Investigating plasma bubble treatment of algae under diverse water conditions

Next Water 2025

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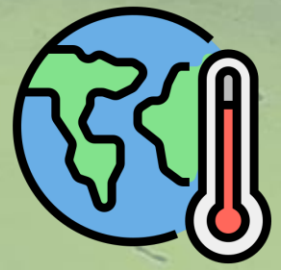
The Problem

Excessive nutrients & rising temperature

- Wastewater discharge
- Over population
- Global warming



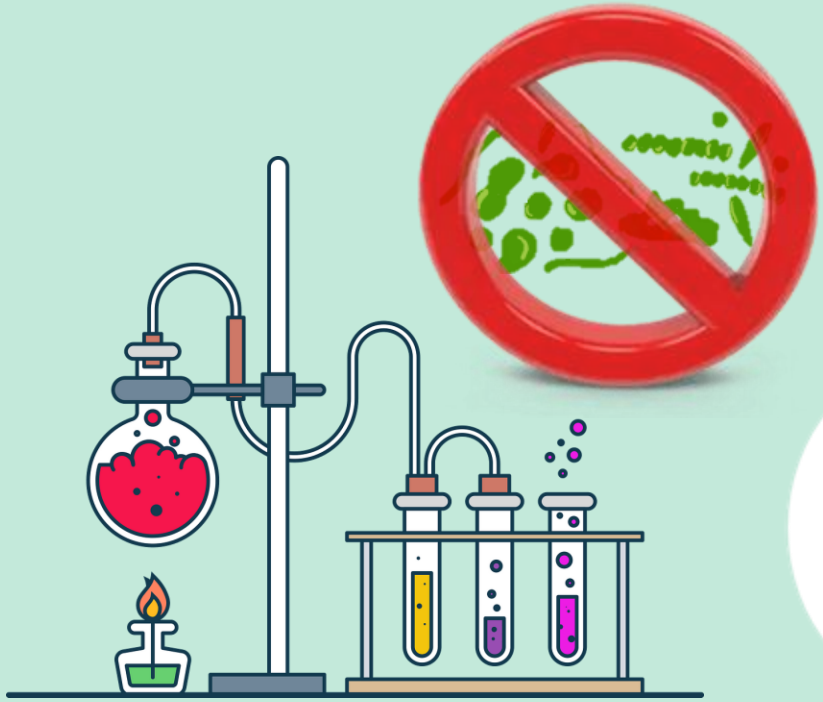
Undesirable quality for potable and industrial usages

- Toxins release
- Taste and odour compounds

Problems in water treatment

- Short filter runs
- Membrane fouling
- Risk of regrowth during distribution

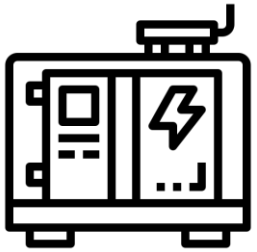
The Problem



Oxidation

Remove algae through the **morphological changes, inactivation** of algae cells and **degradation of associated matters**

Ozonation



Chlorination

UV irradiation

- Single oxidant can be inefficient for treatment of diverse algae species
- Chemical residual and disinfection by-product formation
- Unsustainable

