Human activities such as agricultural runoff and **global warming** have intensified these events. HABs create **anoxic zones**, release **toxins**, and **reduce biodiversity**. *M. aeruginosa* produces microcystins, which damage the liver, kidneys, and reproductive systems and impair DNA repair. *K. brevis* releases brevetoxins, which attack the central nervous systems of marine animals, causing massive fish kills.

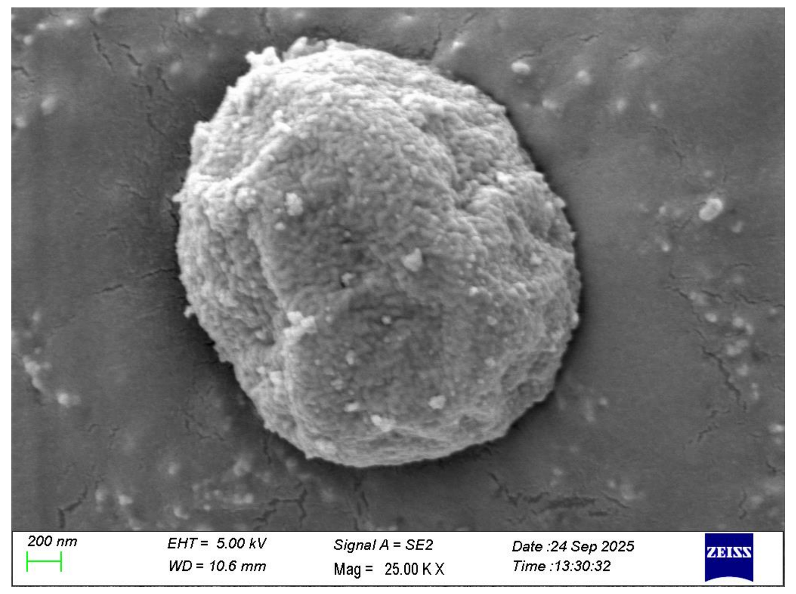
Ozone oxidation using **nanobubbles** (NBs) is a promising method for controlling HABs . NBs are tiny gas spheres about 100 nanometers in diameter. Unlike larger bubbles, they move through Brownian motion, have negligible buoyancy, and remain **stable for hours or days**. This stability enhances gas transfer and persistence in water. When combined with ozone, NBs **increase contact time** and **reduce the ozone dose** required for oxidation. Studies show that ozone NBs can lower the amount of ozone needed for effective contaminant control by roughly 70%, making them an efficient and sustainable water treatment technology.



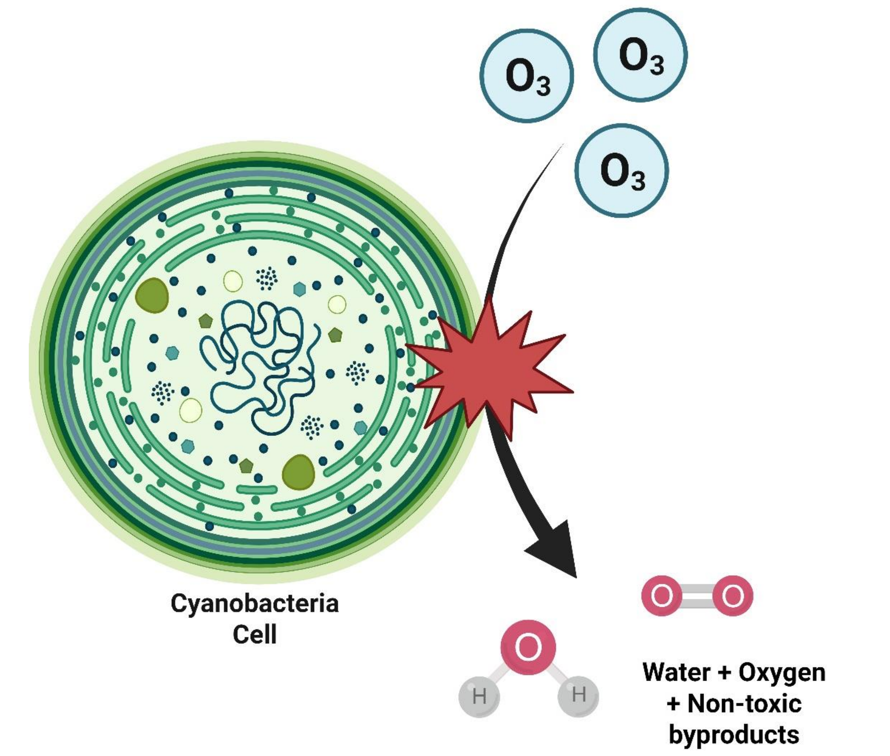


Credit: Morón-López, 2023. Journal of plant interactions, 18, 1.

