# Reduction of Biofilm Formation by Magnetic Treatment

Aidan Foster and Ian Pepper
University of Arizona

**RESEARCH PROGRESS REPORT**
**UA-2023-02**
**STATUS:** ***Continuing, No Additional Funds Requested***

***Relationship to Technology Roadmap:*** ***Novel Water Treatment Technologies***

**Rationale:**

Biofilms can harbor potential pathogens and present a risk to public health if not properly managed or prevented in water systems. Prior studies have demonstrated magnetic water treatment has the potential to kill bacteria in established biofilms and prevent scaling of pipes. Magnetic treatment should be investigated as a tool to help prevent biofilm formation and improve biofilm management strategies.

**Objectives:**

- Investigate magnetic treatment as a tool to prevent biofilm formation under different conditions.
- Observe changes in the rate/frequency of biofilm formation under magnetic treatment.
- Assess if magnetic treatment can be used synergistically with disinfectants for biofilm management.

**Accomplishments:**

- Magnetic treatment appears to delay the formation and frequency of biofilm by ~0.95 log10 CFU and ~1.94 log10 CFU at 8 and 12 hours, respectively.
- Demonstrated magnetic treatment can reduce the concentration of biofilm formation in Tap $H_2O$ and di$H_2O$.

**Approach:**

- Form *Pseudomonas fluorescence* biofilms in a recirculating system under magnetic treatment.
- Measure the presence and magnitude of viable cells on stainless steel coupons over time.
- Evaluate any potential synergistic effects between magnetic treatment and chlorine for biofilm control.

**Key Deliverables:**

- Peer review publications
- Determine the applications and impacts of magnetic treatment to prevent the formation of biofilms.

**Project Duration:**

January 2024– December 2024

**Budget:**

No additional funds requested

# Reduction of Biofilm Formation by Magnetic Treatment

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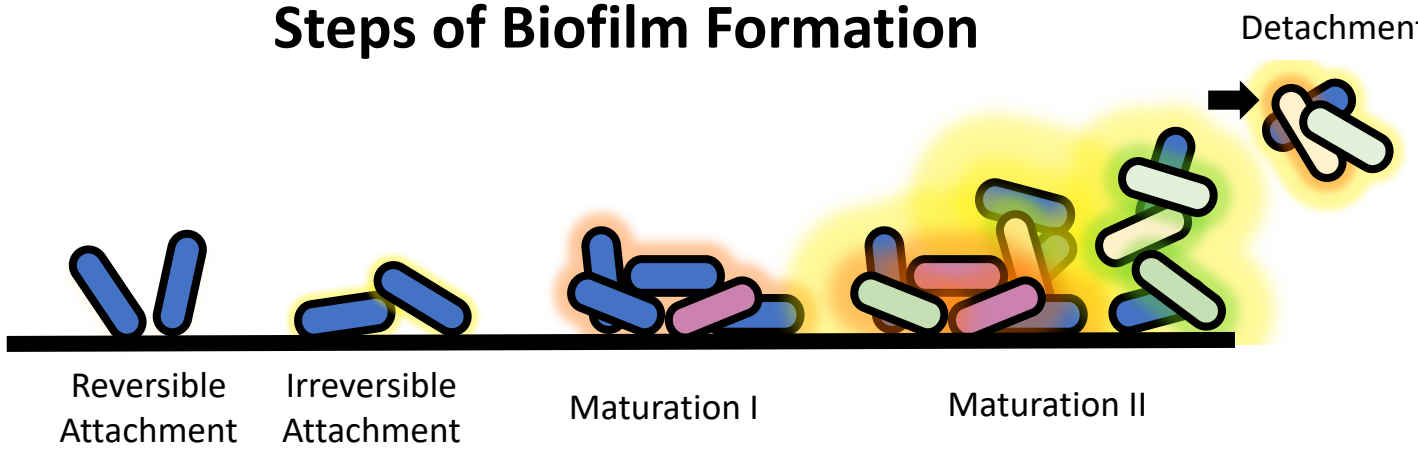
# Introduction: Biofilms

**Biofilms**

- Biofilms are an organized aggregate of extracellular polymeric substances (EPS) and sessile microbial communities irreversibly attached to a substrate or interface.
- May harbor pathogenic bacteria.
  - *ex. Pseudomonas aeruginosa* and *Legionella pneumonia*
- Biofilm associated bacteria have an increased resistance to chemical disinfectants.
- Costly and difficult to manage.

