DISTRIBUTION SYSTEM MANAGEMENT

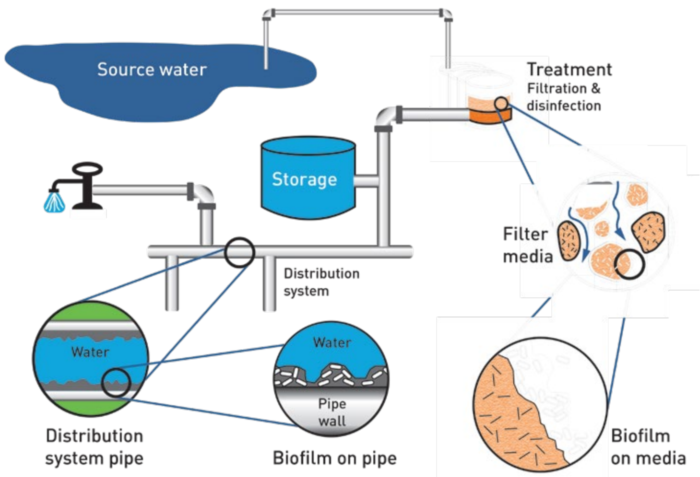
UNDERSTANDING AND CONTROLLING **BIOFILMS**

BIOFILM FACTS

- Organic and inorganic materials form biofilms on the inside of pipes and storage tanks.
- Biofilms are ubiquitous in all distribution systems.
- Diverse microbial communities colonize biofilms.

Biofilms are accumulations of microorganisms (e.g., bacteria, fungi, algae, protozoa, and viruses) and organic and inorganic matter bound by extracellular polymer substances attached to the inner surfaces of pipes and storage tanks in water systems. Biofilms are ubiquitous in all distribution systems, regardless of water quality characteristics and pipe materials (Figure 1), and provide an environment for bacterial replication as well as protection against disinfectants and microbial predators.

Pathogens can enter water systems through treatment break-through, inadvertent contamination of a distribution system (e.g., main breaks, breaches in storage tanks), or deliberate contamination. If any of these occur, introduced pathogens may interact with the surfaces of the distribution system and can become entrained in biofilms. Thus, biofilms can become central to the microbial ecology of opportunistic pathogens (infectious microorganisms that are capable of causing disease in certain risk groups) in distribution systems and premise plumbing.



Source: MSU, Center for Biofilm Engineering 1999

Figure 1. Diagram of a water distribution system showing locations for biofilm growth.

Studies have shown that biofilms in drinking water systems can serve as reservoirs for Helicobacter pylori (bacteria that can cause ulcers and cancer), Legionellae species (bacteria that can lead to legionellosis) and Mycobacterium avium (which can cause lung infections) (Watson et al. 2004, Mackay et al. 1998, Rogers and Keevil 1992, Lehtola et al. 2007). Free-living protozoa can be part of biofilm ecosystems and are increasingly recognized for harboring pathogens. Biofilms are also possible contributors to coliform regrowth. Detection of coliform bacteria in a distribution system is an indication of possible fecal contamination, which can lead to potential risks from all waterborne pathogens.

While biofilms can be a source of concern for water utilities, in drinking water distribution systems they have been associated with the removal of some haloacetic acids (HAAs) including mono-halogenated compounds and di-halogenated species (but not tri-halogenated species) (Bayless and Andrews 2008). The dominant HAA degraders in drinking water system enrichment cultures are Afipia spp. (Hozalski et al. 2010).

BIOFILMS AND OTHER WATER QUALITY CONCERNS

Corrosion
Biofilm growth can increase localized cast iron pipe corrosion by changing oxygen concentration and electrical potential of the pipe wall (Lee et al. 1980). While biofilm growth in a water pipe can be beneficial as a barrier to corrosion, it is generally considered to be detrimental in most aspects of iron corrosion (McNeill and Edwards 2001). Additionally, anaerobic sulfate-reducing bacteria can contribute to microbiologically induced corrosion by generating hydrogen sulfide gas that accelerates corrosion processes (Beech 2003).

