Prevention of water-related corrosion

Water analysis at Sulzer Innotec

Water is the ideal medium for a variety of purposes thanks to its high heat capacity, environmental friendliness, and easy availability. However, if the water quality is ignored, damage can occur due to corrosion, formation of deposits, or growth of microorganisms. Damage totaling billions of dollars occurs worldwide from water-related corrosion every year.

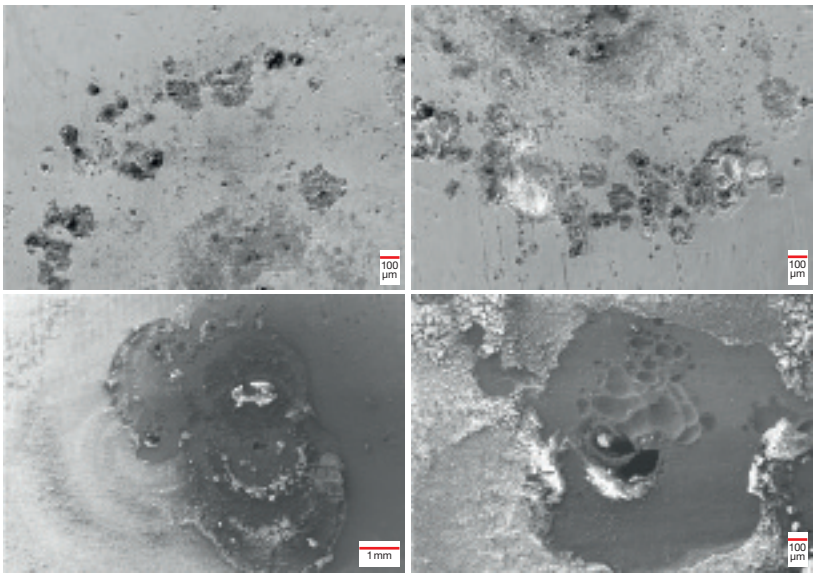
The specialists of Sulzer Innotec have been working for more than 40 years investigating water quality and its impact on materials.

Through many years of practical experience, Sulzer Innotec has acquired significant experience in the field of water-related corrosion and cases of damage, and it passes on this know-how to customers and to workgroups for the specifications of water-conducting equipment and systems.

At present, the water laboratory of Sulzer Innotec operates as a contract laboratory for industrial and private customers. Hundreds of water and glycol-water samples from various applications are analyzed here every year. Among the applications examined are waste incineration plants, industrial factories with heating and cooling circuits, cooling towers, air washers and air-conditioning plants, as well as heating systems in houses.

This vast amount of product knowledge is, therefore, one of the strengths of Sulzer Innotec. Clients are advised indi-

1 Photo of a cooling system used in industry.



2 Piping made from high-alloy stainless steel with clearly visible pitting corrosion.

vidually and receive support in solving their problems—with services ranging from normal standard analyses, through on-site measurements, to customer-specific analyses with the development of specific analytical procedures.

Through preventative water analysis, Sulzer Innotec has been able to avert massive damage to various facilities and equipment in many cases over recent years, thereby saving millions of dollars in costs 1.

Water as the cause of pitting corrosion

At low temperatures, the presence of water is necessary for the corrosion of metals. Due to the special properties of water (dipole moment, oxygen solubility), dissolved ions (such as chlorides and sulfates) can come into contact with the surface of a metal together with oxygen and cause corrosion.

Much of the corrosion damage that occurs could be prevented or delayed if conditioned water of a suitable composition and quality were used and if its quality were monitored regularly. Various cases of damage that have been investigated in recent years have been traced back to the use of unsuitable water.

In one of the cases of damage examined by Sulzer Innotec, a piece of pipe had been delivered with various small holes in it. The pipe was part of a cooling system in a refinery. As the operation of the refinery had been interrupted for a long period due to the damage, a loss of several CHF 100 000 had resulted.

The pipe was made of so-called stainless steel. High-alloy stainless steels have a very thin, but nevertheless protective passive layer, which consists mainly of chromium oxides. Despite this protective layer, the surface of the pipe was partially rusted and showed signs of localized corrosion attack (pitting).

The examination of the material revealed that the material had the correct specifications and had been properly processed. A material defect could therefore be eliminated as the cause of the damage. In order to find the cause of the corrosion, the customer was asked to provide a water sample from the affected cooling system. A high level of chloride was subsequently found in this water sample. Stainless steel is very susceptible to chloride attack because chloride locally destroys the passive layer and thus causes pitting.

If, as a result, even more chloride is accumulated at the said location, a local area arises that is no longer protected by a passive layer. This area is now more susceptible to corrosive attack.

Differences in concentration, potential differences, or even a reduced pH value at the location of the attack promote pitting corrosion and lead to a faster growth of the holes. Small holes can then appear in the steel, even on passivated stainless steel 2. If the water quality had been checked in advance, it would have become clear at the planning stage that this steel was unsuitable for the water quality used 3.

