Ways to control harmful biofilms: Prevention, inhibition, and eradication

Abstract

Biofilms are complex microbial architectures that encase microbial cells in a matrix comprising self-produced extracellular polymeric substances. Microorganisms living in biofilms are much more resistant to hostile environments than their planktonic counterparts and exhibit enhanced resistance against the microbicides. From the human perspective, biofilms can be classified into beneficial, neutral, and harmful. Harmful biofilms impact food safety, course plant and animal diseases, and threaten medical fields, making it urgent to develop effective and robust strategies to control harmful biofilms.

1. Introduction

Biofilms are microbial communities encased within a self-produced matrix of extracellular polymeric substances (EPS) that attach to biotic or abiotic surfaces (Watnick and Kolter 2000; Lohse et al. 2018). About 20-80% of microorganisms on Earth exist as biofilms (Flemming and Wuertz 2019). They can protect the microorganisms inside them, mostly bacteria, from hostile environments, by acting as a layer of "protective clothing" (Yin et al. 2019). Biofilms can comprise single or multiple species (Wolcott et al. 2013; Lohse et al. 2018), and a typical biofilm life-cycle usually includes five stages (Sauer et al. 2002; Stoodley et al. 2002; Monds and O'Toole 2009; Koo et al. 2017; Rumbaugh and Sauer 2020): (i) Reversible attachment on surfaces. At this first stage, initial attachment of cells occurs via non-covalent interactions, such as hydrogen-bonding or the van der Waals' force; (ii) Irreversible attachment. At the second stage, microbial cells become robustly attached to the surface via bacterial appendages such as flagella, pili, adhesive proteins, or exopolysaccharides (Serra et al. 2015); (iii) Development of early biofilms. After stable attachment, cells actively proliferate and produce abundant EPS; (iv) Maturation of structured biofilms. At this stage, stable biofilm forms via constructing a threedimensional architecture; (v) Active dispersal. Finally, cells are disseminated from the biofilm and re-enter into the planktonic phase upon receiving environmental cues, waiting for a new life-cycle.

Microorganisms in biofilms are distinct from their planktonic counterparts (Hathroubi et al. 2017); they usually show increased resistance to hostile environments including chemical biocides (Gupta et al. 2016), bacteriophages (Costerton et al. 1999), antibiotics (Wood 2017; Roy et al. 2018; Wolfmeier et al. 2018), and antibodies (Müsken et al. 2018). Here, according to the microbial properties in the biofilm, biofilms are classified into three main types, beneficial, neutral, and harmful biofilms, depending on their effects on humans, e.g. environment, food safety, plant and animal production, and medical fields.

Beneficial biofilms play key roles in many processes, such as wastewater treatment (Lin et al. 2019), biodegradation and bioremediation (Shukla et al. 2020), and geochemical cycles (Boer et al. 1991; Edwards et al. 2000). During wastewater treatment, biofilms are massively formed in the bioreactor and participate in organic matter removal, adsorption of suspended solids, and purification of raw sewage (Huang et al. 2018). In the processes of biodegradation and bioremediation, biofilms form unique microbial communities to degrade herbicides (Li et al. 2019b), pesticides (Zhang et al. 2019), antibiotics (Zhang et al. 2017), and plastics (Shah et al. 2008) and remediate contaminated water and soil (Wang et al. 2019a; Zhao et al. 2019). In terms of geochemical cycles, biofilms comprising appropriate bacteria are able to decompose a wide variety of organic compounds via redox, cleavage, and hydrolysis reactions to complete the geochemical recycling of carbon, nitrogen, oxygen, phosphorus, sulfur, and other elements (Cui et al. 2018; Meyer-Dombard et al. 2018; Zhang et al. 2020).

2. Strategies to control and eradicate harmful biofilms

Therefore, for effective eradication of microorganisms in biofilms, many biochemical methods have been applied, such as application of phage lysins, degradative enzymes, and microbial metabolites. Combining degradative enzymes with living beneficial bacteria spores has been found to be very effective at eradicating biofilms. Bacteriophages are the enemies of bacteria.

The biofilm matrix of EPS is mainly composed of nucleic acids, proteins, lipids, and exopolysaccharides Because biofilm serves as a “protective clothing” for microorganisms, one can eradicate the harmful biofilm by degrading the EPS and removing this protective clothing by using degradative enzymes.

Therefore, by careful analysis of the individual biofilm, and by treating it with enzymes capable of hydrolyzing different components of the biofilm, one could effectively eradicate different biofilms. Besides, by combining different degrading enzymes or use them as non-antibiotic assistants, we may be able to further improve the effectiveness of biofilm eradication.

3. Concluding remarks

Bacteriophages (beneficial bacteria) and enzymes have also been found to be effective as anti-biofilm agents in recent years.

End of Abstract

Note: The above abstract excerpts are found through the National Library of Medicine; associated with the National Institutes of Health (NIH). The NIH is the primary agency of the United States government responsible for biomedical and public health research.

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