# Campus Energy 2019

# “Microbiological Control & Considerations for Chilled Water & Thermal Storage Systems”

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# Program Considerations

- Ensure efficient chemical distribution throughout system
- Eliminate dead legs and low flow areas ( < 3 ft/s )
- Filter Type, size, & location
  - 0.25 um filter efficiency
  - Turnover is based on investment
    - Is it feasible to turnover 100% in 3 days?
- Corrosion monitoring (i.e., coupons & online corrosion monitors)
- Location of taps for testing
- Understand all Safety, Health, & Environmental requirements

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# Monitoring and Control

- Monitor and control bacterial levels, biocide residuals, chemical inhibitor residuals
- Consult with a water treatment professional prior to all system expansions
- Record test results and trend data
- Evaluate soluble iron, copper, chlorides, inhibitor levels, traced chemistry, pH, conductivity, turbidity, dip-slides & bio-swabs
- Perform system volume study
- Monitor and measure actives

# Monitoring & Control

- Includes Starter fluorometer for traced chemistry and turbidity monitoring.
- Includes toroidal conductivity and pH probes.
- Contains both NCM probes and space for two coupons in same equipment.
- Temperature is from toroidal conductivity probe.
- Options include booster pump, flow regulator and corrosion rack.

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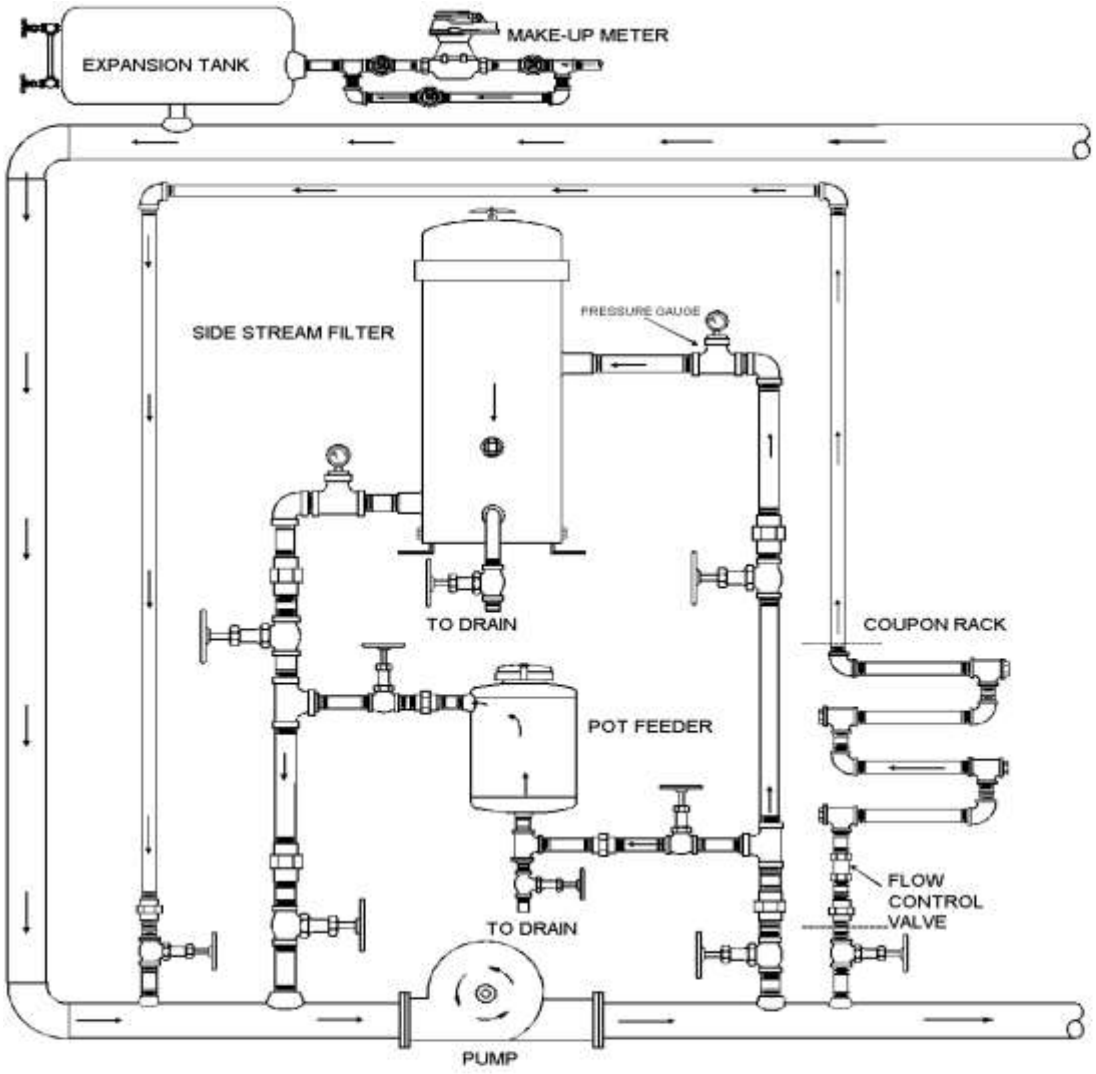
# Minimum Equipment Considerations