The costs of the water analyses and the consultation on the selection of the most suitable material and the conditioning of the cooling water would have only amounted to a fraction of the damage costs.

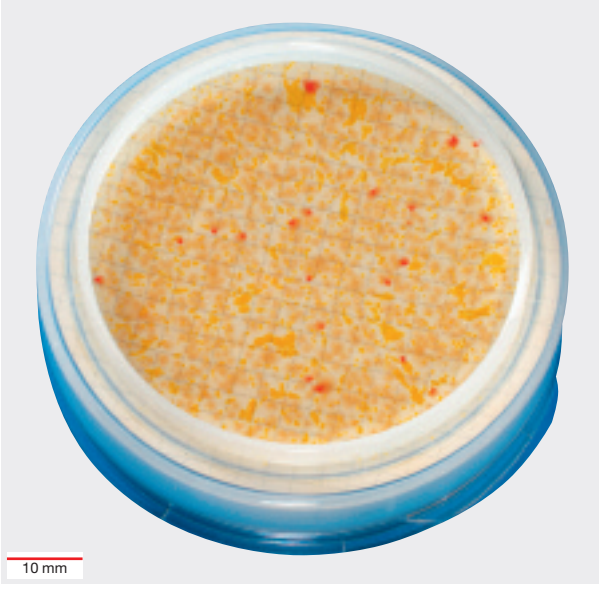
3 A check of the water quality can indicate whether the steel being used is suitable.

Problems due to high microbiological contamination of the water

Damage to plants can be triggered not only by inorganic constituents in the water, but also by microorganisms. If the water has a high level of microbiological contamination, biofouling can occur through the formation of biofilms. Biofilms consist of a mucus layer (film) in which microorganisms are embedded.

The film offers the microorganisms a mechanical anchor and protection from external chemical and physical influences, and it allows them to adapt themselves to changes in the environmental conditions. In this way, the microorganisms can survive extreme pH and temperature fluctuations, pollutants (e.g., bactericides), and even UV radiation and lack of nutrients.

4 Cultivated microorganisms on an agar plate.



This robustness hinders the elimination of the biofilms. The economic damage caused by biofouling is enormous. For example, the flow of water in pipes can be reduced significantly, and the pipes can even clog in extreme cases.

In the case of cargo ships, a biofilm of only one-tenth of a millimeter on the hull can reduce the ship's speed by several percent through the increased friction. This also results in increased fuel consumption.

Another danger posed by water with a high level of biological contamination is microbiologically induced corrosion (MIC). In MIC, the aggressive metabolic products of bacteria lead to corrosive attack of the metal. Sulfate-reducing bacteria (SRB) prevail, and they form aggressive sulfides. In the case of passive materials, chlorides are also necessary for MIC attack to occur. These chlorides destroy the passive layer locally. Biofilms are a frequent source of MIC. Recent estimates suggest that at least 20% of corrosion damage is either triggered, or promoted by MIC.

As it is difficult to eliminate biofilms, preventative measures are highly recommended. Therefore, Sulzer Innotec offers bacterial count checks in order to be able to detect an increased microbiological contamination in the water in time 4. Biofouling or MIC can then be prevented by appropriate countermeasures.

Water as a cause of microbiologically induced corrosion

A perforated CuNi pipe was delivered to Sulzer Innotec for the investigation of corrosion damage to a condenser of a cooling unit. The condenser was cooled with river water. Neither a material defect nor a manufacturing error could be found in the initial investigation. In order to find the cause of the damage, a water sample was also examined.

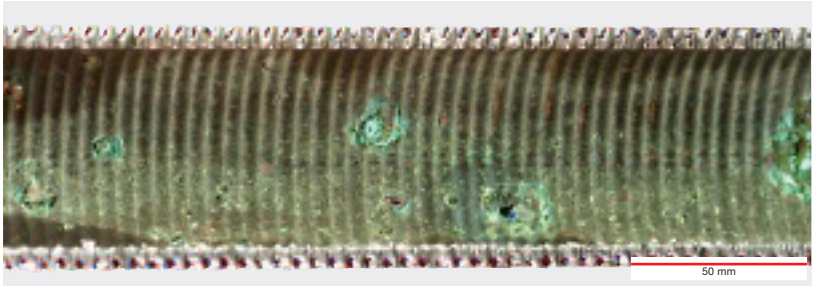
The chemical analysis of the water sample revealed no anomaly, and neither the pH value nor the chloride content could be identified as being responsible for the corrosion. Further investigation revealed a strong microbiological contamination of the river water. As the sample had been delivered in non-sterile containers, however, the sampling had to be repeated for verification using sterile containers.

