CH2MHILL

Jamal Shamas, Sc.D., P.E.

Microbially Induced Corrosion (MIC) in Water & Wastewater Conveyance and Treatment Systems

1st NACE-Jubail Industrial Forum

Water Treatment & Cathodic Protection

17-19 October 2011

Jubail Industrial college (JIC), Al-Jubail Industrial City

1st NACE-JUBAIL INDUSTRIAL FORUM

WATER TREATMENT & CATHODIC PROTECTION

Agenda

- What is MIC
- Causes/Mechanism
- Impacted areas in water and wastewater treatment facilitates
- Detection
- Control & Prevention Best Practices

What is MIC?

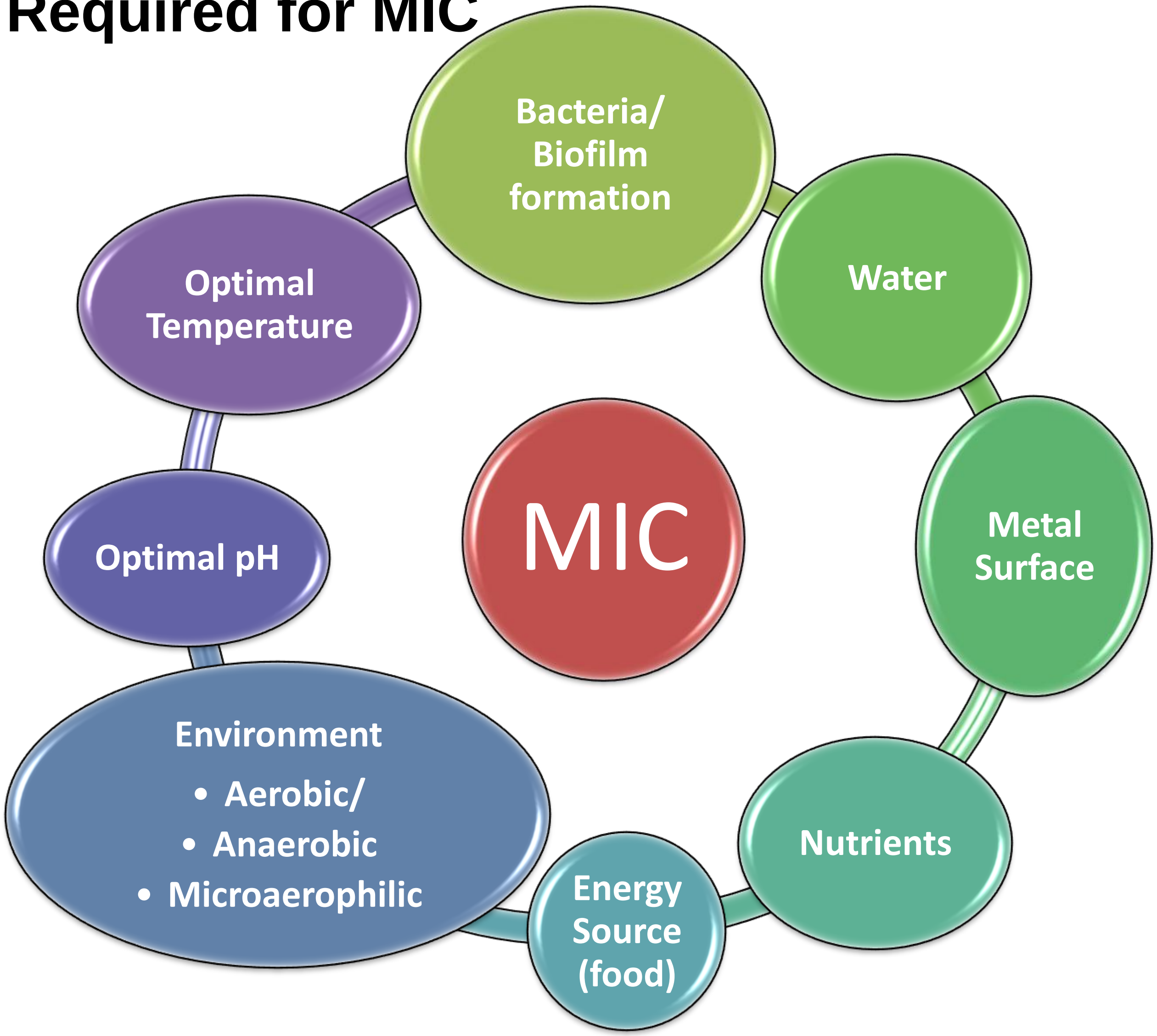
Microbially **I**nduced **C**orrosion

Microbially **I**nfluenced **C**orrosion

Microbiologically **I**nfluenced **C**orrosion

corrosion that is influenced by the presence and activities of <u>microorganisms</u> and/or their <u>metabolites</u>