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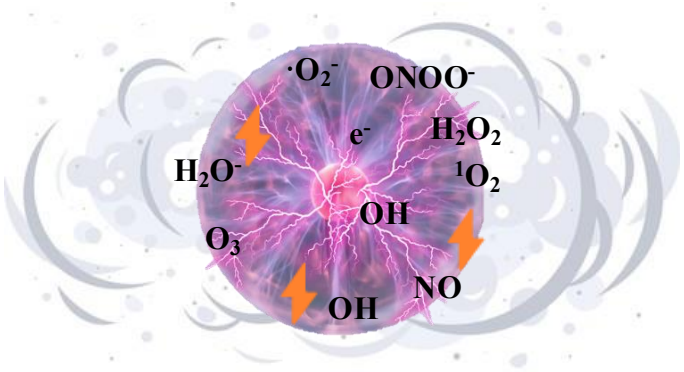
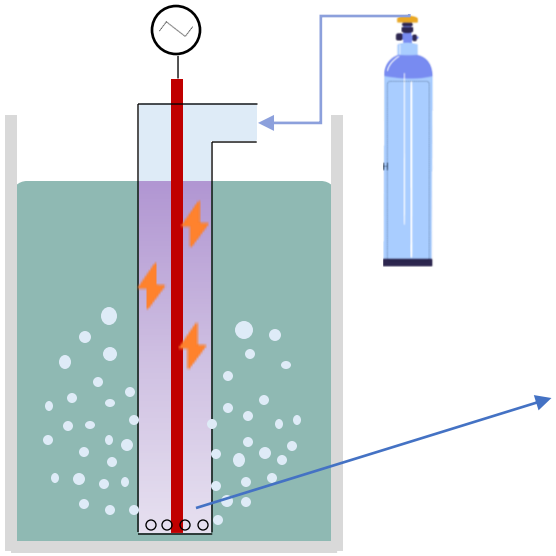
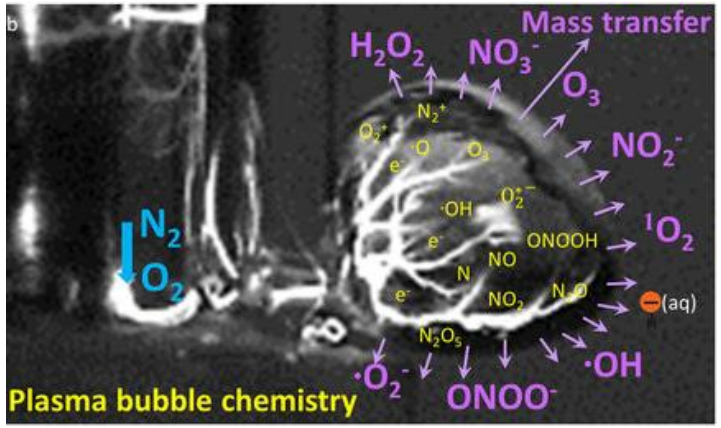
The Solution: Plasma Bubbles for Algae treatment



- Ionisation of atmospheric gas by an electric current
- Multiple **reactive species** generation (e.g. O_3, H_2O_2, $\cdot OH$, $\cdot O_2^-$, $^1O_2$, $\cdot NO$ radicals)





Using **bubble** to extend the lifetime and mass transfer of reactive species in solution

- ✓ Wide range of reactive species – applicable for varying pollutants
- ✓ Eliminate DBPs formation potential and toxins
- ✓ No chemical storage / handling required
- ✓ Sustainable
- ✓ Potential for lower operational costs with energy optimisation and the use of renewable electricity to drive the process.

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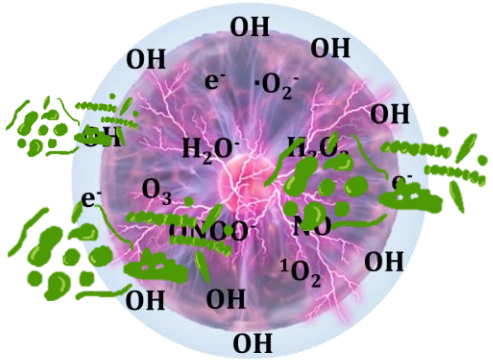
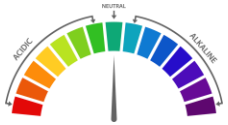
Research Objective & Plan