Materials & Methods



M. aeruginosa SEM photo
Credit: Asma Sattar



Apparatus:

Ozone Generator: Converts oxygen gas in ozone gas. This is then injected into circulated water.

Nanobubble Generator: Static mixer with internal spiral grooves to create NBs through shear force.

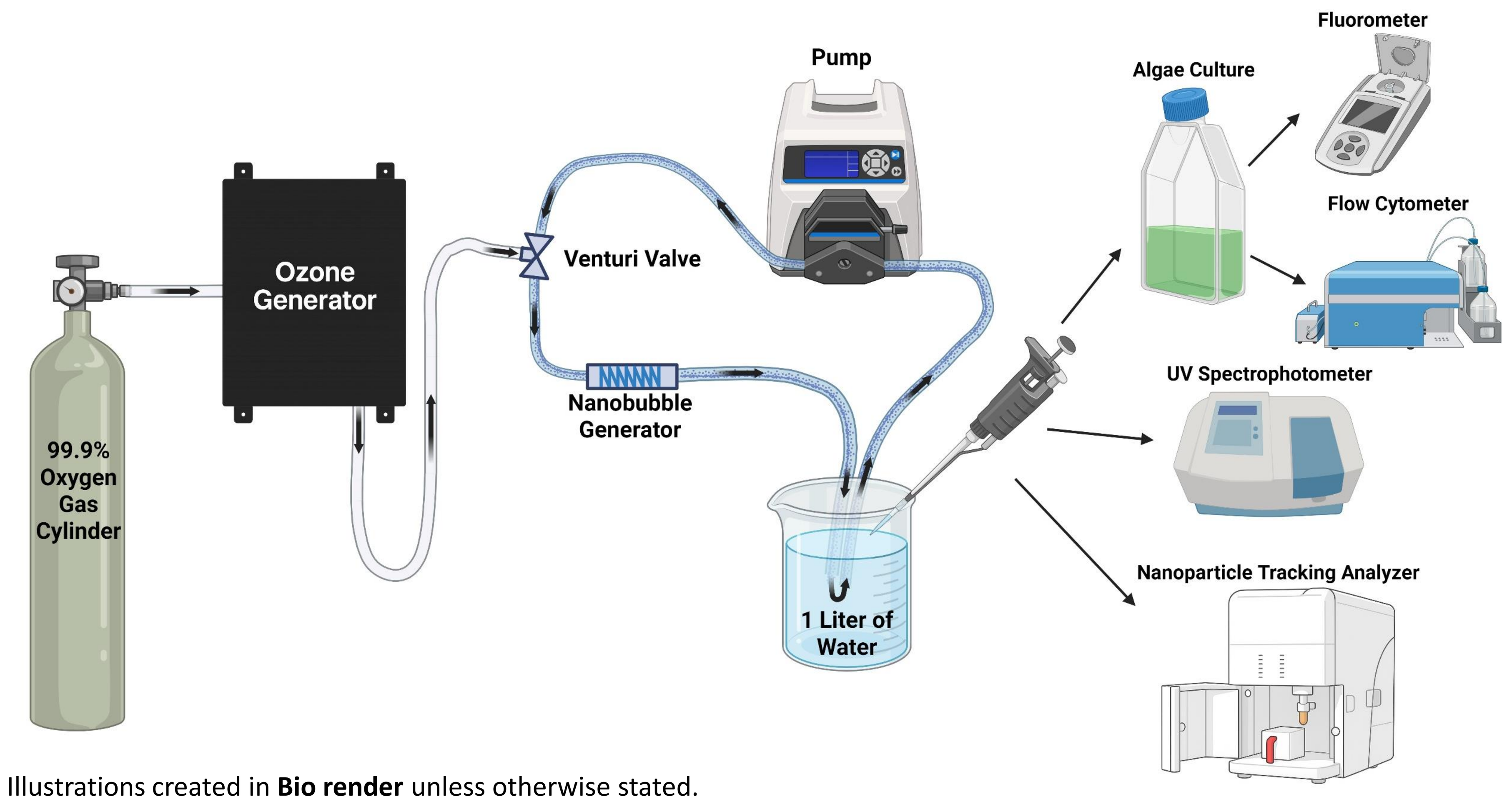
Pump: Circulates the water through a closed loop to generate NBs.

