
IDEA2021
Powering the Future: District Energy/CHP/Microgrids
Sept. 27-29 | Austin Convention Center | Austin, Texas

BIOFILM MONITORING IN CLOSED LOOP WATER SYSTEMS

IDEA2021 – Powering the Future
Austin, TX

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07/02/2020

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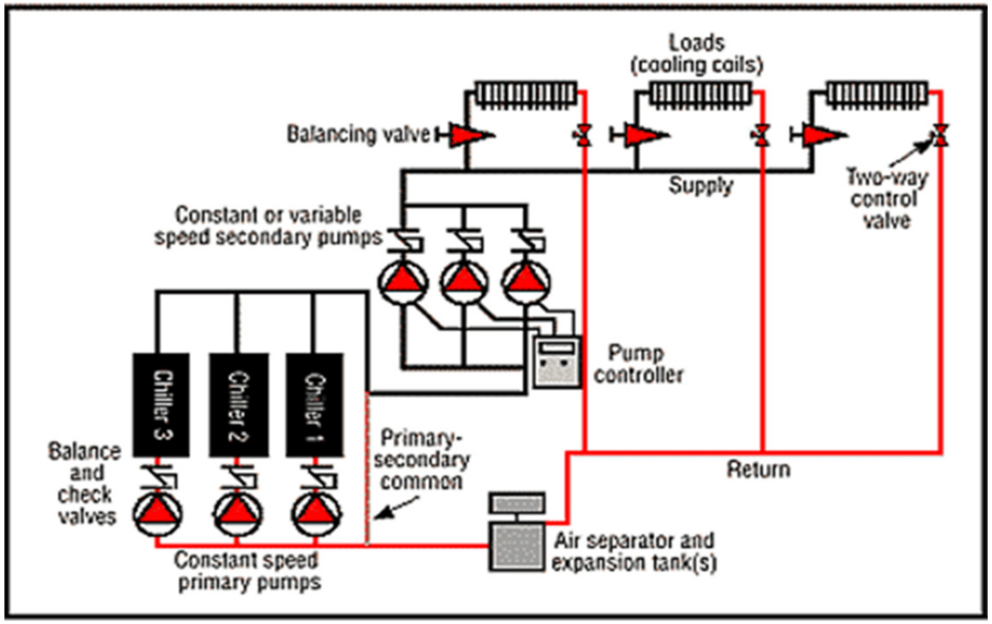
Agenda

1. Closed systems
2. Effects of biofilm
3. Monitoring: how and where
4. Biocide selection methodology

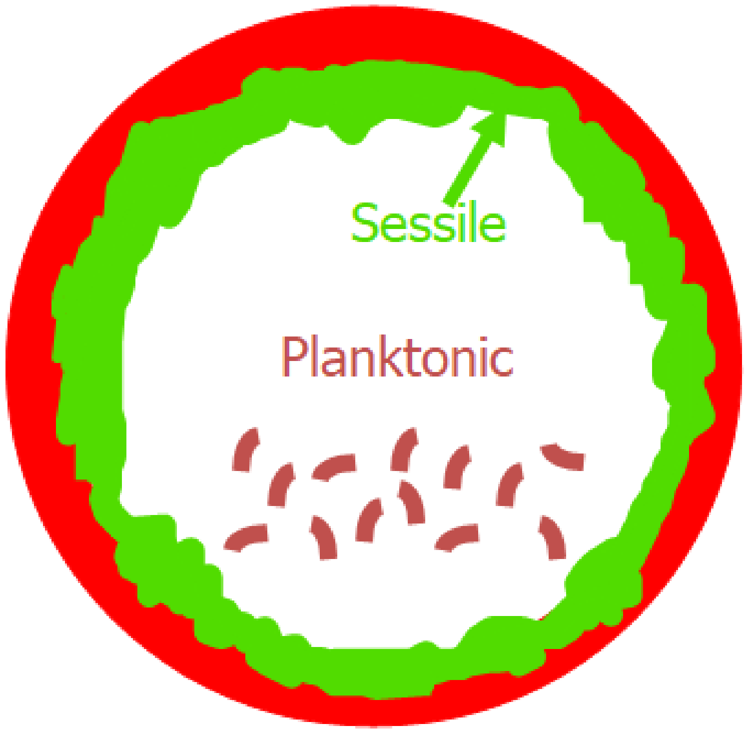
Closed system characteristics

- Not open to atmosphere
- No evaporation
- Designed for minimal water losses
- Used to transport chilled, hot water or both in two pipe systems
- Typically treated with higher dosage levels of chemical treatment than open systems
- Variable speed pumps can reduce velocity and negatively impact system cleanliness. Higher risk in systems with enhanced (rifled) tubes



Biofilms have tangible impacts

- Microbial films consist mostly of water
- Consequently, biofilm exhibits a significant insulating effect
- 1 mm of biofilm = 83 mm of steel exchanger tube



