Anti-Biofouling Surface Treatments for Improved Condenser Performance for Coal-Based Power Plants

The 2021 DOE/FE Spring R&D Project Review Meeting, May 11-12, 2021

Project: DE-FE0031764

DOE Program Manager: Debalina Dasgupta

RTI INTERNATIONAL

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Project Summary

- **DOE Award No.** DE-FE0031483
- **Total project value**: $1,668,172
  - DOE Share: $1,350,537 (80%)
  - Cost Share: $337,635 (20%)
- **Period of Performance**: 9/13/2019 to 9/12/2022 (2 x 18 mos.)
- **Project Team**:
  - RTI International (Prime Recipient)
  - Arkema
  - Agile Sciences

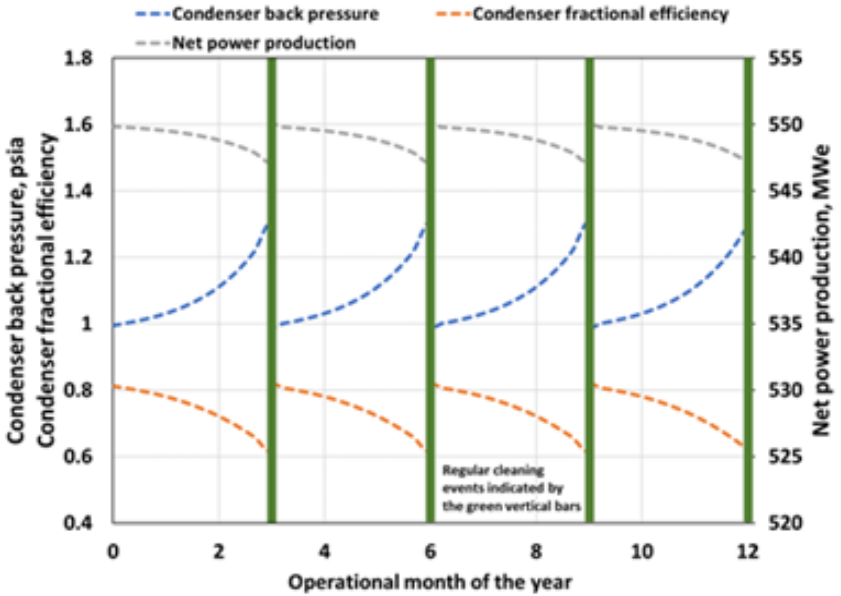
- **Project Objectives**:

  Design and engineer novel surface treatments and secondarily applied remediation components to mitigate biofilm growth on condenser tube surfaces used in coal-fired power plants. Such modified surfaces can potentially disrupt the landscape for emerging anti-biofouling technologies and significantly improve plant efficiency.

Project Team

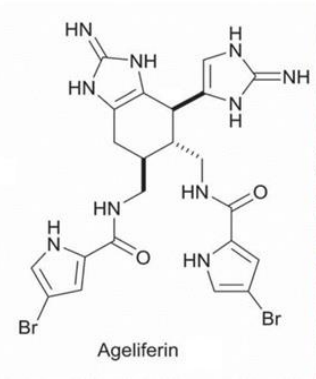
Team Member	Role
RTI International	▪ Prime Recipient ▪ Development and testing of 2-AI surface treatments ▪ MP based secondary additives for a biocidal properties ▪ Bench to prototype technology demonstrating using real cooling water sources (fresh/seawater) ▪ Techno-economic process analyses
Arkema	▪ Industrial partner ▪ Coatings Solutions R&D to provide technical guidance on selection and synthesis of coatings ▪ $80,000 CS
Agile Sciences	▪ Industrial partner ▪ Technology provider – access to 2-AI library (>800 unique compounds) ▪ $10,000 CS

Biofouling in Condensers Limits Power Efficiency



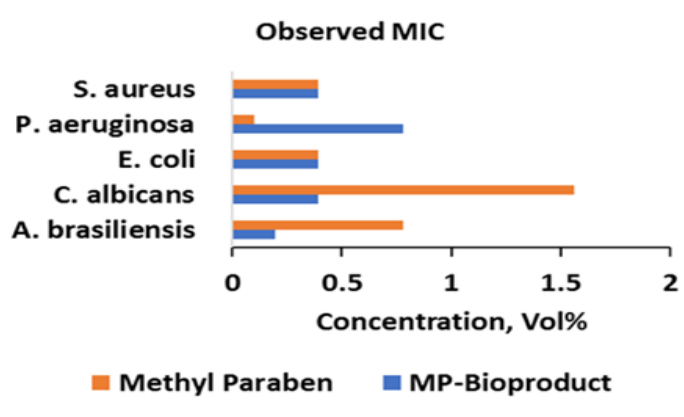
- Backpressure is measure of condenser fouling, both power and efficiency decline as heat transfer decreases.
- Shutdowns for maintenance are high-cost events