Fluorometer: Used to measure the photosynthesis efficiency.

Flow Cytometer: Measures the number, size, and health of cells

UV Spectrophotometer: Determines the ozone concentration.

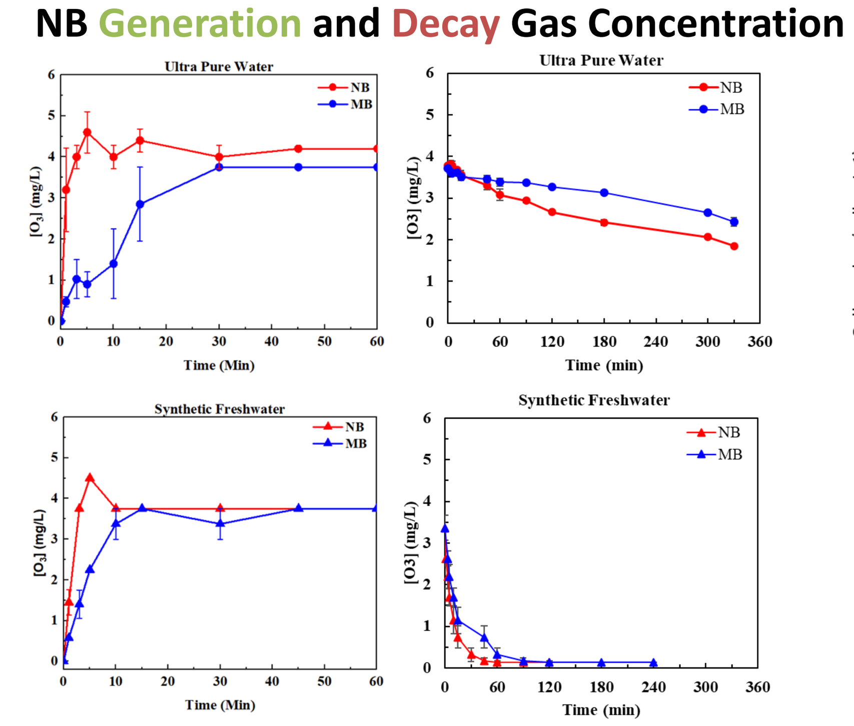
Nanoparticle Tracking Analyzer: Able to size and count nanoparticles, in this case NBs.



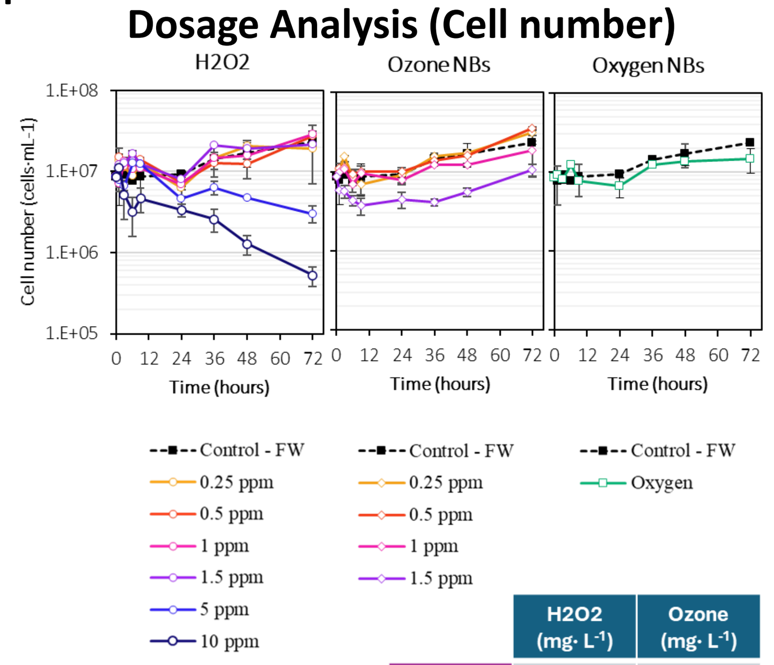
Illustrations created in **Bio render** unless otherwise stated.

