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Efficacy Testing of Biofouling Resistant Materials for Marine Hydrokinetic Technology

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NNSA National Nuclear Security Administration

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Outline

- Background
- Overview of Materials Tested
- Testing Methods
- Testing Results
- Summary

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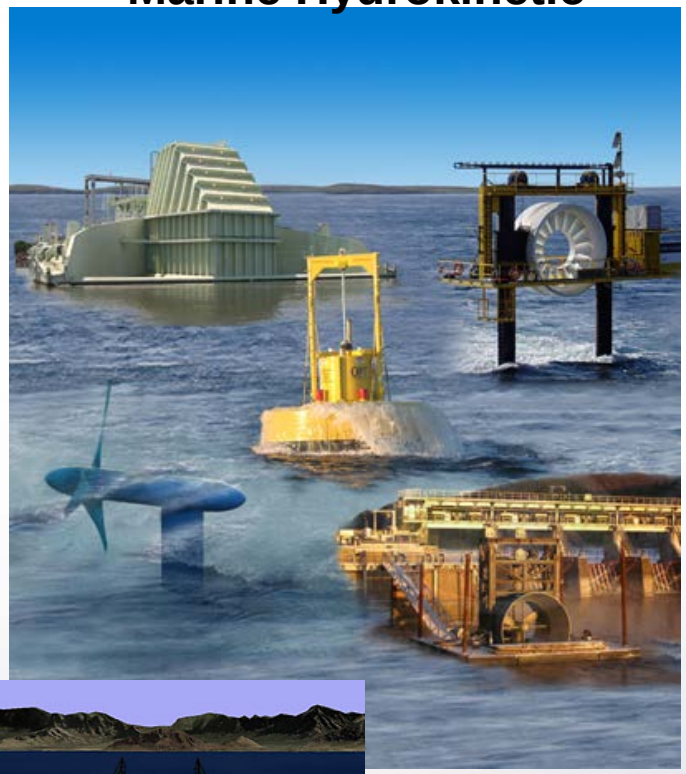
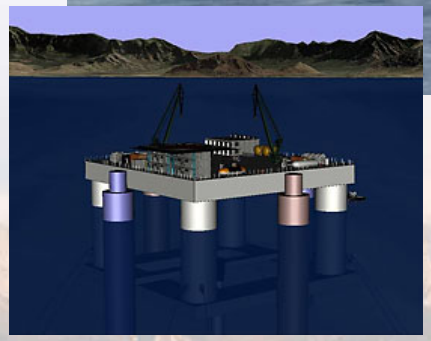
Alternative Water Energy Technology

Conventional Hydropower

Marine Hydrokinetic



Ocean or Marine Energy



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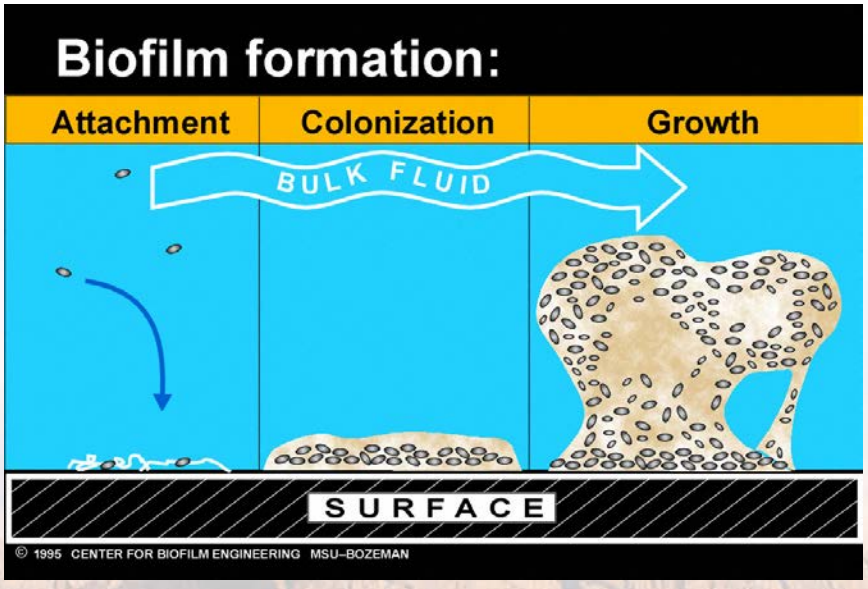
Biofouling Is Caused By Biofilms

Colonies of microorganisms attached to a surface and encased in extracellular polymeric substances (EPS, aka slime).