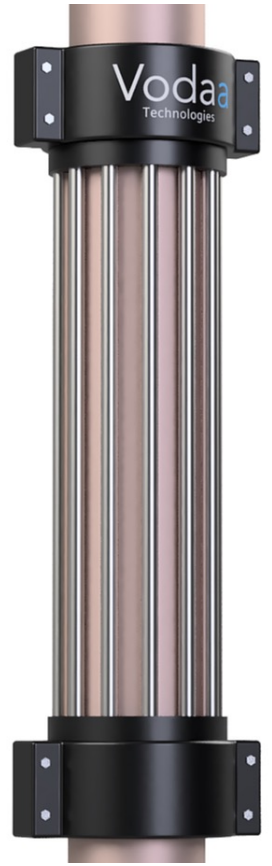
**Steps of Biofilm Formation**



# Introduction: Magnetic Water Treatment

**Magnetic Water Treatment**

- Influences charged particles and reactions.
- Utilized in some industrial settings to remove pipe scaling.
- Alters metabolic processes in bacterial cells.




Vodaa Clamp-on Unit (VCU)

# Introduction: Magnetic Water Treatment

**Magnetic Water Treatment**

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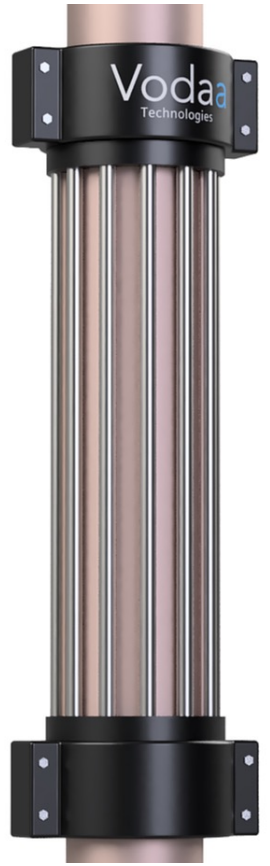
**Previous findings using Vodaa Technology Magnetic Devices:**

- Reduction of chlorine demand in simulated pool systems by 13.8%.

- Decreased the number of viable cells in established biofilms 2.46 Log10 CFU/$cm^2$ over 15 days with no disinfectant.

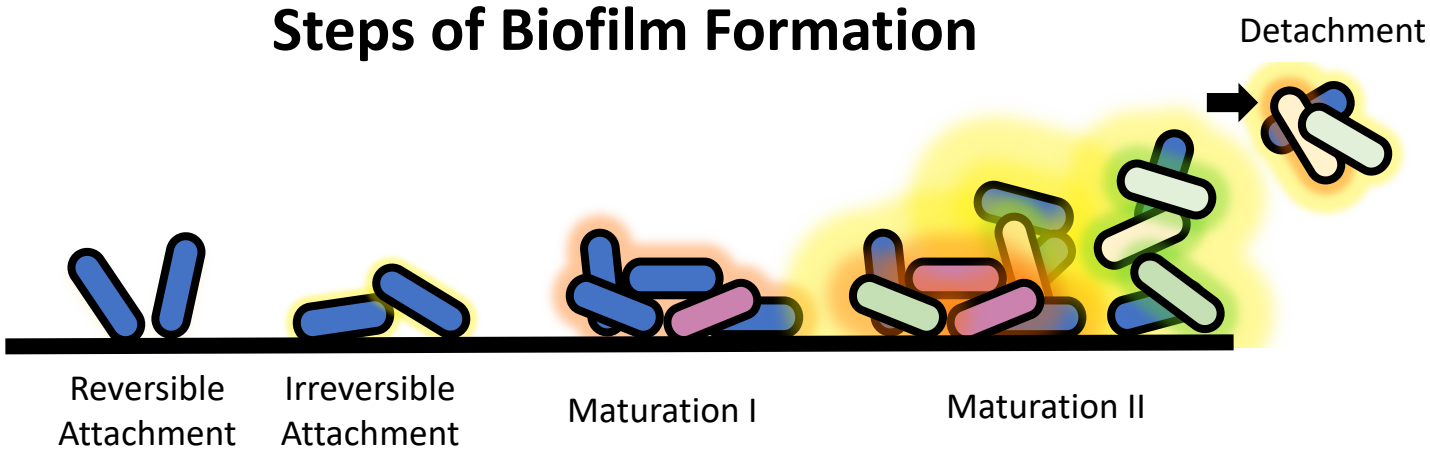


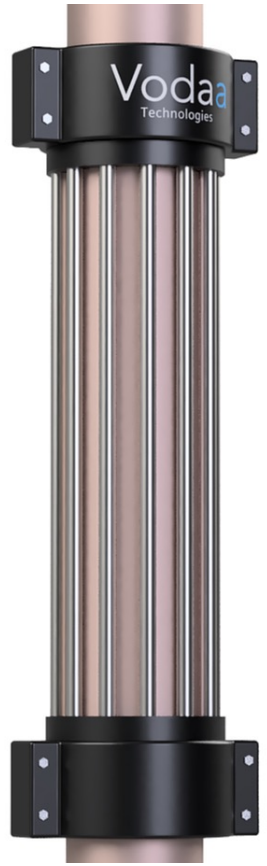

Vodaa Clamp-on Unit (VCU)

# Introduction: Magnetic Water Treatment

**Research Question:**

- Can magnetic water treatment be used to decrease the amount of biofilm that forms?
- Does magnetic treatment enhance the efficacy of disinfectants (free chlorine)?