Two Pathways Proposed for Biofilm Control in Condensers



Pathway 1 – anti-biofilm surface treatment

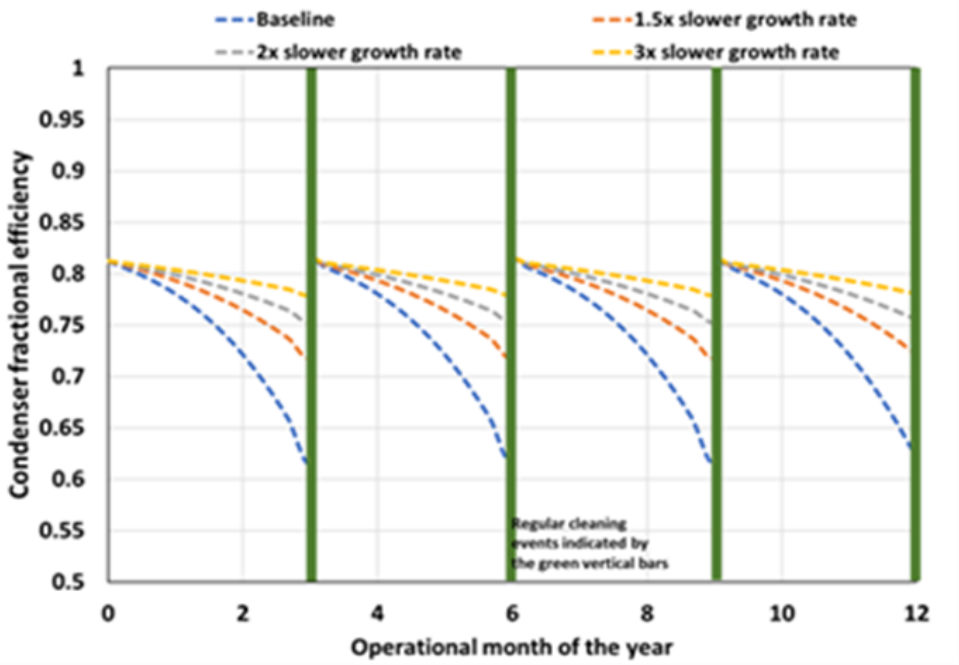
- Goal – develop a 2-AI based coating for stainless steel (SS) and titanium (Ti) condenser surfaces with wide-spectrum bio-inhibitory effects



Pathway 2 – additives to disrupt established biofilms

- Goal – develop a dose-response understanding of MP as a biocide to disrupt established biofilms

Potential for Significant Impact in Energy Savings



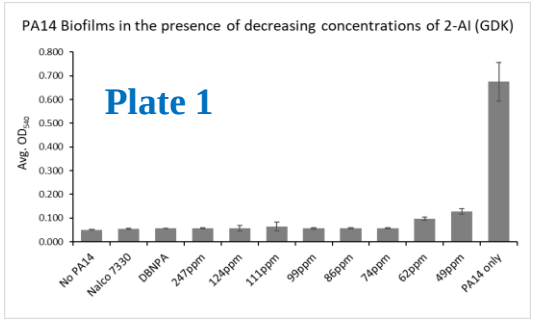
- Blue baseline, relative to growth rate reduction of 1.5x, 2x, and 3x
- Condenser efficiency increases from 62% to 72-78%
- Equivalent to operational revenue savings of more than $0.5M annually (550 MWe)
- This does not include savings from reduction in plant shutdown frequency

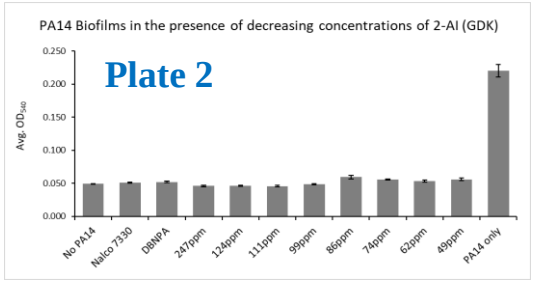
Project Milestones (BP1)

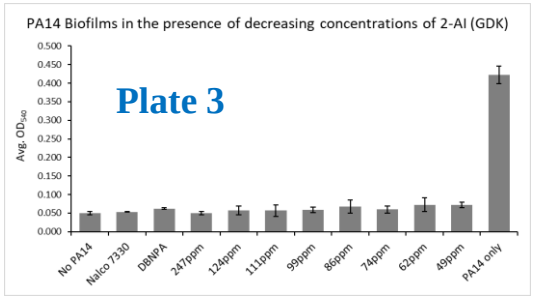
Task No.	Milestone Title & Description
1.0	Updated Project Management Plan (PMP)
1.0	Project Kickoff Meeting
2.1	2-AI Compound Selection – Identification of at least one unique 2-AI that inhibits microbial population growth from power plant source water as demonstrated by 96-well plate format
2.2	2-AI Surface Treatment Formulation – Surface treatment on stainless steel and titanium tube substrates containing 2-AI at target concentration (determined from Subtask 2.1) at thickness <4mil for
2.3	High fidelity test on metal, continuous test of the surface treatment such as integrity and 2-AI release into the water body additive formulation for established biofilm disruption
3.1	Low dose mitigation with MP <0.5 ppm for continuous dosing
3.2	High dose mitigation with MP <2 – 10 ppm for shock dosing
4.0	Go/No-Go Decision Point. High Fidelity Demonstration of Biofilm Inhibition: Experimental data with surface treated tube showing biofilm mitigation, defined as growth reduction by at least 50% relative to control growth system (note: biofilm thickness measured microscopically)

2-AI Compound Selection – Identification of at least one unique 2-AI that inhibits microbial population growth from power plant source water as demonstrated by 96-well plate format