- POT FEEDER
- SIDE STREAM FILTER
- MAKE-UP WATER  METER
- CORROSION COUPON RACK

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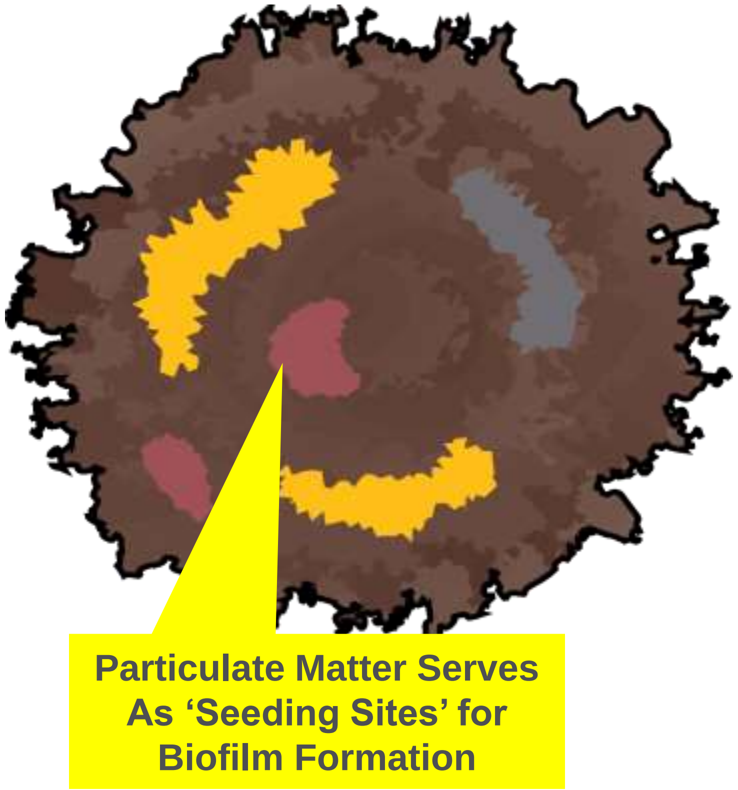
# *Filtration*

## *Removing the particulate*

Removing the particulate…




**Biofilm is the most insulating contaminant**

- Reduces Bio-Film formation
- Improves Heat Transfer Efficiency
- Saves Energy

**Thermal Conductivity(Wm-1/K-1)**

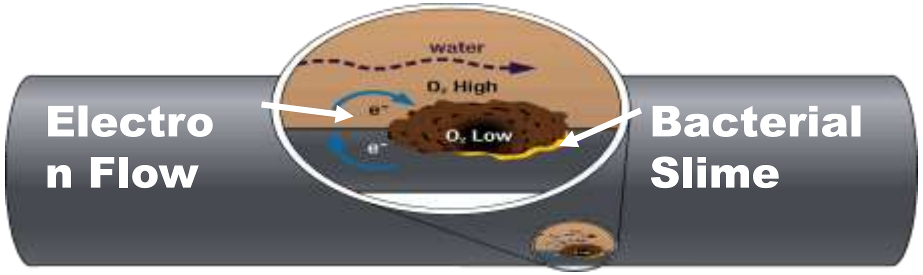
| | |
|---|---|
| **Copper** | **2400** |
| **$CaCO_3$** | **2.6** |
| $CaSO_4$ | 2.3 |
| $Ca_3(PO_4)^2$ | 2.6 |
| $Fe^2$ | 2.9 |
| Analcite | 1.3 |
| **Biofilm** | **0.6** |

**The Lower The Number, The More Insulating The Substance Is...**

# High Efficiency Filtration

**The majority of the particulate is removed via filtration, and therefore the bacteria attached to these particles is removed.**