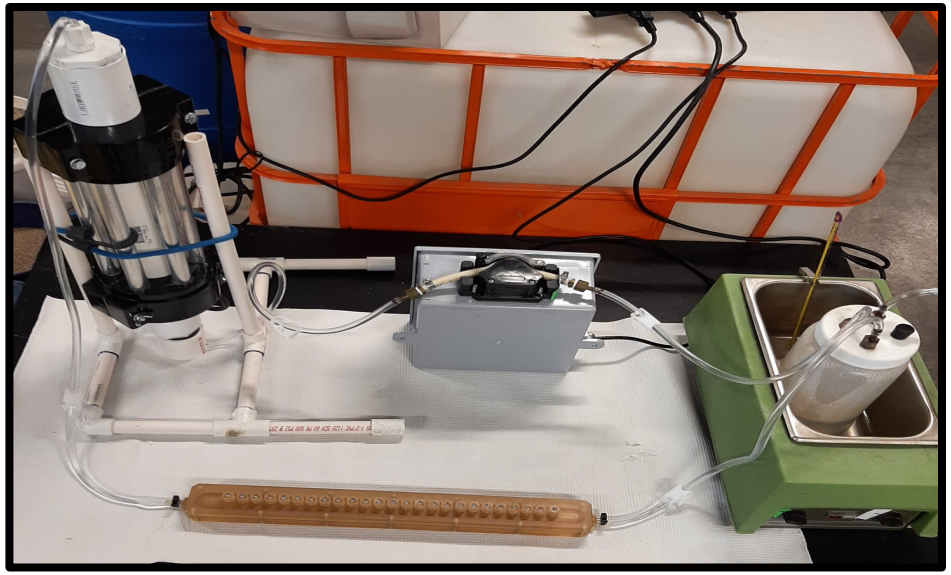




Vodaa Clamp-on Unit (VCU)

# Experimental Methods

Magnetic water treatment

- Use either tap $H_2O$ or di$H_2O$.
- Supplement with 0.1% nutrient broth (v/v).
- Add *Pseudomonas fluorescence* at a concentration of $10^4$ CFU/mL.
- Apply magnetic treatment.
- Recirculate at 100mL/min at 26°C.



Experimental setup for magnetic treatment

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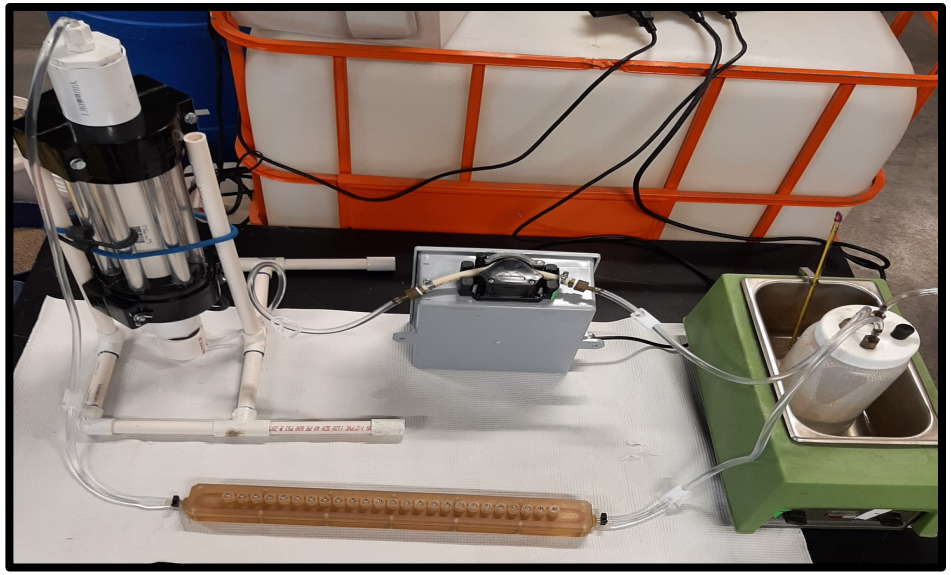