Results & Conclusions

NB Generation and Decay Gas Concentration



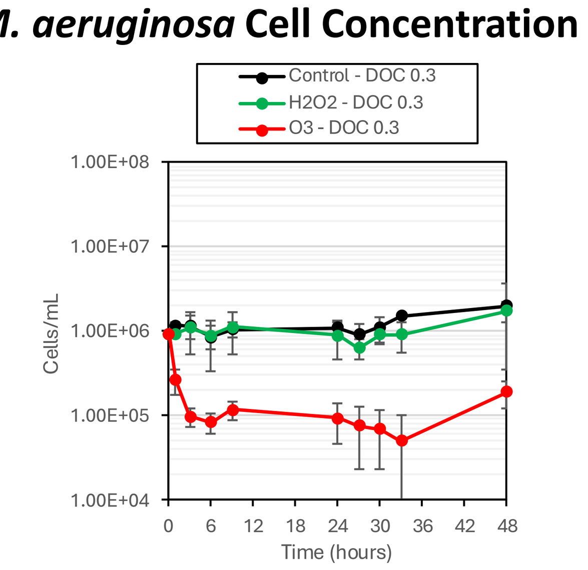
M. aeruginosa Treatment Optimal Dosage Analysis (Cell number)



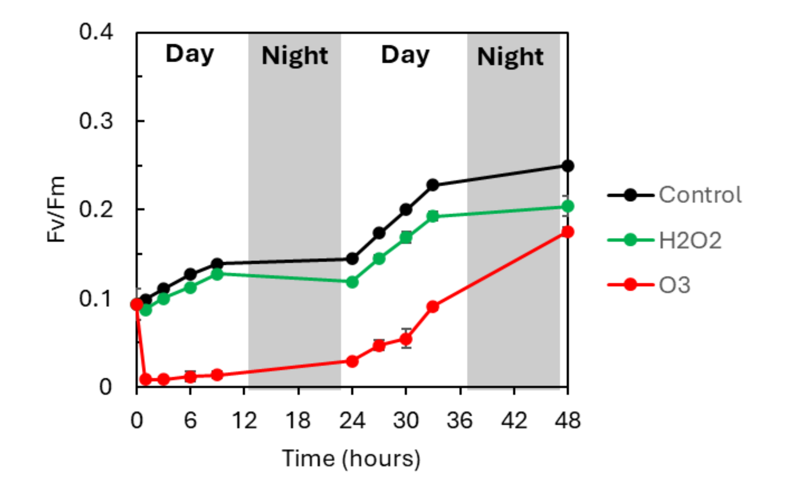
	H2O2 (mg·L⁻¹)	Ozone (mg·L⁻¹)
LC 50	6.50	<1.5

LC 50 : Concentration to neutralize 50% of individuals

M. aeruginosa Cell Concentration



M. aeruginosa Photosynthetic Efficiency



Ozone NBs **increased dissolved ozone concentrations more rapidly than macrobubbles.** They also were more reactive in freshwater, indicating limited persistence in natural environments, **potentially reducing harm to non-target organisms**. Ozone oxidation was **more effective than hydrogen peroxide** (a common algal bloom treatment) at reducing cell concentrations and photosynthetic efficiency. In dosage tests, **a quarter of the dose was required to neutralize 50%** of the *M. aeruginosa* population with ozone compared to hydrogen peroxide.

Future Work

During this research, blue-green algae became the primary focus since they are the most common organisms responsible for HABs in lakes across the United States and worldwide. Future work will test the stability of NBs in seawater and their effectiveness in controlling *K. brevis*. Additional experiments will compare NB stability across water matrices of varying salinities. Because salinity can influence NB behavior, one hypothesis is that increasing salinity enhances ozone NB reactivity.

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