- **Able to trap nutrients for their own growth**
- **Protected from anitbiotics and other anti-microbial agents**



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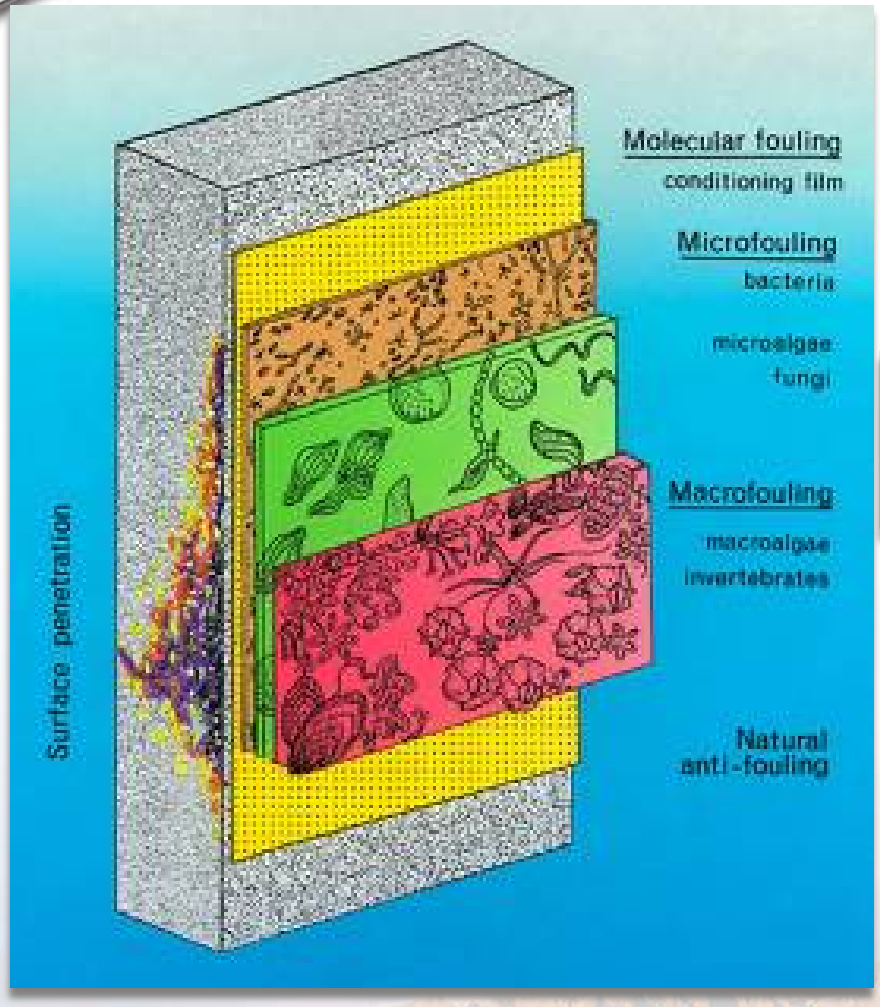
Marine Fouling Occurs Over Both Time & Length Scales

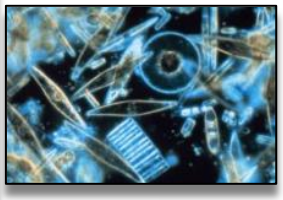


Molecular Fouling (1 min.)

↓

Bacteria (1-24h)

↓



Microalgae/Fungi (1 wk)

↓

Macroalgae/Invertebrates (2-3 wks)

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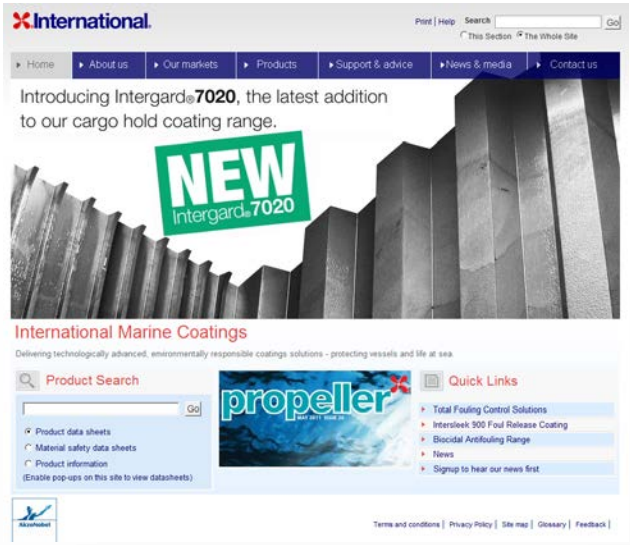
Tested Commercial Coatings