Experimental setup for magnetic treatment

**Note:** The magnetic field does not extend into the MRD.

# Quantification of Bacteria

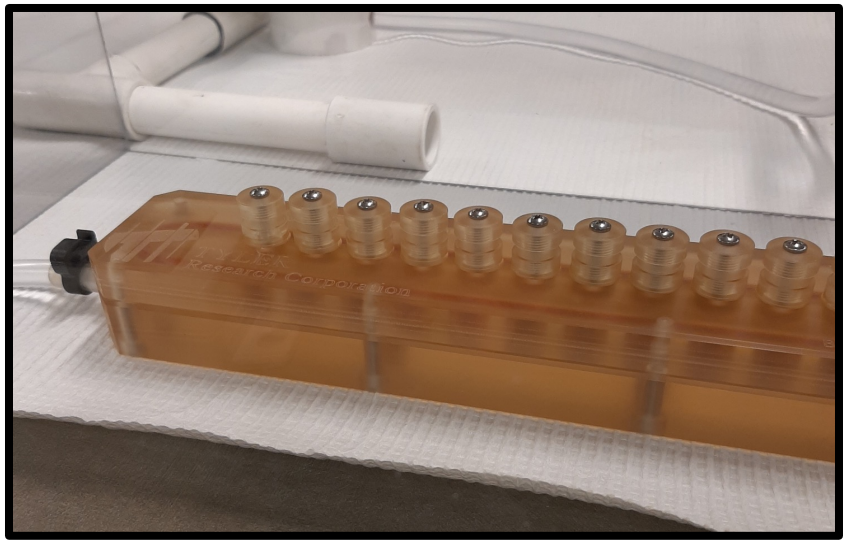
Dilution and Plating

- Number of viable *P. fluorescence* determined by dilution and plating on nutrient agar.

