BACTERIAL CORROSION

SAMER SUHAIL NAJIM

NAZAR RAHEEM HADI

INTRODUCTION TO BACTERIAL CORROSION

- Bacterial corrosion, scientifically referred to as Microbial Influenced Corrosion (MIC), is a complex phenomenon where microorganisms—primarily bacteria—interact with metallic and non-metallic materials, leading to their degradation. This type of corrosion is a significant problem across multiple industries, including oil and gas, maritime, wastewater treatment, and healthcare.

WHAT IS BACTERIAL CORROSION?

- Bacterial corrosion occurs when microorganisms, either directly or indirectly, alter the electrochemical conditions at the material's surface, initiating or accelerating the corrosion process. Unlike traditional corrosion, which is driven by chemical or electrochemical reactions, MIC introduces a biological component where specific microbes play an active role.

HISTORICAL REVIEW

- The study of bacterial corrosion gained traction in the mid-20th century when industries began noticing unexplained failures in pipelines, storage tanks, and other infrastructure. Subsequent research linked these failures to microbial activity, leading to a new understanding of how biological agents impact materials.

TYPES OF BACTERIA CAUSING CORROSION

- Sulfate-Reducing Bacteria (SRB): Produces hydrogen sulfide (H_2S) that accelerates corrosion.
- Iron- and Sulfur-Oxidizing Bacteria (IOB): Contribute to rapid deterioration in wet environments.
- Manganese-Oxidizing Bacteria (MOB): These organisms oxidize manganese, which can lead to pitting and crevice corrosion.
- Sulfur-Oxidizing Bacteria (SOB): These bacteria produce sulfuric acid, leading to acidic conditions that corrode concrete and metals.
- Acid-Producing Bacteria (APB): Secretes organic acids that degrade metal surfaces.

MECHANISM OF SRB-INDUCED CORROSION

Sulphate-Reducing Bacteria (SRB): These bacteria are the most commonly implicated in MIC. They reduce sulfates to sulfides, producing hydrogen sulfide (H_2S) that accelerates the corrosion of metals like steel.

- SRBs reduce sulfate ions (SO_4^{2-}) to hydrogen sulfide (H_2S) under anaerobic conditions.
- Reaction: $SO_4^{2-} + 8[H] \rightarrow H_2S + 2H_2O + 2OH^-$
- H_2S reacts with metal (Fe), forming iron sulfide (FeS):
- $Fe + H_2S \rightarrow FeS + H_2$
- Iron sulfide weakens the material, leading to structural damage.

MECHANISM OF IOB-INDUCED CORROSION

- Under aerobic conditions, iron-oxidizing bacteria catalyze the following reaction:

$$4Fe^{2+} + O_2 + 6H_2O \rightarrow 4Fe(OH)_3 .$$

- Explanation.

Fe^{2+} (ferrous iron) is oxidized to Fe^{3+} (ferric iron).

Fe^{3+} reacts with water to form ferric hydroxide , an insoluble precipitate.

The reaction releases protons (H^+), lowering the pH and potentially accelerating corrosion.

MECHANISM OF MOB-INDUCED CORROSION

- Basic Oxidation of Manganese

Under aerobic conditions, MOB facilitate the oxidation of manganese:

$$2Mn^{+2} + O_2 + 2H_2O \longrightarrow 2MnO_2 + 4H^+$$

- Explanation:

(manganous ion) is oxidized to (manganese dioxide).

he reaction releases protons (H^+), lowering the pH and promoting corrosion.