Biocidal Coating

- **EP-2000**
  - Zinc pyrithione
- **SN-1**
  - SeaNine211
  - Used in > 95% of coast guard aluminum fleet

Foul Release Coating



- **INT-757**
  - Fouling release coating
  - Silicone based polymers
- **INT-970**
  - Fouling release coating
  - Silicone based polymers

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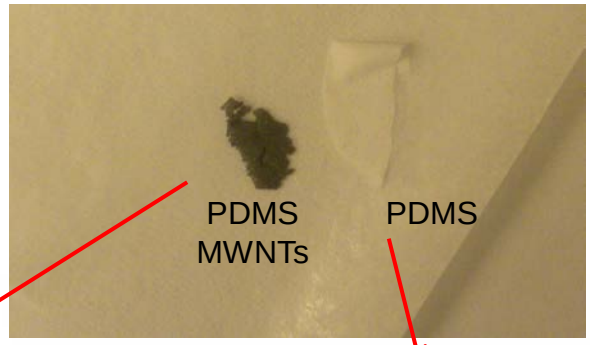
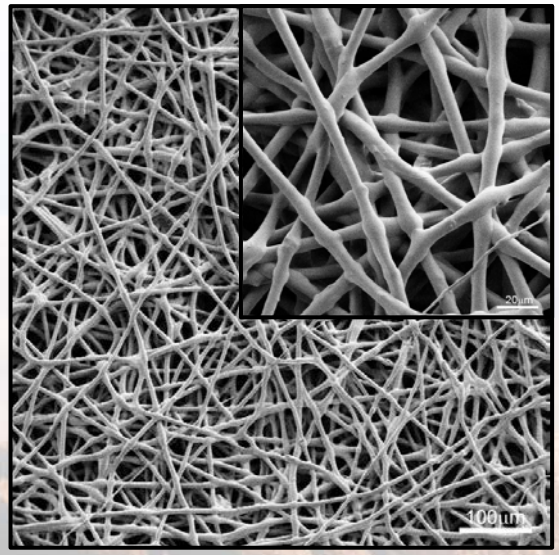
Tested Carbon Nanotube Coatings

- **Electrospinning technique developed by Dirk (SNL) and Hedberg-Dirk (UNM)**
- **Based on antimicrobial activity observed by Schiffman and Elimelech (2011)**