Factors Required for MIC

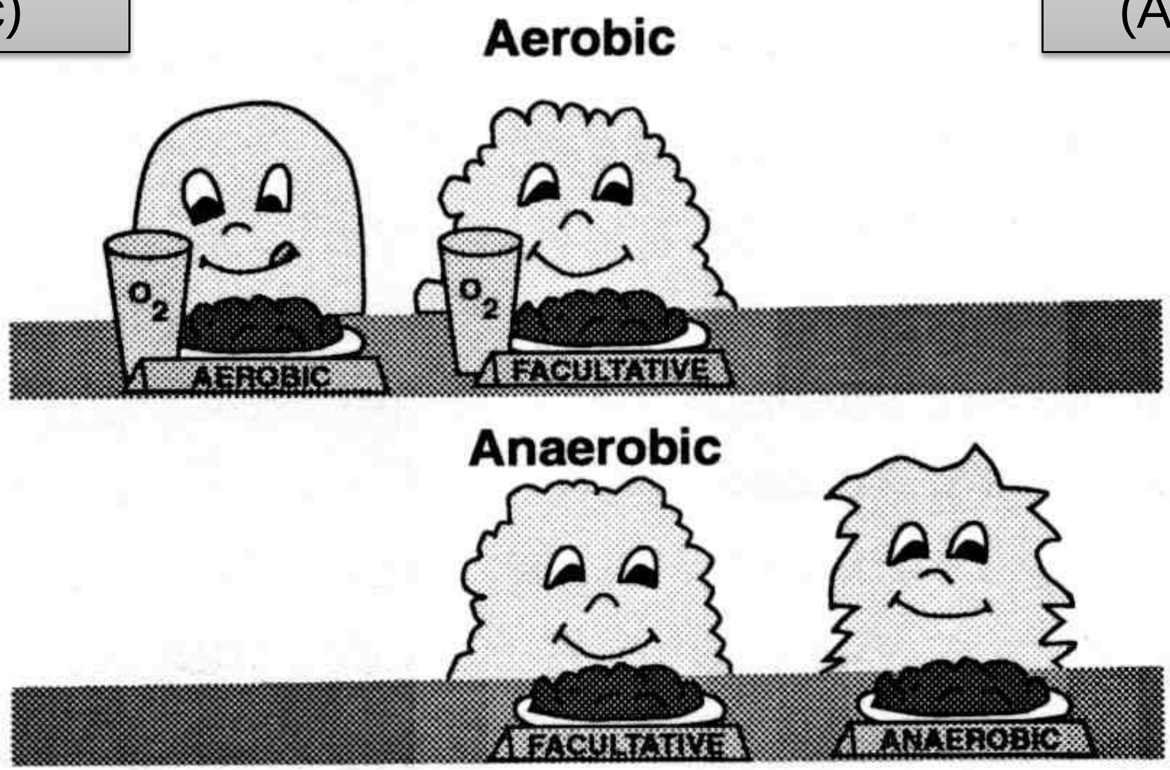


Bacteria Types

Dissolved Oxygen O2 (Aerobic)

Bound Oxygen (SO_4, NO_3) (Anoxic)

Absence of O2 (Anaerobic)