Performance changes

- Varying cell concentration
- Varying solution pH
- Varying solution salinity



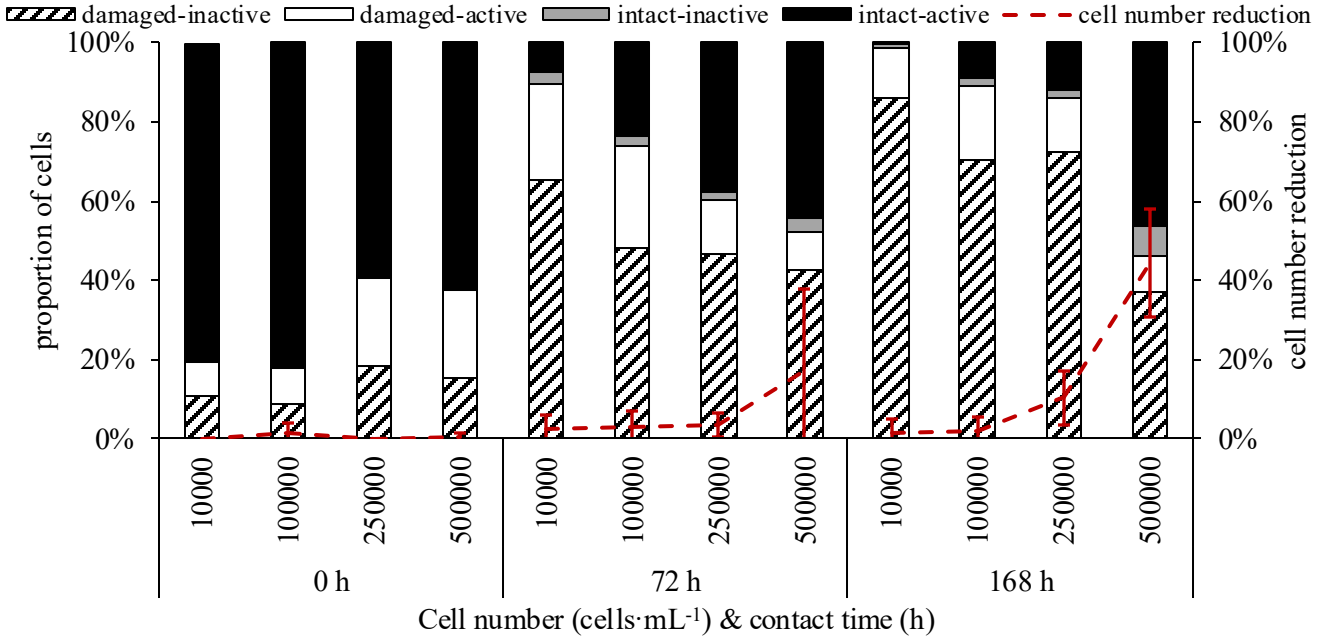
air

Chlorella vulgaris (CS-42/7)

Discharge in 10 min.
Store up to 168 h

- Cell count, integrity, and viability measurement
  - Flow cytometry – PI-FDA staining
- RONS measurement
  - H_2O_2 assay
  - NO_2^- assay
  - NO_3^- assay
  - O_3 assay

