SRB’s and MIC
Water Conditioning Services UK – Own Label
Introduction

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• BSC Microbiology
• Working in different areas of water treatment for a long time.
• Medical Microbiology – Pseudomonas aeruginosa.
• Biotechnology
• Food Microbiology
• Water Microbiology
Introduction

Microbes and Man by John Postgate
(24 June 1922 – 22 October 2014)

• Postgate's research in microbiology investigated nitrogen fixation, microbial survival, and sulphate reducing bacteria.

• In 2011 he was described as a "father figure of British microbiology“

• in 1948 Postgate obtained a Research Fellowship to investigate the biochemistry of the sulphate-reducing bacteria. Postgate's research formed the basis of world-wide research on these bacteria.
Introduction

Oliver Postgate
(12 April 1925 – 8th December 2008)
Definitions

**Microbiologically influenced corrosion (MIC)**

MIC is metal deterioration as a result of the metabolic activity of various microorganisms.

This type of corrosion applies to non-metallic objects as well as metals. Microbiologically influenced corrosion has previously been referred to as biological corrosion and microbial corrosion.
Sulphate Reducing Bacteria: (John Postgate)

The Sulphate Reducing bacteria, the microbes we first met in chapter one, are very strict anaerobes which, whilst they are not killed by the air, will not grow in its presence. What they do is reduce sulphate to sulphide while oxidising organic matter to acetic acid and CO2: they thus produce a horrible smell and since sulphide reacts fairly rapidly with oxygen, they remove oxygen from any neighbourhood where they get established.
**Definitions**

**Sulphate Reducing Bacteria**

SRB’s are those bacteria that can obtain energy by oxidising organic compounds or molecular hydrogen (H₂) while reducing sulphate (SO₂⁻⁴) to hydrogen sulphide (H₂S). In a sense, these organisms "breathe" sulphate rather than oxygen in a form of anaerobic respiration.

Sulphate-reducing bacteria can be traced back to 3.5 billion years ago and are considered to be among the oldest forms of microorganisms, having contributed to the sulphur cycle soon after life emerged on Earth.
Definitions

The corrosion of iron by Sulphate Reducing Bacteria

• SRB’s, or their characteristic corrosion product FeS, are ubiquitously found on anaerobically corroded iron.

• With corrosion rates of up to 0.9 mm Fe\(^0\) year\(^{-1}\) (35 mils per year [mpy]), laboratory-grown SRB cultures corrode iron to an extent that matches even severe cases of corrosion in the field.

• Chemical microbially influenced corrosion (CMIC) of iron by hydrogen sulphide from microbial sulphate reduction occurs with “natural” organic substrates.

• SRB’s also corrode iron by direct utilization of the metal itself. This occurs via direct electron uptake. Such electrical microbially influenced corrosion (EMIC) is assumed to be widespread and of considerable technical relevance.
Sulphur bacteria have very little biological relationship. The main thing they have in common is that their metabolism is based on the Sulphur atom.
Definitions

Sulphur oxidising Bacteria

• Sulphur oxidation involves the oxidation of reduced sulphur compounds (such as sulphide H2S), inorganic sulphur and thiosulphate to form sulphuric acid (H2SO4).

• Oxidation of sulphur or sulphides for energy production is restricted to the bacterial genus *Thiobacillus*, the genus *Thiomicrospira*, and the genus *Sulfolobus*. These bacteria all produce sulphuric acid (i.e. hydrogen ions, H+, and sulphate ions, SO₄²⁻) as a metabolic product.

• Microbially induced concrete corrosion in sewer systems has been a serious problem for a long time and is mainly caused by Sulphur oxidising bacteria.
Sulphate occurs naturally in many source waters after contact with sedimentary rocks such as limestone, gypsum rock and rock salt.

Concentrations found in drinking water <250 mg/l.

