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Commentary

Silent Cities on Surfaces: Understanding the Structure and behaviour of Biofilms

Riven Solar*

Department of Microbial Sciences, Northbridge University, Melbourne, Australia

DESCRIPTION

Biofilms represent organized communities of microorganisms that attach to surfaces and produce a self-generated matrix composed of extracellular substances. These communities can develop on natural and artificial surfaces, including rocks in streams, plant tissues, medical devices and industrial pipelines. Unlike free-floating microbial cells, organisms in a biofilm live in close association, forming a structured environment that supports survival under varying conditions. This mode of growth allows microorganisms to coordinate activities, share resources and withstand challenges that would affect isolated cells more severely. The formation of a biofilm begins when individual microbial cells encounter a surface and adhere to it through weak, reversible interactions. Over time, this attachment becomes stronger as cells produce sticky substances that anchor them more firmly. These substances, often composed of polysaccharides, proteins and nucleic acids, create a protective matrix that surrounds the cells. As more microorganisms join, the biofilm grows and develops into a complex structure with channels that allow the movement of water, nutrients and waste products. Within a biofilm, microorganisms exhibit a level of organization that resembles multicellular systems. Cells communicate with each other through chemical signals, a process known as quorum sensing. This communication enables the population to coordinate gene expression based on cell density. For example, certain genes may be activated only when a sufficient number of cells are present, allowing the community to respond collectively to environmental changes. This coordinated behavior enhances the ability of the biofilm to adapt and persist.

The internal structure of a biofilm is not uniform. Gradients of oxygen, nutrients and metabolic waste develop across the community, leading to variations in microbial activity. Cells located near the surface may have greater access to oxygen and nutrients, while those deeper within the biofilm may exist in low-oxygen conditions. This diversity in microenvironments contributes to the overall stability of the community, as different cells can perform specialized roles that support the group as a whole. Biofilms are widely distributed in natural environments and play an important role in ecological processes. In aquatic systems, they contribute to nutrient cycling by breaking down organic matter and facilitating the transformation of chemical compounds. In soil, biofilms help stabilize particles and support plant growth by interacting with roots. These interactions can enhance nutrient availability and protect plants from harmful microorganisms. In medical settings, biofilms are associated with persistent infections. They can form on tissues and medical devices such as catheters, prosthetic joints and implants. The matrix surrounding the cells acts as a barrier that limits the penetration of antimicrobial agents, making infections difficult to treat. In addition, cells within a biofilm can enter a state of reduced metabolic activity, which further decreases their sensitivity to antibiotics. This combination of physical protection and physiological adaptation allows biofilms to survive treatments that would typically eliminate free-floating cells.

The resistance of biofilms to antimicrobial agents is a major concern in healthcare. Traditional treatments often target actively growing cells, but many cells within a biofilm grow slowly or remain dormant. This makes it necessary to develop strategies that can disrupt the biofilm structure or enhance the effectiveness of existing treatments. Approaches may include the use of enzymes to degrade the matrix, physical removal methodsor the development of agents that interfere with cell communication. Biofilms also have implications in industrial systems. They can accumulate on surfaces in water treatment facilities, food processing equipment and pipelines, leading to reduced efficiency and contamination. The buildup of biofilms can cause blockages, corrosion and increased energy consumption. Managing biofilm formation in these settings requires regular cleaning, monitoring and the use of materials that resist microbial attachment.

Correspondence to: Riven Solar, Department of Microbial Sciences, Northbridge University, Melbourne, Australia, E-mail: riven.solar@biofilmscience.org

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CONCLUSION

Biofilms demonstrate how simple organisms can organize into complex systems that are capable of adaptation, cooperation and survival under challenging conditions. Their presence across diverse environments and their impact on health, industry and ecology make them an important subject of study. By exploring how biofilms form, function and respond to external factors, researchers can develop new approaches to manage their effects and utilize their capabilities in beneficial ways.