Cell stress

- ATP, AMP, and AMPi (cell stress) are determined through LuminUltra DSA kit

$$AMPi = AMP/ATP$$



Modified Robins Device for biofilm formation

# Quantification of Bacteria

## Dilution and Plating

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## Cell stress

- ATP, AMP, and AMPi (cell stress) are determined through LuminUltra DSA kit

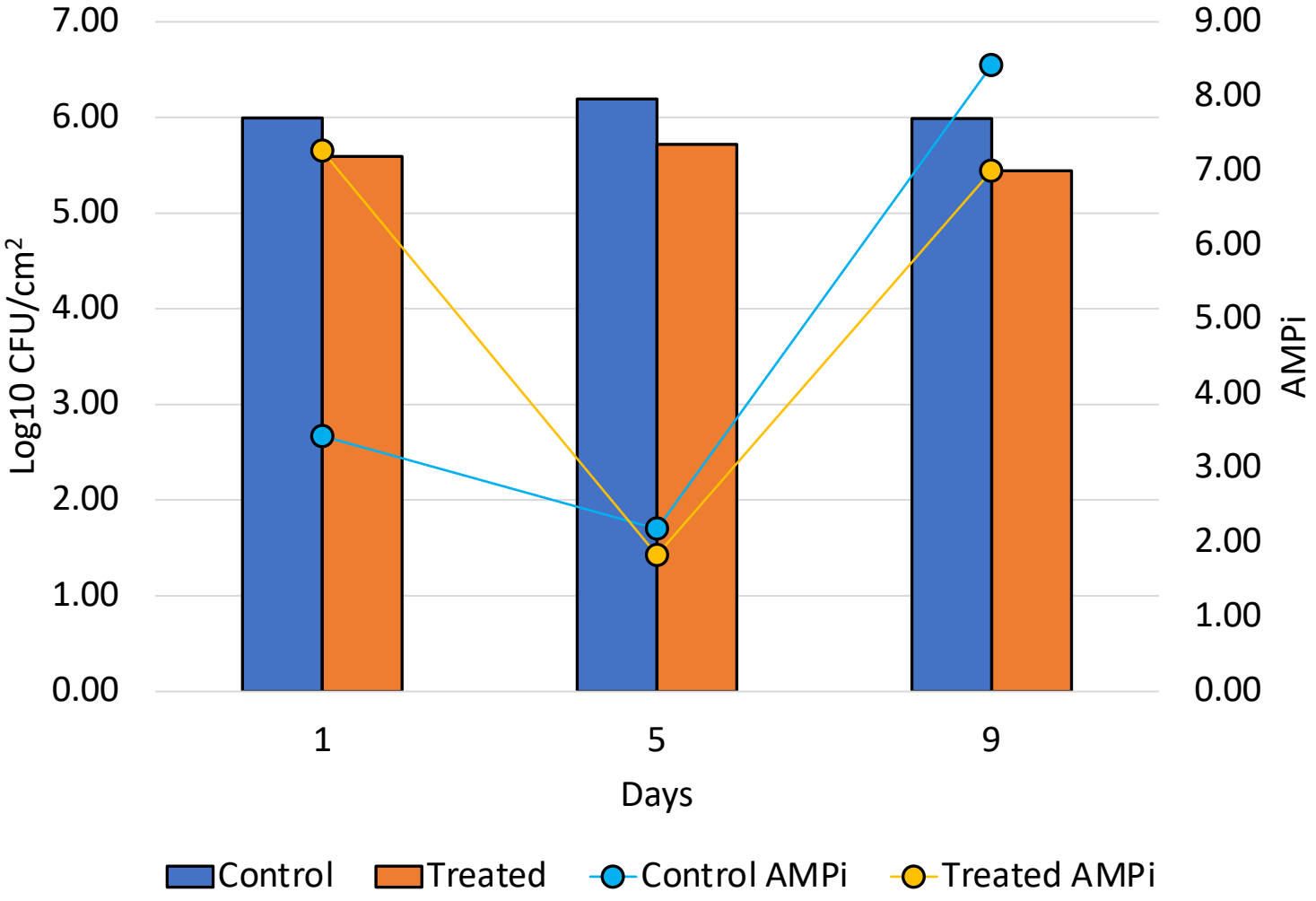
$$AMPi = AMP/ATP$$

Stainless steel coupon
(surface for biofilm)

Dilution and Plating


Cell Stress

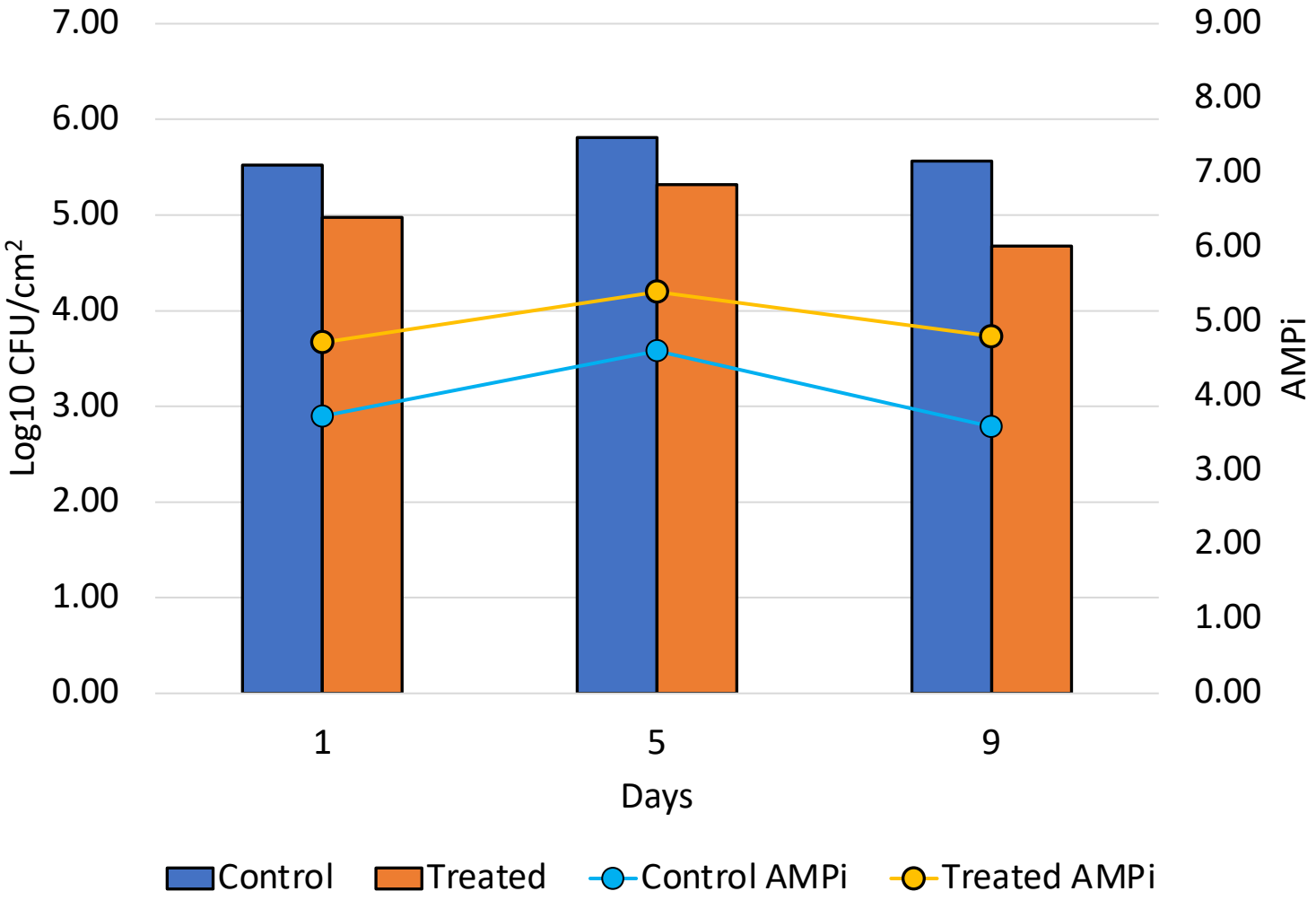
# Prevention of Biofilm by Magnetic Treatment - Tap $H_2O$




| Tap H2O | | |
|---|---|---|
| **Days** | **Log10 reduction** | **% reduction** |
| 1 | 0.40 | 60.32 |
| 5 | 0.47 | 66.18 |
| 9 | 0.54 | 71.36 |