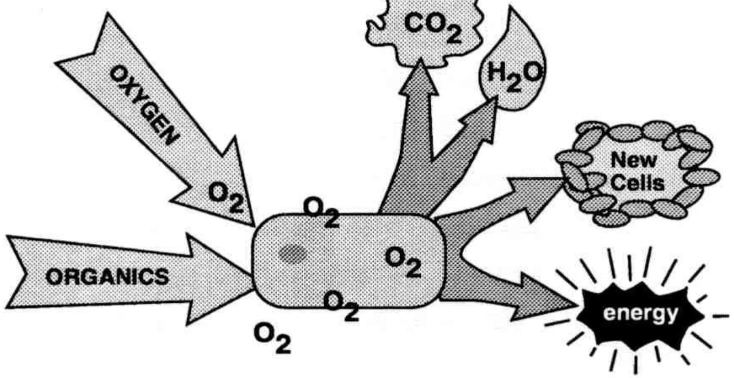


Aerobic versus Anoxic

SO_4= Sulfate to H_2S

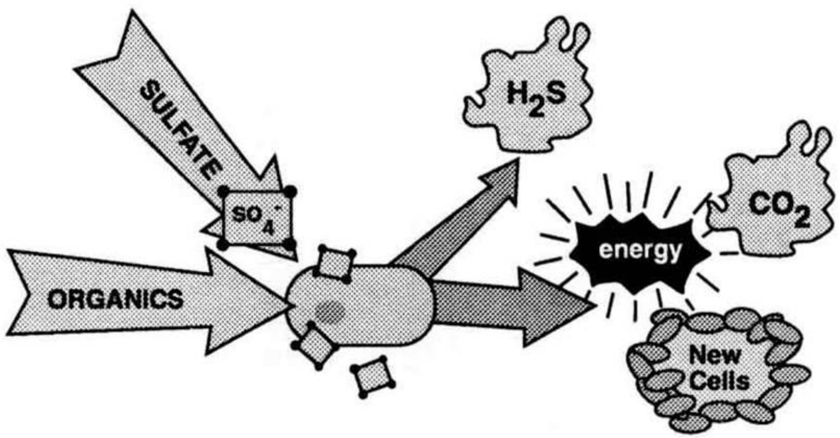
NO_3-= Nitrate to N_2

O2

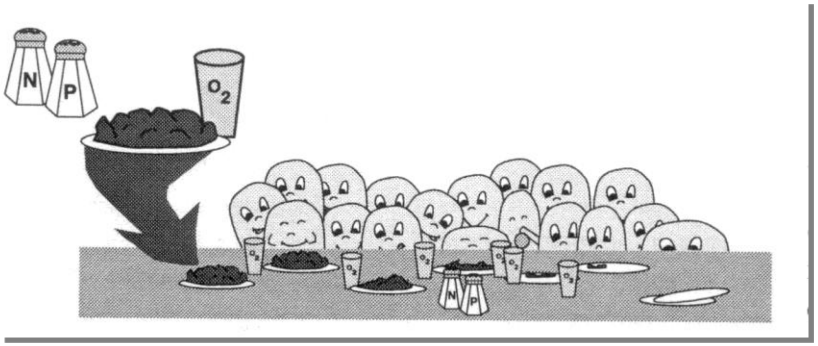


Aerobic Respiration

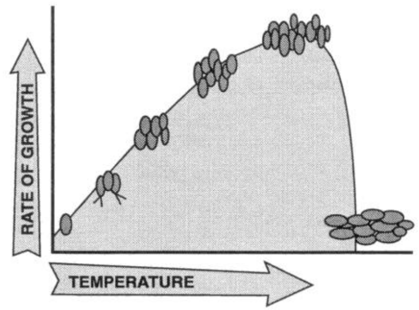
Anoxic Respiration



Environmental Conditions

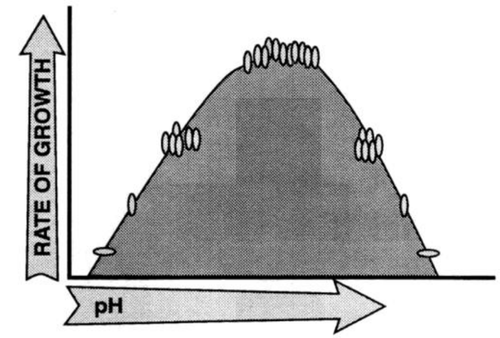


O_2, N, P



Temperature

- *Mesophyllic : 20-35 ºC*
- *Thermophillic : 55-65 ºC*
- *Psychrophillic: <0 ºC*



pH

- *Ideal pH: 6.5-8.5*
- *Filamentous organisms can withstand acidic conditions*

Bacteria Involved in MIC

- **Acid Producing Bacteria**
  - Chemical corrosion is a major player in the MIC corrosion Process.
- **Sulfate Reducing Bacteria**
  - **SRB** are probably the most destructive group of the MIC bacteria as they are a primary cause of pitting & pin-hole leaks.