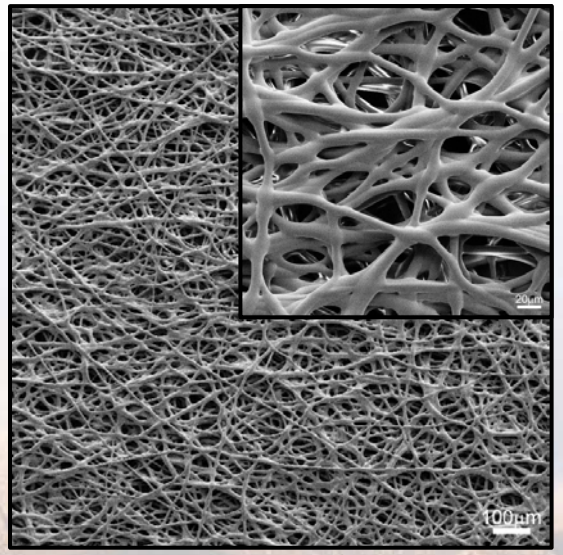
Electrospun PDMS

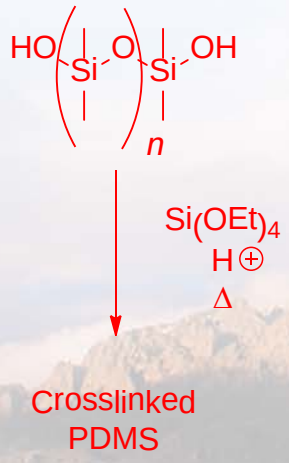


PDMS/MWNTs



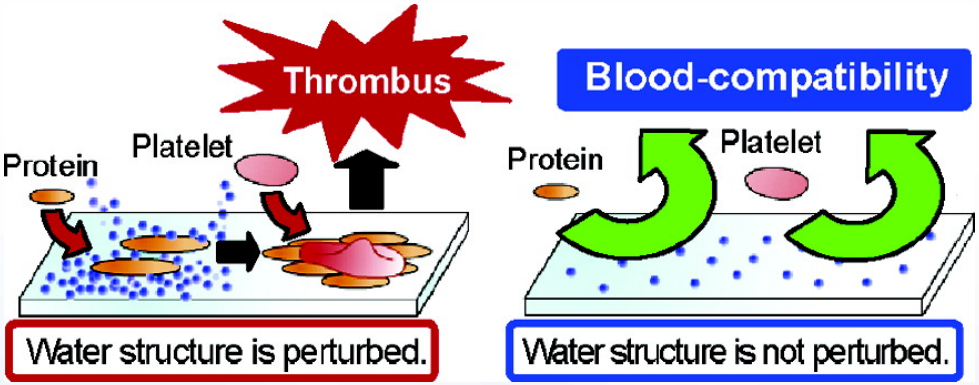
PDMS



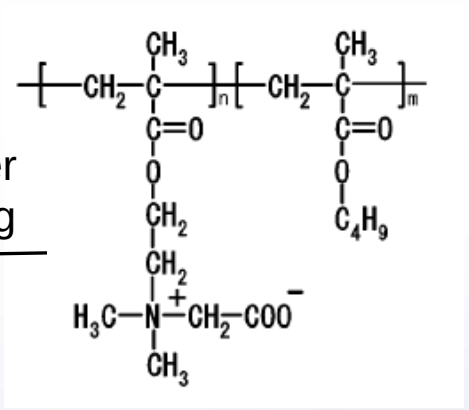


Tested Zwitterionic Polymer Coatings

- **Zwitterions are neutral dipolar molecules with nonadjacent positive and negative charges (amino acids)**
- **Show resistance to adsorption of proteins**



polymer coating



- **Do not perturb the native hydrogen bonded network of water near the surface**

Published in: Hiromi Kitano; Susumu Tada; Takayuki Mori; Kohei Takaha; Makoto Gemmei-Ide; Masaru Tanaka; Mitsuhiro Fukuda; Yoshiyuki Yokoyama; *Langmuir* **2005,** 21, 11932-11940.
DOI: 10.1021/la0515571

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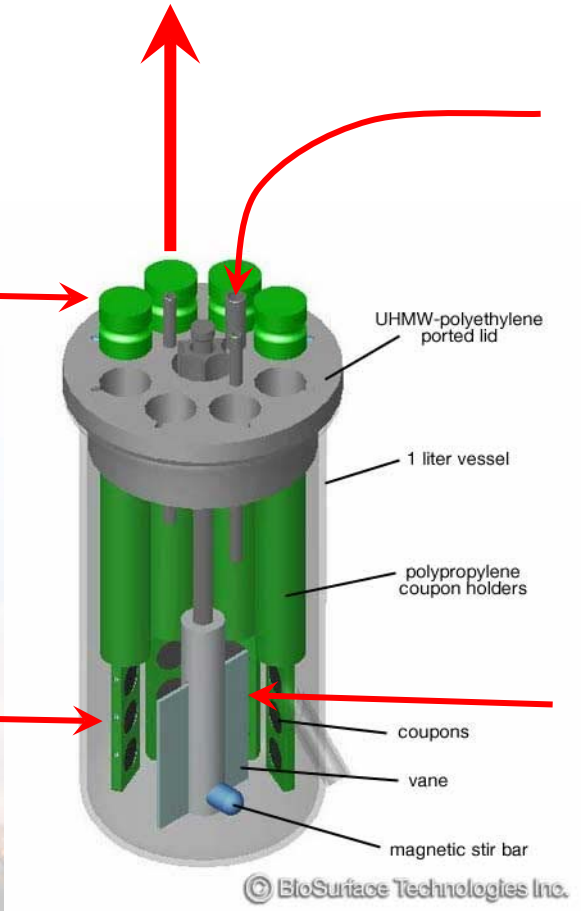
Used CDC Reactor for Biofouling Testing