**The reduction in particles and bacteria allows the chemical treatment program to be more effective in 3-ways:**




**1) Bio-Film formation is reduced**

**2) Metal surfaces are cleaner, allowing corrosion inhibitors to form a more protective film**

**3) Sub-Deposit Corrosion such as Differential Cell Corrosion and Microbio Induced Corrosion are reduced**

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# Filtration

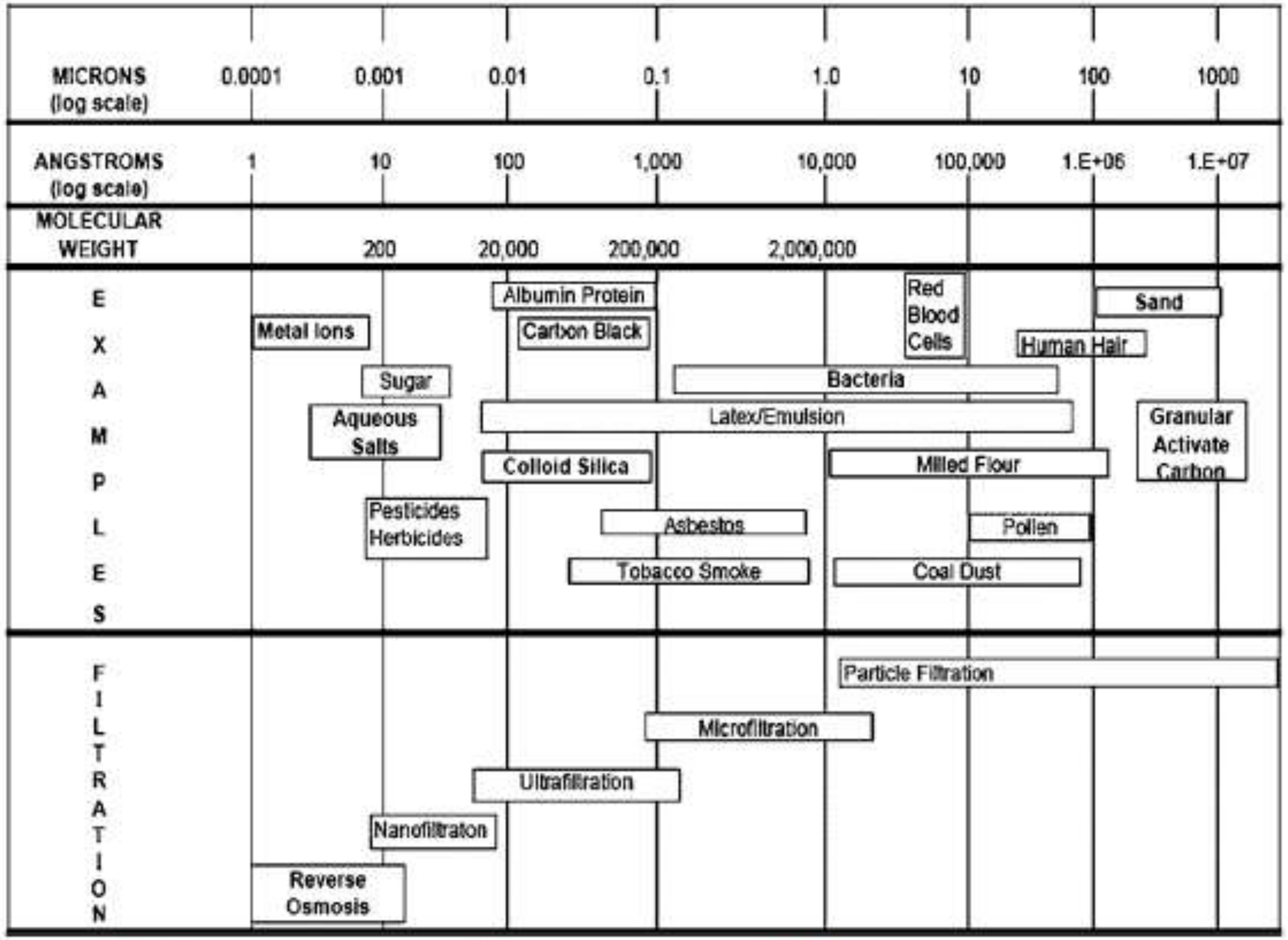


*Figure 2.5.1 – Filtration methods and particle size relationships*

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# Monitoring and Control-Corrosion

- Corrosion monitoring via corrosion coupons and online corrators
- Orientation of coupons is important
  - Mild steel should be first followed by copper
- Online corrators can give instant results and trend data.
- Monitor at various locations to help determine overall health of system

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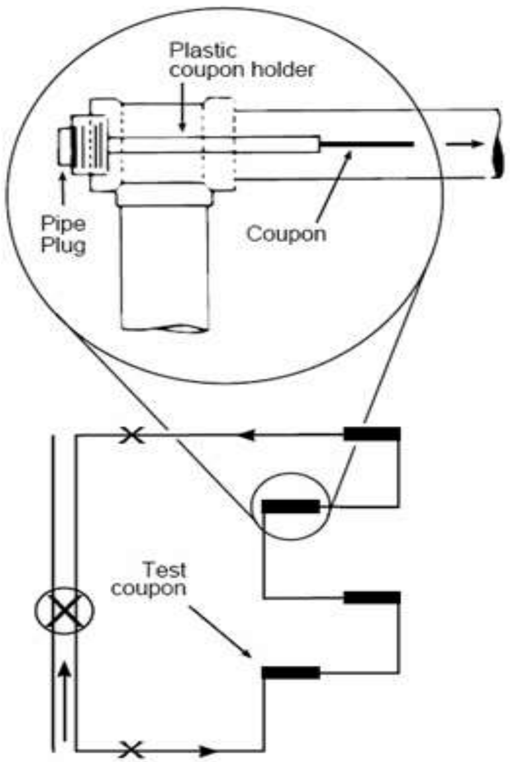
# Measuring Corrosion

**Coupons**

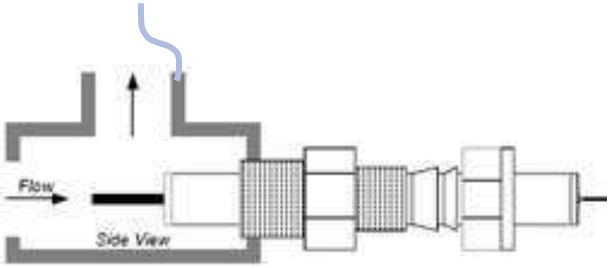
- Average measurement over the exposure period
- Simple low cost technique




