Curtin University

CURTIN CORROSION CENTRE

JOINT INDUSTRY PROJECT (JIP)

Preventing and Managing MIC for the Oil & Gas Industry - A pragmatic holistic approach

Make tomorrow better.

JOINT INDUSTRY PROJECT (JIP)

THE BUSINESS CASE

Microbiologically influenced corrosion (MIC) is corrosion initiated, facilitated or accelerated by microorganisms and their metabolic functions. MIC is one of the costliest forms of corrosion and remains highly unpredictable. MIC can lead to the fast, localized dissolution of the metal substrate at rates as high as 10 mm/y. Moreover, MIC management is difficult and costly and more research, data integration, and advances are needed to develop effective practices and approaches to assess, monitor, and mitigate MIC.

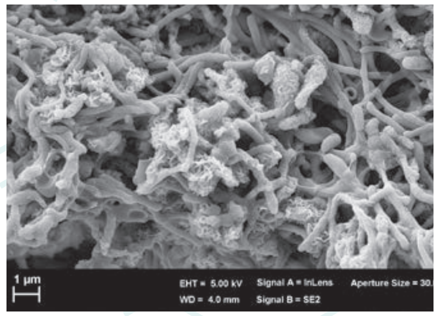
OBJECTIVE

The objective of the MIC-JIP is to develop novel tools and approaches to assess, monitor, and mitigate MIC by advancing the understanding of MIC phenomena. The MIC-JIP will result in the safe and effective MIC management of oil and gas production, storage, and transportation facilities.

BENEFITS

The MIC-JIP will provide:

- MIC risk assessment of JIP member facilities.
- Critically assess current MIC treatment methods (if any) of member facilities.
- Optimise MIC treatments.
- Training and education of JIP company staff.
- Access to world-class, state of the art, MIC laboratories and staff.
- Innovation and technology.
- Knowledge sharing and networking.



WHO

The MIC-JIP will be overseen by an Industry Steering Committee. Dr Laura Machuca Suarez, MIC-subject matter expert, and Prof. Mariano Iannuzzi, Director of the Curtin Corrosion Centre, will be Curtin University's delegates. The Steering Committee will meet quarterly via teleconference. Milestones will be revised twice a year during the biannual Steering Committee Review seminar.

- Participation fee is **AU$ 80K** per annum.
- Expected start-up: **Q1 2020**
- Deadline for EOI: **September 2019**
- Duration: 3 years with a provision to extend for a further 2 years.
- A minimum of **five (5)** companies is required.
- Curtin University will sponsor one PhD scholarship.

ABOUT US

The Curtin Corrosion Centre (CCC) has developed world-class capabilities to study MIC phenomena. By cooperation with several research centres at Curtin University and around the globe, CCC has expanded its research capabilities providing high-end technology and methods to study microorganisms and their effects on infrastructure and processes in the resources sector.

The multidisciplinary MIC team has developed fruitful collaborations with industry groups that have resulted in more than 40 funded projects valued at ~$3 M in the past 4 years.

CCC's unique approach combines expertise in microbiology, materials, and corrosion science to investigate MIC mechanisms and help the industry understand the risk of MIC.

Through fieldwork and close collaboration with industry, the CCC has established the first bank of microorganisms containing at least 50 different species from Australian oilfields.

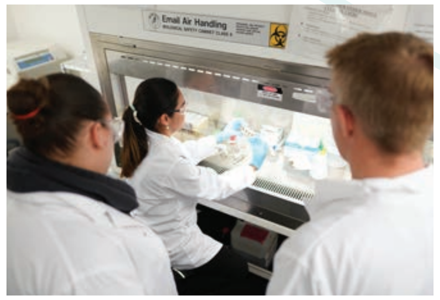
Specialised MIC facilities at the CCC include PC2 laboratories equipped with biofilm devices (CDC bioreactors, flow biofilm systems with biostuds), wire beam electrode (WBE) system to study the spatiotemporal electrochemical behaviour of metals under biofilms, state-of-the-art potentiostats and optical and fluorescence microscopes. The MIC facility also has a molecular microbiology laboratory to perform a variety of cutting-edge DNA and RNA-based analysis. International collaborations resulted in the development of pioneer MIC research using advanced metagenomics, metatranscriptomics, and bioinformatics to study the relationship between microbial activities and corrosion.

