"An Introduction to Recognition and Treatment of Microbial Corrosion (MIC): Practical Tips for Engineers."

Reza Javaherdashti, PhD

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Poll Question

What is your job title?

Poll Question

How many years of experience you have with corrosion management?

Poll Question

What industry sector are you from?

Poll Question

What oil and gas specialty are you?

Poll Question

What geographical region are you from?

Poll Question

Who is your employer?

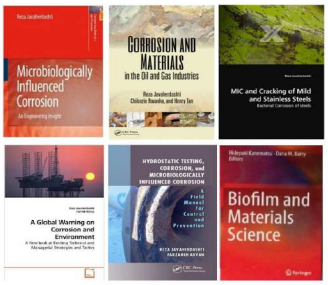
I am an SPE presenter also certified by ASME . I have more than 18 years of industrial and academic experience in microbial corrosion and all my publications (including my books published by Springer and CRC Press) are referenced internationally. I have more than 4000 hours of experience in designing and delivering international courses /workshops for industries in the USA, Australia, South Africa, GCC countries, Malaysia and so on. I have done two webinars before on concepts related to corrosion and MIC.

Reza Javaherdashti

A Brief Resume

- Over 18 years of consulting and field experience in various industries such as, but not limited to, Oil& gas, pipeline, marine, chemical, power plants, mining industries
- Has taught more than 4000 hours about corrosion, corrosion management and microbial corrosion to various industries around the world,
- International expert witness on legal disputes related to MIC
- Author of six internationally referenced books on corrosion and MIC
- Instructor of MIC at SPE and ASME
- Long standing Member of NACE (USA), ACA (Australia) and Institute of Corrosion

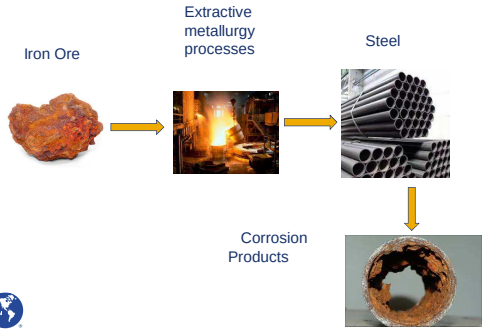
Some books authored by Reza Javaherdashti



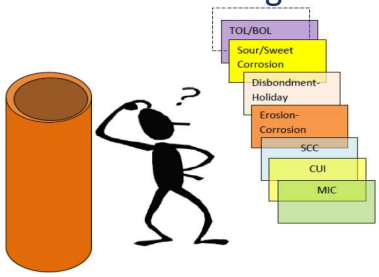
Organisation of the presentation

1. What is corrosion? A confusing issue.
2. What is MIC and why it is important?
3. Where could MIC be a problem?
4. Bacteria and Archaeaq and their role in corrosion
5. Biofilm formation mechanism
6. Issues in MIC: Recognition, treatment and monitoring
7. Two general categories for MIC recognition
8. Four ways to treat MIC
9. Corrosion Management (CM) and Corrosion Knowledge Management (CKM)
10. Some tips and myths related to MIC
11. Self-Exam!

What is Corrosion?



Corrosion: A Confusing issue!

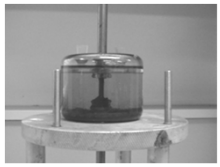


Microbiologically Influenced Corrosion (MIC)

What is MIC?

MIC is a type of corrosion, In other words, it is, in simple terms, an electrochemical corrosion process induced and influenced by living organisms such as, but not limited to, bacteria.

Stress corrosion Cracking (SCC) enhanced by the corrosive action of sulphate reducing bacteria (SRB)



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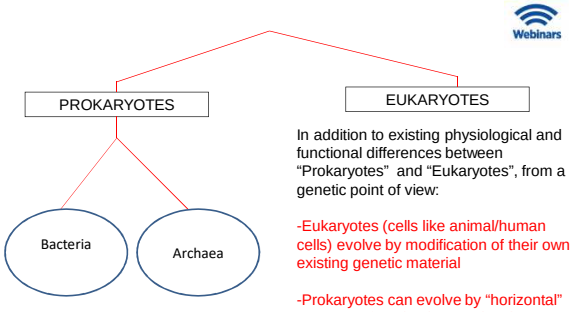
COST OF MIC