Sampled after 24 hours of flow

Inflow seawater and nutrients

8 rods

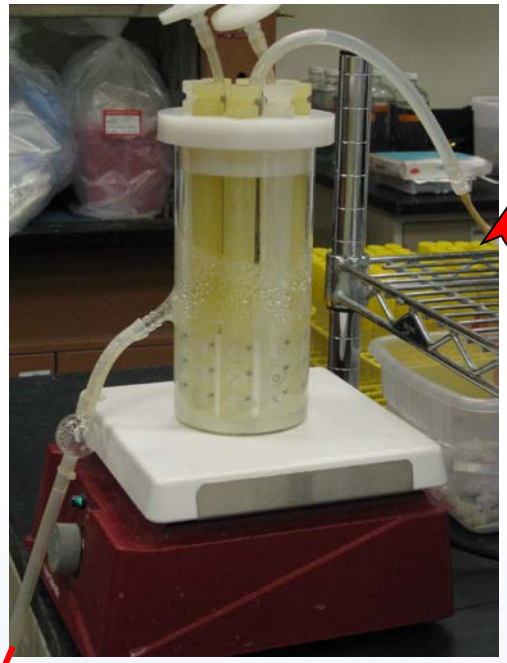


3 coupons per rod
24 samples total

Stir bar provide a moderate shear environment

Tested biocical activity against P. fluorescens

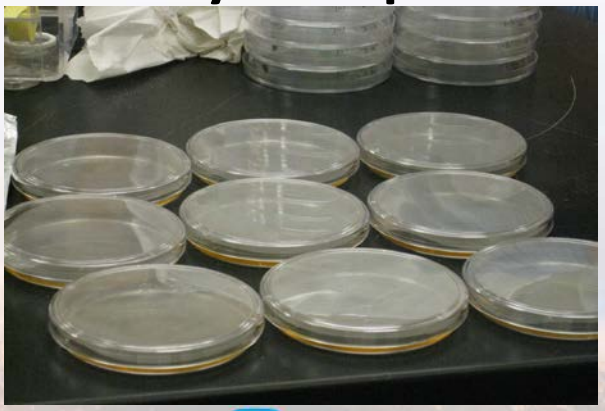
CDC Reactor



Nutrients and seawater in

Outflow

- Fill reactor with seawater and nutrient solution
- Inoculate
- 24 hour batch phase
- 24 hour phase with nutrient and seawater flow
- Sample
- Quantify biofilm density with plate counting



- Tested coatings on 6 different materials

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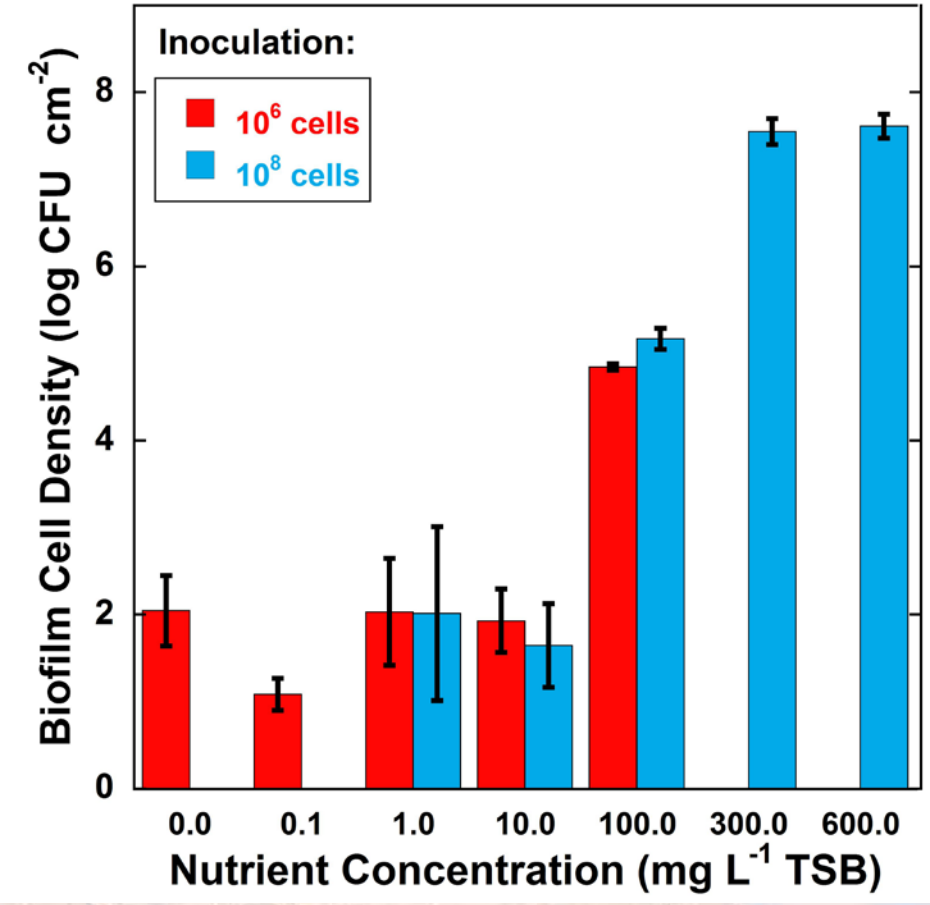
Used ASTM Protocol E 2562-07