HOW

Specific themes with independent milestones will be developed in consultation with the Industry Advisory Board. The proposed Themes are:

THEME 1: MIC assessment

- **Baseline assessment:** the project will include a baseline assessment phase to sample and characterize sessile (attached) microbial communities in facilities of the MIC-JIP member companies. MIC-susceptible areas in the various facilities will be identified during this phase. This characterization will be conducted using both DNA and novel RNA-based approaches and advanced bioinformatics tools, which is one of CCC's core areas of expertise.



- **Advance the understanding of MIC in the O&G industry:** there is still limited understanding of biofilms and the conditions that result in microorganisms causing MIC. Although CCC has advanced the knowledge in this area (e.g., effect of deposits [1,2], nutrients, and temperature [3] on the risk of MIC in carbon steel), there remain questions to answer with regards to design aspects (e.g., dead legs), water chemistry, gases and fluid dynamics for both carbon steel and corrosion resistant alloys.
- **Expand methods and biomarkers for MIC assessment:** the industry still relies on inaccurate traditional cultivation techniques for evaluating and monitoring the risk and efficacy of chemical treatments. CCC has adapted the latest molecular microbiology methods to assess microorganisms from complex samples such as corrosion products and oilfield samples. An experimental approach will be designed to expand our understanding of genes and proteins involved in MIC and define potential novel targets for the assessment of MIC risks. Specialized protocols for sampling and preservation for MIC assessment will be generated as well as inspection time and inspection methods for specific equipment and facilities.

THEME 2: MIC Mitigation

- **Baseline assessment:** this theme will start with a baseline assessment of conventional biocides used by the MIC-JIP members across the different facilities and will collect information about scenarios when treatment chemicals prove effective vs ineffective.
- **Chemical efficiency and optimization:** the objective of this phase will be to develop a fundamental understanding of biofilm response and resistance to commonly used biocides. CCC has developed relevant expertise in the assessment of chemical treatment efficiency against biofilms and in the application of in-situ and ex-situ approaches (e.g., surface science, molecular microbiology, and electrochemistry) to study biofilms on metals and MIC inhibition. For example, we have adapted a wire beam electrode (WBE) system for online assessment of MIC and its inhibition. The better understanding of the biofilm response to antimicrobial and chemical inhibitors and the factors triggering resistance will lead to the development of better treatments regimes to mitigate MIC, including a more accurate frequency of treatments and developing integrated practices that will result in MIC mitigation while reducing the unnecessary cost of treatment chemicals.
- **Innovative approaches for MIC mitigation:** The objective of this phase will be to develop a fundamental understanding of biofilms with regards to their structure, quorum sensing (QS) communication, and exo-polymeric substances (EPS) components that can be used as targets for biofilm disruption. Novel biofilm and MIC control methods based on, e.g. use natural plants extracts with both corrosion and microbial inhibition capabilities [4], will reduce or replace the use of toxic biocide chemicals, reducing environmental and health impacts.

THEME 3: MIC Monitoring

- **Baseline assessment:** The first objective will be to collect information on MIC/corrosion monitoring technologies presently used by the MIC-JIP members across the different facilities. The consolidated database of MIC and Corrosion monitoring approaches will allow the identification of good practices leading to early detection of areas at risk.
- **Advance the understanding of electrical MIC mechanisms:** Studies involving EMIC mechanisms have shown that direct electron transfer can result in corrosion rates as severe as those reported in the field (>5 mm/y), which suggests that, against the general perception, EMIC can be significant in industrial systems. Electrotrophic organisms in the bulk fluids, potentially leading to corrosive conductive biofilms, can be investigated and represent important targets for early MIC detection. These microbes can be monitored using bioelectrochemical systems.
- **Development of real-time MIC detection methods:** the objectives of this phase are to study (i) MIC in-situ using a combination of electrochemical and electrical-resistance sensors [5] and (ii) in-situ biofilm formation and activity using biosensors, e.g. detection of key biomolecules in real time [6], under experimental conditions. We will be able to identify MIC initiation events by coupling the detection of corrosion and biological signals in real-time. Biofilms associated with active corrosion can be further studied ex-situ to identify genes and proteins (using OMICS approach) that can be associated with MIC (biomarkers of active MIC process). This phase will lead to the development of innovative tools based on a scientific foundation for the early detection of MIC that could be applied in the field as well as to new methods for monitoring the efficacy of MIC treatments.

