Learning Objectives

1. Describe the formation of the biofilm matrix and explain under what conditions a biofilm forms
2. Discuss biofilm’s known health implications for humans
3. List some practical tips for controlling biofilm formation

Biofilm: Getting dangerous slime out of your hospital

Biofilm presents itself differently to different people. Some see the slime coating in their birdbath. Others see it as a green coating on the bottom of their boat. Healthcare providers understand that it is a potential source of pathogenic organisms in some hospital equipment and water supplies. No matter where biofilms are found or what they look like, they share one common trait; they are hard to get rid of.

Biofilm explained

By scientific definition a biofilm is a population of bacteria, algae, yeast or fungi that is growing attached to a solid substrate and typically found within a fluid-rich environment. This community of microorganisms forms complex structures and communication methods that allow some organisms within the film to survive and even thrive in inhospitable environments. Biofilms can form on living structures such as teeth or the walls of intestines. They are also common on non-living surfaces like rocks, water pipes and even some incompletely processed medical devices.

Looking like an alien planet, a mature biofilm has many peaks and valleys, channels, caves and coves. Several species of microorganisms can inhabit the same mature biofilm mass, and the mass can liberate some of its organisms for colonization of new areas. The mature form of biofilm is also the most difficult to remove; it has been shown to be resistant to many detergents and antibiotics. To successfully control biofilms, one must prevent them or destroy them, preferably in the early stages of their development.

The origin of a matrix

The typical biofilm starts with a few free floating microorganisms. These microorganisms contact a surface and stick. In fact, some microbes have special extensions called pili (pie-lie) to grab the surface, or adhesion molecules that act like glue sticking the microbe to the surface. Once attached, these microbes begin to produce and secrete an extracellular polymeric substance (EPS) which builds into a matrix and cements the microbes in place. The newly attached microbes change their morphology to promote attachment. They begin to produce new chemical signals that alert other microbes in the area that there is a matrix forming, in essence inviting them to join the party. Soon, enough organisms have been collected in the matrix to secure its hold on the surface. The monolayer begins to build upwards away from the surface, creating several layers.

5 stages of Biofilm Development

As mountains of organisms grow channels form, allowing fluid exchange within the mass. New microbial species can join the party, creating a complex matrix of extracellular material and microbes. Ongoing growth leads to the formation of a mature biofilm.

Throughout the mass, special molecules called quorum molecules allow the microbes to communicate with each other. Quorum sensing tells the microbe when to attach, 

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Biofilm in humans

The National Institutes of Health estimates that 65% of all human microbial infections are due to a biofilm formation. For example, Paresk and Singh found that 80% of chronic sinusitis patients tested positive for biofilms. Hall-Stoodley, Hu, Gieseke, Nistico, Nguyen, Hayes et al found that 92% of children suffering with chronic otitis demonstrated a biofilm within the middle ear. Even outbreaks of *Pseudomonas aeruginosa* have been traced to biofilm formations within the alveoli of cystic fibrosis patients.

Biofilms within a patient present a serious challenge. Typical treatments reduce the presence of organisms but may not be able to eliminate all organisms within a biofilm. Surviving organisms known as Persistor Cells can rebuild the biofilm. Often the person appears healthy. The biofilm is kept in check by the immune system but the danger of illness still exists. Once the person’s immune system is again compromised, the biofilm grows and the person becomes ill again. This cycle can continue for several months or years and is believed to be the cause of some chronic infections. In severe cases as with immune-suppressed patients, this may lead to death. It’s easy to see why healthcare practitioners must make every effort to prevent biofilms from forming within patients, on or in medical devices and within facilities.

Device cleaning and recent studies

Among medical devices, endoscopes have been considered to be most susceptible to biofilm formation. However, rigid scopes, cannulated devices and other lumened devices can also develop biofilms. The best way to prevent biofilm formation is to physically clean all devices immediately after use. At this stage, new microbes and soils are at the earliest stages of biofilm formation.

The EPS matrix of an immature biofilm consists mostly of polysaccharide material with some non-cellular materials. The bond between the surface and the biofilm is at its weakest, so physical removal is at its easiest at this stage. Some cleaning chemicals can also reach the organisms through the thin layer of EPS.