MECHANISM OF SOB-INDUCED CORROSION

- Oxidation of Hydrogen Sulfide (H_2S)
- SOB oxidize hydrogen sulfide under aerobic conditions to form sulfur or sulfate:
- Partial Oxidation (to elemental sulfur):

$$H_2S + \frac{1}{2}O_2 \rightarrow S + H_2O$$

- Complete Oxidation (to sulfate):

$$2H_2S + 3O_2 \rightarrow 2H_2SO_4$$

MECHANISM OF ACID-PRODUCING BACTERIA (APB)

- 1. APBs produce organic acids such as acetic acid (CH_3COOH).
- 2. The acids lower pH and dissolve protective oxide layers on metals.
- 3. Reaction example: $Fe + 2CH_3COOH \rightarrow Fe^{2+} + 2CH_3COO^{-} + H_2$
- 4. The dissolved metal ions weaken the structure and enhance degradation.

ROLE OF BIOFILMS IN CORROSION

1. Biofilms are microbial communities attached to surfaces, providing a stable environment for bacterial activity.
2. They trap nutrients and accelerate chemical reactions leading to corrosion.
3. Protective oxide layers on metals are dissolved beneath biofilms, enhancing degradation.

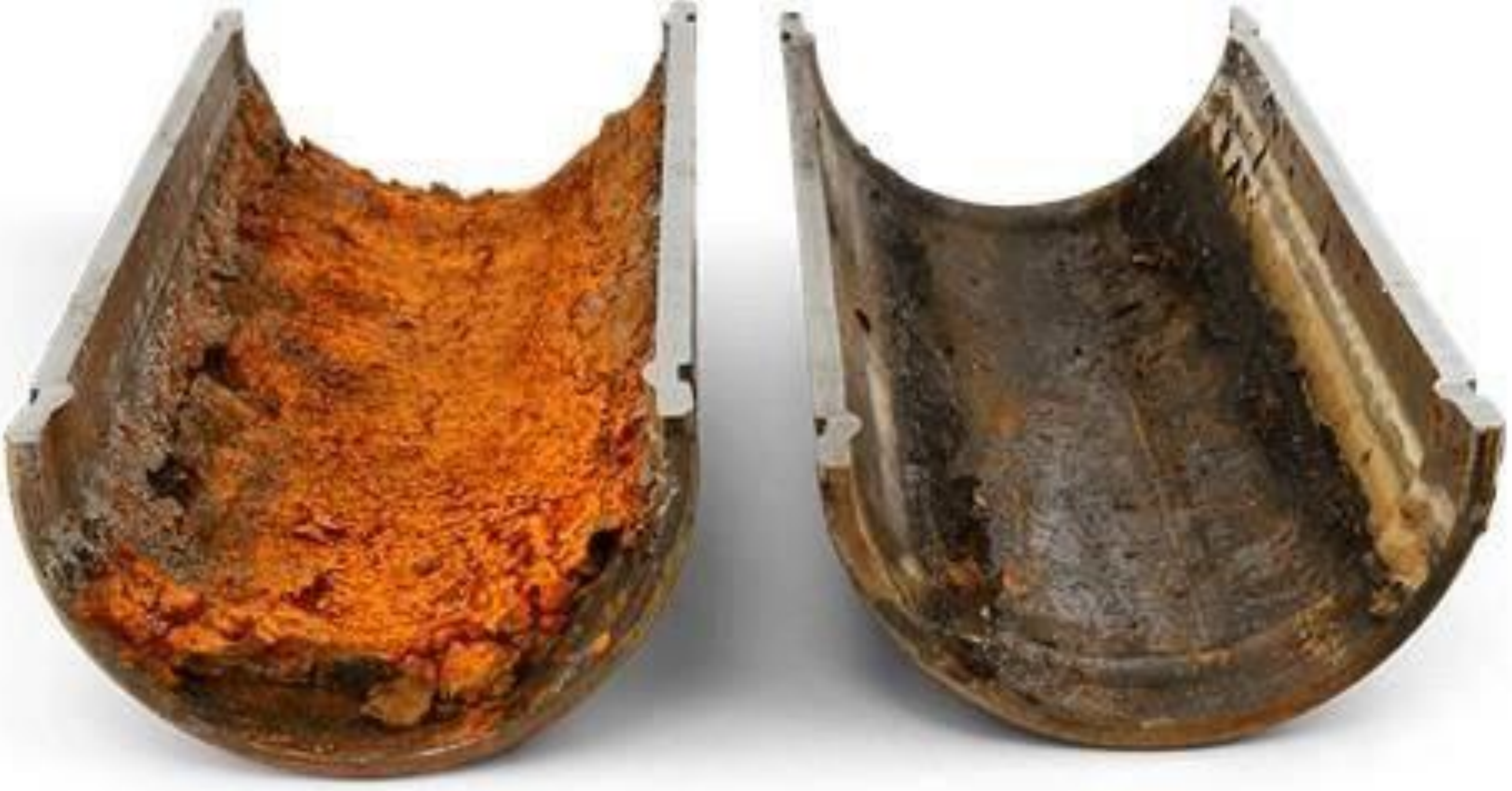
INDUSTRIES AFFECTED BY BACTERIAL CORROSION