- Vary number of number of cells added
- Varied concentration of nutrients during batch phase
- Varied concentration of nutrients during flow phase



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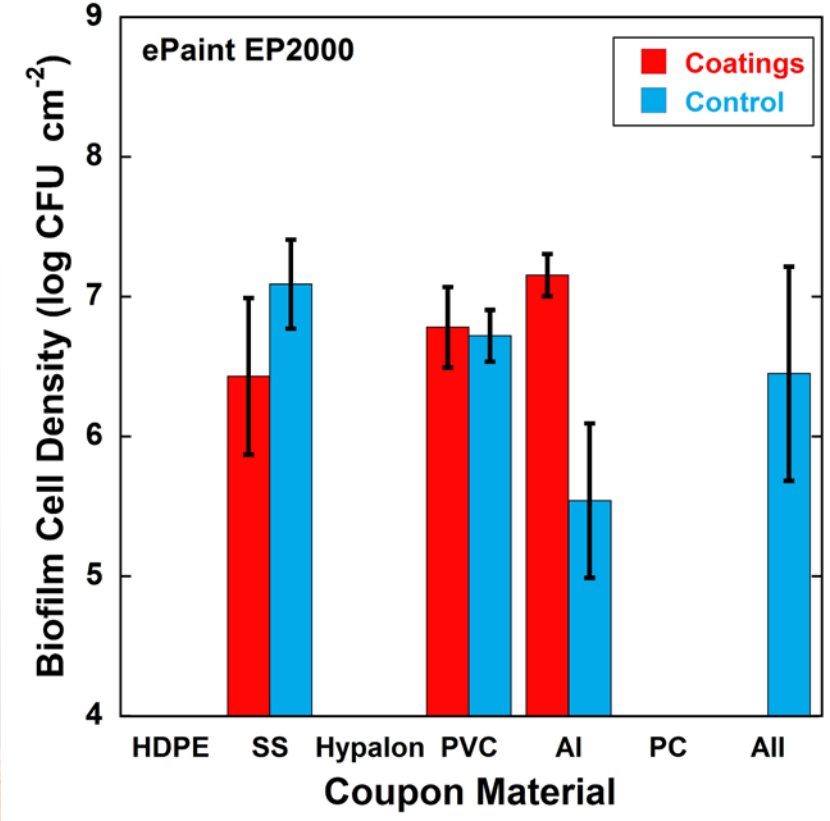
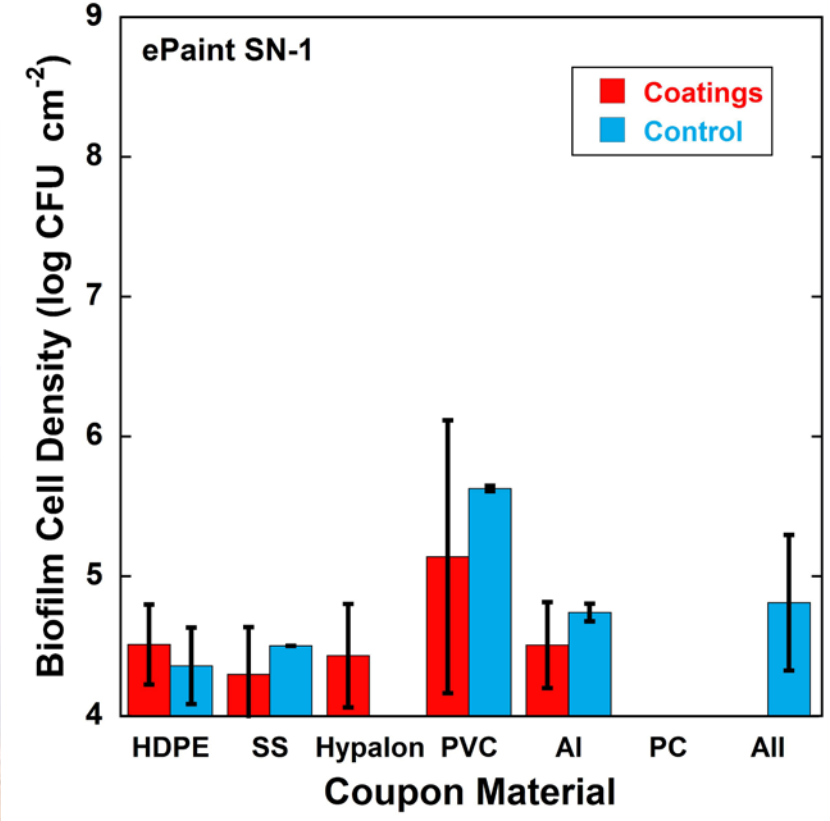
ePaint – EP2000

