Microfluidic Device for the Evaluation of Biofilm Removal under Shear Stress

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Biofilms are a relevant problem in the medical field and many other industries. Biofilms can lead to proliferation of pathogens, loss of life, equipment failure, and loss in productivity [1]. Biofilms also have increased resistance to antibiotics and are harder to remove than planktonic bacteria [2]. Motile bacteria behave differently than the immotile bacteria that compose biofilms, and so studies that focus specifically on biofilms are necessary.

The experiments consisted of growing biofilms *Pseudomonas aeruginosa*, subjecting them to stress in the presence of a removal agent, and capturing images of the biofilms. A microfluidic device allowed for the use of existing microscope setups to image the biofilms, which allows for broad application of the device. The microfluidic device also mimicked the scale at which bacteria operate. Pressure was applied at increasing magnitude to find the threshold at which the biofilm began to be removed. The images were then analyzed to determine the amount of biofilm removal that occurred.

Polydimethylsiloxane (PDMS) microfluidic devices were used to evaluate treatment methods in conjunction with shear stress. The experiments that were conducted show the differences in the effect of shear stress with two removal agents on a biofilm. The pressures at which phosphate buffered saline (PBS) and sodium dodecyl sulfate (SDS) removed biofilms were statistically different. SDS required a lower pressure threshold to remove the biofilm than PBS. The percentage of biofilm that was removed was also statistically different between the PBS and SDS. At their respective removal pressures and in the same time span, SDS removed more of the biofilm than PBS.

The biofilms were characterized using confocal imaging, which creates a 3D reconstruction of the biofilm. The biofilms were 2.5 μm thick and had one to two layers of bacteria. The biofilms in the microfluidic device have an average radius of 28.3±11.5 μm after overnight growth.

The shear stress applied to the biofilm was modeled using COMSOL Multiphysics® software. The model includes a profile of the shear stress in the fluid as a function of position in the working fluid. Pressure-driven flow rates and biofilm size were varied in the model. The location of the maximum shear correlates with the portion of the biofilm that faces and extends into the fluid flow. The model shows, as expected, that increasing biofilm size decreases shear stress and increasing flow rate increases the shear stress.

The described device has been used to successfully to compare chemical treatment methods while applying a shear stress to the biofilms. The microfluidic device was advantageous because it was easy to image, operated at the scale of bacteria, and minimized costs.

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1. **Chmielewski, R.A.N, Frank, J.F.,** "Biofilm Formation and Control in Food Processing Facilities," *Comprehensive Reviews in Food Science and Food Safety*, **2** (1) pp. 22-32 (2003)
2. **Høiby, N, *et al.*,** "Antibiotic resistance of bacterial biofilms," *International Journal of Antimicrobial Agents*, **35** (4), pp. 322-332 (2010)