1. Oil and Gas: Corrosion of pipelines, tanks, and offshore structures.
2. Water Treatment: Degradation of distribution systems and reservoirs.
3. Marine Environments: Damage to ships, docks, and coastal infrastructure.

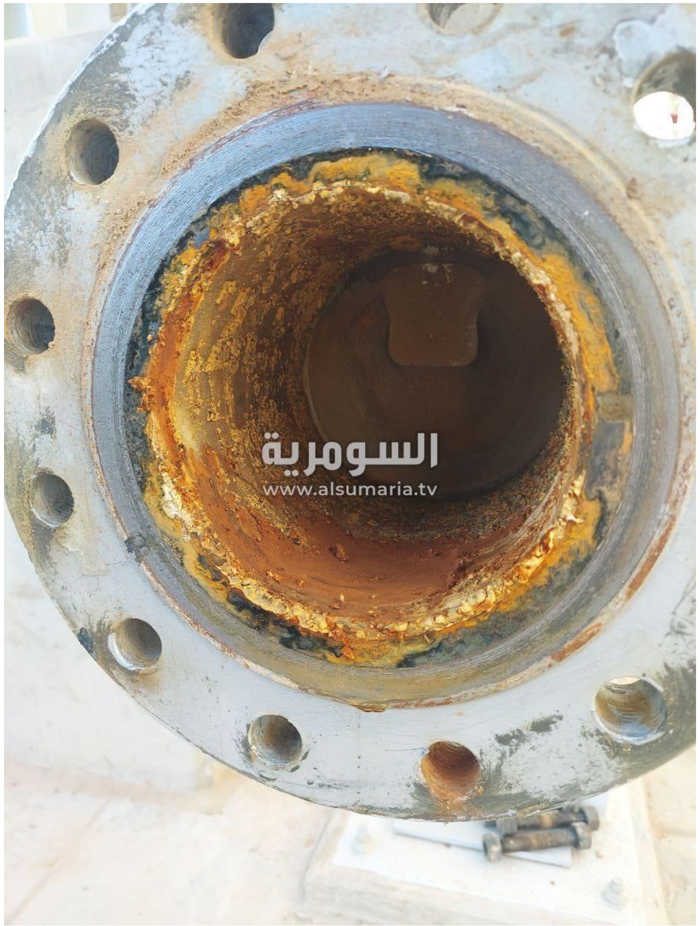
I- OIL AND GAS INDUSTRIES

- Bacterial corrosion is one of the primary challenges in pipelines and storage tanks in the oil and gas sector, especially in environments with sulfur or saline water.
- Sulfate-Reducing Bacteria (SRB): These bacteria reduce sulfates to hydrogen sulfide, a highly corrosive compound.
- Impact:
- Oil or gas leaks from pipelines.
- Increased costs due to equipment replacement and maintenance.
- Environmental hazards caused by pollutant leaks.