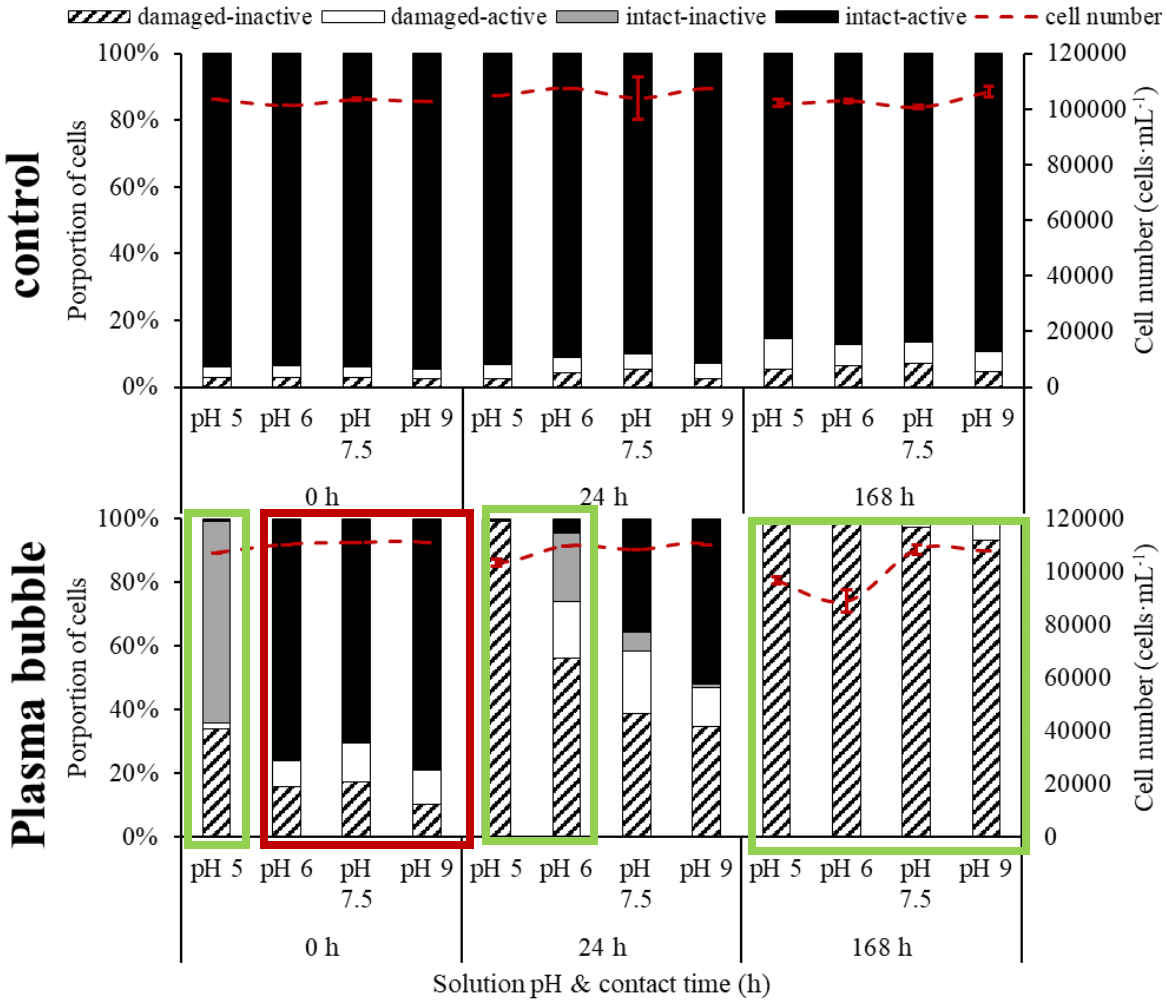
High density promotes reaction but consumes reactive species faster



- For water with lower algal cell numbers (< 10^5 cells·mL^{-1}), such as oligotrophic reservoirs or drinking water facilities. → Reactive species availability per cell would remain higher due to reduced competition

- Water with high algal cell numbers (10^5 – 10^7 cells·mL^{-1}), such as algal bloom events in source water, such as eutrophic lakes, or reservoirs → Greater immediate cell inactivation due to increased reactive species interactions Increasing reactive species generation is needed to ensure 100% cell inactivation.

Acidic conditions → faster oxidation by stronger oxidants



- Acidic conditions (pH 5 – 6) promoted immediate oxidative stress and greater algal inactivation.
- Neutral and alkaline conditions would have slower but steady oxidation.
  - ➢ pH adjustment before treatment

Acidic (pH 5-6)

$O_2^- + H^+ \rightarrow HO_2^{\cdot}$

$ONOO^- + H^+ \rightarrow ONOOH \rightarrow \cdot OH$ and NO_2

(more reactive)

Alkaline (pH 7.5-9)

decomposition of H_2O_2 into HO_2^-

$\cdot OH \rightarrow O^{\cdot -}$

(less reactive)