As the biofilm matures, the polysaccharide material becomes heavily embedded with non-cellular materials. Mineral crystals, corrosion particles, and even blood components, if present, may combine to create a strong bond with the surface and a shield against some cleaning agents and physical removal. Many of the non-cellular materials can also interfere with a cleaning chemistry’s ability to remove biofilm.

Vickery et al demonstrated that enzymatic cleaning agents with a low enzymatic activity did little to reduce biofilm, while products with a high enzymatic activity were very effective. In addition, specific combinations and cleaning sequences also affected efficacy. Marion et al indicated that when two components were used simultaneously (Pronetron β4 and Pronetron α) cleaning was ineffective at removing biofilms. However, if cleaned in sequence, first with Pronetron β4 and then with Pronetron α, the method was effective at reducing the biofilm.

Combining good physical cleaning with the right cleaning chemistry can help to prevent the formation of biofilms. However, even the few viable organisms that might remain after cleaning can accumulate into a biofilm over time. In order to control and remove viable organisms, disinfection is the next critical step. Proper disinfection kills vegetative microbes and prevents the formation of biofilm.

All devices undergo a disinfection process. Endoscope users perform a chemical disinfection process following cleaning. In some cases the disinfection process is the final step before reuse.

Either an oxidative or aldehyde-based chemistry is used. However, some disinfection chemistries have demonstrated a tendency to promote the formation of biofilms. Alfa and Howie reported that gluteraldehyde solution buildup over several uses promoted the formation of biofilms within the lumens of endoscopes. They also found that enzymatic solutions used to clean the endoscopes in this study contributed to the formation of biofilms. Conversely disinfectants employing oxidative chemistries were more effective at controlling the formation of biofilms.

This study demonstrated the hardness and versatility of biofilms and the microbes that live within it. Even the harsh environment created by some disinfectants can be survived by these well-protected microbes, which can survive by using several food sources not typically thought to be possible. It’s important to remember that any solution, even alcohol or a cleaning chemistry such as glutaraldehyde can develop a biofilm if the conditions are right.

Biofilm in the water pipes

Even if your department takes great care to prevent biofilm formation in your medical devices, they can still become contaminated with biofilm from your facility’s water supply. *Legionella pneumophila* causes 90% of reported Legionnaire’s Disease. This organism is spread through potable water systems (tap water). Normally, it does not cause disease. However, transmission can occur when the water vapors are inhaled. It’s estimated that 60-85% of the water distribution systems in healthcare facilities today have this organism. Once a biofilm is established, it is nearly impossible to eliminate from the water system. Instead, control measures can be used to prevent outbreaks. Legionnaire’s bacterium can often be controlled through physical and chemical means.

Maintaining hot water temperatures at 55°C/133°F has been found to be effective for controlling outbreaks. However, maintaining those high temperatures creates the risk of scalding.

Chlorine-based chemicals such as free chlorine, chlorine dioxide and monochloramine have been successfully used to “shock” the system and as a continuous feed control measure. However, the application of these chemicals can be difficult and can require special equipment, and concern about the carcinogenic by-products leaves many facilities questioning their use.

Metal ions are a good alternative to chlorine compounds. Ions of silver or copper are added to the water supply. Relatively low concentrations are used. Studies have demonstrated a reduction in *Legionella* bacteria and an overall reduction in nosocomial infection rates after implementation. However, the equipment used for this intervention can also be expensive. In addition, higher levels
of metal ions may increase mineral deposits on medical devices after washing and steam sterilization. If this method is employed in a facility, it is especially important to use cleaning chemistries with good chelating capabilities, and deionized rinse water to prevent mineral deposits.

Given the challenges of chemical and metal ion water treatment, some newly-built facilities have incorporated UV irradiation of their water. UV irradiation kills Legionella bacteria in the water without leaving a hazardous by-product or changing the water’s chemistry. Since implementation, a study at one facility indicated that colonization has been avoided for 13 years. Though this shows the best promise of control, it is limited to new construction since old construction sites are most likely already colonized. The number of units and placement must also be considered carefully to avoid colonization in the new water lines. Once the biofilm has formed, it is not easily removed.