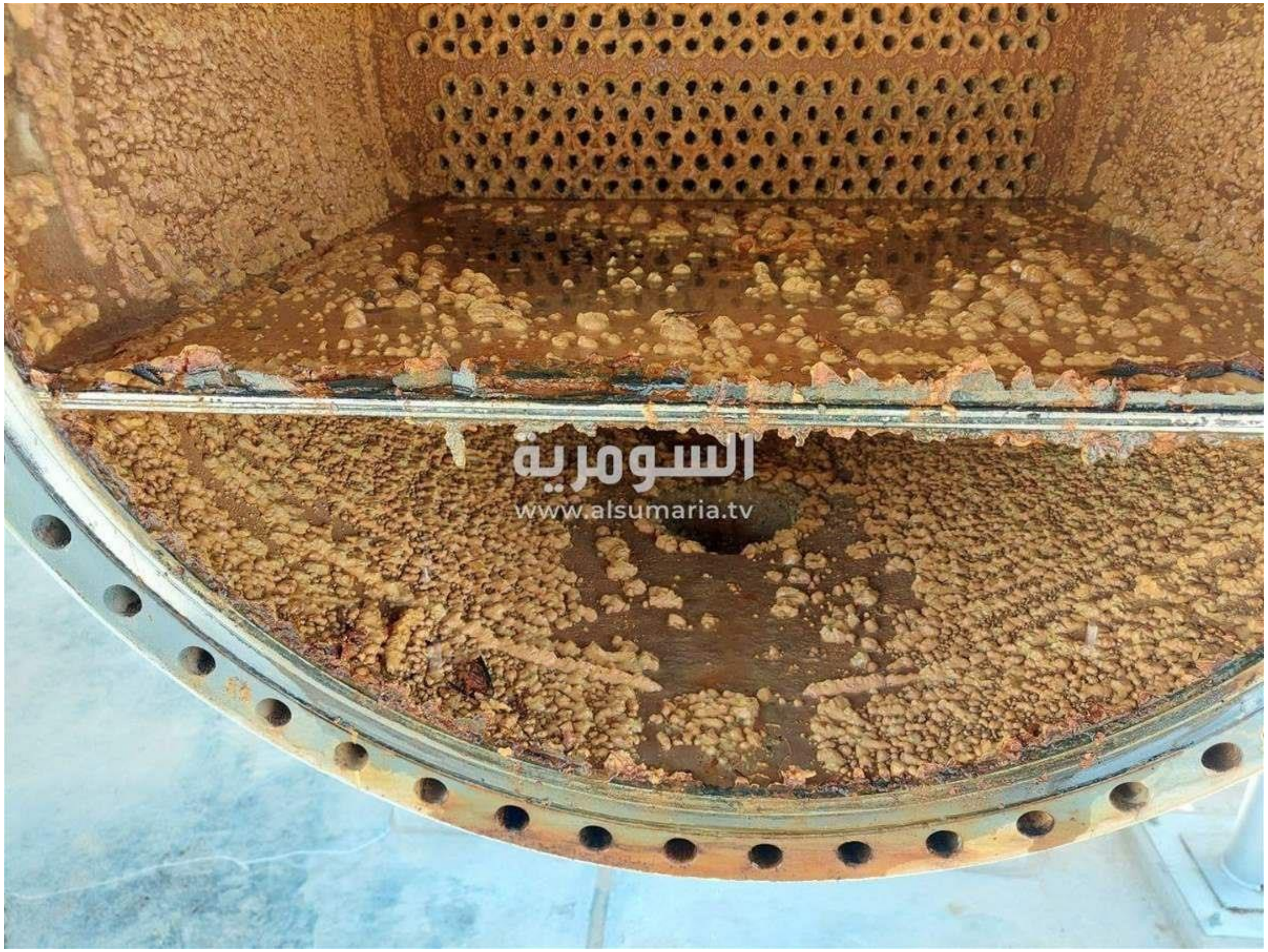
1- OIL AND GAS INDUSTRIES



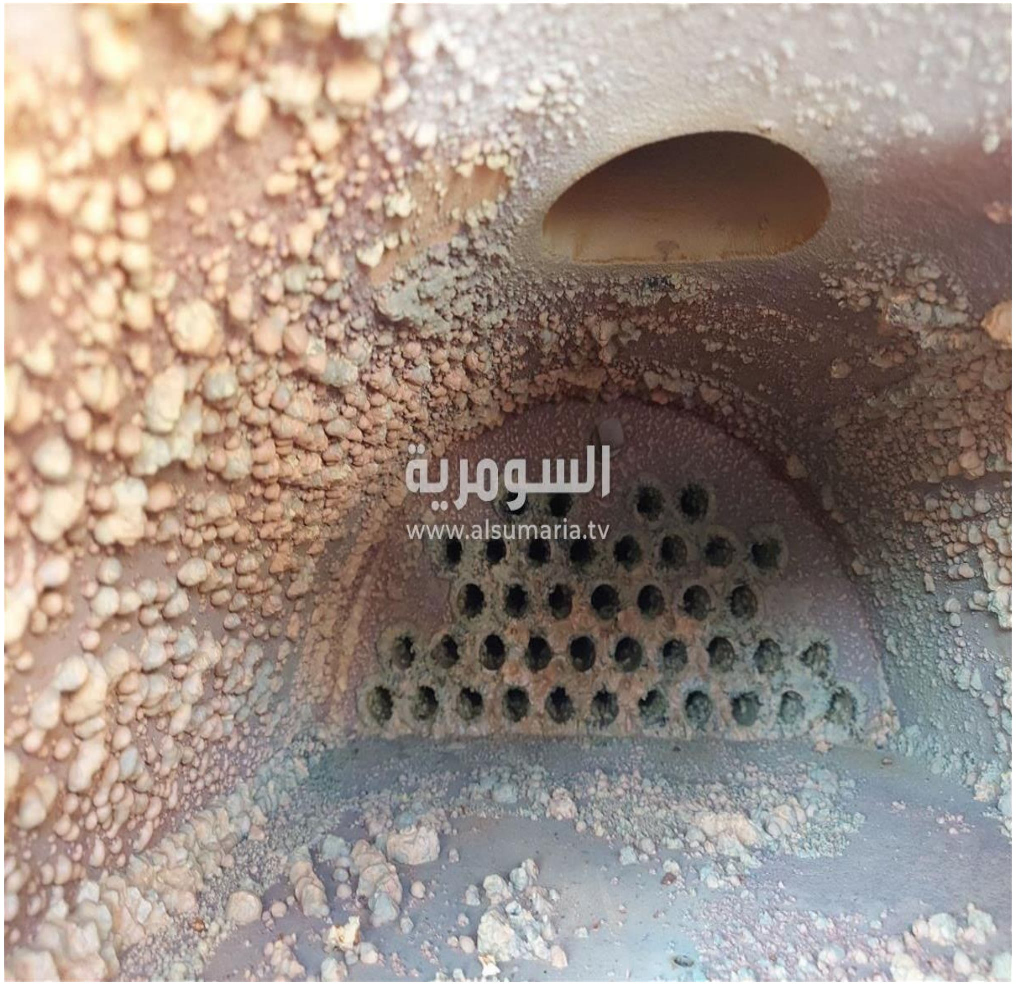
1- OIL AND GAS INDUSTRIES

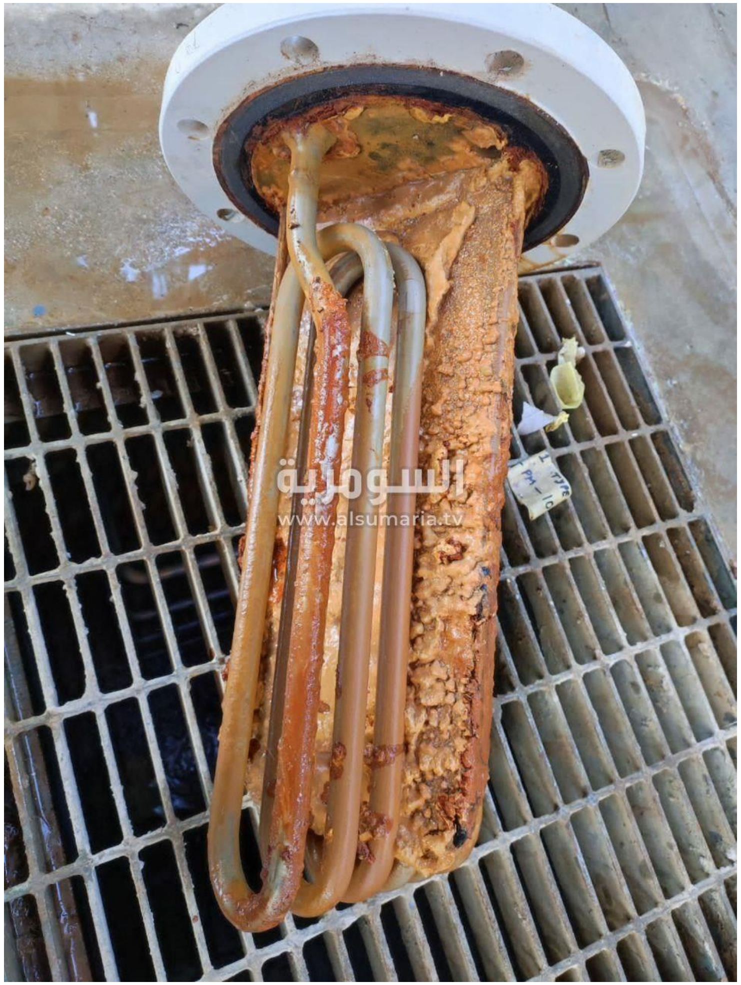


1- OIL AND GAS INDUSTRIES



1- OIL AND GAS INDUSTRIES





2- WATER AND WASTEWATER TREATMENT SYSTEMS

- In water and wastewater treatment plants, bacteria cause severe degradation of pipes and storage tanks.
- Sulfur-Oxidizing Bacteria (SOB): These bacteria produce sulfuric acid by oxidizing sulfides , leading to concrete and metal corrosion.

Impact:

- Structural weakening of sewage systems.
- Increased maintenance and repair costs.
- Risk of contaminants leaking into groundwater.