**Electronic Measurements**

**NCM100**

- Instantaneous on-line reading
- Continuous data log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# Corrosion Rate Guidelines

| | Open Cooling System | | | | Closed System | | | |
|---|---|---|---|---|---|---|---|---|
| | Carbon Steel Ferrous Metals | | Copper Alloys Yellow Metals | | Carbon Steel Ferrous Metals | | Copper Alloys Yellow Metals | |
| | mm/yr | mpy | mm/yr | mpy | mm/yr | mpy | mm/yr | mpy |
| Excellent | < 0.025 | < 1 | < 0.0025 | < 0.1 | < 0.005 | < 0.2 | < 0.0025 | < 0.1 |
| Very Good | 0.025 – 0.051 | 1 – 2 | 0.0025 – 0.0076 | 0.1 – 0.2 | 0.005 – 0.008 | 0.2 – 0.3 | | |
| Good | 0.051 – 0.076 | 2 – 3 | 0.0076 – 0.0127 | 0.2 – 0.3 | 0.008 – 0.013 | 0.3 – 0.5 | 0.0025 – 0.005 | 0.1 – 0.2 |
| Fair | 0.076 – 0.127 | 3 – 5 | 0.0127 – 0.0203 | 0.3 – 0.5 | 0.013 – 0.020 | 0.5 – 0.8 | 0.005 – 0.008 | 0.2 – 0.3 |
| Poor | 0.127 – 0.254 | 5 – 10 | 0.0203 – 0.0254 | 0.5 – 1.0 | 0.020 – 0.025 | 0.8 – 1.0 | | |
| Very Poor | > 0.254 | > 10 | > 0.0254 | > 1.0 | > 0.025 | > 1.0 | > 0.008 | > 0.3 |

mm/yr = millimeters per year

mpy = mils per year where 1 mil = 1/1,000 inch

Key Point : Corrosion rates will vary depending on system operating conditions and the corrosivity of the water. Generalization can be misleading at times.

# Preventative and On-going Microbial Control

- Pre-cleaning and Passivation for protection of plant equipment
- Use high biocide doses when system is first turned-on
- Use on-line filtration and maintain the filters
- Monitor bacterial concentrations at least once a month – adjust accordingly
- For idle equipment, explore if rotating systems is needed to keep flow and treatment to all equipment
- Consider including biocide dosing or cleaning prior to season ending operation
  - It should be planned strategy as system ages and potential for MB growth increases

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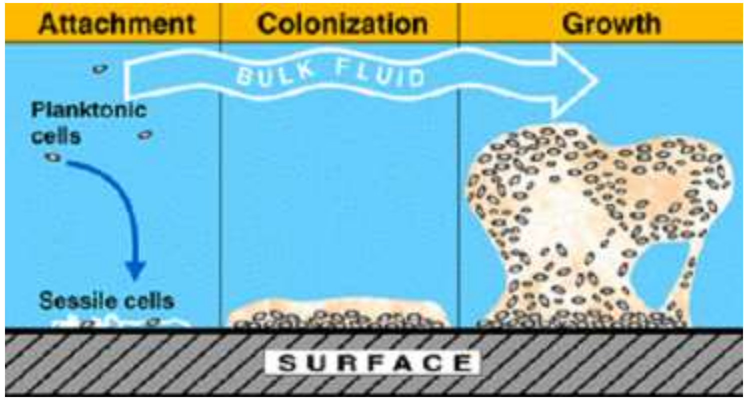
# Biofilm – where over 90% of the microbes Live




**The instant a metallic surface is immersed in water, a biofilm begins to form.**

## Development occurs in four stages:

- **Conditioning –** chemical adsorption of organics on the water-wetted surface.
- **Attachment –** “pioneer” bacteria, individual cells adhere to the surface and surround themselves with extracellular polymeric substances *(Hours)*.
- **Colonization –** other varieties of bacteria become associated in a community of organisms *(Days)*.
- **Accumulation –** entrapment of particles within the polysaccharide matrix *(Dead Cells, Corrosion Products, Silt, etc.)*.

# How Does Biofilm Affect your Operation?

- **Development of Biofilm**
  - Loss of cooling capacity *(Biofilm can infiltrate all parts of your cooling system)*.
  - Increased energy consumption *(restricting flow, higher pump pressures)*.
  - Wood Decay
  - Premature equipment replacement, unscheduled maintenance or downtime due to corrosion and plugging.
- **Health and Safety Related Issues**

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# Biofilm Affects Heat Transfer

| Deposit | Thermal Conductivity (W/m-K) |
|---|---|
| Calcium Carbonate | 2.26 - 2.93 |
| Calcium Sulfate | 2.31 |
| Calcium Phosphate | 2.60 |
| Magnesium Phosphate | 2.16 |
| Magnetic Iron Oxide | 2.88 |
| Biofilm | 0.63 |

*N. Zelver et al., CTI Paper No. TP81-05*

**Thermal Conductivity is measured in watt per meter-Kelvin. It is a measure of the material's ability to conduct heat. The lower number indicates a better insulator.**

