Biofilm Formation: A Multifaceted Problem Requiring Urgent Attention Encompassing Human, Environment and Animals

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ABSTRACT

Biofilm formation is a new, emerging, multifaceted problem that hinders microbial control in different environmental settings, such as hospitals, the food industry, houses, farms, and the general environment. It also plays a key role in antimicrobial resistance to drugs and environmental stress, making them more persistent. It also makes conventional sanitization procedures useless by providing an external barrier in the form of extracellular polymeric substances (EPS). In developing countries like Pakistan, Bangladesh, and Afghanistan. It is also a great economic burden for the public as well as the government. This is a multifaceted problem involving multiple sectors that need a multifactorial approach for proper handling.

Keywords: Biofilm, Multifaceted, Antimicrobial resistance, Sanitization procedures, Extracellular polymeric substance, Persistent, Tackling

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Introduction

Biofilm, first observed in dental plaque, is a sticky, protective matrix of microbial populations (such as bacteria, fungi, and algae) that adhere to surface and to one another to form intricate communities that are enveloped in self-synthesized extracellular polymeric substance (EPS) matrix and are resistant to antibiotics, disinfectants, biocides, dessication, and host defense[1,4]. Initially, the microbe attaches to the surface, and after successful attachment, bacteria divide and produce EPSs that lead to the maturation of biofilm, and finally, the bacterial cells are released. The EPS matrix includes polysaccharides, proteins, lipids, and nucleic acids [5]. Biofilm increases disease burden by antimicrobial resistance, which is also an emerging threat, rendering many antibiotics ineffective that were effective in the past [4]. Healthcare-associated infections (HAIs) and other microbial diseases are largely caused by biofilms such as dental diseases, surgical site infections, and chronic wounds [2,3]. Moreover, biofilm production is a major threat to food safety and quality. Microbes are widely distributed in food industrial areas and are harder to deal with due to their notorious property of being resistant to chemical sanitization procedures and antimicrobials [5]. Due to past strategies being ineffective against microbial biofilms, new therapies such as microneedles, phase therapy, nano drug therapy, photodynamic therapy, microbial therapy, and combinatorial drug therapy [6]. Out of these nano drug carriers hold substantial weight [7].

Mechanism of Biofilm Formation

Biofilms in terms of species population can be simpler containing only a single species or can be diverse containing more than one species.Polymicrobial biofilms show more intricate patterns and enhanced virulence,networking and antibiotic resistance. The first step is attachment of microorganisms to biotic and abiotic surfaces permanently. Secondly, microbes start proliferating on the surface. Thirdly, biofilm matures and releases more diverse signals and chemicals. Lastly, microbial cells are released from mature biofilm colonies into the environment for further dissemination [7].The overall mechanism of biofilm formation is shown in Figure 1.

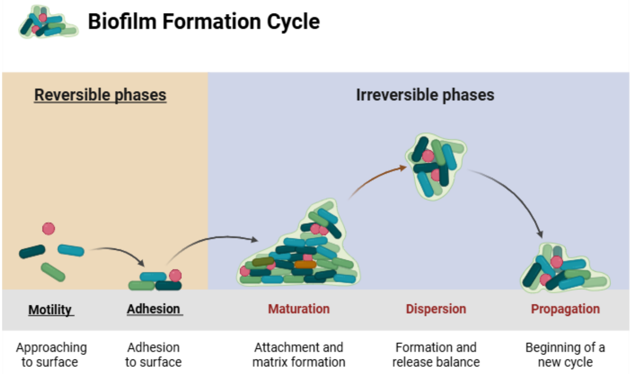

Figure 1: Shows mechanism of biofilm formation on biotic and abiotic surfaces.

Biofilm's Role in Antibiotic Resistance

Antibiotic resistance indicates defiance or tolerance acquired by microbes against certain kinds of antibiotics that were previously effective due to the ignorant administration or usage of antibiotics. Biofilm provides a physical barrier to antibiotics absorption and an intricate city for horizontal gene transfer and plasmid transfer. In a biofilm bacterial community or communities, each cell has more chances of survival than a freely floating bacterial cell. Antibiotic resistance itself is a problem, and combined with the biofilm factor, it's menacing and needs proper attention.[4]

Biofilm's Role in Dental Health

Human oral cavity is a habitat for more than 700 species of microbes identified up until now. Many dental infections are polymicrobial, causing dental caries, periodontitis, endodontic infections, alveolar osteitis, and tonsillitis. These microbes having the capacity to form biofilms can also result in the failure of dental implants.[3]

Biofilm's Role in Hospital Acquired Infections (HAIs)

Biofilms are excellently adaptive to not only moist surfaces but also to dry surfaces that pose serious threat, especially the dry surface biofilms (DSBs). Biofilms can be found anywhere from hospital beddings to drainage pipes. This otherwise impossible survival of microbes in dry environment is made possible only due to retention of moisture by EPS matrix. Consequently, medical devices can also be infected by the same principle, such as causing bloodstream infections. Polymicrobial biofilms including bacterial as well as fungal species can negatively impact the healing of chronic wounds as compared to acute wounds.[2]

Biofilm Role in Food Industry

With population explosion food safety, prolonged storage is of utmost importance.But biofilm formation deteriorates food quality.It can be tackled by using different physical and chemical techniques such as thermal processing, bioelectric effects, ultrasound, quaternary ammonium compounds, acidulants and enzyme-based approach.[5]

Prevention Strategies

Biofilm formation is a topic of concern that requires utmost vigilant efforts for its effective handling. It involves using natural as well as advanced therapeutic options according to the needs and requirements. Naturally, plant based natural compounds like phytochemicals and essential oils can be used as natural anti-biofilm agents[8,9].Advanced technologies like Nanoparticles or nanomaterials are used for better drug delivery that do so by targeting antimicrobial substances, biofilm penetrating efficiency, destabilizing EPS and acting synergically with antibiotics.Using nanoparticles have many positive sides and it is emerging as a new popular concept for drug administration. Lipid-based, polymeric-based,metallic based and silica based nanocarriers are used. Despite their useful nature microbes in biofilm can develop resistance against them and they can be potentially toxic to human cells and tissues [7].

Limitations

The biofilm problem is of grave concern but conventional therapeutic procedures are not valid and certain natural compounds pose dose dependent cytoxicity.Biofilms mask the bacteria rendering standard diagnosis method useless.It also poses great economic burden.[2].Some advanced techniques are still in pipeline, underdeveloped and unregistered for clinical usage.Even some advanced technologies like nanocarriers have certain drawbacks such as scalability, consistency and cellular toxicity[7].

Future Goals

Biofilm is a rigid, intricate, complex system of EPS matrix and the need of the hour is to develop unique antimicrobial drugs and novel therapeutic agents targeting biofilm. A surveillance system, for biofilm prevention coupled with advanced sanitation procedures, is necessary [2]. Advancement in nanotechnology such as using metallic, functionalized metallic nanoparticles, polymeric nanoparticles and liposomes may prove to be critically important anti-biofilm agents [10].

Conclusion

In conclusion, microbial biofilm formation is a multifactorial problem that is a major threat to animals, humans as well as environment requiring unique and novel interventions for its containment. Biofilm acts as a shield for microbes that help them evade conventional diagnosis methods, sterilization techniques, and treatment procedures. This is a major global crisis right now that is also exacerbating antimicrobial resistance. This is an urgent matter that requires utmost care and attention and should be taken seriously.

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