    They mine iron from the pipe, take sulfur from the water & produce iron sulfide (black solids) & hydrogen sulfide gas (rotten egg smell).
- **Iron Related Bacteria**
  - **IRB** are iron utilizing. They build tubercles & are responsible for the destructive corrosive process in iron & steel. They cause pitting & pin-hole leaks.

    IRBs are known to have a symbiotic relationship with other groups of MIC bacteria.
- **Slime Forming Bacteria**
  - Slime forming bacteria live in conjunction with APB, SRB & IRB.

    They are an important part of the MIC process, often acting as the transient from aerobic to anaerobic conditions & as a support system for the corrosion process.

Bacteria Involved in MIC

Aerobic Bacteria

Thiobacillius Thioxidans:

- Produce Sulfuric Acid.

Thiobacillis Ferrooxidans:

- Oxidize Ferrous to Ferric.

Gallionella & Sphaerotilus:

- Oxidize Ferrous to Ferric. Form Tubercles.

Pseudomonas:

- Can Reduce Ferric to Ferrous.

Fungi:

- Some Can Produce Organic Acids.

Anoxic Bacteria

Desulfovibrio:

- Promotes formation of Sulfide films. Affects Iron & Steel, Stainless Steels, Aluminum, Zinc & Copper Alloys.

Desulfotomaculum:

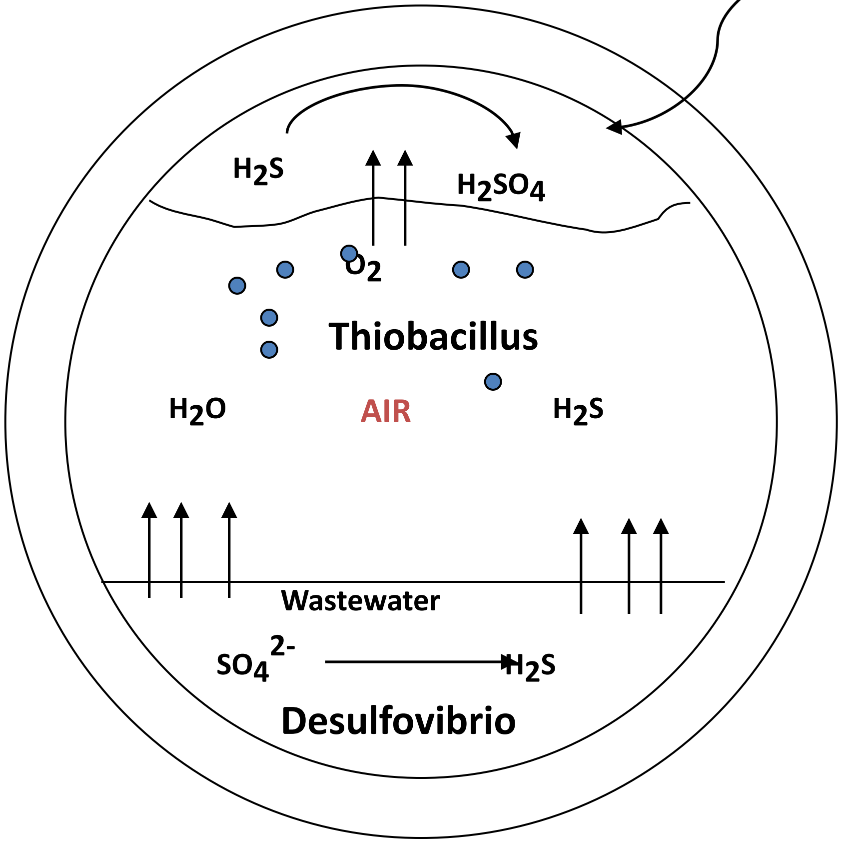
- Produces Hydrogen Sulfide Gas. Affects Iron & Steel, and Stainless Steels. Spore Former.