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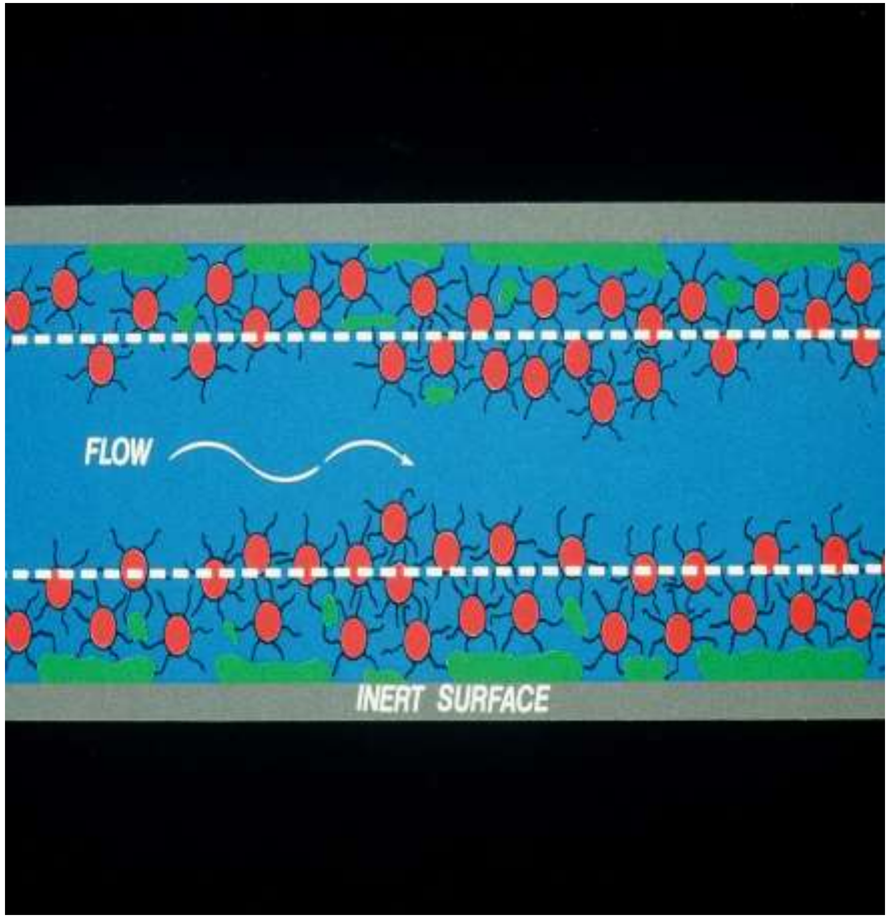
# MICRO-ORGANISM ACTIVITY

- ANAEROBIC IN NATURE
- FEED ON ORGANICS IN SYSTEM
- CAN ACCELERATE CORROSION
- WILL CONSUME CORROSION INHIBITOR & GLYCOL
- WILL AFFECT HEAT TRANSFER

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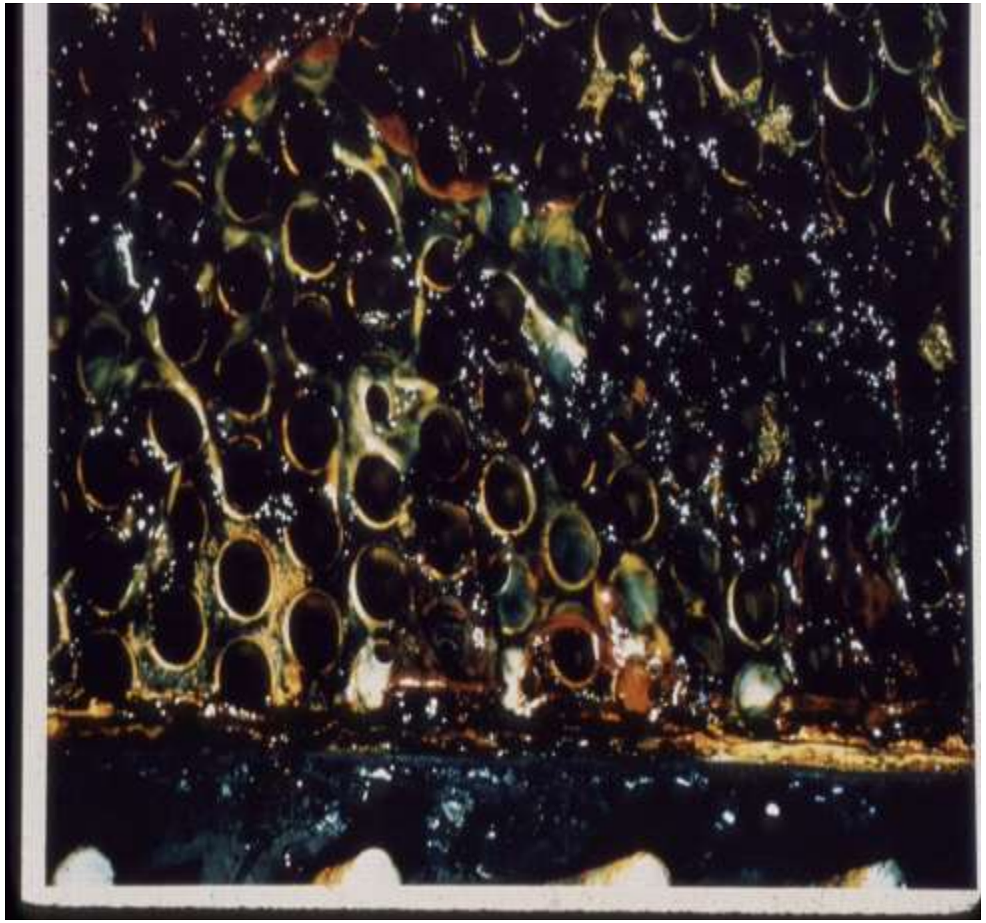
# MICRO-ORGANISM CONTROL