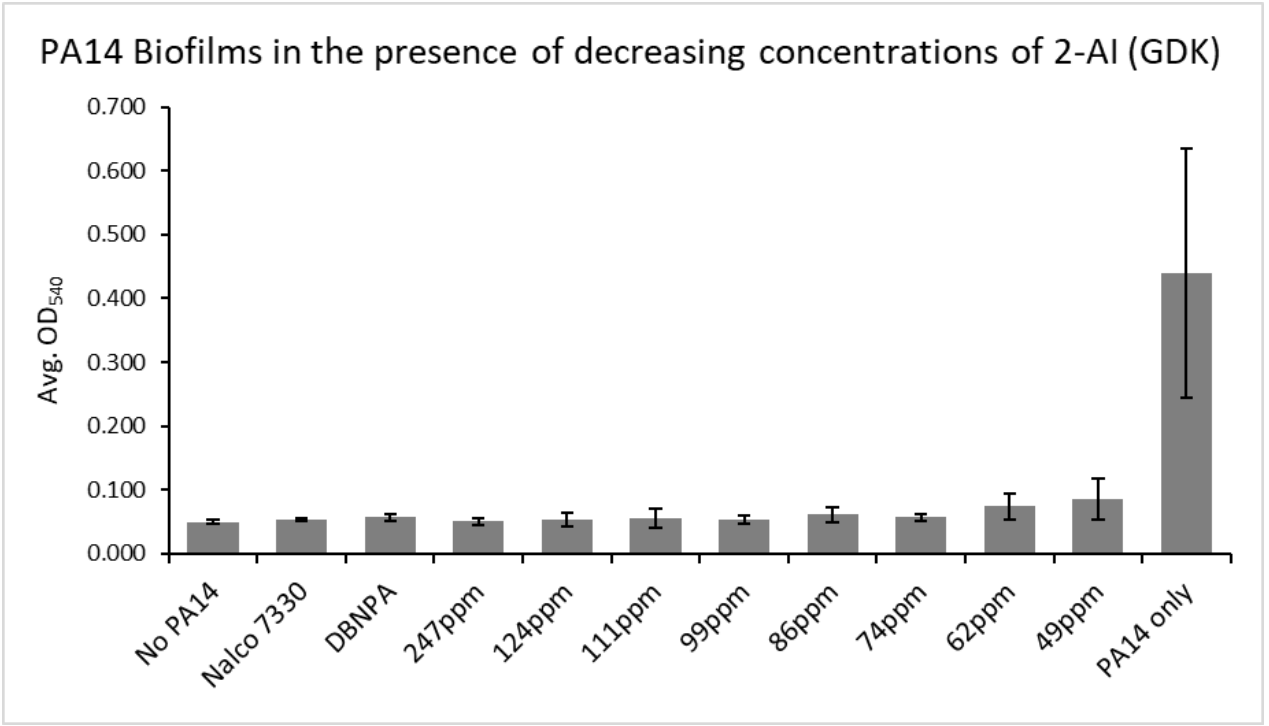
Plate Layout x3 (Run 2-AI test in triplicate)



