

Biofilm in water systems: why early action matters

Roy Middelbosch, WATTER B.V.

Clear water can be deceptive. Even when water looks clean and has no unusual smell, there may still be bacteria hiding inside pipes, tanks, filters and heat exchangers. This biofilm can remain unnoticed for a long time. By the time recurring microbial contamination, blocked filters or declining system performance reveal the problem, removing it may be considerably more difficult than controlling it at an early stage.

Understanding biofilm and how it forms

Biofilm is a community of bacteria and other microorganisms that attaches itself to a moist surface. These microorganisms produce a protective, slime-like layer in which they can settle, retain nutrients and withstand external influences. Microorganisms living in a fully developed biofilm can therefore be more difficult to control with disinfectants than microorganisms floating freely in the water (1, 2).

Biofilm formation begins when microorganisms attach themselves to a surface. More cells, nutrients and other substances follow, allowing the layer to grow. A fully developed biofilm can eventually break away, travel with the water and colonise other areas of the system (2).

Long water-retention times, infrequently used pipe sections, dead ends and areas with limited flow provide good conditions for biofilm growth. In these places, there is less physical force to remove newly formed deposits. The concentration of any residual disinfectant may also decline before it reaches the end of the system (2, 3).

Temperature can accelerate microbial growth as well. Warm or lukewarm water is particularly relevant when controlling organisms such as *Legionella*. Maintaining sufficiently low cold-water temperatures and ensuring regular water exchange are therefore important parts of good water-system management (4).

Recognising warning signs

Biofilm is not always visible to the naked eye. Possible warning signs include recurring high microbial counts, slimy or discoloured deposits, unusual odours, cloudy water and filters that become dirty unusually quickly. In technical systems, additional signs may include declining flow, increasing pressure loss, corrosion or reduced heat-transfer efficiency (3, 5).

A single water sample does not necessarily reveal the complete problem because it mainly measures microorganisms suspended in the water. A more reliable assessment combines samples from several locations with operating data, trend analysis and visual inspection of accessible components (3).

Why early action matters

The older and thicker a biofilm becomes, the more difficult it can be to control. Its protective slime layer may prevent disinfectants from reaching microorganisms located deeper inside

the deposit. Scale, corrosion products and other sediments can provide additional protection (1, 3).

A short disinfection treatment may consequently reduce the number of microorganisms in the water without completely removing the deposit attached to the pipe wall. Once the treatment ends, surviving organisms will continue to multiply. Biofilm therefore acts as a continuing source of contamination rather than as a one-time problem (2, 3).

The consequences depend on the application. In drinking and service-water systems, biofilm can provide a habitat for undesirable microorganisms. In process and cooling-water systems, it may also contribute to blocked filters, corrosion, restricted water flow and poorer heat transfer (2, 3, 5).

An effective control strategy begins with identifying the causes. The entire system should first be examined: Where are the storage tanks, circulation loops, dead ends and infrequently used outlets? Which sections have low flow or long water-retention times? Temperature, pH, flow, microbial counts, organic contamination and the amount of active disinfectant remaining in the water can then be assessed.

The appropriate response will usually combine several measures. Depending on the system, these may include:

- Flushing pipes and infrequently used sections.
- Mechanically cleaning accessible components.
- Removing unnecessary dead ends.
- Improving circulation and water exchange.
- Removing scale and other deposits.
- Replacing heavily contaminated components.
- Applying an appropriate chemical or thermal disinfection procedure.

Dosing strategies: continuous vs. periodic disinfection

Periodic disinfection treats a water system at set intervals, often using a comparatively high concentration of disinfectant. It can be useful after an extended shutdown or between production cycles. Its limit is the untreated period between applications: surviving microorganisms may attach themselves to surfaces and start growing again.

With continuous disinfection, a lower and controlled dose is added during normal operation. Maintaining an appropriate disinfectant residual can help prevent the multiplication of free-floating microorganisms and make it more difficult for biofilm to start regrowing itself between cleaning procedures (2, 6).

Continuous treatment does not automatically remove all biofilm, however, nor does it replace proper system design, flushing, mechanical cleaning or microbiological monitoring. Its effectiveness depends on whether the disinfectant reaches critical locations at a sufficient concentration and for sufficient contact time. Water composition, organic contamination, temperature, pH and material compatibility must also be considered (1, 3).

The two methods should therefore not always be viewed as alternatives. Where established biofilm is present, a combination may be more effective: first clean and remediate the system, then use appropriate operating practices and, where suitable, continuous disinfection to limit regrowth.

HOCl in practice

One practical example comes from a manufacturer of water-based industrial adhesives. The quality of the process water directly affects the stability of these products. The company had previously used UV disinfection but continued to experience fluctuations in microbiological water quality. Additional preservatives consequently had to be added to the adhesives, increasing costs and complicating product labelling and safety documentation.

After trials confirmed that continuous HOCl disinfection did not adversely affect the adhesives' bonding properties, specifications, colour or odour, it became the main water-disinfection method. Better microbiological control of the process water allowed the manufacturer to reduce its use of preservatives by approximately 40%. This resulted in fewer hazard symbols, simpler safety data sheets and lower exposure to preservatives during production and subsequent product use for this company. The shelf life of the adhesives increased from three to six months, while complaints, microbial contamination and product rejection reportedly decreased. (7).

A second example concerns a manufacturer that uses considerable quantities of process water to produce cooling products for the food, pharmaceutical, retail and logistics sectors. Its previous approach combined UV treatment with periodic cleaning. This required substantial attention, cleaning agents, labour and energy, while stable water quality remained essential for product quality.

A five-month trial was conducted to determine whether continuous HOCl disinfection could maintain water quality with less operational effort. During the trial, microbial counts remained consistently below the company's existing internal limit. Following implementation, the production process became more stable, while cleaning procedures were needed less frequently and took less time to complete. The operator also reported reductions in transport, waste and carbon emissions (8).

These examples illustrate that the benefits of continuous disinfection can extend beyond microbial control. More stable process water may reduce reliance on periodic corrective treatments, simplify cleaning, decrease the need for preservatives and improve the consistency or shelf life of water-based products. These field findings reflect the practical application of established European Norm (EN) standards for microbiological control. Integrating continuous treatment alongside routine maintenance provides a documented baseline for long-term system stability.

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