Sulphur Reactions and Corrosion

WAT-E2180 Biological Treatment of Water and Waste

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March 30, 2021

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- **Corrosion in sewer network and wastewater treatment**
- **Microbially induced corrosion**
  - Biogenic sulphur corrosion
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Corrosion in sewage systems

- **Corrosion in sewers, pumping stations and wastewater treatment plants**
  - Pipelines
  - Machinery
  - Basins and other structures
- **Corrosion of concrete and steel structures in liquid or vapor phase**
- **Corrosion a huge issue!**

Causes of corrosion

- **Wastewater Quality**
  - Municipal/industrial wastewater
  - In general highly corrosive
- **Structure of sewer systems and wastewater treatment plants**
- **Ventilation**
- **Exceptional situations**
  - Abnormal wastewater discharges
  - Process disturbances
- **Climate, weather**

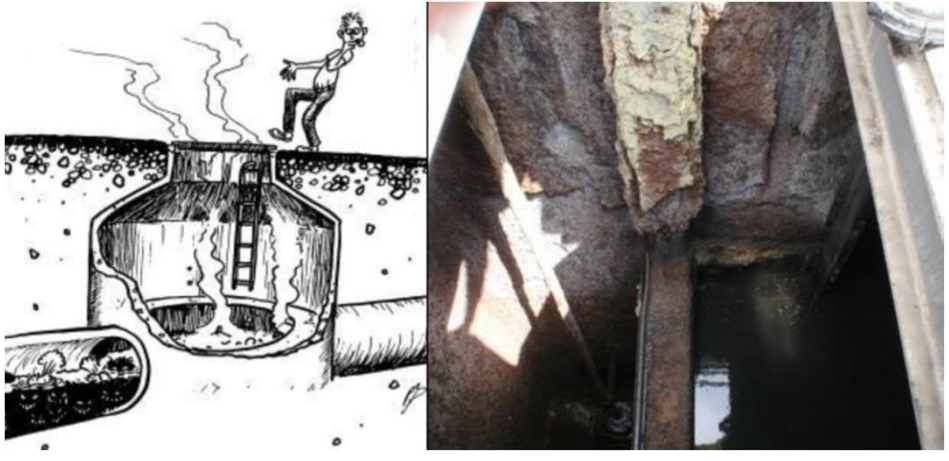
Causes of corrosion

- **Physical causes**
  - Temperature and humidity
  - Wastewater flow
  - Grit and other particles in wastewater
- **Chemical causes**
  - pH, alkalinity
  - Cl
  - NH_4, Mg_2
  - SO_4
  - O_2, CO_2

Hydrogen sulphide corrosion

- **Sulphate (SO_4^{2-}) in wastewater maybe the most important cause of corrosion**
- **Reduction and oxidation by microbes to hydrogen sulphide (H_2S) and sulphuric acid (H_2SO_4)**

  ➡ **corrosion**
- **Typically in sewage network, influent channels and pretreatment units**



Cesca & Crosby, 2015

Biogenic sulphur reactions

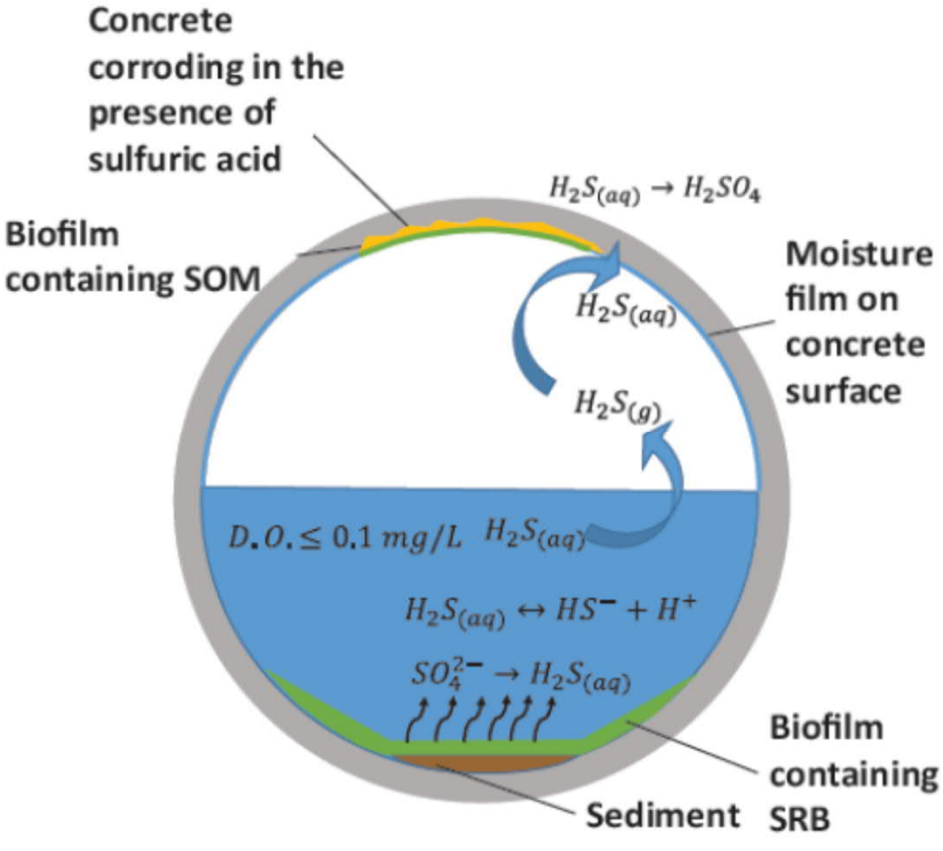
Anaerobic sulphate reducing bacteria (SRB) form hydrogen sulphide in biofilm below water level