Log10 reduction = Control - Treated

# Prevention of Biofilm by Magnetic Treatment - diH2O



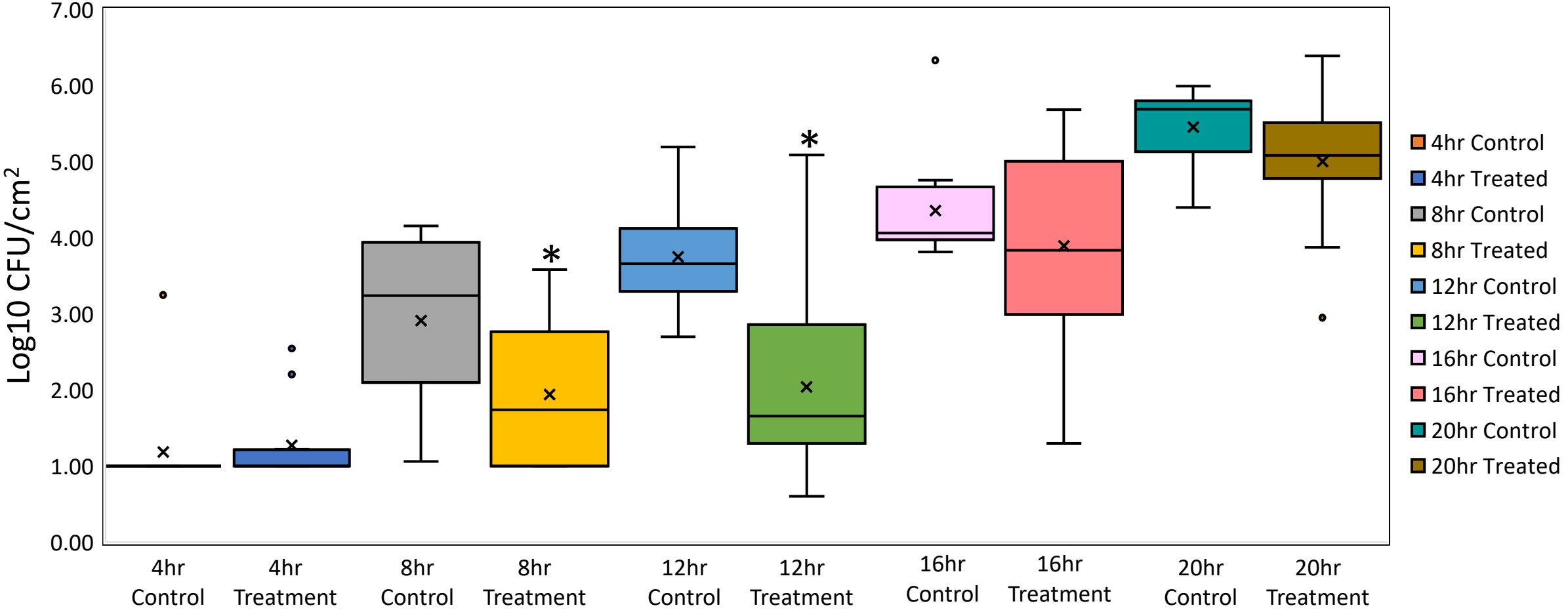

| diH2O | | |
|---|---|---|
| **Days** | **Log10 reduction** | **% reduction** |
| 1 | 0.55 | 71.56 |
| 5 | 0.49 | 67.97 |
| 9 | 0.89 | 87.07 |

