Fact Sheet

Issue: 2 Volume: 2 Year: 2016

WCWC Walkerton Clean Water Centre
An agency of the Government of Ontario
CWAE Centre de Walkerton pour l'assainissement de l'eau
Un organisme du gouvernement de l'Ontario

Distribution Factors that Control Biofilm

Key Words: biofilm, heterotrophic bacteria, microbes, distribution system

Biofilm Background

Although, water treatment and disinfection processes provide high quality water and the distribution system can be well treated and strictly managed, microbes can still be present in water and biofilms (Table 1).

Table 1. Areas where microbes can be found in the distribution system (Liu et al. 2013)

Area	Key Points
Bulk Water	Can be used as a source of nutrients, microbes and particles.
Suspended Solids	Solids suspended in bulk water can provide an opportunity for bacteria to attach and grow.
Pipe Wall Biofilm	A major portion of bacteria (95%) in the distribution system is found in biofilm attached to pipe walls. Biofilm protects bacteria from disinfection.
Loose Deposits	Deposits found at the bottom of a pipe can be re-suspended in high flow rates. Accumulated deposits protect bacteria and other microbes.

Biofilm in the distribution system usually consist of coliforms, heterotrophic and nitrifying bacteria, but it can also consist of fungi, algae, protozoa, dead cells, corrosion products, organic and inorganic matter (USEPA 2008) (Figure 1). Typically, biofilm does not cause health problems; however, they can cause operational or aesthetic issues (USEPA 2008). Aesthetically, biofilm can produce taste, odour or colour issues (USEPA 2008).

Biofilm can protect bacteria and other microbes from disinfection. Approximately 90-95% of bacteria are located in biofilm adhered to the pipe wall (Liu et al. 2013, Lin et al. 2013). Additionally, biofilms can shield opportunistic pathogens, such as mycobacteria or *Legionella* from disinfection (USEPA 2008). Depending on the biofilm thickness, there are aerobic and anaerobic zones within biofilms, which house different microbial communities.

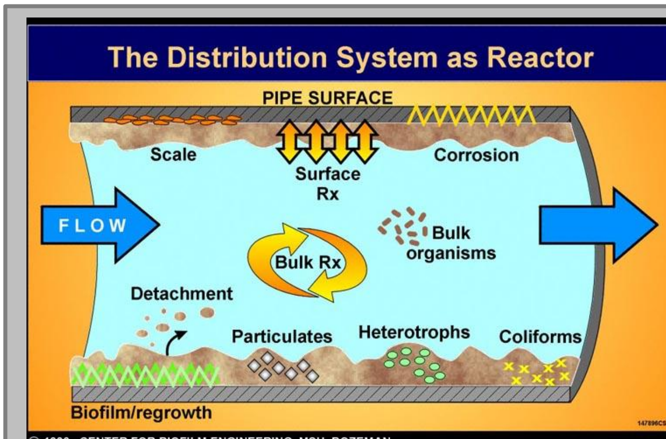

Figure 1. Interactions with water and the pipe wall, which affects water quality in the distribution system. (Image obtained from Montana State University Center for Biofilm Engineering).

Microbes prefer to adhere to surfaces when conditions are favourable. Microbes will attach to plastic or metal surfaces and begin to produce a material called, extracellular polymeric substances (EPS). EPS is adhesive and allows bacteria to multiply while sticking together, forming biofilm.

Biofilm can form a three-dimensional raised structure that provides an increased access to nutrients for the microbes. Overtime, the biofilm and microbes may detach from the surface of the pipe wall and may re-attach further along the distribution system (Figure 1). This allows the biofilm to reach new nutrients within the distribution system. Additionally, the subsequently detached microbes can lead to cells in the bulk water (Figure 1).

How Can We Monitor Biofilm?

Several methods are available to measure microbes in the distribution system.