- Indicators of biological activity
  - Turbidity
  - Odor
  - Low pH
  - Unexplained treatment loss
- Perform closed system cleaning/filtration
- Addition of Chlorine Dioxide
- Biocide Addition NOT  ALWAYS Recommended



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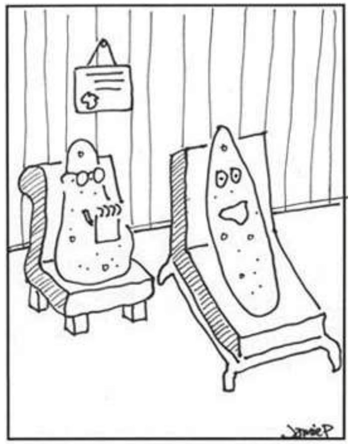
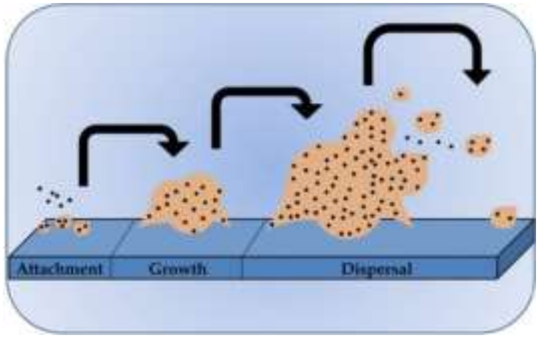
# Microbiological Definitions

- **Planktonic** – Mobile free floating organisms
  - Organisms that are **not** attached – they are freely floating in the bulk water.
  - Tested in grab samples.
  - Kicked out of the nest, looking for new place to colonize.
  - More vulnerable to the effects of biocides.



I just can't go with the flow anymore. I've been thinking about joining a biofilm.

- **Sessile** – Attached organisms (polysaccharide slime)
  - Troublemakers – the vast majority of microbes found in cooling water systems are sessile and live in biofilms (roughly 90%).
  - More difficult to test. Must swab or test a surface.
  - Biofilms are dynamic – biomass slough off and transition from being attached to freely mobile.

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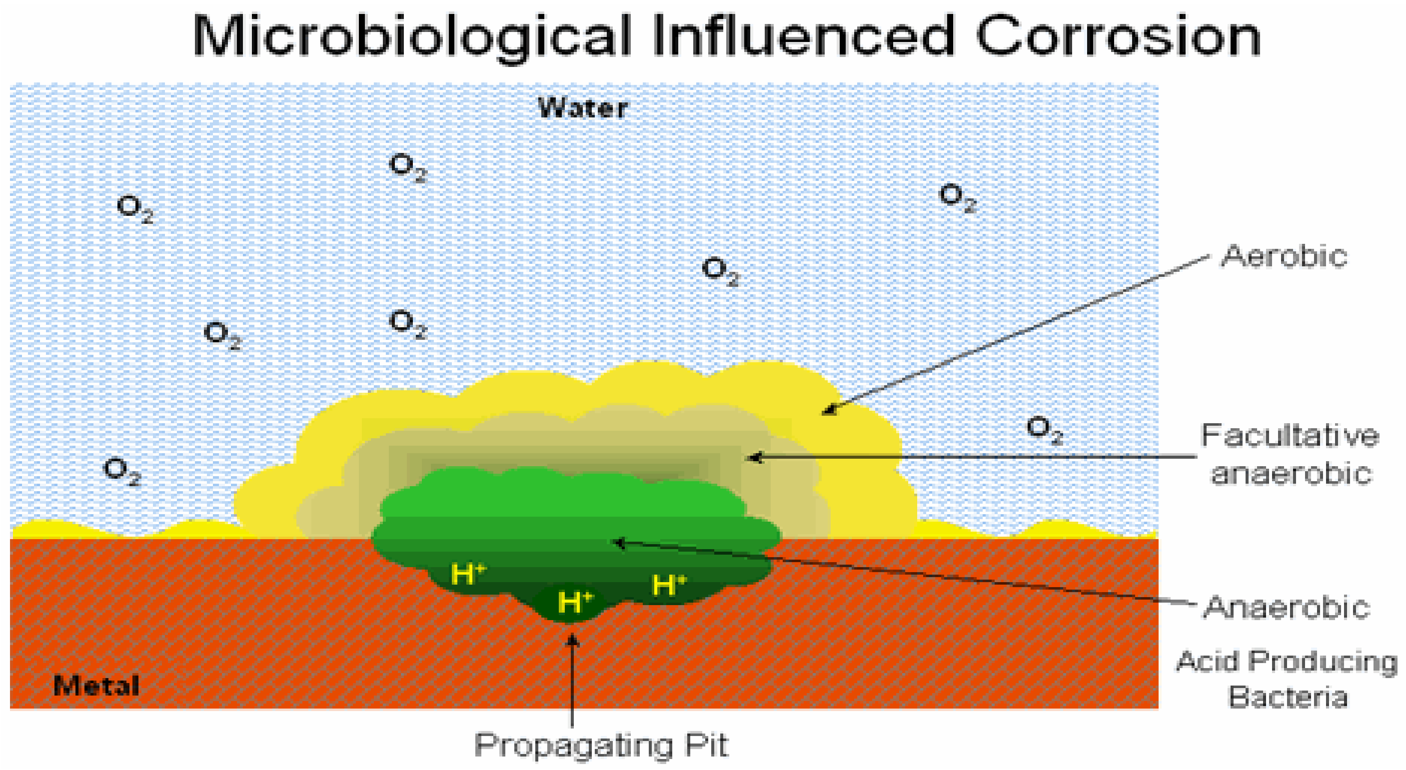
# Bio-deposits and Fouling