Much of the sulphate in the atmosphere is sulphur dioxide from the combustion of fossil fuels.
Sources of Sulphate in closed circuit systems

- Mains water
- Sulphite added to the system as an oxygen scavenger. \( \frac{1}{2} \text{O}_2 + \text{Na}_2\text{SO}_3 \rightarrow \text{Na}_2\text{SO}_4 \)
- Inhibitor formulations – sulphonate polymers and other raw materials
- Degradation products of some biocides eg THPS

Optimal growth conditions for SRB’s

- pH 4 – 8
- Temperature optimal 20°C – 50°C. Some thermophiles grow up to 70°C or even higher in specific niche habitats.
- Presence of sulphate
- Absence of oxygen for optimal growth. SRB’s grow preferentially underneath deposits / biofilm.
Biofilm

- Biofilm has 4 x greater insulating power than Calcium Carbonate scale of equal thickness → Increased energy use.

- Microbiologically Induced corrosion (MIC) underneath the biofilm leads to localised corrosion and pitting. It is estimated that 20% corrosion in all fluid transfer piping and systems is MIC.

- Biofilm lead to increased friction resistance against the bulk water which leads to increased energy consumption used to operate the circulating pumps.

- Biofilm protects underlying bacteria from biocides. When the biocide is become depleted the system will become re-contaminated from the bacteria in the
Effect of Biofilm on heat transfer efficiency

Biofilm is the second greater insulator after silicate scale
Case study

1. The heating services for a 12 storey office block were completed in late 2014. This was constructed using a system of externally galvanised, thin-walled steel piping and couplings.
2. Flushing and pre-commission cleaning the new systems commenced several weeks after first fill. At that time, the systems were partially air-locked and contained black water.
3. Pre-commission cleaning was completed satisfactorily to BSRIA standards.
4. The system suffered pinhole failures within 5 months of commissioning.
5. A number of sections of pipe were received, with a number of perforations. The subsequent analysis is documented pictorially.
Case study

Figure 1 – Pipe cut open to show internal surfaces

The tubes were mainly defect free, with occasional patches of deposits, where the corrosion had also occurred. The corrosion patches also contained small, isolated deep pits.
Case study

Showing significant number of pits penetrating substantially through the whole wall, indicating it is beyond recovery. The undercutting and widening of the pit (rather than vertical sided or inverted cone), suggests the possibility of more than one mechanism – perhaps chemical attack, initially and then microbial factors, latterly.
Case study

Figure 3 – Pit on inside of wall resulting in a perforation

Figure 4 – Same “pit” on outside of wall – “hole”
Case study

Figure 5 – Dried deposit on surface

Deposit which has dried and curled at the edges. There were deep pits along the very edge of the deposit
Case study

The white appearance was from a dry, shiny material on the metal surface.

Dried, slight shiny finish could be seen on the metal, particularly around the pit, as if there had been an organic slime layer on the metal at one time.
Case study

Figure 8 – Pitting Attack of Tube – Through wall

Electron micrograph of pit cut by transverse section of the pipe showing abnormal debris in the pit of a non-layered structure (most 'normal' corrosion deposits accumulate in layers) Section 1.88mm across

Figure 9 - Sectional pit

Section 400µm across. Bacteria visible.
Conclusions

1. The conclusion is one of deposition of corrosion product from mal-treatment of the system prior to commissioning, as the result of partial filling (or filling and partial draining) of the pipe in its history of construction and pressure testing, without responsibly applying inhibitors or management control.

2. This left the thin-walled tubing exposed to differential amounts of air and water promoting pitting attack.

3. The potential presence of organic film forming coatings, to help prevent fly rusting under normal storage, is likely to have been compromised by full-filling and draining, exacerbating this differential aeration mechanism of corrosion, as well as providing nutrient for micro-organisms.

4. The subsequent enhanced pitting, throughout the whole of the samples of pipe supplied, was promoted by microbial induced corrosion.
Conclusions

Closed circuit failure (BSRIA)

Early corrosion failure in heating and chilled water systems is generally caused by

• Delays between first fill and pre-commission cleaning, resulting in prolonged stagnation.
• Inadequate maintenance of water treatment between pre-commission cleaning and practical completion.
• Persistently high dissolved oxygen.
• Lack of circulation in use.

If the pipework system survives the first three years following construction without any major problems then the chances are that, subject to normal levels of maintenance, it will achieve a life of 25 years or more.