Desulfomonas:

- Produces Hydrogen Sulfide gas. Affects Iron & Steel.

Bacterial Action Leading to MIC

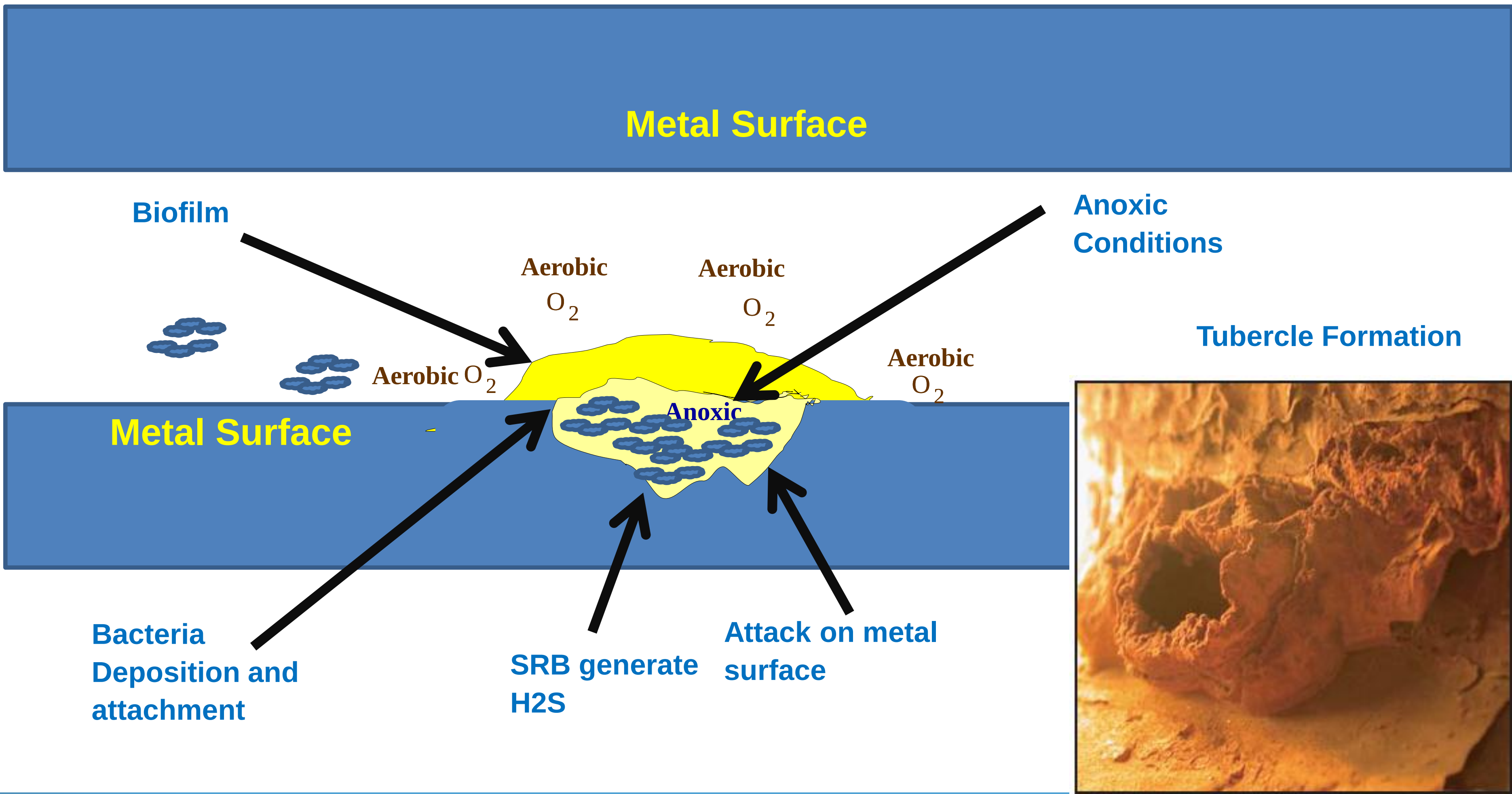
$$H_2S_{(gas)} + 2O_2 \xrightarrow{\text{Aerobic bacteria}} H_2SO_4$$



