////Title: **Combatting Corrosion in Heating and Cooling Systems**

////Standfirst:

Water heating and cooling systems have become incredibly efficient in recent years, but unfortunately, their pipes and components provide ideal environments for corrosion. Dr Oliver Opel at the West Coast University of Applied Sciences in Germany explores the reasons why this corrosion problem appears to be growing. His team's work could soon provide engineers with updated techniques to tackle corrosion in modern heating and cooling systems, which could prove critical in ensuring that new, energy-efficient buildings continue to operate smoothly.

////Main text:

Corrosion is one of the most significant threats faced by our buildings and infrastructures. In fact, the annual global cost of corrosion has been recently estimated to be $2.5 trillion, which is equivalent to more than 3% of the world's gross domestic product.

Corrosion occurs when a metal reacts with chemicals, such as dissolved oxygen, in its surrounding environment. This reaction transforms the metal into an unwanted build-up of minerals. Ultimately, corrosion is inevitable in virtually every engineered system that uses water as a medium for storage or heat transfer. To keep these systems operational, their owners may spend millions on repairing and replacing their parts, which include expensive components such as pumps, pipe surfaces, and sensor technologies.

Dr Oliver Opel at the West Coast University of Applied Sciences states that in recent years, the owners of many modern, non-residential buildings are finding that problems related to corrosion are now worse than they used to be. In the past, these issues were virtually non-existent for buildings less than two years old, but now, corrosion appears to be becoming commonplace in modern heating and cooling installations.

These modern systems require far less energy and water to run than their older counterparts. But somewhat counter-intuitively, they are also proving to be ideal environments for corrosion to occur. In a recent study published in *Energy Procedia*, Dr Opel and his colleagues aimed to get to the bottom of this mystery, and to find ways that engineers could update their corrosion prevention techniques for modern systems.

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In this field study, the research team investigated 64 heating and cooling systems, installed across 21 different buildings. After leaving the systems to operate for one full day to reach a thoroughly mixed, representative state, they used specialised sensors to measure several properties of the water they contained, including their pH level, temperature, oxygen levels, ion concentrations, and variety of microbes. They then compared these readings with reference values made during similar measurements of older systems.

This detailed analysis allowed the researchers to identify several of the reasons underlying the growing corrosion problem in the latest systems, and to suggest new measures to prevent the damaging reaction.

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In the past, heating and cooling systems needed to keep the water they contained at temperatures higher than 60 degrees Celsius, in order to deliver the much higher power needed for heating older buildings. This continual heating may have been inefficient, but it also came with an incredibly useful side-effect. Initially, the corrosion on the pipes' steel surfaces rapidly consumed the oxygen dissolved in the surrounding water, which at high temperatures, results in the build-up of a black mineral named magnetite. Forming thin layers on top of pipe surfaces, magnetite is itself unreactive, meaning the steel underneath is protected from further corrosion. Because of this effect, pipes did not usually need to be replaced for many years. Furthermore, bigger pumps and valves were less vulnerable to corrosion products compared to modern, highly energy efficient and automated systems.

Dr Opel's team realised that improvements in engineering mean that the water within heating and cooling systems can be kept at lower temperatures while remaining pressurised. Whilst these conditions mean that magnetite is still formed in oxygen-depleted conditions, these layers could be more vulnerable to higher oxygen concentrations found in systems with lower temperature. However, Dr Opel and his colleagues found that oxygen is not the only problem facing today's high-efficiency systems.

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Previously, the hot, oxygen-depleted environments characteristic of older heating and cooling systems were difficult places for microbes to survive, which meant that only a few types, specially adapted to extreme conditions, could grow. In modern systems, however, the cooler temperatures allow for a wide variety of microbes to thrive.

These microbes can eat away at metals in a variety of ways, including iron reduction, nitrogen fixation, the breakdown of complex organic molecules and sulfate reduction. Overall, the researchers identified around 600 different species, which fell into a few distinct groups – each of which promoted corrosion in a unique way. Especially sulfate reducing bacteria – as is known from the oil and gas industry – could result in severe corrosion of steel pipes via elemental sulfur and polysulfides, which can form from sulphides via reaction with iron oxides.

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Having identified these corrosion mechanisms, Dr Opel and his colleagues then aimed to provide engineers with updated solutions to tackling the problem in modern heating and cooling systems. Currently, many owners of these systems add specialised chemicals to the mediating water, but clearly, this doesn't seem to be working. In fact, the team's experiments show that this technique actually appears to be making the problem worse, all while driving up costs due to the invasive monitoring required. However, there was one prevention technique that the researchers found to be effective in combating corrosion: the use of demineralised water.

Many heating and cooling systems use softened water, in which certain ions have been largely removed. Dr Opel's team suggests that instead, all impurities should be removed through the process of reverse osmosis, in which water is passed through a fine, sieve-like membrane. Without these impurities, microbes find it far more difficult to locate the nutrients they need to survive, keeping systems sterilised even at milder temperatures. In addition, reverse osmosis also removes many of the chemicals that can directly corrode metal.

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Confirming their predictions, the team's experiments revealed that heating and cooling systems that use demineralised water, created through reverse osmosis, remained the most resilient against corrosion. They suggest that if a system using demineralised water were continuously monitored using sensors, the growing problem of corrosion could finally be curtailed. The insights gathered by the team could prove critical to ensuring that modern heating and cooling systems can continue on their trend in increasing efficiency while maintaining their functionality over the years.

Meet the Researcher

Dr Oliver Opel
Professor for Energy-optimised Buildings
West-Coast University of Applied Sciences
Heide
Germany

Contact

E: opel@fh-westkueste.de
W: https://www.fh-westkueste.de/hochschulprofil/ansprechpartner/professoreninnen-technik/prof-dr-oliver-opel/

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