- Did not show significant decrease in biofilm growth



ePaint - SN-1

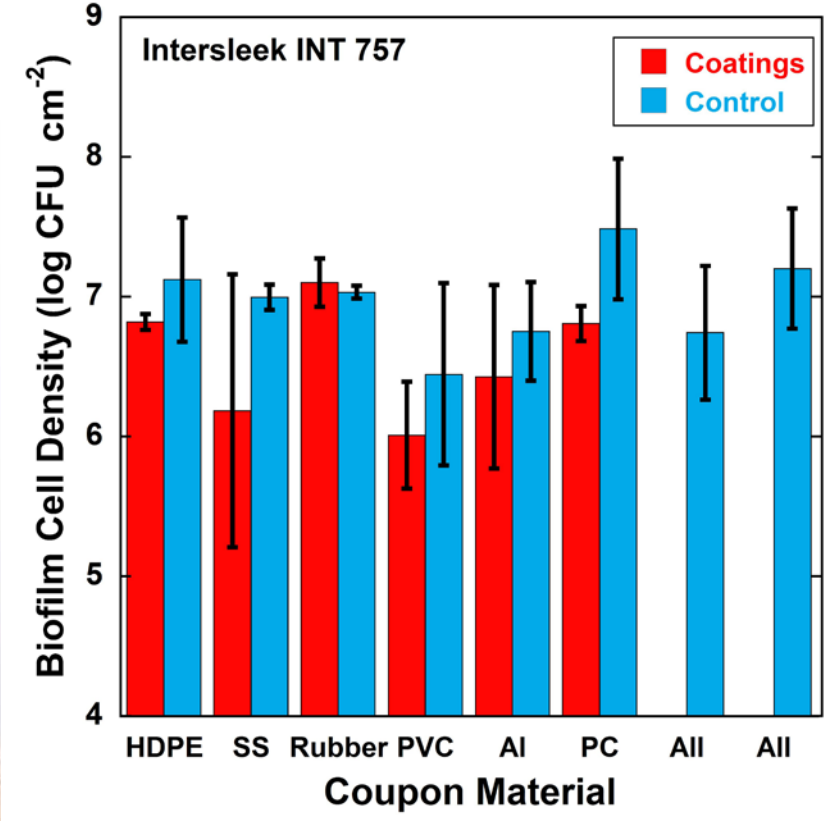
- ~ 4 log reduction in biofilm density compared to other coatings
- Low biofilm density also observed on control coupons
- SeaNine211 leaching into the reactor?



International Paint – INT-757

- Biofouling reduction observed
- Difference statistically significant for polycarbonate (79% reduction)
- Difference statistically significant for stainless steel (85% reduction)
- Less than 1 log reduction