In 2006, BP Exploration Alaska (BPXA) Inc. experienced something which was quite extraordinary: it was the spill of 200,000 gallons (or 4,790 barrels) of oil through their Trans-Alaskan (Prudhoe Bay Field) oil transit line. The reported most probable cause of the problem: MIC

Where could MIC be a problem

- Fire water rings
- Cooling Towers/cooling systems
- Post-hydrotest failures
- Desalination units
- Concrete structures
- Hydrocarbon carrying pipelines
- Water/waste water treatment facilities
- Off-shore platforms (eg RO systems)



In addition to existing physiological and functional differences between "Prokaryotes" and "Eukaryotes", from a genetic point of view:

-Eukaryotes (cells like animal/human cells) evolve by modification of their own existing genetic material

-Prokaryotes can evolve by "horizontal" gene transfer, simply meaning that, among other s, a certain bacteria are capable of being multifunctional. For example, they can produce hydrogen as well as iron reduction.

MIC, CRB & CRA

❖ In this presentation we will focus on micro-organisms (mainly bacteria) that are capable of inducing corrosion.

❖However we have to also consider the fact that bacteria are not the only micro-organims that in addition to micro-algae and micro-fungi may affect corrosion severity.

❖"Archaea" are also to be considered in this regards as there are many corrosion-related Archaea (CRA) that can survive the environmental conditions that could be detrimental to corrosion related bacteria (CRB).

Bacteria involved in MIC

A common mistake among industry experts is that they baselessly assume that MIC can be caused by one or two types of bacteria,

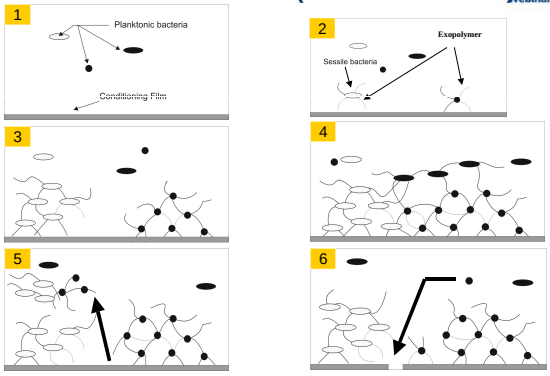
The most referenced type of the CRB by these professionals is sulphate reducing bacteria (SRB)

Unfortunately, this illusion about the CRB and their link to MIC can also be seen in some of the presentations issued by well-known companies and currently quite freely available on the internet

Some examples of "Corrosive" Bacteria

General hetrotrophic Bacteria/Archaea	Thiosulphate oxidising bacteria (TOB)	Acetogenic Bacteria	Slime-forming bacteria
Acid –producing Bacteria/Archaea	Metanogens	Nittrate-reducing Bacteria/Archaea	Sulphur oxidising Bacteria/Archaea
Sulphate reducing bacteria/Archea	nitrite-reducing m sulphur-oxidising bacteria (NR-SOB)	Thiosulphate reducing bacteria (TRB)	Thiosulphate reducing Archaea (TRA)

MIC Mechanism (Biofilm Formation)



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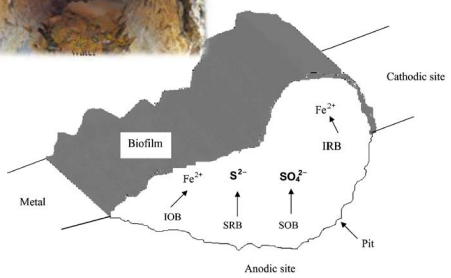
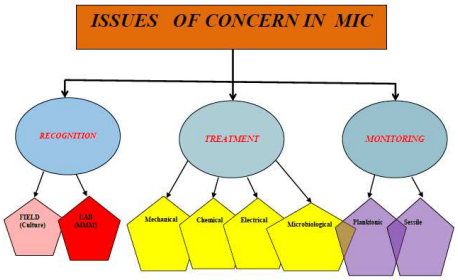
Biofilm



ISSUES OF CONCERN IN MIC



Recognition of MIC:

- Recognition methods can be grouped into two categories:

a) Field Tests

b) Laboratory Tests

- In addition, there is also another categorisation procedure as follows:

d) culture-dependent methods

e) Culture-independent methods

Recognition of MIC:

- Polymerase Chain Reaction (PCR)
- Denaturing Gradient Gel Electrophoresis (DGGE)
- Fluorescence in-situ Hybridisation (FISH)
- Microbial Diagnostic Microarray (MDM) {Gene Chips}
- Metabolic activity Measurement techniques such as ATP measurement
- Next Generation Sequencing (NGS)

.