THEME 4: MIC Education & Training

One of the main objectives of the MIC-JIP is to provide education and training to the MIC-JIP members. For this purpose, CCC will develop a new web portal exclusive to MIC-JIP members within the new CCC web platform. The education and training program will provide:

- Annual MIC Workshops,
- Hands-on laboratory training,
- MIC International symposium,
- Online training platform with MIC modules and access to MIC-JIP member-exclusive content.

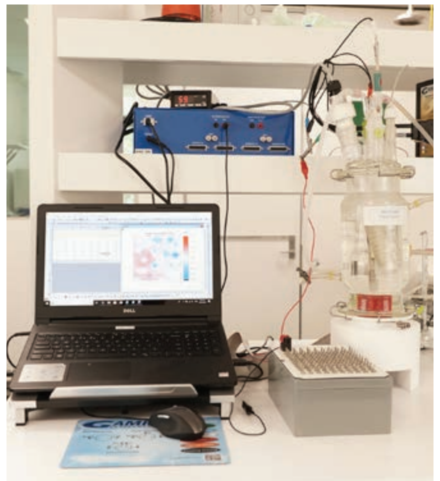
THE SCIENCE AND THE DETAILS

Microbiologically influenced corrosion (MIC) is the electrochemical corrosion process of metals and alloys “initiated, facilitated or accelerated by microorganisms and their metabolic functions” [7]. The process is intimately linked to biofilm establishment on metallic surfaces such as carbon steel and corrosion resistant alloys (CRAs) [8-10]. MIC can occur by microbial direct electron extraction from the metal surface as in electrical MIC mechanisms (EMIC) [11]. It can also occur indirectly through corrosive microbial metabolites, a process known as chemical MIC (CMIC) [12,13].

As a topic, MIC has generated scientific interest since the 1930s, owing to its impact on the industry [14-16]. MIC is known to be highly unpredictable and occurs typically as a non-uniform localised attack that can result in the fast dissolution of the metal substrate at rates as high as 10 mm/y [17].

In 2001, MIC alone was predicted to cost the oil and gas industry around US$3 - $7 Billion [18,19]. Recent NACE estimates for general corrosion are in excess of US$2.5 Trillion annually, [20] which was revised in 2018 to a figure of US $4 trillion [21]. This sum is spent globally on preventing and responding to corrosion failures; damage for which MIC contributes around 20% [22].

Any metal surface in contact with water is susceptible to biofilm formation. Once a biofilm is formed, it provides a physical barrier that protects microbes against biocides. It has been demonstrated that bacteria in biofilms (attached to the surface) can resist antimicrobial compounds at concentrations up to **1000 times higher** than those active on the same bacteria in the fluid. Biofilms on metallic surfaces are dynamic, continually changing in response to inhibitor/biocide compounds, which typically result in enhanced resistance of the microorganisms to chemical treatments [23,24]. **The more mature a biofilm is, the more difficult to eradicate.** However, there is little understanding of biofilm resistance to conventional biocide treatments used in the oil and gas industry, resulting in expensive yet ineffective mitigation treatments that drive a worldwide market for microbial control that is worth billions of dollars annually [25].



MIC mitigation is difficult and costly, both to the environment and the economy. Today, many biocides and chemicals are being phased out due to environmental toxicity concerns and production costs. Environmentally sustainable practices and compounds are now generating more interest as a result [4,26]. Likewise, understanding of the fundamental aspects of multispecies biofilms on active metallic surfaces is an area that requires further attention since most research has been conducted on planktonic (free-swimming) microbes [27]. **The fundamental understanding of biofilm-metal interactions is pivotal for targeting novel, effective approaches to disrupt biofilms and mitigate against MIC.**

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