Log10 reduction = Control - Treated

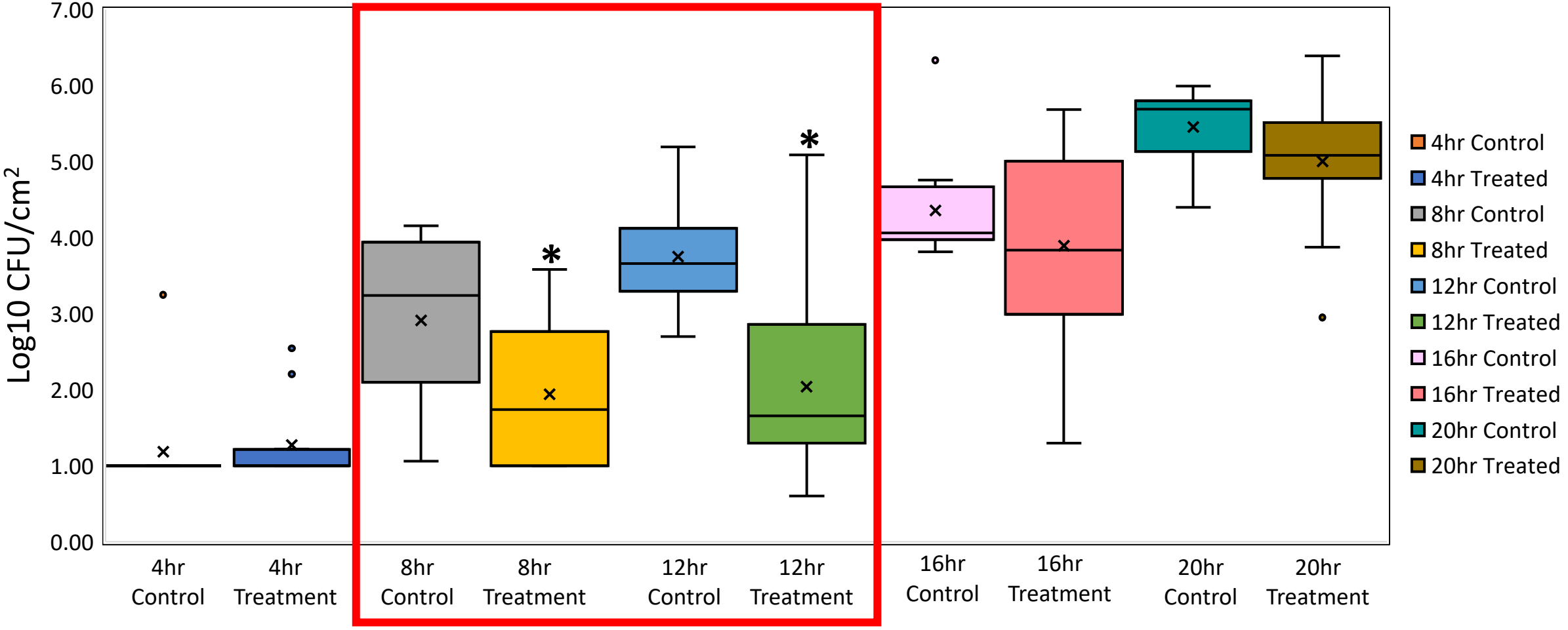
**Conclusions**

- Slight decrease in number of bacteria in treated systems.
  - Treatment more effective in $diH_2O$
- AMPi indicates stress levels are similar across treated and untreated.