Prevention is best, control is mandatory

Biofilms are complex matrices of microbes, polysaccharides and non-cellular materials that have been linked to several chronic infectious conditions and can, in extreme cases, cause illnesses that result in death. By understanding where and how they form and under what conditions, healthcare biomeders and SPD professionals can proactively work to prevent or control biofilms and the threat they pose to human health. 

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References:
1. Nosocomial Legionellosis: Prevention and Management; Anna S. Levin; Published: 04/23/2009; Expert Review of Anti-Infective Therapy; (ISSN: 1478-7210, 1744-8360).

### Practical tips for getting the slime out

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<th>Tip</th>
<th>What does it do</th>
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<tr>
<td>Physically clean lumens and channels thoroughly every time, as soon after use as possible (follow device manufacturers’ directions)</td>
<td>Prevents young matrices from maturing into harder-to-remove mature biofilms</td>
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<tr>
<td>Use cleaning chemistries that are specifically formulated to include chelating agents</td>
<td>Prevents instrument discoloration and mineral deposits from copper or silver treated water. Some formulations can help detach and destroy biofilms</td>
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<td>Select disinfectants that are effective on biofilm removal and destruction</td>
<td>Will remove residual vegetative microbes left after physical cleaning that can accumulate over time to form biofilm</td>
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<td>Ensure compliance with expiration date limits for hospital-made solutions (follow cleaner and disinfectant manufacturers’ directions)</td>
<td>Assures the validated efficacy of the solution for cleaning or disinfection</td>
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<td>Do not ever ‘top off’ bottles of solutions</td>
<td>Assures proper concentration and validated effectiveness</td>
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<tr>
<td>Consider using ultraviolet light water treatment systems for new construction projects</td>
<td>Prevents colonization of water lines with Legionella bacterium</td>
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### Biofilms: Getting dangerous slime out of your hospital

Circle the one correct answer:

1) What types of surfaces can form biofilms?
   a. Teeth  
   b. Water pipes  
   c. Endoscope channels  
   d. All of the above  
   e. A and B only  

2) Pili are used by microbes to catch food.
   a. True  
   b. False

3) Which chronic diseases have been linked to biofilms?
   a. Sinusitis  
   b. Cohn’s Disease  
   c. Otis  
   d. A and B only  
   e. A and C only

4) Which component of the EPS matrix interferes with cleaning chemistries?
   a. Microbes  
   b. Polysaccharides  
   c. Non-cellular materials like mineral crystals, corrosion particles, etc.

5) Which method can be used to physically remove biofilms from devices?
   a. Soak for 2 hours in an enzymatic cleaner  
   b. Brush channels and lumens with detergent  
   c. Rinse all channels with 70% alcohol  
   d. All of the above

6) All enzymatic cleaners perform equally in removing biofilms.
   a. True  
   b. False

7) Which types of chemicals have been found to promote the formation of biofilms in endoscopes?
   a. Enzymatic cleaning agents  
   b. Glutaraldehyde disinfection solutions  
   c. Oxidative disinfection solutions  
   d. All of the above  
   e. A and B only

8) Which tap water treatments are effective at controlling Legionella outbreaks?
   a. Hot water maintained at 55°C; addition of chlorine-based chemicals; addition of silver or copper ions; UV irradiation of the water supply  
   b. Hot water maintained at 35°C/95°F; addition of chlorine-based chemicals; addition of silver or copper ions; UV irradiation of the water supply  
   c. Hot water maintained at 55°C/131°F; addition of iodine-based chemicals; addition of silver or copper ions; UV irradiation of the water supply

9) Which cleaning chemistry ingredient must be confirmed when implementing silver or copper ion water treatments?
   a. Low foaming ability  
   b. Good chelating agent  
   c. Low pH  
   d. Low concentration

10) When is the best time to install a UV irradiation process for facility water?
    a. When a new facility is being constructed  
    b. When the facility is renovated  
    c. In an established facility

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