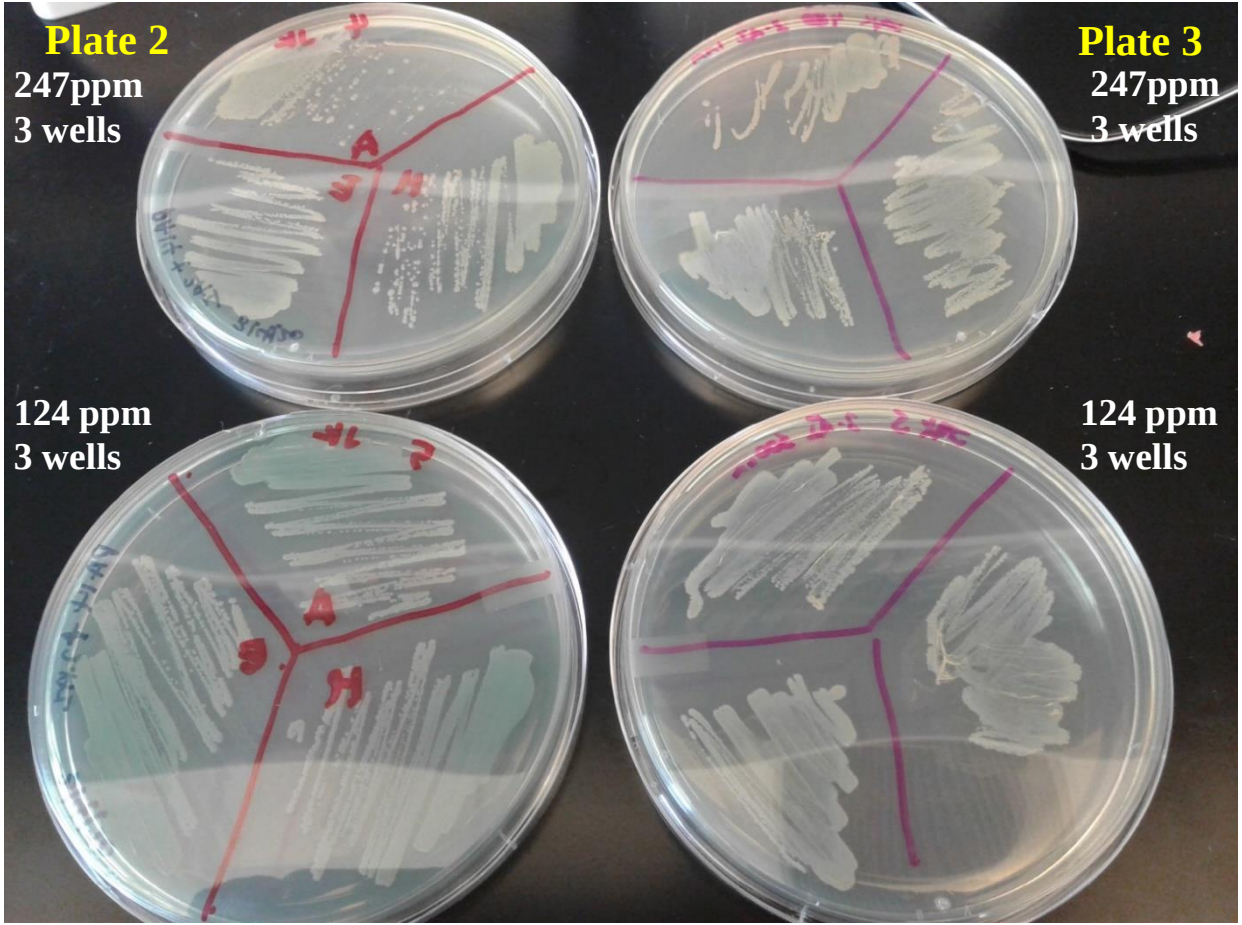




PA14 Stained Biofilms (all plates combined) – OD_{540}



Higher Concentrations of 2-AI Did Not Kill The Bacteria

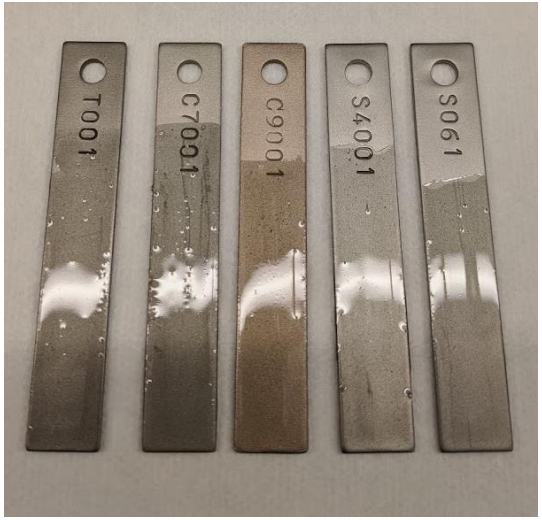


2-AI Surface Treatment Formulation –
Surface treatment on stainless steel and titanium tube substrates containing 2-AI at target concentration (determined from Subtask 2.1) at thickness <4mil for

Coupon Coating Application

Different copolymer formulations were tested including:

- **Different coupons (Ti & SS)**
- **Powder coating stoichiometry : adhesion promoter**
- **Hydrophobic/hydrophilic balance variations**
- **2-AI concentration**
- **Film thickness**
- **Biofouling performance**

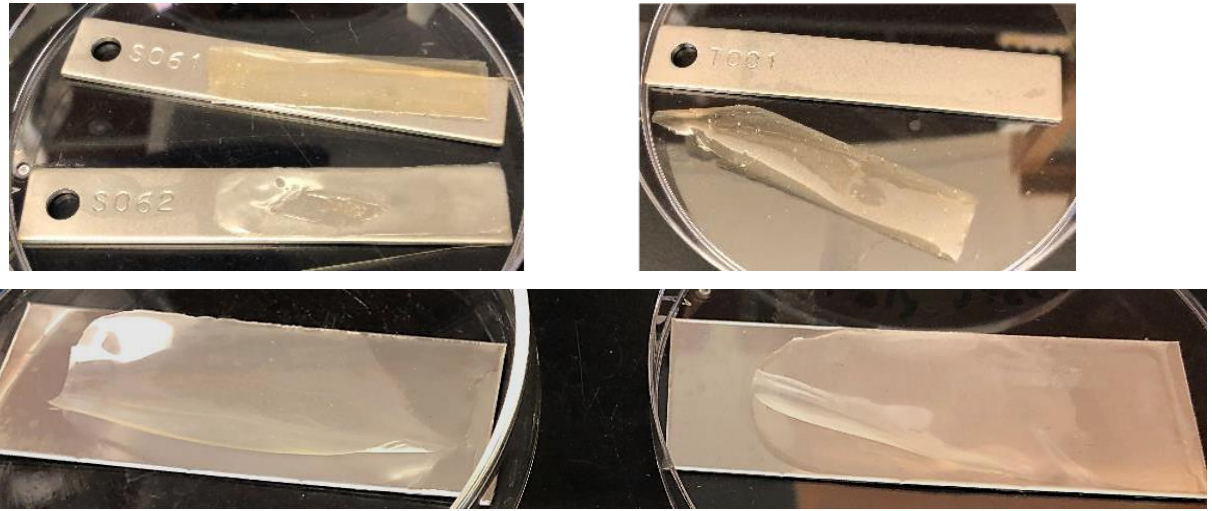


Antibiofilm coating stability in water

After 48-hours drip flow

- Most of the polymers (w/ and w/o 2-AI) detached partially or completely from the surface of the coupons (SS and Titanium).

