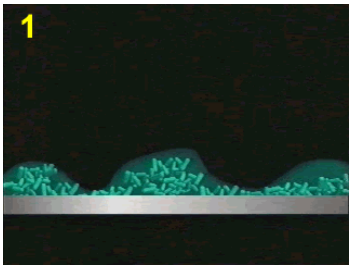
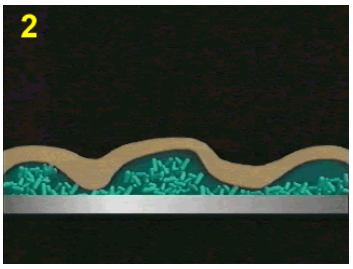
STEPS IN BIOFILM FORMATION

Biofilm formation takes place in a sequence of steps. At each step, the biofilm becomes more firmly attached and the microorganisms within it become more protected from the action of cleaners and sanitizers.

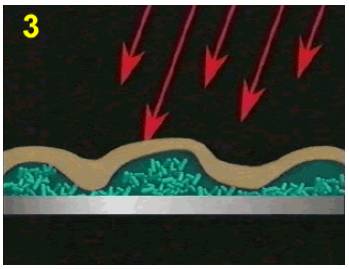
Step 1: Conditioning. The first step is the formation of a conditioning layer **(Fig. 1).** This consists of a loose collection of organic soils such as proteins and carbohydrates that combine with minerals in hard water. The conditioning step may begin within seconds of exposure to the surface.



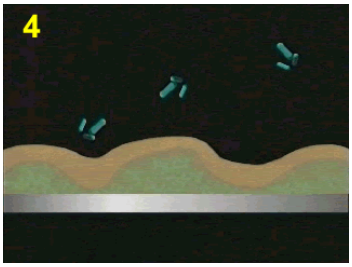
Step 2: Attraction. As the conditioning layer forms, an electrical charge builds on the surface and it becomes increasingly attractive to bacteria carrying an opposite charge. The electrostatic forces are weak and reversible at this stage and the microorganisms are easily removed and killed by mild cleaners and sanitizers.



Step 3: Attachment. Within 8 to 24 hours, bacteria in the growing biofilm become firmly attached to the surface and to each other by means of tendrils or filaments. They do this by exuding a polysaccharide material that entraps cells and debris within a glue-like matrix **(Fig. 2)**.



The biofilm environment is now a rich layer of nutrients that is capable of supporting rapid growth of the microorganisms within the biofilm. As the biofilm becomes more established and grows in thickness and is capable of blocking cleaners and sanitizers from penetrating **(Fig. 3)**. For sanitizers to work effectively, vigorous scrubbing is required to first break up the biofilm. This emphasizes the need to regularly clean and sanitize areas where biofilms form before they become firmly attached.



Step 4: Metabolism. A mature biofilm can contain as many 100 billion bacterial cells per milliliter. Complex diffusion channels deliver nutrients, oxygen and other elements that cells need to grow and carry away metabolic waste products, debris, and cells. The thriving and well protected colony provides a continuous supply of cells that easily slough away and contaminate other surfaces **(Fig. 4)**.

REMOVING BIOFILMS

Because biofilms form rapidly and once established are difficult to remove, prevention is the best strategy. Cleaning and sanitizing on a regular and frequent basis keeps conditioning layers from forming and minimizes bacterial attachment. The best way to keep biofilms from accumulating is to identify areas where they are likely to form and regularly clean and sanitize them.

Chemical sanitizers alone are usually not adequate to completely eliminate biofilms because they are not able to penetrate the biofilm and may be inactivated by the large amount of organic and inorganic matter present. Removing biofilms requires the use of cleaners that penetrate and solubilize the polysaccharide matrix and the underlying soils so that the bacteria are no longer protected from sanitizers.

Hot water at 180°F (82°C) or higher will rapidly kill microorganism within a biofilm but will not physically remove soils. In fact, at high temperatures, protein accumulations in the biofilm may coagulate making them even more difficult to remove. These residual deposits leave nutrient rich sites that support future bacterial growth.

Most experts agree that the best procedure for removing biofilms is to use an alkaline cleaner with plenty of brushing, scrubbing and scraping to break up the structure. A peroxy acid or quaternary ammonium compound sanitizer can then be applied to kill the remaining microorganisms. Work with your chemical supplier to select and evaluate a cleaning system specifically formulated for eliminating biofilms in your plant.