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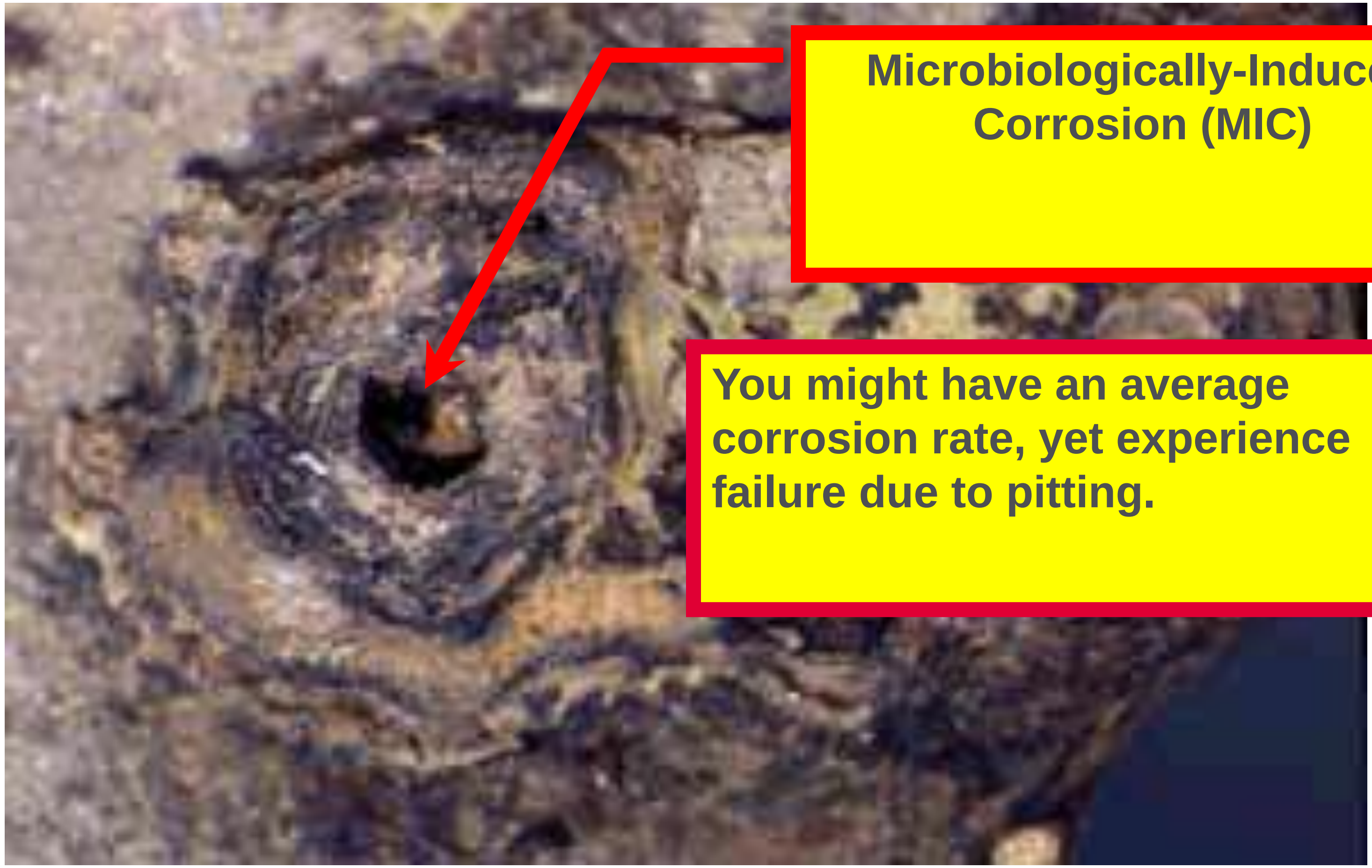
# Microbiologically Influenced Corrosion (MIC)

- **Accelerated localized corrosion (pitting) caused either directly or indirectly by the microbial metabolic processes.**
- **Biofouling Increases the risk of MIC.**
- **Almost always associated with deposits.**
  - Sulfate reducing bacteria (SRBs)
  - Acid producing bacteria
  - Microbiologically catalyzed metal precipitating bacteria
  - Slime-forming bacteria

# An example of fouling



# Microbiologically Influenced Corrosion (MIC)

# Biocide Program

## Flow Distribution

- Areas of poor flow creates stagnant water zones, leading to nutrient accumulation & deposit formation.