- **Images are example:**

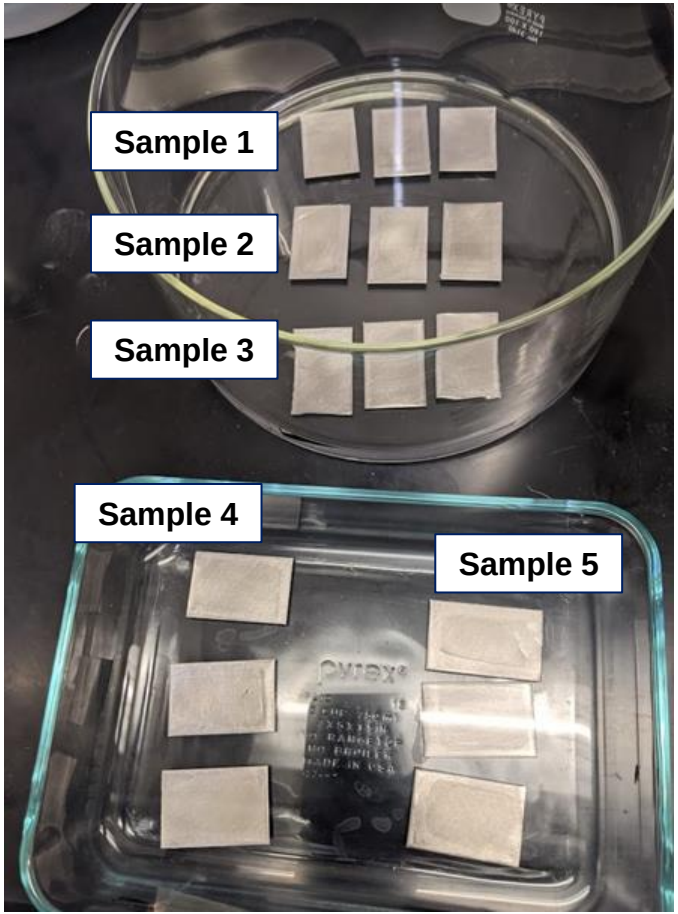


Antibiofilm coating stability in water

- The surface abraded Stainless steel 316 coupons with various polymer coating shown in the table have been immersed in DI water in the hood for **6 days**. No noticeable changes have been observed and the films appear to still be well adhered to the stainless-steel coupons.

- This suggest that the surface abrasion has helped provide a better bond of the film to the coupon.

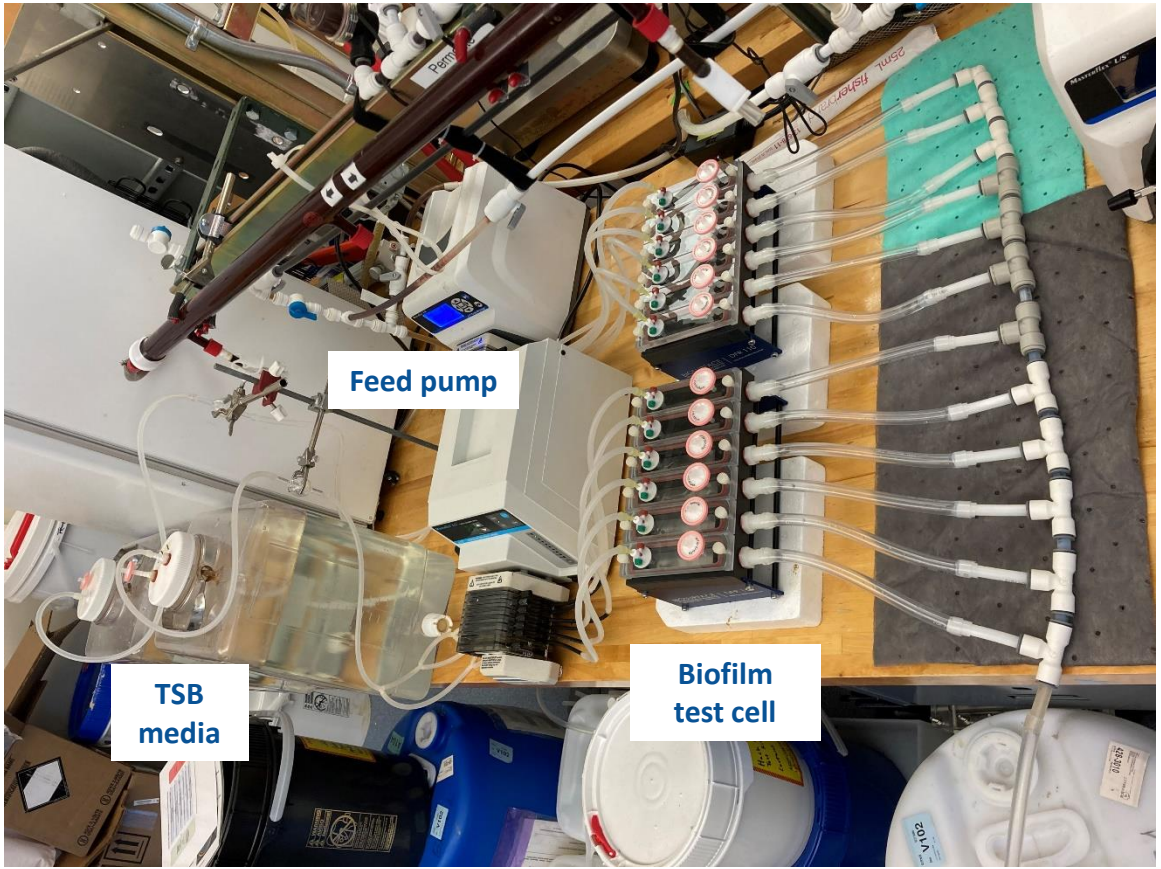
Sample #	% Hydrophilic Monomer	% Hydrophobic Monomer	Samples with 2-AI	Sample w/o 2-AI
1	100	0	2	1
2	75	25	2	1
3	50	50	2	1
4	25	75	2	1
5	0	100	2	1



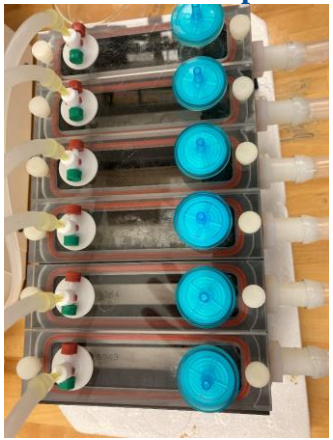
High fidelity test on metal, continuous test of the surface treatment such as integrity and 2-AI release into the water body additive formulation for established biofilm disruption