Trapped Water ⇨ Stagnant Water ⇨ Poor Heat Conductance

Frictional effects of biofilms on flow

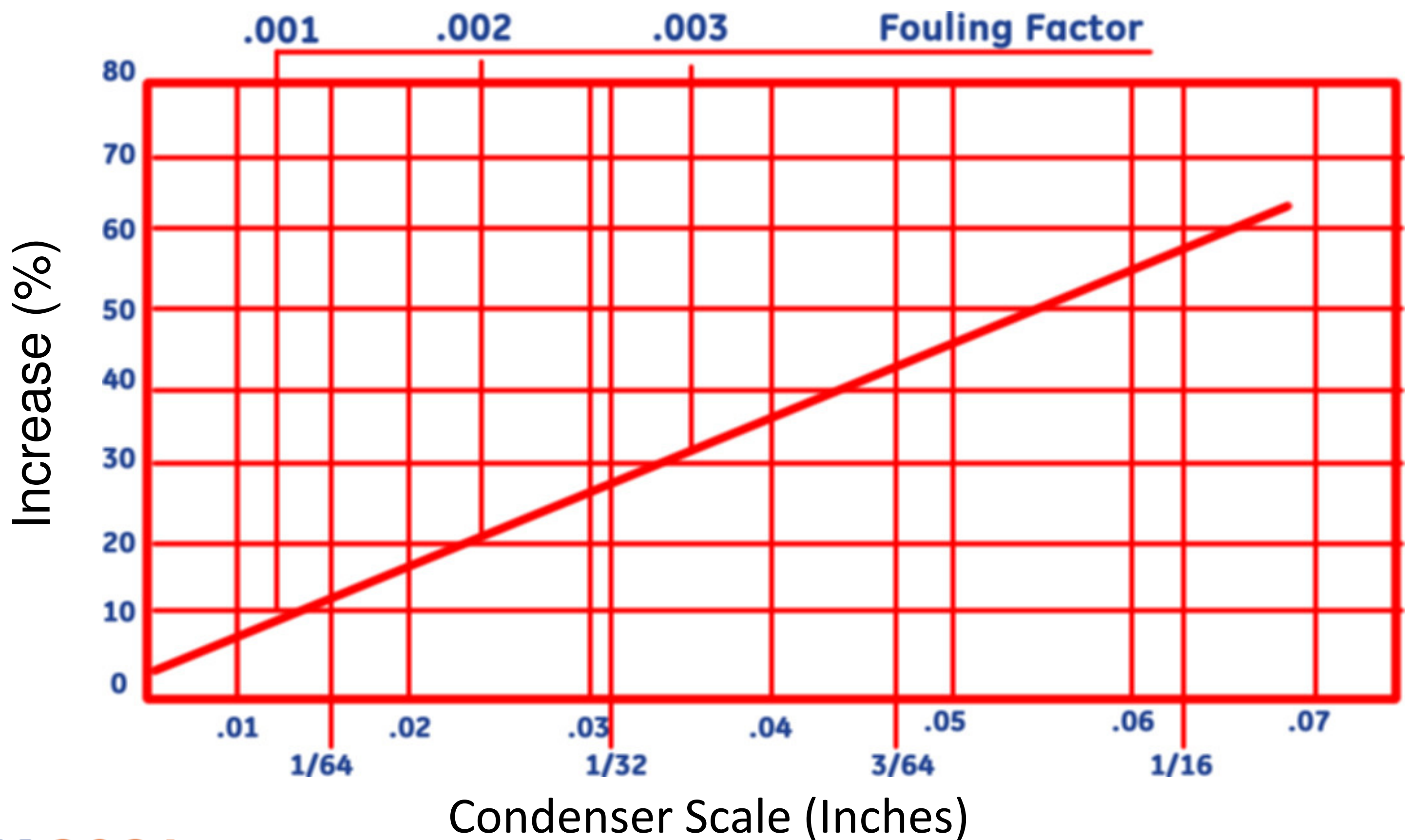
Diameter, m	Length, km	Surface	Biofilm Thickness, mm	Loss in Capacity, %
0.91	35.2	Steel	3.2-5.4	16
0.61	80	Steel	0.6	55
0.36	2	Steel		35

- Restrictions are NOT the result of reduced diameters (additive film thicknesses in mm).
- Biofilm surface generates high friction resistance to flow
- This effect absorbs flow energy, normally directed toward fluid movement

Compound thermal conductivity

Compound	Thermal Conductivity (Watts / Meter Kelvin)	Common Name	Density (g/cm³)
Fe_2O_3	7.2	Hematite	5.24
Fe_3O_4	2.9	Magnetite	5.18
$CaCO_3$	2.9	Calcite	2.71
Ca_3PO_4	2.6	Tricalcium phosphate	3.14
$CaSO_4$	2.3	Anhydrous calcium sulfate	2.96
Biofilm	**0.6**	Dry biomass	**1.60**
$Zn_3(PO_4)_2$		Zinc phosphate	4.00
$MgSiO_3$		Magnesium silicate	3.41
CuO		Cupric oxide	6.40

