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Microbiologically Influenced Corrosion: Causes, Remedies, Facts & Semi-facts

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Microbiologically Influenced Corrosion (MIC) is in essence an electrochemical corrosion process in which living organisms (either microscopic such as bacteria and macroscopic such as algae and fungi observable by naked eye) can influenced the course of corrosion by accelerating (and sometimes decelerating) the associated kinetics. While MIC encompasses both micro- and macro-organisms , the main focus –perhaps by a mistake that stemmed from first days of exploring MIC in late 19th century- has been on bacteria.

The main organisms of interest from a corrosion point of view are bacteria, archaea, algae and fungi. Some of these organism accelerate corrosion by directly electron take up from the metal (this is called Electrical MIC or EMIC. In case of sulphate reducing bacteria (SRB) EMIC-driven corrosion could reach unbelievable rates of more than 30 mpy). Other organisms can modify the surrounding environment by changing its chemistry, for example sulphur oxidising bacteria (SOB) or Clostridia can lower pH by generating acids (in case of SOB, sulphuric acid and in case of Clostridia, it will be organic acids. In both cases, the normally neutral environment becomes acidic and aggressive to the metal. Producing acid could also be the way some fungi may use to attack metals such as Aluminium have Organisms such as algae that have day-night cycles during which they establish high and low oxygen partial pressure environments can contribute to corrosion by facilitating differential aeration cells.

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)

Table 1: Selection of bacteria and archaea found in marine environments that could potentially very dangerous from a corrosion point of view

Some examples of marine-dwelling bacteria and archaea important in MIC

MIC affects all engineering materials except Titanium alloys. MID (Microbiologically influenced deterioration) is the counterpart of MIC affecting non-metals such as polymers, composites and concrete. This differentiation is to further emphasize on using right terminology: corrosion only happens in metals and on non-metals, it is deterioration/degradation that occurs and these two have completely different mechanisms. It follows then that polymers or composites can't corrode but degrade/deteriorate.

As MIC is an electrochemical corrosion per se, the ways by which it is treated are almost the same as any other electrochemical corrosion process, but with some minor modifications. Measures for prevention/control of MIC are:

1. Mechanical measures (such as pigging)
2. Physical measures (use of anti-microbial coatings/paints)
3. Chemical measures (use of biocides or corrosion inhibitors with biocidal effects)
4. Electrical measures (Cathodic protection)
5. Biological measures (bio-augmentation, bio-competitive exclusion, use of phages)
6. Design measures (materials selection, change of layout to eliminate potential spots for stagnant water collection)

MIC treatment will differ from another electrochemical based corrosion process such CUI (corrosion under insulation) particularly in items 3 and 5.

There are a lot of misunderstandings and semi-facts about MIC /MID that we would like to mention just a few of them below:

1. Biofilm: it is a wrong term to address a right process. When bacteria are freely moving in a fluid (their state in this case is referred to as planktonic), there will come a time they will not be able to find their required nutrients in the surrounding bulk solution anymore. One of the reasons could be that the required nutrients would fall under their weight and in interaction with the gravitation force so that the nutrients will be found more on the surfaces than in the bulk solution. In this case, bacteria will need to "sit on" the surfaces to feed on the nutrients. This will bring them to another state which is addressed as "sessile bacteria", or alternatively, a biofilm. Contrary to its name, a biofilm is neither a 100% biological fabric nor even a film. In our recent paper published in Journal Corrosion Engineering, Science and Technology, The International Journal of Corrosion Processes and Corrosion Control (June 2020) We have suggested an alternative term, Temenos.
2. Importance of SRB: Sulphate reducing bacteria (SRB) are not the most important bacteria when it comes to MIC. This may sound like a surprise to many but There are other MIC-related bacteria that

are more important than SRB in terms of both the mechanism(s) by which they contribute to corrosion and their physiological features.

3. The more SRB, the more severe the corrosion and the higher the corrosion rate: in fact this is not true at all. Research show that there is no relationship between the number of SRB and corrosion rate. These numbers can be useful when it comes to monitoring the system. Such as (1) indicating the possibility of getting more sessile bacteria and (2) the effect of biocide application in a closed system containing stagnant water.

4. If there is no sulphate in the environment, there is no need to look for SRB. No! This is not true either. Research has shown that in the absence of sulphate, SRB can switch to fermentation and ferment a variety of substances and produce hydrogen carbon dioxide and acetate. These products can then be used by other bacteria such as methane-producing bacteria (methanogens),that by consuming hydrogen, can accelerate corrosion through mechanisms such as cathodic depolarisation.

5. Regarding MID of polymers and composites, over a long-term period it has been viewed by corrosion researchers that the general corrosion and chemical resistance of polyurethane is not as great as other corrosion resistant coatings. In fact, the more the polymer/composites structure is similar to natural polymers, the higher the likelihood of MID.

6. Some corrosion experts without practical skills in MIC believe that pit morphology can show if the corrosion case is microbially induced or not. This is not true. Pit morphology can, at best, show the dimensions of the bacterial cells that have adhered onto the surface, that in turn, may suggest that the pits have been initiated at the microbial attachment sites.

Myths and semi-facts related to MIC and MID are not limited to the above and in fact there are more which are even more important. We need to address all of them within the context of MIC and MID. This workshop discussed the essentials for corrosion cases where involvement of living organisms can contribute to corrosion in one way or another.