Some examples of Culture-independent methods

How MIC can be treated?

Mechanical: Pigging

Electrical: Application of Cathodic Protection (CP)

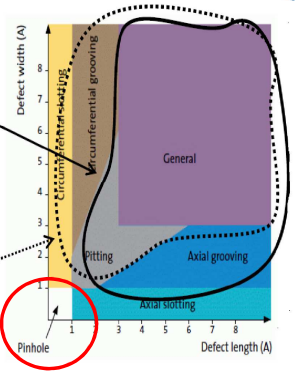
Chemical : biocide

Biological : use of denitrifying bacteria vs. SRB.

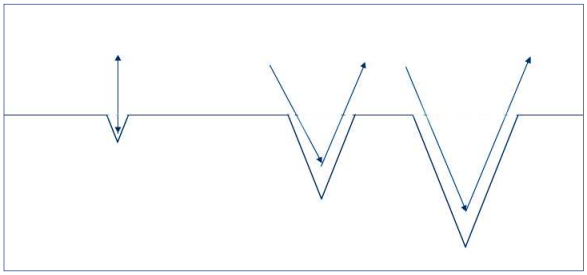
Smart Pigging

Circumferential MFL is best at finding/sizing anomalies in this region

Axial MFL is best at finding/sizing anomalies in this region



Pinhole



One of the most important characteristics of MIC is formation of pinholes. When these pinholes are not detected, MIC is in fact being neglected

Pros and Cons of some biocides (oxidising)

Chlorine:
(+):
- Economical
- Broad spectrum activity
- Effective
- Monitoring dosages and residuals is simple.
(-):
- Hazard concerns for the operator
- Ineffective against biofilm bacteria.
- Ineffective at high pH
- Inactivation by sunlight and aeration
- Corrosive to some metals
- Adverse effect on wood
- Feeding (Dosing) equipment is costly and requires extensive maintenance
- Limitations imposed by environmental authorities on the discharge of chloramines and halomethanes

Ozone:
(+):
- A natural biocide, effective as a detachment agent against sessile bacteria on stainless steel surfaces
- Resembles advantages of chlorine
- Non polluting and harmless to aquatic organisms
(-):
- Like chlorine, it is affected by pH, temperature organics etc.
- Its oxidising effect does not resist throughout the system so ozone is used in small systems or specific sites within larger systems
- Ozone must be generated on site, requiring investment for installation and running the equipment.

Pros and Cons of some biocides (Non-oxidising)

1. Glutaraldehyde:
(+):
- Broad spectrum activity
- Relatively insensitive to sulfide
- Compatible with other chemicals
- Tolerates soluble salts and water hardness
(-):
- It is de-activated by ammonia, primary amines and oxygen scavengers.

Quaternary phosphonium salts (quats):
(+):
- Broad spectrum of killing activity and good stability. They are generally most effective against algae and bacteria at neutral to alkaline pH.
- Low toxicity
- Stable and unaffected by sulphides.
(-):
- Not effective fungicides at any pH
- Their activity is mostly reduced by high chloride concentrations, high concentrations of oil and other organic foulants and by accumulations of sludge in the system.
- Excessive overfeed of some types of quats may contribute to foaming problems especially in open recirculating systems with organic contaminations.

REMINDER

Why is MIC important?