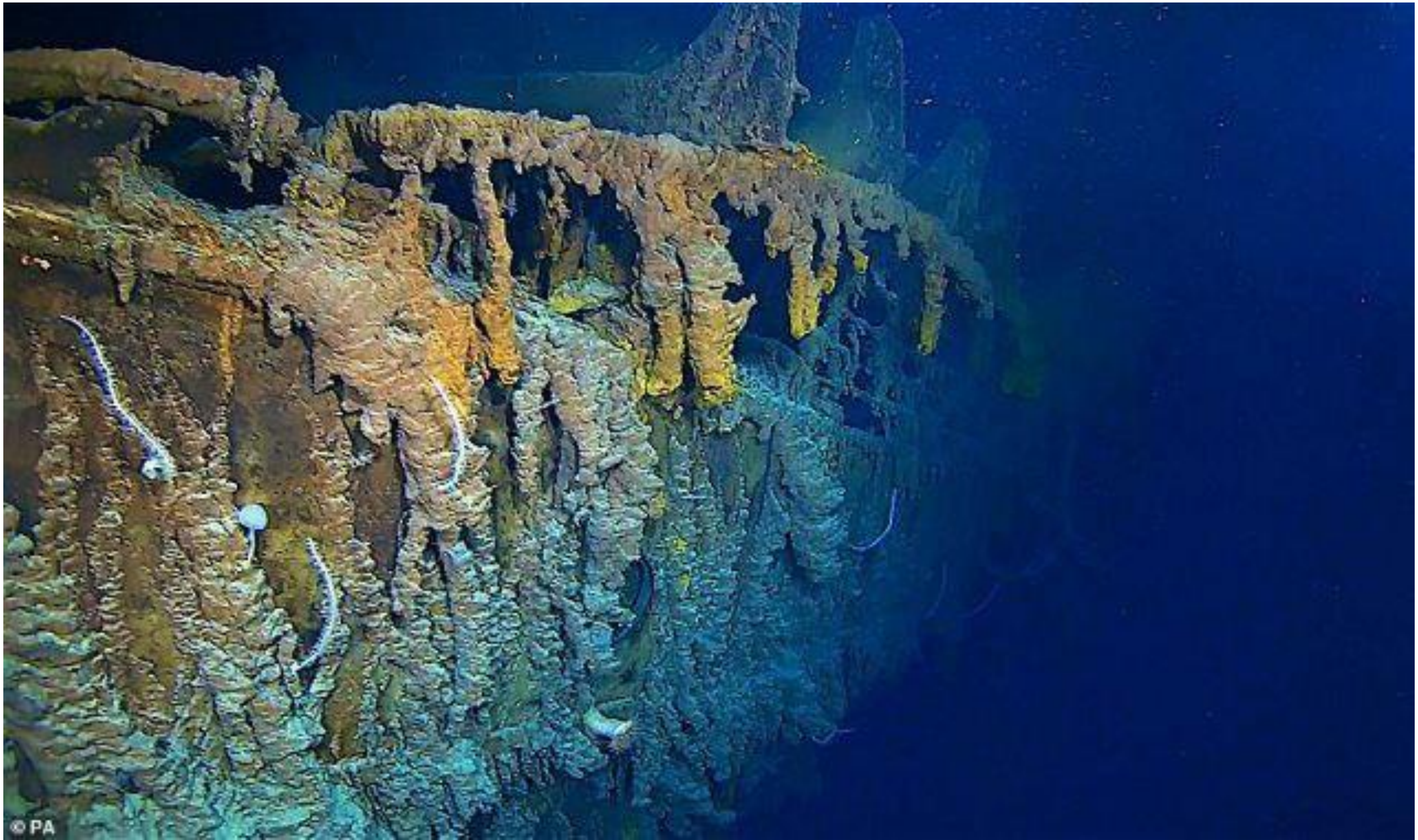
3. MARINE AND SHIPPING INDUSTRY

- Metallic structures in ships, offshore platforms, and storage tanks face significant bacterial corrosion due to the moist, nutrient-rich environment.
- Iron-Oxidizing Bacteria (IOB): These bacteria oxidize ferrous iron to ferric hydroxide , causing mechanical weakening of metal.

Impact:

- Structural damage to ships and reduced lifespan.
- High maintenance and frequent repairs.
- Safety risks for personnel due to structural failures

3. MARINE AND SHIPPING INDUSTRY



METHODS FOR DETECTING BACTERIAL CORROSION IN METALS

- Detecting microbial-influenced corrosion (MIC) is essential for preventing damage and maintaining the integrity of industrial structures and systems. Below is an overview of the primary methods used to identify and monitor bacterial corrosion in metals:

METHODS FOR DETECTING BACTERIAL CORROSION IN METALS

- 1. Visual Inspection
- 2. Microscopic Analysis
- 3. Microbial Culture Testing
- 4. Molecular Biology Techniques

METHODS FOR DETECTING BACTERIAL CORROSION IN METALS

- 5. Electrochemical Techniques
- 6. Chemical Analysis
- 7. Surface Analysis Techniques
- 8. Biofilm Testing
- 9. Enviromental Monitoring

METHODS TO MITIGATE AND REDUCE MICROBIAL CORROSION (MIC):

- 1. Material Selection:

Use corrosion-resistant materials such as stainless steel or coated metals that are less susceptible to microbial attack.