Impact of fouling thickness on power consumption



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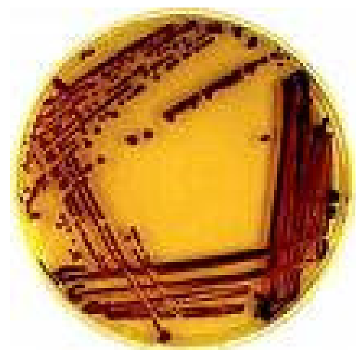
Types of biological monitoring

Bioscan ATP



Aerobic Count Plates
(Petri dish)

Sani Check SRB
Dipslides

Microbial guidelines for closed systems

MB count level within a system (cfu/ml)	Biocide Program Performance
$>10^7$	Biocide failed to provide protection
$10^5 - 10^6$	Unsatisfactory biocide control
$10^3 – 10^4$	Biocide control satisfactory
$<10^2$	Excellent biocide control

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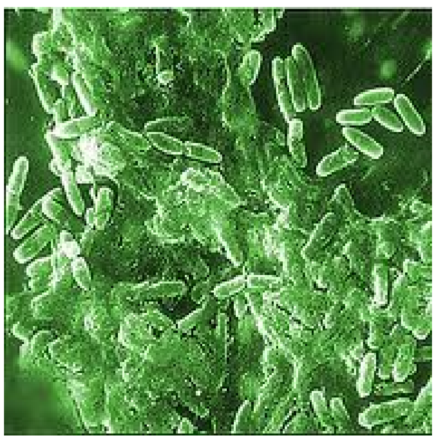
Types of bacteria associated with bio-fouling

Bacteria of concern in closed systems:

- Sulfate reducing bacteria (SRB's)
- Nitrite reducing bacteria
- Pseudomonads (biofilm pictured below)



SRB induced corrosion

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Filtration of closed systems

- Some form of routine filtration is best practice
- Size on system turnover rate (1 to 4 days)
- Filter selection is normally based on system volume,
- Validate performance with particle size analysis

Locations where sessile bacteria can reside and flourish

- Heat exchangers
- Strainers
- Dirt and air separators
- Magnetic filtration
- Hydro-cyclones
- Disposable media filtration
  - Cartridges
  - Bags
- Automated filtration
  - Sand Filters
  - Media Filters
  - Membrane Systems

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Sessile versus planktonic microbial monitoring

- Bulk monitoring (planktonic)
  - Pro: easy
  - Con: false sense of security (sessile counts typically 10-100x higher)
- Surface Monitoring (sessile)
  - Pro: the hard truth
  - Con: additional effort
- Organisms seek to dwell on surfaces
- They secrete biofilms for protection- their “PPE”
- “Microclimates” can exist in closed systems i.e. low flow areas
- Biofilms are not completely removed so “re-colonization” is a risk
- Only true control when sessile populations minimized

Factors affecting biocide choice

- Concentration
- Temperature
- pH (hydrolysis)
- Compatibility with other treatments present
- Cost effectiveness
- Resistance/Immunity
- Broad spectrum of activity
- Compliant with EPA End-Use Label Criteria
- Safety Considerations (oxidizers vs. non-oxidizers)
- Ultimate proof…performance in system

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On-site toxicant evaluation: eliminate the guessing game

- Collect surface samples from SSF media
- Dilute scrapings into system water to make robust “broth” against which to evaluate biocides/bio-dispersants
- Toxicant evaluation just like running wastewater jar test
- Measure initial MB count compared to counts after 4 and 24 hour exposure to different doses
- Measure SRB in initial “broth” vs. treated samples at 24 hours
- Add bio-dispersants to some samples before biocide to determine if they improve % kill
- Evaluating biocides/bio-dispersants vs. robust sessile populations only true test of efficacy

Toxicant evaluation example

- Initial MB count of “broth”: 15,000 RLU
- 80 ppm DBNPA:
  - 4 hour count 1000 RLU (93.3% kill)
  - 24 hour count: 300 RLU (98% kill)
- 120 ppm isothiazoline:
  - 4 hour count 3000 RLU (80% kill)
  - 24 hour count 600 RLU (96% kill)
- 120 ppm isothiazoline w/30 ppm bio-dispersant:
  - 4 hour count 500 RLU (96.7% kill)
  - 24 hour count 50 RLU (99.67% kill)

Desired % kill: >99%

Toxicant evaluation merits

- Repeat every 3-6 months depending on criticality of system
- Use to optimize dosage and frequency of biocide additions to achieve desired performance at lowest cost
- Best to administer “knockout” dose of non-oxidizer rather than sub-lethal dose which typically reduces frequency of applications and reduction in overall usage/cost w/optimum results
- Can identify whether bio-dispersant in conjunction with biocide can wick away biofilms well enough to prevent re-colonization of microbes
- When deploying these procedures and tactics we have seen overall biocide program cost drop by up to 30% with excellent sessile control in critical closed systems

Toxicant evaluation: Case Study

- Automotive plant had a 12-stage cooling circuit struggling with bio control
- Weekly commodity biocide treatment was costly and ineffective
- SUEZ conducted toxicant "bio-screening" evaluation with dipslides and bioscan to identify the highest performing treatment for the lowest cost
- Treatment frequency was changed from weekly to every 6 weeks, with superior results
- Treatment cost was reduced by $85,000

Thank you!

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