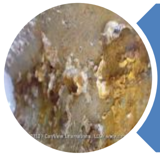
Chemical Attack of Concrete and manhole covers by H_2SO_4

$$SO_4^{--} \xrightarrow{\text{Anoxic bacteria}} H_2S_{(gas)}$$

Mechanism for MIC



Metals Affected


Carbon Steels


Stainless Steels


Aluminum Alloys


Copper Alloys


Nickel Alloys

Ideal Environments for MIC

Welds

provide attachment points for bacteria

Threads

provide attachment points for bacteria

Low Velocity

bacteria have time to attach

Temperature

bacteria thrive at higher temperatures

Nutrients

bacteria grow at a faster rate with adequate nutrients

High Oxygen Level

oxygen cell corrosion can jump start the MIC colonization process and aerobic bacteria thrive

Low Oxygen Level

anaerobic bacteria thrive here

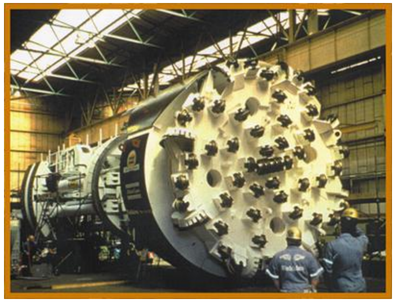
Low spots in the system

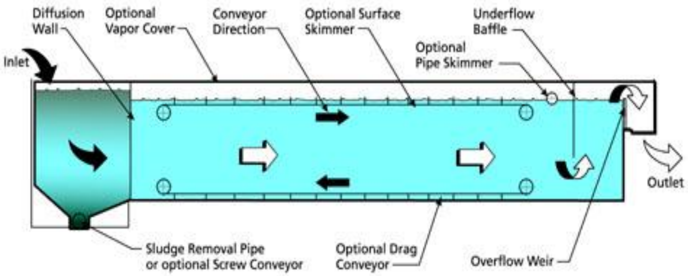
sediments from the water settle here and provide nutrients and attachment points for bacteria

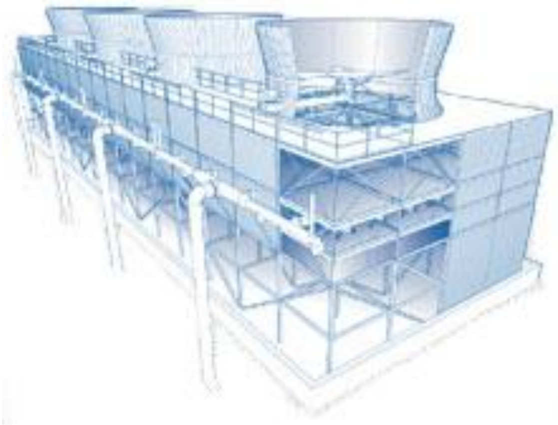
High spots in the system

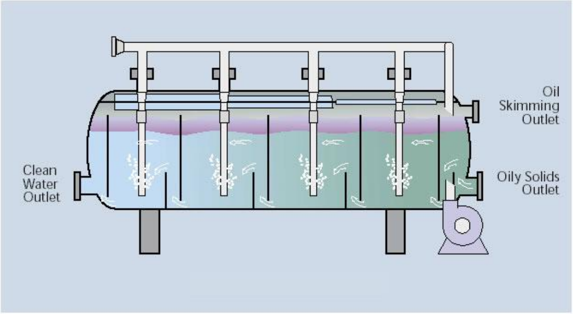
air pockets can be trapped here and provide oxygen for oxygen cell corrosion and aerobic bacteria colonization