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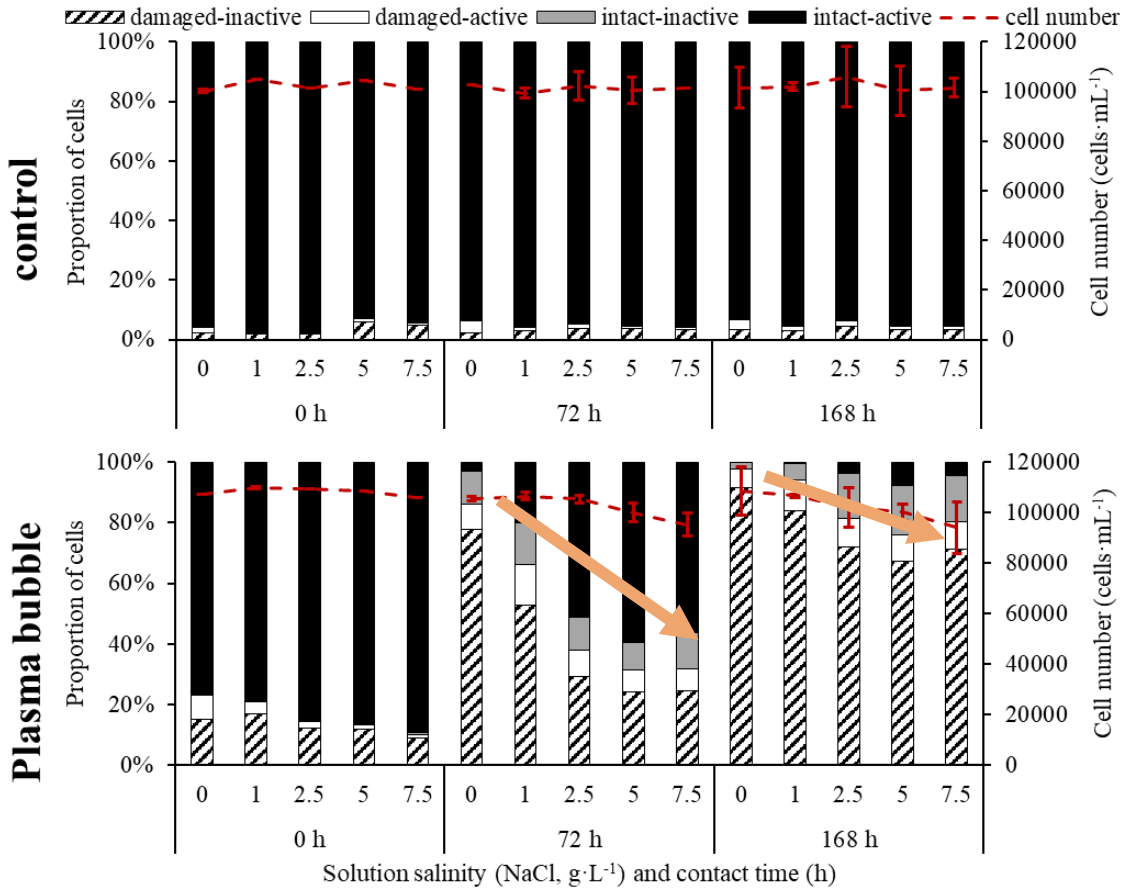
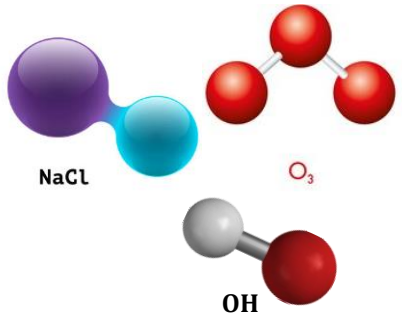
High salinity = poor performance



- Plasma bubble treatment efficiency is reduced due to the dominance of Cl^- reactions that quench reactive species
- Not ideal for water with high salinities (≥1 g NaCl/L)

$$Cl^- + OH \rightarrow Cl + OH^-$$

$$Cl^- + O_3 \rightarrow ClO^- + O_2$$



Key Takeaways

- ✓ Plasma bubble oxidation effective but sensitive to water conditions.
- ✓ By optimising plasma bubble treatment across diverse water qualities, we can enhance the resilience of water treatment processes in the face of climate change.

Factor	Better Outcome When…	Implication for Industry
Concentration	Low-to-medium algal density	Use for pre-oxidation, early intervention
pH	Acidic (pH 5–6)	Potential pH adjustment before treatment
Salinity	Low (≤1 g/L NaCl)	Not ideal for brackish or seawater

- ➢ Next steps: Scale-up, real water systems, combine with other treatment methods for optimisation.

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