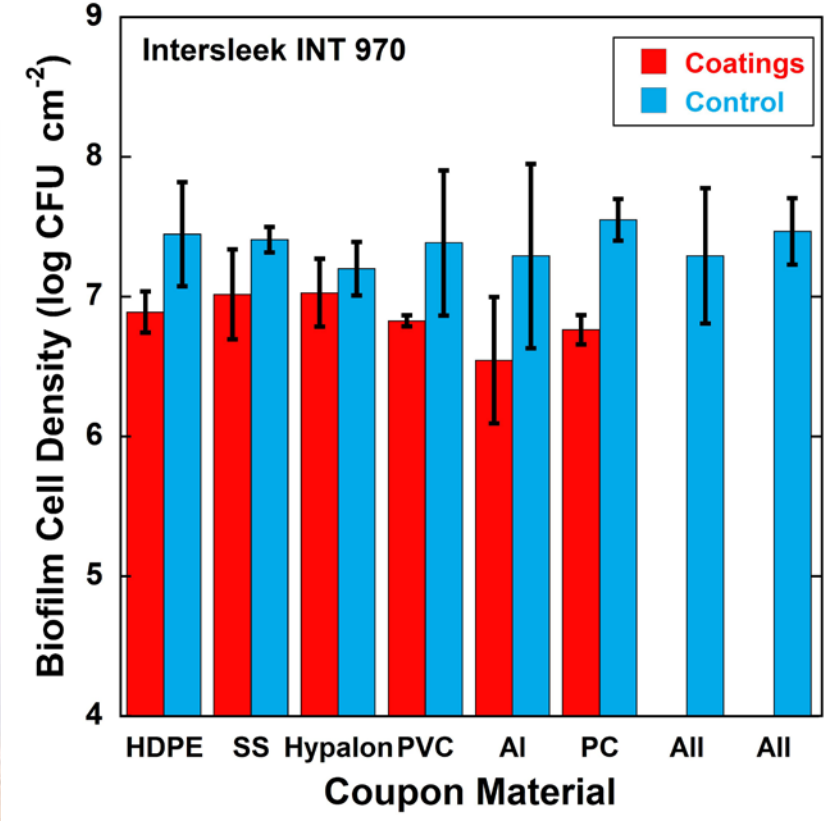
Fouling Release Coating



International Paint – INT-970

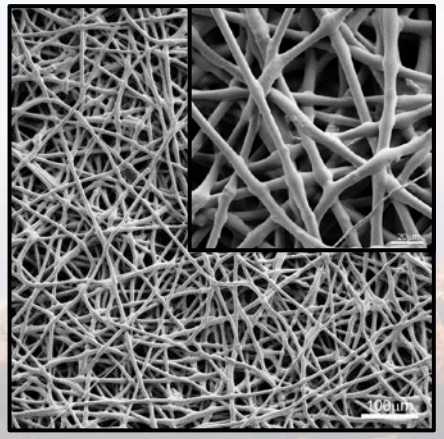
- Biofouling reduction observed
- Difference statistically significant for all materials except hypalon rubber
- Reduction ranged from 59% to 84%
- Less than 1 log reduction

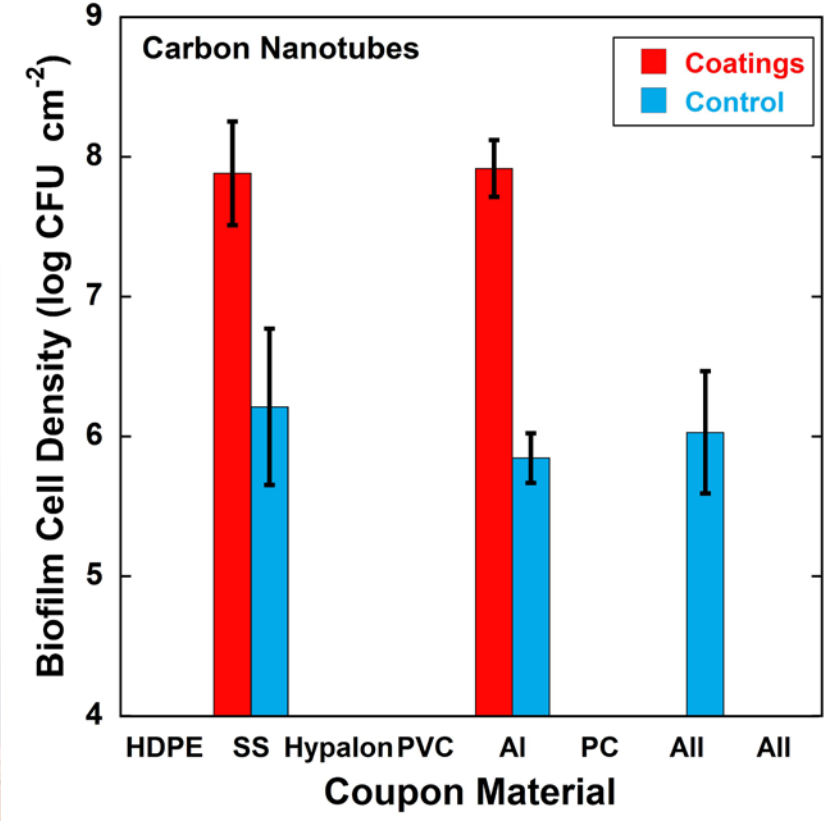
Fouling Release Coating



Carbon Nanotube Coatings

- Cell densities *higher* for carbon nanotube coatings
- Assume due to higher surface area of the coating for cell attachment
- Developing additional coatings with lower surface area





Zwitterionic Coatings

- Biocidal activity only observed on PVC
- 47% reduction observed