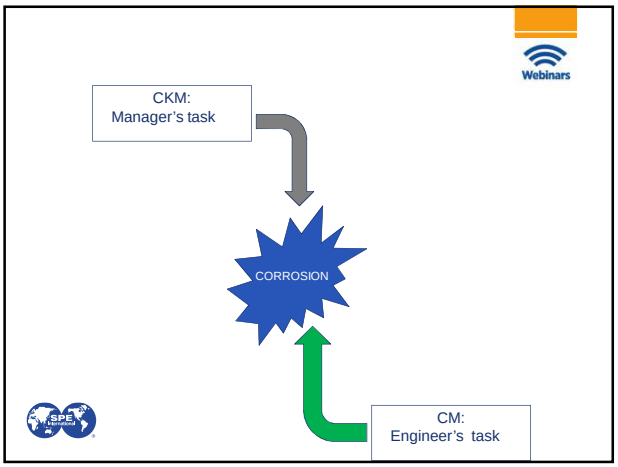
Cost X Risk =Importance

How to deal with Corrosion?

There are two ways to do this

:Corrosion management (CM)
- ✓ Technical treatment of corrosion by engineers and technologists
- ✓ Characteristics:
  - Use of a too- technical “jargon” only understanable by their fellow-engineers.
  - Main concern is to control the “**RISK**” of corrosion

2. Corrosion Knowledge Management (CKM):
- ✓ Managerial Treatment of corrosion
- ✓ Characteristics:
  - A tool-box necessary for top and middle managers
  - Main Concern is to control the “**Cost**” of corrosion



How to deal with MIC?

1. Make sure that the case is indeed MIC! Don't move from "Corrosion Morphology"
2. Consult with Standards
3. Apply good recognition methods (combine filed with laboratory methods)
4. Apply Treatment strategies (such as materials selection, biocides, CP, coating….)
5. Avoid MIC treatment myths
6. Observe tips!

Some Standards related to Bacteria and MIC

- **NACE Standard TM0212-2012 :" Detection, Testing, and Evaluation of Microbiologically Influenced Corrosion on Internal Surfaces of Pipelines "**
- **NACE Standard TM0106-2006: "Detection, Testing, and Evaluation of Microbiologically Influenced Corrosion (MIC) on External Surfaces of Buried Pipelines"**
- **ASTM D4412 – 84 (Reapproved 2009):" Standard Test Methods for Sulfate-Reducing Bacteria in Water and Water-Formed Deposits"**
- **ASTM D932 – 85 (Reapproved 2009): "Standard Test Method for Iron Bacteria in Water and Water-Formed Deposits"**
- **ASTM E645 – 07 : "Standard Test Method for Efficacy of Microbicides Used in Cooling Water Systems"**
- **ASTM D6990 – 05 (Reapproved 2011): "Standard Practice for Evaluating Biofouling Resistance and Physical Performance of Marine Coating Systems"**
- **...**

TIP 1

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Any system where stagnant, untreated nutrient-rich water comes into contact with a relatively rough surface.

TIP 2

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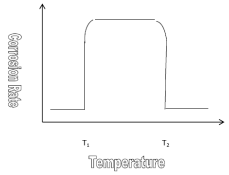
- Collect samples fresh and carefully! Do not contaminate them!
- Check corrosion rate pattern!



- Check factors such as pH, temperature, TDS, COD, certain chemicals such as sulphides, nitrites, …
- Detect bacteria by both conventional methods such as culturing and rather "fancy" methods such as genetic profiling of microbial communities in corrosion samples using SSCP method. Bear in mind their advantages and limitations!

TIP 3

Webinars

Egg or Chicken!

Role of Iron in initiating of MIC in MARINE MIXED CULTURES OF SULPHATE REDUCING AND IRON REDUCING BACTERIAL SPECIES (SRB +IRB)

Myths of MIC (3/11)

- *There is a relationship between the numbers of SRB and the rate of corrosion; the higher the numbers, the more severe the corrosion.*
- *Bacteria get used to biocides so you need to change your biocide every now and then*
- *If there is no sulphates in the environment, there is no need to look for SRB*

Self-Exam

1.Microbiologically influenced corrosion (MIC) occurs when in your system you have bacteria only. True/false.

2. An effective way that can always be used to mitigate MIC is use of biocides. True/false

3. CP can always mitigate MIC. True/false

4. As soon as a biofilm forms, it will be leading to Corrosion. True/False.

5. If we keep the fluid flowing (flow rates more than1.5 m/s), this will prevent MIC. True/false

Thank you!