CORROSION & ENVIRONMENTAL SERVICES LTD.

Microbially Influenced Corrosion in Water Systems

Phillip Munn, Ph.D., C.Eng., MIM, MICorr, MWMSoc

Introduction

Microbially influenced corrosion (MIC) refers to the aqueous corrosion of metals that is influenced by the presence of microorganisms or the products produced by their metabolism. Bacteria, fungi and other microorganisms play a major part in soil corrosion. Although damage due to MIC is less common in water systems, it can also occur in adverse circumstances. All common metals are thought prone to MIC. In water systems, it is more likely to occur on copper and copper alloys and cast iron and mild steel, although it has also been reported on stainless steels and aluminium.

Types of Micro-organisms

There are many different types of microorganisms responsible for MIC. Some need oxygen to grow, whereas others will only grow in anaerobic conditions. They can grow in complete darkness, the only requirements for growth being the presence of water and a nutrient source. Thus, they may be present in all types of water systems, including hot and cold domestic water, and closed or open heating and cooling systems. Most types thrive at temperatures between 25-40°C, although some thermophilic types grow at temperatures >60°C. At low temperatures, bacteria may not grow but can survive and will then propagate as the temperature increases. Microorganisms, which are implicated in MIC, include the following groups:

- Sulphate reducing bacteria (SRB)
- Iron/manganese oxidising bacteria
- Organic acid producing bacteria
- Acid producing fungi
- Aerobic slime formers

In both drinking water and closed recirculating heating and cooling systems, the most important microorganisms, as far as MIC is concerned, are SRB’s. These are anaerobic but can grow in aerated drinking water systems under deposits, where oxygen levels are very low. As their name implies, SRB’s reduce sulphates in the water to sulphides. The bi-product is corrosive hydrogen sulphide and iron II sulphide or copper I sulphide, depending whether iron or copper is present. The presence of SRB’s, therefore, can usually be detected by the characteristic smell of hydrogen sulphide.

Iron/manganese oxidising bacteria derive their energy by oxidising $Fe2+$ to $Fe3+$. They are usually found in tubercles covering pits on steel surfaces. They thus play a role in stimulating pitting attack on steel.

Certain anaerobic bacteria such as Clostridium produce organic acids during their metabolism. Although, unlike SRB's, they cannot exist in open recirculating water systems, they can grow in the anaerobic conditions in closed water systems. In aerated systems, organic acids may also be produced by certain fungi. They have been implicated in the failure of aluminium fuel tanks by MIC.

Aerobic slime formers form large colonies of bacteria on metal surfaces in oxygen rich waters, such as in open-evaporative cooling systems.

Corrosion Damages caused by MIC in Water Systems

The presence of the above-mentioned types of microorganisms in water systems does not necessarily mean that MIC will take place. In fact, instances of MIC leading to system damage are relatively rare. Nevertheless, it is useful to be able to identify such attack when it occurs in order to effectively counteract it.

In copper pipes carrying drinking water, MIC due to SRB has been found beneath deposits. This has generally been confined to private supplies where little or no chlorination has been carried out and/or in little used pipework and dead-legs. The attack manifests itself in a group of small, steep sided pits and has thus been termed 'pepper-pot' corrosion. Within the pits is a layer of crystalline cuprous oxide and the pits are capped with sulphates, oxides and organic material. Damage on copper/copper alloy components due to MIC is not restricted though to wall perforation. The formation of copper sulphide layers due to the action of SRB has resulted in the seizing of precision control valves.

Under-deposit corrosion due to MIC can also result in wall perforation on steel and cast iron components in closed recirculating heating and cooling systems. This is more common in larger more complex systems, where it is more likely that temperatures and flows in parts of the system are more conducive to rapid growth of bacteria. The cause is again mainly due to the presence of SRB's but, as discussed above, may also involve iron/manganese oxidising bacteria and organic acid producing bacteria.

Aerobic slime formers are a potential problem in open recirculating cooling systems. Large colonies of bacteria with associated sticky polymers grow on metal surfaces and prevent oxygen reaching the underlying surface. This can often lead to under-deposit attack (a form of crevice corrosion) usually on steel surfaces. In addition, the anaerobic conditions produced are ideal sites for SRB growth, which can increase the rate of attack.

Prevention of MIC

The quality of the water supply has an important influence on the likelihood for MIC. Waters carrying high amounts of organic material and inorganic nutrients, such as phosphates and nitrates, promote the growth of microorganisms. The water quality can be improved by filtration and other water treatment methods.

Large hot and cold domestic water systems and open cooling systems should be sterilised on commissioning and regularly during service to prevent the risk of legionella. This has the added benefit of destroying the microorganisms responsible for MIC. Sterilisation (chlorination) should be carried out according to ACOP 2000. If MIC has been found in a small system, this can also be sterilised in a controlled manner using chlorine release tablets. Shock doses of chlorine or bromine are often used in conjunction with non-oxidising biocides in cooling towers to control the growth of microorganisms.

Systems, which have accumulated large amounts of corrosion or organic debris, should first be cleaned using a suitable chemical cleaner. Afterwards, the system should be thoroughly flushed using fresh water. This should also prevent under-deposit corrosion occurring even in the absence of microorganisms.

Dead-legs and regions of low flow should be eliminated at much as practical by changing the design or valve settings. In addition, temperatures should be set to >60°C for heating systems or < 25°C for cooling systems.

Summary

Microbially influenced corrosion can occur in recirculating or once-through drinking water or heating/cooling systems. It can manifest itself in wall perforation due to pitting or seizure of components. It has been found to occur on copper and copper alloys, ferrous metals and aluminium.

The risk of MIC can be virtually eliminated by control of water quality, sterilisation of the system, use of biocides (in non-drinking water systems) and improved system design and operation.