$$SO_4^{2-} + 8\,H \leftrightarrow H_2S + 2\,H_2O + 2\,OH^-$$

Aerobic sulphur oxidizing bacteria (SOB) form sulphuric acid from stripped hydrogen sulphide in biofilm above water level

$$2\,H_2S + O_2 \leftrightarrow 2\,S + 2\,H_2O$$

$$2\,S + 3\,O_2 + 2\,H_2O \leftrightarrow H_2SO_4$$



House, M. W., and Weiss, W.J. (2014). "Review of Microbially Induced Corrosion and Comments on Needs Related to Testing Procedures." *4th International Conference on the Durability of Concrete Structures*, 24–26 July 2014, Purdue University, IN.

Variety of microbes involved

TABLE 1. Microorganisms Involved in Microbiologically Influenced Corrosion (MIC)

Genus or Species	pH	Temp. (°C)	Materials affected	Bioactivity
Desulfovibrio desulfuricans	4–8	10–40	Iron/steel, SS; alum., zinc, copper alloys	Anaerobic—Reduces sulfates to sulfide ions and hydrogen sulfide; promotes sulfide formation
Desulfotomaculum nigrificans (Clostridium)	6–8	10–40 (some 45–75)	Iron/steel, SS	Anaerobic—Reduces sulfate ions to sulfide and hydrogen sulfide (spore former)
Desulfomonas	5–9	10–40	Iron/steel	Anaerobic—Reduces sulfate ions to sulfide and H_2S
Thiobacillus thiooxidans	1–8	10–40	Iron/steel, copper alloys, concrete	Aerobic—Oxidizes sulfur & sulfides to sulfuric acid; harms protective coatings
Thiobacillus ferrooxidans	1–7	10–40	Iron/steel	Aerobic—Oxidizes ferrous (Fe^{2+}) ions to ferric (Fe^{3+})
Gallionella	7–10	20–40	Iron/steel, SS	Aerobic—Oxidizes Fe^{2+} to Fe^{3+} & manganous (Mn^{2+}) to manganic (Mn^{3+}) ions; promotes tubercle growth
Sphaerotilus	7–10	20–40	Iron/steel, SS	Aerobic—Oxidizes Fe^{2+} to Fe^{3+} and Mn^{2+} to Mn^{3+} ; promotes tubercle growth.
S. natans pseudomonas	4–9	20–40	Iron/steel, aluminum, SS	Aerobic—Some strains reduce Fe^{3+} to Fe^{2+}

Source: *Metals Handbook*, 9th ed., vol. 13. Materials Park, OH, USA: American Society of Metals, 1987, p. 118.

Increased sulphur corrosion rate

- **High sulphate (SO_4^{2-}) concentration in wastewater**
  - Typically ~10-20 mg/l
  - Limits for discharges to the sewage network, e.g. 400 mg/l
- **Long hydraulic retention times**
  - Long sewer transfer lines
- **High hydrogen sulphide (H_2S) concentrations in vapor phase**
  - Stripping from water phase
  - Poor ventilation
- **Temperature**
  - Enhanced microbial activity in higher temperatures

Examples on microbiological activity contributing to corrosion in WWTPs

- **Activated sludge process**
  - Formation of hydrogen sulphide during process disturbances (low DO, varying influent load)
- **Nitrification**
  - Lowering alkalinity/pH
  - Higher NH_4 during process disturbances
- **Denitrification**
  - Lower alkalinity/pH during process disturbances
- **Anaerobic digestion**
  - Low pH during process disturbances/starting phase

Prevention of corrosion

- **Moderation of corrosive environment**
  - Control of (industrial) wastewater quality; pH, SO_4
  - Chemicals
- **Choice of structures**
  - Sewer network
  - Ventilation
- **Choice of materials**
  - Concrete type (exposure class)
  - Quality of metal structures
  - Coating
- **Regular monitoring**

Monitoring corrosion

- **Wastewater quality analyses**
- **Air quality analyses**
- **Sewer camera inspection**
- **Inspection of basins etc. during regular maintenance work**
- **Material tests**
- **Corrosion tests**
    - Exposure of samples to corrosive environment

Further reading

A practical guide to the basics of wastewater related corrosion:

Bennett, D. C. & Nixon, R. A. 2016. *Corrosion and materials fundamentals for engineers in wastewater treatment plants & collection systems*. Third edition. Houston, TX: NACE International.

Thank you!
Questions?

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