Heterotrophic plate count (HPC) is a test that will measure heterotrophic bacteria (i.e. bacteria that rely on organic matter for food) in water samples from a distribution system. HPC results can give a general idea of the level of organic-feeding bacteria that are present.

Typically if HPC results are high, then there is a higher risk of biofilm formation. Comparing results with historical trends will identify if bacteria levels are abnormally high for that system.

Adenosine triphosphate (ATP) is a test that will indicate the total living biomass in water samples or from the surface of the distribution pipes. ATP is a molecule found in all living organisms. If there is an increase in biofilm, there would be an increase in ATP results. The ATP method is not intended to replace HPC, but it can enhance microbial monitoring. ATP kits are commercially available for water samples or from a surface (e.g. pipe wall).

It is possible to directly test for biofilm or bacteria levels that have adhered to the surface of the pipe wall. Typically, collecting pipe samples from actual field distribution systems can be costly. Alternatively, distribution pipes can be sampled by collecting a drilled core sample, called a coupon (Liu et al. 2013). Once the coupon is extracted, biofilm can be tested (Liu et al. 2013).

What Influences Biofilm Growth?

Several factors can influence the biofilm development in the distribution system, such as water quality, disinfection, operational and maintenance factors and pipe wall interactions (Table 2).

Table 2. Factors that influence microbes and biofilm growth in the distribution system

Factors	Key Points
Water Quality	
pH	• pH less than 7 can increase corrosion activity, which provides protected areas for microbes to attach to pipe surfaces and form biofilms. • pH greater than 9 can promote scaling, which can shelter microbes and promote biofilm development.
Turbidity	• Higher turbidity can reduce chlorine residual and shelter microbes from disinfection.
Temperature	• Temperature affects the chlorine demand and free chlorine residual, which is necessary to control biofilm (Ndiongue et al. 2005). Higher water temperatures increase microbial growth and diversity in pipes. • Generally, water temperatures at or greater than 15°C favour microbial growth (USEPA 2008).

Table 2. Factors that influence microbes and biofilm growth in the distribution system (continued)

Factors	Key Points
Water Quality (continued)	
Nutrients	• Reducing nutrients can reduce biofilm growth (USEPA 2008). Carbon, phosphorus, nitrogen, carbohydrates, humics, polysaccharides, biodegradable dissolved organic carbon (BDOC) and assimilable organic carbon (AOC) influence microbial growth (Chowdhury 2012). Dead bacteria can also be a source of nutrients. • BDOC is the biodegradable fraction of dissolved organic carbon that causes microbial growth, whereas AOC is the organic carbon that has been converted to biomass (Chowdhury 2012, Liu et al. 2013). Generally, BDOC < 0.25 mg/L, and AOC < 10 µg/L are recommended for biologically stable water (van der Kooij, 1992).
Biologically stable water	• Biological Stability refers to the concept of maintaining microbial water quality from the point of drinking water production up to the point of consumption. In other words, biologically stable water is water that does not promote microbial growth in distribution (Rittmann and Snoeyink 1984) due to limited availability of nutrients and presence of disinfectant residuals. • Producing biologically stable water will reduce biofilm development.
Disinfection	
Disinfectant type and dosage	• Secondary disinfection is the addition of disinfectant after the water treatment plant to maintain a disinfectant residual preventing microbial regrowth in the distribution system (e.g. free chlorine and monochloramine). • Compared to free chlorine, monochloramine is more stable and effectively infiltrates the biofilm; however if biofilms detach and are suspended, free chlorine is considered to be more effective (Hu et al. 2008).
Operations and Maintenance	
Water age and flow	• Generally, lower flow conditions favour microbial growth. Decreased disinfectant residual or increased taste and odour, colour, disinfection by-products, bacteria counts or nitrogen levels can indicate a water age issue (USEPA 2008). Tanks, pipe size and pumping rates also impact water age (USEPA 2008). • Cycling tanks, installing mechanical mixers, or adjusting pressures can increase flow and minimize water age (USEPA 2008).
Cleaning and flushing	• It is best to implement a flushing or cleaning program regularly; however, it does not address the root problem (Health Canada 2012, LeChevallier 2003, USEPA 2008). • Flushing rates at or greater than 5 feet per second (approximately 1.5 metres per second) can effectively remove sediments and biofilm. Mechanical cleaning may include swabbing, scraping, pigging, ice pigging or jet flowing. Chemical cleaning may involve food-grade chemical cleaners in the pipes.
Pipe Wall	
Corrosion	• Corroded pipes can develop cracks that will support the growth of heterotrophic bacteria, coliforms and opportunistic pathogens, which can reduce chlorine residual and increase biofilm development (Chowdhury 2012).
Pipe material	• Pipe material can affect biofilm development and chlorine residual (e.g. cast iron pipes release iron, which can promote iron bacteria growth, form corrosion scales and favour biofilm development). • Generally, pipes with rough surfaces (e.g. cast iron) have a higher opportunity for biofilm