# Prevention of Biofilm by Magnetic Water Treatment

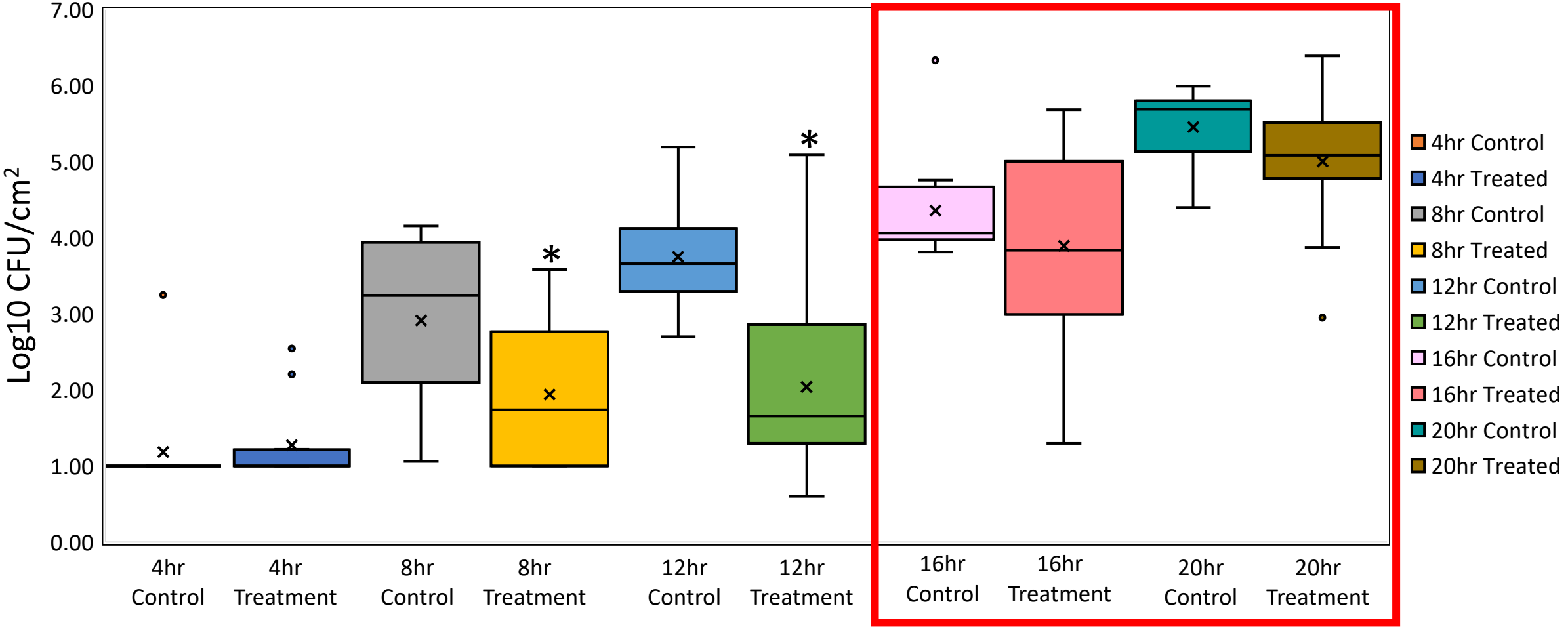


# Prevention of Biofilm by Magnetic Water Treatment




- The number of viable cells in the biofilm were significantly reduced ($p < 0.05$) when formed under magnetic treatment when compared to the control.
  - 0.95 Log10 CFU/cm$^2$ fewer (88.7%) after 8hr of magnetic treatment.
  - 1.94 Log10 CFU/cm$^2$ fewer (98.8%) after 12hr of magnetic treatment.

# Prevention of Biofilm by Magnetic Water Treatment




- 0.67 and 0.5 Log10 CFU/cm² difference in viable cells at 16hr and 20hr respectively.

# Conclusions

- Biofilms formed under magnetic water treatment have fewer viable bacteria than the control across 9 days.
  - 71% and 87% less in Tap $H_2O$ and di$H_2O$ respectively.

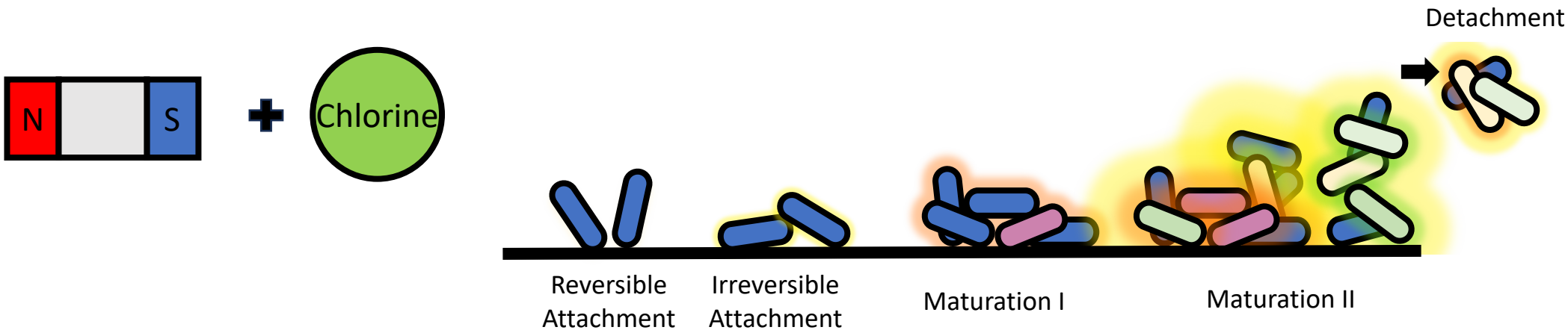
- The amount of biofilm was significantly ($p < 0.05$) lower at 8hr and 12hr of treatment.
  - 0.95 Log10 CFU/$cm^2$ less at 8hr of magnetic treatment.
  - 1.94 Log10 CFU/$cm^2$ less at 12hr of magnetic treatment.

- Magnetic treatment appears to hinder initial attachment of cells.

# Future Works

- Evaluating the effect of magnetic water treatment with the addition of a disinfectant (free chlorine).

- Evaluation of biofilm structure after magnetic water treatment using microscopy.



# Acknowledgements

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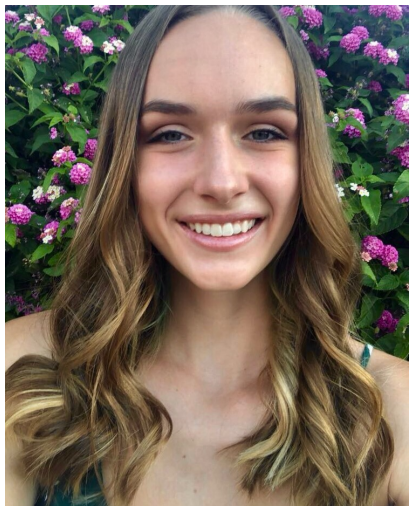

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**Water & Environmental Technology Center**

Vodaa Technologies

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# Questions?

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