Dynamic Biofilm Test System

Biofilm test started using PA14 microbes with TSB media

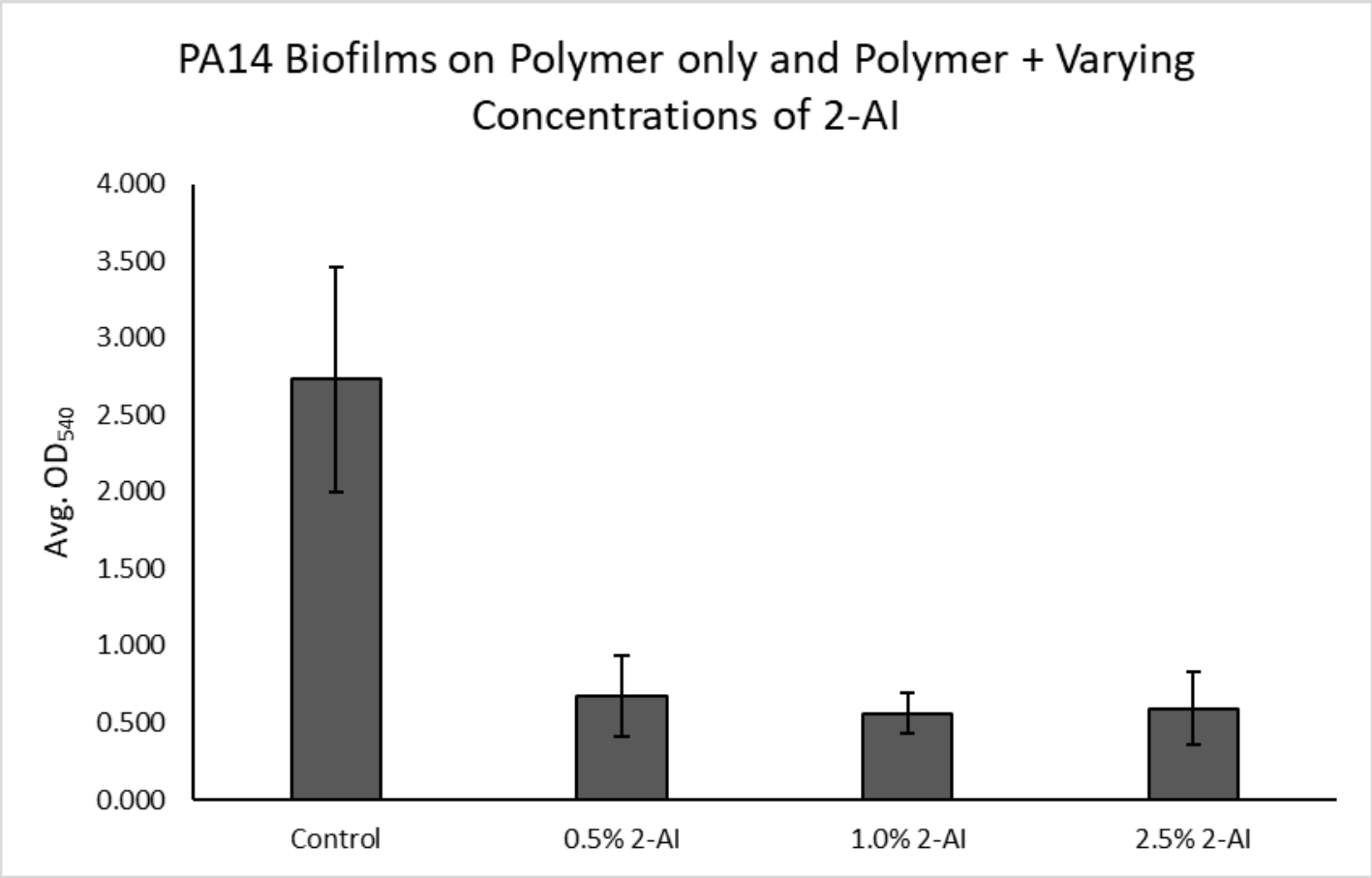


Test cell with coupons



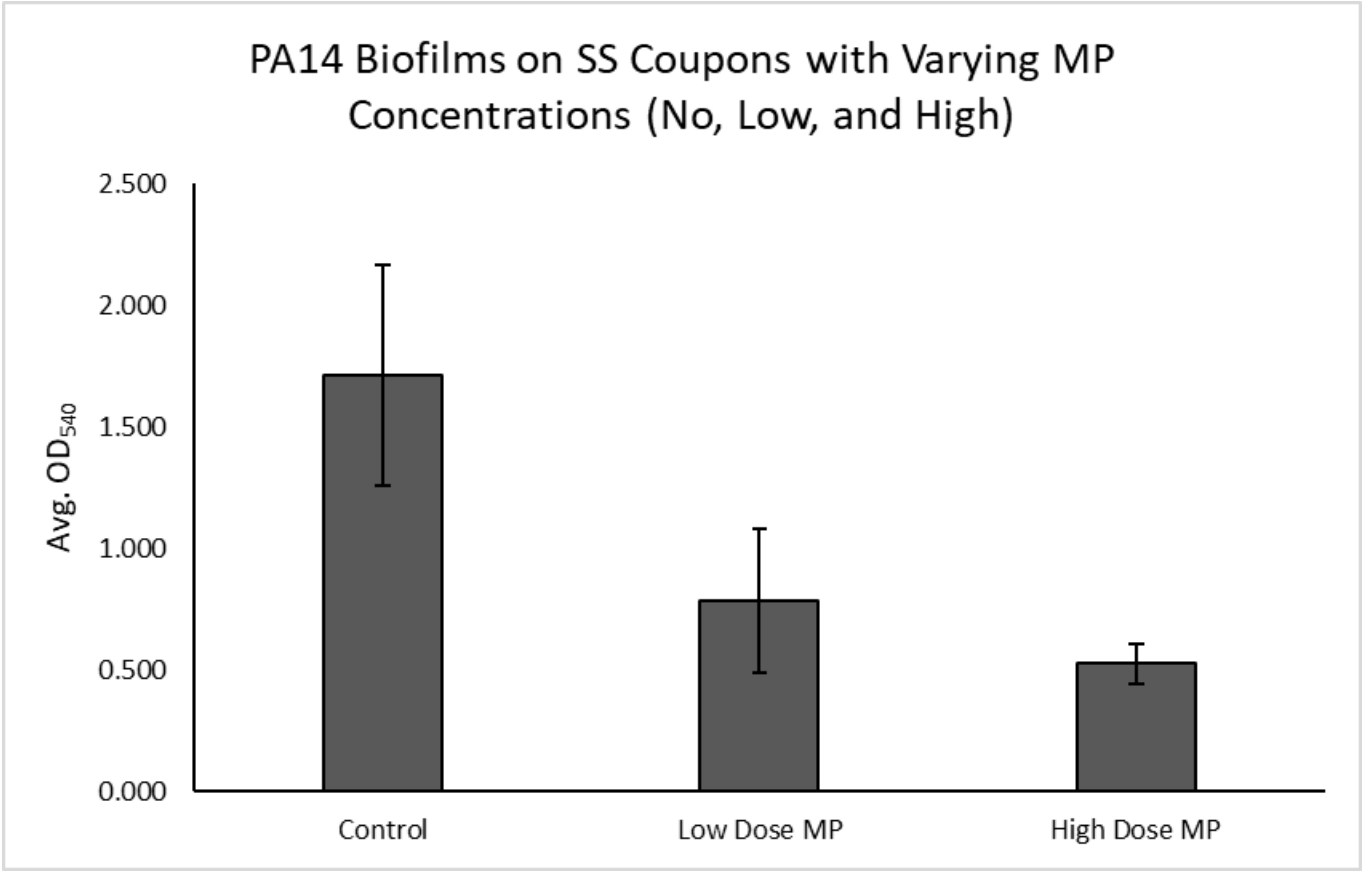
Rinsing with DI water

OD_{540} Measurements



