

Microbiologically Influenced Corrosion in Drinking Water Pipelines – Old Deposits or Active Process?

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ABSTRACT

In the Netherlands, a large part of the drinking water distribution system consists of cast iron pipelines of which some have been installed and are used since the beginning of the last century. Previous investigations showed that corrosion deposits are present in many of those pipes and follow-up research showed that microbial processes have been involved in the corrosion damage. Due to the increase in water quality over the decades, the question was raised whether the MIC processes were still active in the water distribution system. To investigate whether the MIC processes were still active, RNA technology was used to investigate the microorganisms in the water distribution pipelines at corrosion defected areas. RNA is the genetic material which occurs in biological cells only when they are active. We applied two genetic technologies: RNA qPCR and RNA metagenomics by Next Generation Sequencing. With a combination of those techniques we could confirm that, despite the good water quality, MIC processes were still active and could form a direct risk in cast iron water pipes. Interestingly there seemed to be no relation between the water quality and the activity of MIC.

Key words: Microbiologically Influenced Corrosion, MIC, Molecular Microbiological Methods, drinking water, NGS, qPCR, RNA, cast iron, water supply, water distribution.

INTRODUCTION

In the Netherlands, a large drinking water distribution system exists which composes of a complex network of underground pipes owned by several water companies. Part of the drinking water distributions pipes consist of cast iron pipes of which some have been installed more than 80 years ago.¹ To prevent leaks, it is desirable to have insight into the condition of these pipes and the risk of

leakages or even pipe bursts. During local replacements and maintenance work, corrosion is regularly found in the pipes and previous research⁷ has indicated that Microbiologically Influenced Corrosion (MIC) may be involved in this corrosion that is found in the pipes. However, because the water quality has improved significantly over the years, the risk of microbial activity and thus of active MIC might be limited. To investigate this, a selection has been made from the chemically most diverse water streams. From those different streams a pipe section has been excavated to investigate in detail. The main questions for this investigation have been:

1. Is damage caused by MIC?
2. Does it still concern active MIC?
3. Which variables give the greatest threat of MIC?

Based on those results, suggestions are given about the management of MIC in cast iron drinking water systems.

EXPERIMENTAL PROCEDURE

Sampling

Cast iron pipe fragments were excavated from 8 different sites containing 8 different water qualities or origins. The variations used for selection were based on the complexity of the water treatment before entering the distribution network (complex/biological treatment versus simple/no treatment); which resulted in samples from 4 different water treatment plants. Furthermore, the water quality (low versus high organic matter) and flow rate in the pipe was analyzed for a selection of the cast iron samples, giving the following variations:

- a. EWD (HLC) - High flow rate, low organic matter, complex treatment;
- b. EWO (LLC) - Low flow rate, low organic matter, complex treatment;
- c. HFH (HHS) - High flow rate, high organic matter, simple treatment;
- d. HFE (LHS) - Low flow rate, high organic matter, simple treatment;
- e. NWI (HLS) - High flow rate, low organic matter, simple treatment;
- f. NWO (LLS) - Low flow rate, low organic matter, simple treatment;
- g. SKW (HHC) - High flow rate, high organic matter, complex treatment;
- h. SKB (LHC) - Low flow rate, high organic matter, complex treatment.

The different pipes supplied water from 4 different water treatment plants indicated by the first letter in the above reference code (E, H, N and S), the following codes indicate the exact location and in brackets the flow rate, organic matter and treatment complexity H=high, L=low, S=simple, C=complex)

All samples have been investigated for MIC damage and if there is still activity of MIC as described below.

MIC investigation

When corrosion defects were found on a water pipe where MIC is suspected, the following four lines of evidence were collected to investigate if it involved MIC:

1. Visual inspection

MIC manifests itself in pitting corrosion in which the edges have an irregular course and where a parabolic shaped defect is visible. In addition, the presence of tubercles and a white / gray deposit can be an indication of MIC.

2. Mineralogical analyses

The corrosion products found were analyzed for the elements present and corrosion products formed by means of X-Ray Diffraction (XRD) and X-Ray Fluorescence (XRF). These analyses provide insight into the corrosion processes that have occurred.

3. Microbiological analyses

The affected area was screened for bacteria and archaea that have a proven relationship with MIC. The screening takes place by means of a quantitative PCR (qPCR) analysis^{2;3} and focuses on the total amount of bacteria, sulfate-reducing bacteria, sulfur-oxidizing bacteria, iron-oxidizing and iron-reducing bacteria, total amount of archaea and methanogens. These analyses were performed to determine the presence of those microbial groups on DNA.⁴

Microorganisms have genetic material (DNA) in which all possible functions that a microorganism can perform is located. When a microorganism actually performs a function, a certain piece of DNA is translated into RNA and from there proteins are produced and certain functions are performed. The amount of RNA therefore gives an indication of what is active. Thus, active MIC can be determined from RNA of microorganisms or functional properties known to be involved in MIC. To get a picture of the active MIC related species, all active species were identified using Next Generation Sequencing on RNA (RNA-NGS). To be able to quantify the activity qPCR analyses on total bacteria and archaea were performed not only on DNA but also on RNA.

4. Environmental conditions

The prevailing conditions of the water were mapped to assess whether the environment was favorable for microbiological growth or activity. Water quality samples were collected from within connected households, as close as possible to the sampling location.

The samples were analyzed for acidity, nitrate, ammonium, ortho-phosphate, organic and inorganic carbon and sulfate. In addition, the water samples were analyzed for iron and nitrite.

RESULTS

The results are separated in four lines of evidence for MIC Visual inspection, Mineralogical analyses, Microbiological analyses and Environmental conditions. After this, the results for Determining active MIC are presented.

Visual inspection

The visual inspection showed significant variation between the different locations and samples. An overview of pictures is given below:

High flow rate, low organic matter, complex treatment (EWD) – diameter pipe 15 cm	
Before cleaning	After cutting and cleaning
	
	Clear damage is visible on the internal side of the pipe.

Low flow rate, high organic matter, complex treatment (EWO) – diameter pipe 15 cm	
Before cleaning	After cutting and cleaning
	 Clear damage is visible on the internal side of the pipe.
High flow rate, high organic matter simple treatment; (HFH) – diameter pipe 12.5 cm	
Before cleaning	After cutting and cleaning
	 Clear damage is visible on the internal side (top side) of the pipe and on the external (bottom side)
Low flow rate, high organic matter simple treatment; (HFE) – diameter pipe 10 cm	
Before cleaning	After cutting and cleaning
	 Clear damage is visible on the internal side of the pipe and on the external side.