A sample of the river water was taken before and after it passed through the condenser. A microbiological investigation was also carried out directly on the corroded tube. A very high level of microbiological contamination was found in both water samples. The sample taken after the water had passed through the heat exchanger also indicated agglomerations of bacteria, which is a clear indication of the formation of biofilms. A significant quantity of microorganisms were also detected at the corrosion locations by means of direct microbiological analysis.

After further investigations, microbiologically induced corrosion (MIC) was definitively confirmed as the mechanism for the damage. Recommendations to prevent biofilms and corrosion were provided to the customer. Further corrosion of the system could therefore be successfully avoided. Without the analytical work of Sulzer Innotec, the piping of the condenser would have had to be replaced at regular intervals 5.

Hazard of *Legionella* in cooling towers and water systems

In addition to the hazards of corrosion and fouling, microorganisms can also present problems for human health.



5 CuNi pipe with clearly visible local attacks of microbiologically induced corrosion (MIC).

Legionella 6 are particularly critical, and represent a significant hazard in air conditioning plants, ventilation systems, and cooling towers in particular.

Legionella are rod-shaped, gram-negative bacteria that belong to the family Legionellaceae. They have one or more flagella with which they can move around and occur in both freshwater and salt water, where a temperature of 25–50 °C is a precondition. Water standing for long periods (stagnant conditions) also promotes their growth.

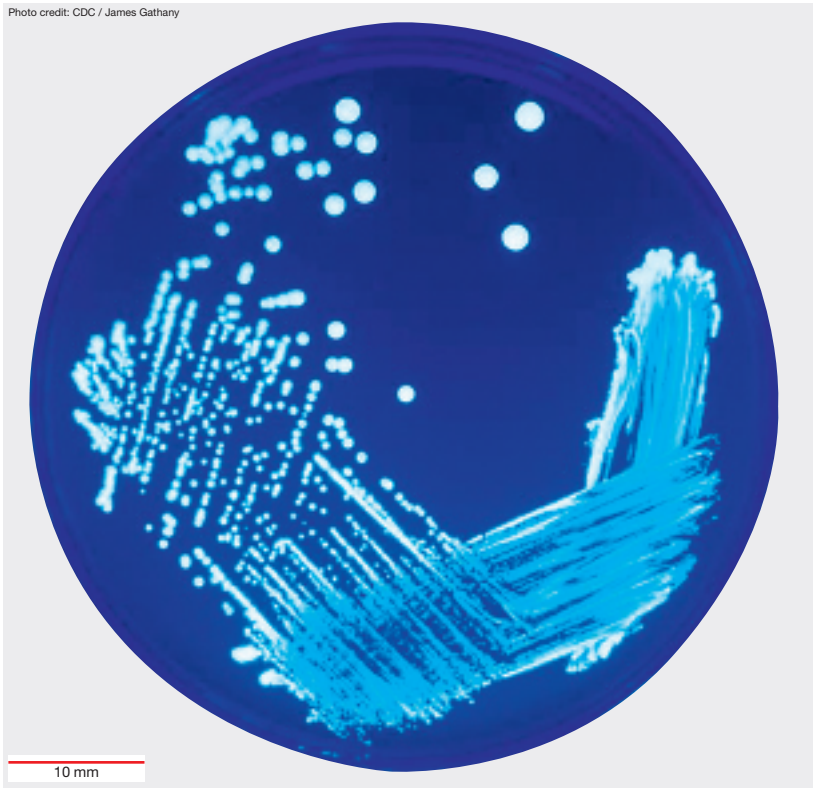
Forty-eight species and 70 serogroups of *legionella* are currently known, all being classified as harmful to human health. The most important type for human illness is the pathogen *legionella pneumophila*, as this can cause Legionnaires' disease or the so-called "Pontiac Fever." In healthy people, Legionnaires' disease is fatal in approximately 15 % of cases, while mortality can be up to 70 % for people with compromised immune systems.

The Legionnaires' disease was first identified in 1976 at a meeting of the US war veterans association, the "American Legion State Convention," from which it also received its name. At this meeting, 181 people became ill with severe pneumonia at this meeting. All of the affected people were either participants in the war veterans' conference, or were guests in the same hotel.

As a result of this epidemic, the US American health authorities began investigating the causes, and, in 1978, were able to identify the responsible *legionella pneumophila* pathogen, which had established itself in the air conditioning system of the hotel. Other epidemics were retrospectively attributed to the same *legionella pneumophila* pathogen, as well as the Pontiac Fever, which was described for the first time in Pontiac in 1968.

Through the routine testing of water for *legionella*, Sulzer Innotec has been able to identify a number of cases of *legionella* infestations in the last few years and has thereby been able to prevent illness outbreaks. With the early detection of *legionella*, the affected system can be cleaned and be refilled with fresh water, so as to ensure safe operation.

6 *Legionella* colonies growing on an agar plate illuminated with ultraviolet light.



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