- **Low dose mitigation with MP for continuous dosing**
- **High dose mitigation with MP for shock dosing**

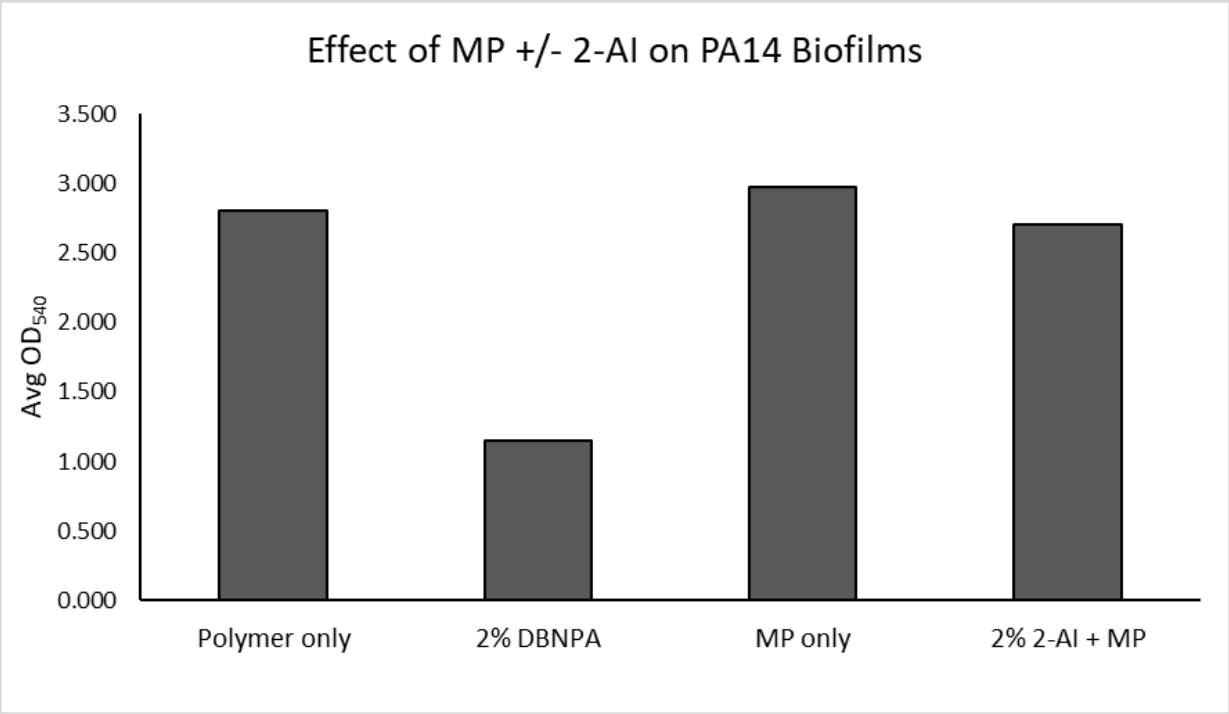
OD_{540} Measurements



Low dose is a continuous low dosing, and the high dose is a shock dosing at high concentration.