Disclaimer

This fact sheet is presented solely for information purposes and is not intended to provide specific advice or recommendations in any circumstances. This fact sheet is a compilation of information from different sources and such information has not been independently confirmed for correctness or completeness. The information provided does not imply on the part of the Government of Ontario, the Walkerton Clean Water Centre (Centre) or its employees, any endorsement or guarantee of any of the information. The Government of Ontario, the Centre and its employees, do not assume and are not responsible for any liability whatsoever for any information, interpretation, comments or opinions expressed in the fact sheet.

Reference

Chowdhury, S. (2012) Heterotrophic bacteria in drinking water distribution system: a review. *Environ. Monit. Assess.,* 184: 6087-6137.

Health Canada (2012) Guidance on the use of heterotrophic plate counts in Canadian drinking water supplies.

Hu. J.Y., Fang, W. and Yu, B (2008) Biofilm control using chlorine-based disinfectants in model drinking water distribution systems. *Water Sci. Technol.,* 8(5):489-497.

LeChevallier, M.W. (2003) Conditions favouring coliform and HPC bacterial growth in drinking water and on contact surfaces. In Heterotrophic Plate Counts and Drinking-water Safety. World Health Organization. Edited by Bartram, J., Cotruvo, J., Exner, M., Fricker, C., Glasmacher, A. IWA Publishing, London, UK. 177-199.

Lin, W., Yu, Z., Chen, X., Liu, R., Zhang, H. (2013) Molecular characterization of natural biofilms from household taps with different materials: PVC, stainless steel, and cast iron in drinking water distribution system. *Appl. Microbiol. Biotechnol.,* 97: 8393-8401.

Liu, G., Verberk., J.Q.J.C., Van Dijk, J.C. (2013) Bacteriology of drinking water distribution systems: an integral and multidimensional review. *Appl. Microbiol. Biotechnol.* 97:9265-9276.

Ndiongue, S., Huck, P.M., Slawson, R.M. (2005) Effects of temperature and biodegradable organic matter on control of biofilms by free chlorine in a model drinking water distribution system. *Water Res.,* 39:953-964.

Rittmann, B.E. and Snoeyink, V.L. (1984). Achieving Biologically Stable Drinking Water. *J. AWWA.* 76(10):106.

USEPA (2008) Water Quality in Small Community Distribution Systems. A Reference Guide for Operators.

van der Kooij, D. (1992). Assimiliable organic carbon as an indicator of bacterial regrowth. *J. AWWA*. 84:57-65.

Related Training Courses

WCWC may offer courses related to this topic. Please browse our course descriptions to learn more about related training: www.wcwc.ca/registration

For More Information

For further information and resources on drinking water research and water operator training programs, please visit our website: www.wcwc.ca

Walkerton Clean Water Centre
20 Ontario Road, P.O. Box 160
Walkerton, ON, N0G 2V0
519-881-2003 or toll-free 866-515-0550