## Estimation of System Volume or Turnover

- Inaccuracy causes over- or under-dosing of biocides

## Management of Biocide Consumption

- Dosing strategy must be optimized

## Poor Monitoring

- Difficult to control what you can't measure

# Biocide options

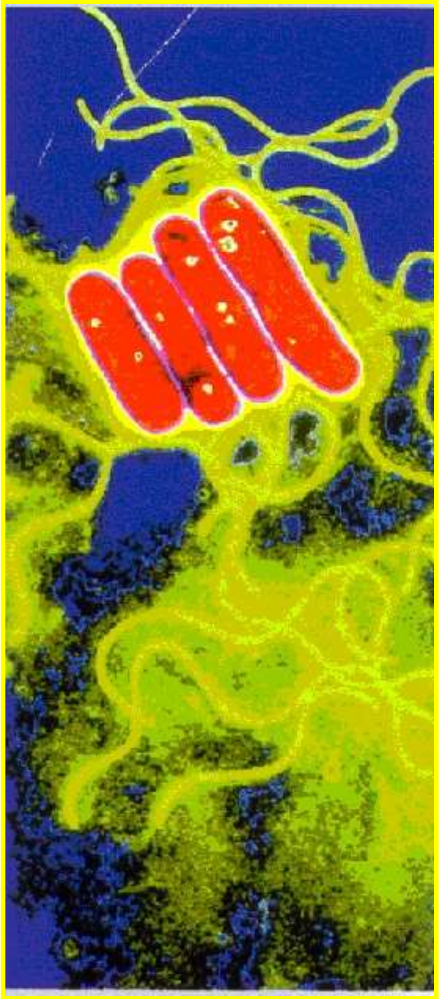
| Non-oxidizer Programs | Advantages | Disadvantages |
|---|---|---|
| 77352NA<br>(Copper Free Isothiazolone) | Will not degrade active ingredients<br>Broad spectrum and persistent<br><br>Degrades to non-toxic by-products | Can become cost prohibitive<br>Deactivated by reduced forms of sulfur (e.g., sulfite)<br>No residual testing in the field |
| 7338 (Gluteraldehyde) | Will not degrade active ingredients<br>Broad spectrum(SRB) and persistent<br>No heavy metals | Can become cost prohibitive<br>Deactivated by ammonia<br>Difficult to monitor residual in field |
| **Oxidizer Programs** | **Advantages** | **Disadvantages** |
| ACTI-BROM 1318<br>and bleach | Broad spectrum and very quick kill<br>Lower program cost<br>Easy to measure residual in field<br>Very effective | Very short half-life<br>Chloride/bromides may build-up<br>May deactivate active ingredients<br>System dispersion may be difficult |
| Chlorine Dioxide ($ClO_2$) | Effective biocide<br>No pH effect on activity<br>Does not react with ammonia or amines<br>Works well in high chlorine demand systems<br>Does not react with organics to produce AOX | $ClO_2$ is volatile and must be generated on site<br>Handling reactants is safety concern<br>Equipment commissioned and maintained<br>Not persistant in system<br>Corrosive anions may build-up (chlorides) |
| Nalco 7341 (Bleach) | Effective for bacteria, fungi and algae<br>Fast acting<br>Breaks down rapidly<br>Useful in short and long HTI cooling systems<br>Inexpensive | Not effective alone > pH 7.5<br>Reacts with amines, sulfide<br>Chloride accelerates corrosion<br>Contribution to AOX<br>Storage unstable |

# Chlorine Dioxide

- Chemical formula: $ClO_2$
- Forms a molecular solution of $ClO_2$ in water (does not dissociate like Chlorine or Bromine)
- $ClO_2$ is chemically different to $Cl_2$
- $2^1/_2$ times the oxidizing capacity of bleach ($Cl_2$)
  - Selective, does not react with organic or inorganic species like chlorine, bromine, ozone, hydrogen peroxide
  - Does not produce THM's like other $Cl_2$ based programs
  - What it does target, it kills rapidly and effectively
- Biocidal activity up to pH 10

# Advantages of $ClO_2$

- Water-soluble gas forming yellow solution
- Effective Biocide At Low Concentrations
- Excellent penetration of Biofilm, rapid kill
- Not pH Dependent
- Environmentally Friendly
  - no toxic by-products (by-product chloride or chlorite)



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# Biocidal Efficacy

- Oxidizing biocide, penetrates cell wall & reacts w/ amino acids to kill organism ***(increases effectiveness at low doses)***
- Eliminates planktonic AND sessile microorganisms
- Neutral species migrates into and destroys biofilm habitat
- Biofilm/Amoebae/Legionella
- Kills algae, molds, fungi

# $ClO_2$ Feed Strategy

- Impact of existing iron in system
  - Discoloration of water
  - Filters are critical, will clean up over time
- Acid / No Acid Program
- Slug or continuous feed
  - Know current bioactivity
  - Slug can free-up biofilm causing coil issues
  - Continuous feed is slow, monitor dip slides, no residual most of the time
- Analytical monitoring
  - Continue corrosion monitoring (coupons, online systems)
  - Weekly dipslides results are best guidance
  - **Treating to a performance not to a residual!!**

# The Goals of Biofouling Control

- To Find the most effective, least costly, and most environmentally friendly way to **Control Biofilm.**
- **Not to *Sterilize*** the system, but to…….
- ***Manage*** the fouling process to a level that minimizes operational and public health problems.
- **Minimize *Diversity***
  - the **key** to effective microbial control.

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# Questions??