Nitrification
Nitrification is a biological process by which ammonia is sequentially oxidized to nitrite and nitrate. Ammonia-oxidizing bacteria (AOB) are ubiquitous in chloraminated distribution systems, and biofilms can help AOB survive disinfectant residuals. AOB growth in biofilms is much greater than in the bulk water and is implicated in the onset of nitrification events.

Taste and Odor
Some microbes, such as actinomycetes and iron and sulfur bacteria, are common in pipe biofilm. These may detach into the water and proliferate in the system, frequently leading to taste, color, and odor problems in drinking water.

DECIDING IF A PROBLEM EXISTS
How: Monitoring diagnostic parameters (e.g., taste and odor, high residual demand, heterotrophic plate count)

ASSESSING BIOFILM GROWTH
How: Developing and executing a biofilm sampling plan considering sampler types, sample location, biofilm analytical methods, data analysis

FACTORS AFFECTING BIOFILM GROWTH ANALYSIS
How: Reviewing water quality and distribution system operation data (e.g., pipe materials, system hydraulics, pH, temperature, disinfect residual)

BIOFILM MANAGEMENT STRATEGIES
How: Developing a mitigation plan
- Target biofilm with strategies identified in existing guidance
- Mitigation plan might be tailored toward elimination of dominant species or other species of interest identified by community analysis

Source: Hausner et al. 2012

Figure 2. Diagram of biofilm assessment and management steps.

BIOFILM CONTROL

Biofilms are heterogeneous, inherently patchy, and colonized with diverse microbial communities— qualities that make biofilm control challenging for water utilities.

There are several biofilm mitigation strategies, such as flushing, swabbing/pigging, chemical treatments, and ice pigging. Flushing is the most popular method, but it is not always effective. It is suited to water mains fewer than 12" in diameter and may not work well on some deposits, such as manganese coatings or adherent corrosion scale. Figure 2 shows the four steps for biofilm assessment and management decision-making (Hausner et al. 2012).

Biofilms are a major concern for water utilities for many reasons, including proliferation of pathogens and coliforms, and increased pipe corrosion.

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ACEPSIS® AQUASOAR® AND OPTIMAL WATER HYGIENE TECHNOLOGY

CHLORINE DIOXIDE has been proven to remove biofilm and disease-causing pathogens from water systems and prevent them from reforming when dosed at a continuous low level. Sodium hypochlorite (bleach), and hydrogen peroxide, on the other hand, have been proven to have little effect on biofilms (see Figures 3 and 4).

Measurement of Oxidizing Agent ORP Values In Pathogen Disinfection*

OXIDIZING AGENT	OXIDIZING AGENT ORP VALUE RANGE (mV)
CHLORINE DIOXIDE (CLO_2)	600 → 1000 MV
OZONE* (O_3)	700 → 1000 MV
IODOPHORS (I_2)	400 → 600 MV
HYDROGEN PEROXIDE	300 → 500 MV
SODIUM HYPOCHLORITE	250 → 500 MV

Figure 3.

BIOFILM REMOVAL

AquaSoar™ enhances primary water hygiene effectiveness by penetrating and breaking down the structural components of biofilm, removing deposits that facilitate the growth and protection of dangerous pathogens. In other words, AquaSoar™ breaks up the "organic glue" that holds biofilm together, binding them to the surfaces within water systems. Adding AquaSoar™ to the water system provides the ultimate "one-two punch": AquaSoar™ destroys the biofilm structure and eliminates the bacterial presence within the water system.

ORP Values In Pathogen Disinfection**

PATHOGEN SURVIVAL IN SECONDS (S) OR HOURS (H) AT ORP LEVELS (MV)

Pathogens	<500 ORP (mV)	500 - 600	600 - 700	700+
E. COLI (0157:H7)	> 300 S	< 60 S	< 10 S	< 1 S
SALMONELLA SPP.	> 300 S	> 300 S	< 20 S	< 1 S
LISTERIA MONOCYTOGENES	> 300 S	> 300 S	< 30 S	< 1 S
THERMO-TOLERANT COLIFORM	> 48 H	> 48 H	< 30 S	< 1 S

Figure 4.

*Ozone is greatly influenced by the water quality and ozonation system.

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