Assessment of Synergistic Effects of Biofilm Mitigation and Disruption

MP – OD_{540} Measurements

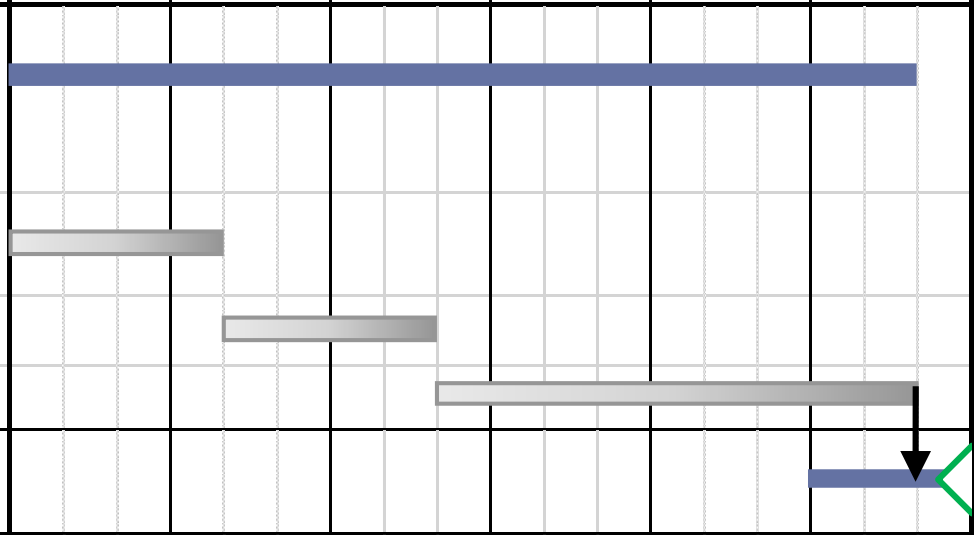


- DBNPA – decreased PA14 biofilm compared to control
- Continuous low dose of MP did not inhibit PA14 biofilm compared to control
- It seems that there is no synergistic effect with the combination of MP and 2-AI

BP2

Task Structure for BP2

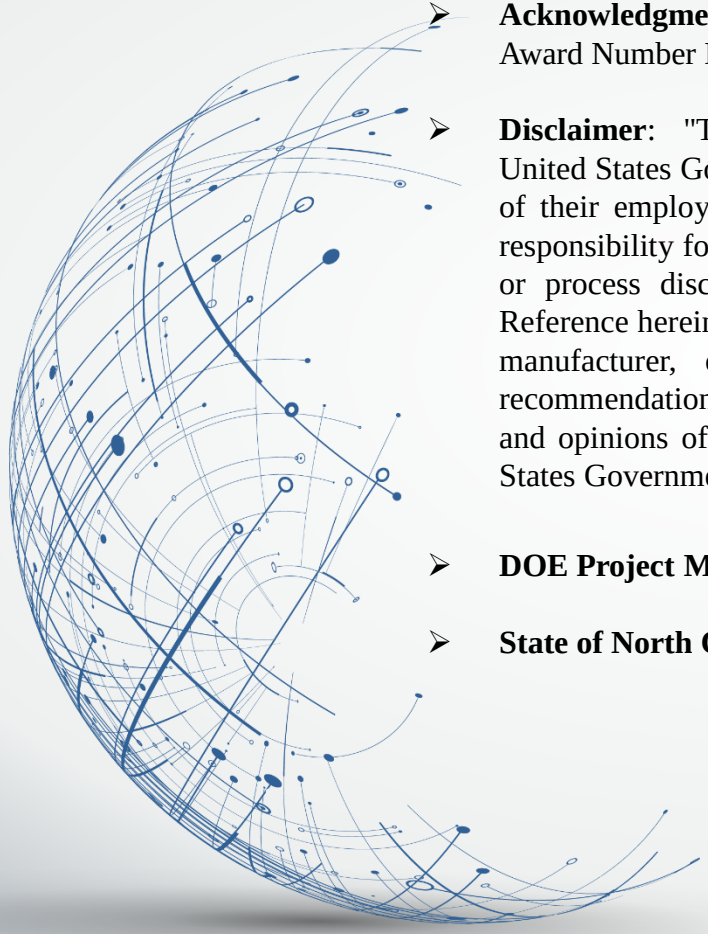
Task	Task title	Budget Period 2 (BP2)					
		Q7	Q8	Q9	Q10	Q11	Q12
5.0	Relevant Environment Demonstration of Biofilm Mitigation on Condenser						
	Subtask 5.1 - Test Skid Design & Construction						
	Subtask 5.2 - Test Skid Commisioning						
	Subtask 5.2 - On-site Bench Test @CFPP						
6.0	Techno-economic Assessment						



Project Milestones (BP2)

Task No.	Milestone Title & Description
5.1	Test Skid Design: A bench scale condenser system will be designed and constructed for field test purpose.
5.1	Test Skid Commissioning: Hydrotest of condenser skid unit demonstrating steam generation and leak free performance.
5.2	Onsite Test Summary: Pressure drop data as function of time for onsite test at power plant facility
6.0	Techno-Economic Assessment: CAPEX and OPEX of the developed technology will be assessed for a representative power plant size and the results will be compared with a conventional option for the fouling mitigation/cleaning.
1.0	Submission of the Final Technical Report Assessment

Thank You!



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- **State of North Carolina for Cost Share**

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