Consider non-metallic materials like polymers or composites for specific environments.

METHODS TO MITIGATE AND REDUCE MICROBIAL CORROSION (MIC):

- 2. Environmental Control:

Oxygen Limitation: Limit oxygen availability to inhibit the growth of aerobic bacteria such as Iron-Oxidizing Bacteria (IOB).

pH Control: Adjust the pH to create conditions unfavorable for microbial activity. Most MIC-related bacteria thrive in neutral to slightly acidic environments.

METHODS TO MITIGATE AND REDUCE MICROBIAL CORROSION (MIC):

- 3. Biocides Application:

Use biocides (chemical agents that kill microorganisms) to control bacterial growth. Examples include:

Chlorine-based compounds for general microbial control.

Glutaraldehyde or quaternary ammonium compounds for targeted bacterial elimination.

Regular monitoring is necessary to prevent the development of biocide-resistant bacteria.

METHODS TO MITIGATE AND REDUCE MICROBIAL CORROSION (MIC):

- 4. Coatings and Surface Treatments:

Apply protective coatings such as epoxy, polyurethane, or polymer-based paints to isolate the metal surface from the microbial environment.

Use anti-microbial coatings infused with agents that prevent bacterial colonization.

METHODS TO MITIGATE AND REDUCE MICROBIAL CORROSION (MIC):

- 5. Cathodic Protection:

Use sacrificial anodes or impressed current systems to reduce the electrochemical potential and minimize metal dissolution.

METHODS TO MITIGATE AND REDUCE MICROBIAL CORROSION (MIC):

- 6. Mechanical Cleaning and Maintenance:

Perform regular cleaning to remove biofilms, sediments, and other deposits where bacteria thrive.

Use pigging systems in pipelines to mechanically clean and prevent microbial buildup.

METHODS TO MITIGATE AND REDUCE MICROBIAL CORROSION (MIC):

- 7. Proper Design:

Avoid dead zones, crevices, and poorly drained areas in system designs to prevent stagnant water, which promotes bacterial growth.

Ensure good ventilation and drainage in tanks and pipelines.

METHODS TO MITIGATE AND REDUCE MICROBIAL CORROSION (MIC):

- 8. Monitoring and Early Detection:

Use advanced monitoring techniques such as:

Biofilm sensors to detect early bacterial colonization.

Chemical analysis for detecting metabolic byproducts of bacteria (e.g., hydrogen sulfide).

Conduct periodic microbial analysis to identify specific bacteria and determine effective mitigation strategies.

METHODS TO MITIGATE AND REDUCE MICROBIAL CORROSION (MIC):

- 9. Chemical Inhibitors:

Add corrosion inhibitors that create a passive film on the metal surface, reducing microbial attachment and corrosion rates.

METHODS TO MITIGATE AND REDUCE MICROBIAL CORROSION (MIC):

- 9. Chemical Inhibitors:

Add corrosion inhibitors that create a passive film on the metal surface, reducing microbial attachment and corrosion rates.

METHODS TO MITIGATE AND REDUCE MICROBIAL CORROSION (MIC):

- 10. Temperature Control:

Increase or decrease the temperature of the system to levels that inhibit bacterial activity. Most MIC-related bacteria have optimal growth temperatures.

METHODS TO MITIGATE AND REDUCE MICROBIAL CORROSION (MIC):

- Integrated Approach:

Combine multiple methods (e.g., biocides, coatings, and design improvements) for a comprehensive strategy to reduce microbial corrosion effectively.

Regular monitoring, maintenance, and adaptation of strategies based on the specific environment are key to long-term control of microbial corrosion..

THANKS

SAMER SUHAIL NAJIM

NAZAR RAHEEM HADI