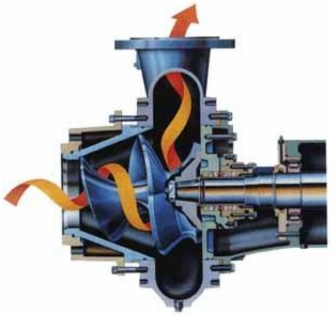
Areas Impacted











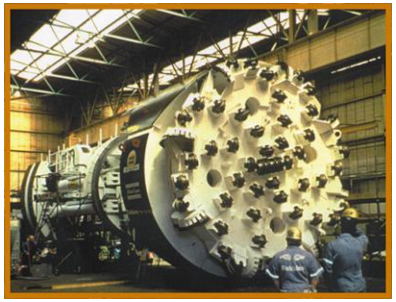
Detection Strategies of MIC

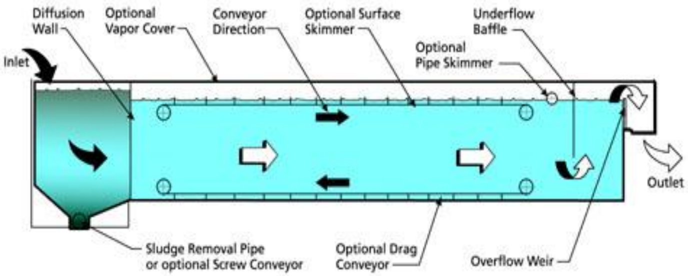
Inspection	• Visual inspection • Removal of specimens for closer inspection • Cameras • Divers
Identify environmental conditions leading to MIC	• Oxygen concentrations • Temperature/pH • Stagnant conditions • Excessive nutrients
Identify bacteria responsible for MIC:	• Direct bacterial testing • Detection of specific metabolites • DNA testing (useful in postmortem investigations)
Investigate design and installation issues:	• Minimum velocity in pipes • Bends and low spots • Coating material • Coating applications

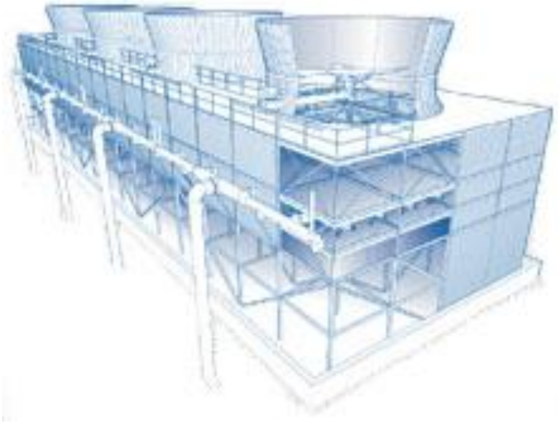
Prevention and Control Best Practices

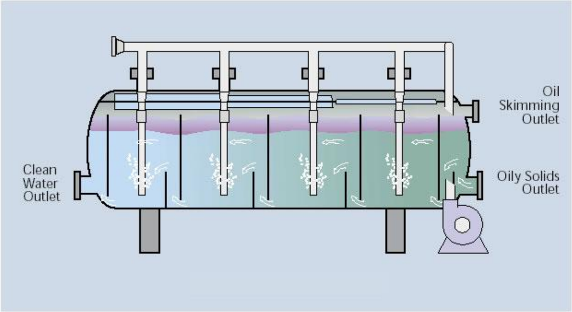
- Cleanliness & general corrosion prevention techniques
- Remove solids and debris that can promote bacterial growth
- Avoid stagnant water where feasible
- Limit bacterial nutrients
- Remove water where appropriate (gas, air and fuel lines)
- Material substitution is of limited value since, MIC affects almost all industrial metals (not titanium)
- Use non-metallic material where appropriate
- Use biocides (continuous or pulse dosing)

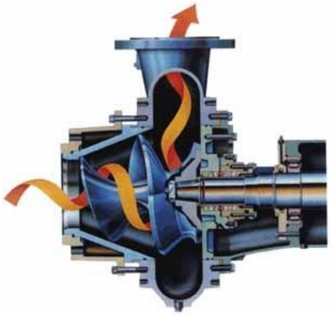
Control/Prevention Examples











CH2MHILL

Jamal Shamas, Sc.D., P.E.

Microbially Induced Corrosion (MIC) in Water & Wastewater Conveyance and Treatment Systems

1st NACE-Jubail Industrial Forum

Water Treatment & Cathodic Protection

17-19 October 2011

Jubail Industrial college (JIC), Al-Jubail Industrial City

1st NACE-JUBAIL INDUSTRIAL FORUM
WATER TREATMENT & CATHODIC PROTECTION

Thank You