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Design optimization and validation of a simulated microgravity biofilm reactor for simulating spacecraft wastewater systems

Biological growth within spacecraft has posed a challenge to human spaceflight since the first long-term missions to space began. Biofilms, a surface attaching biological mass of bacteria and fungi, have clogged space station water systems since we sent up the first space stations. Skylab, the Russian Mir program and the International Space Station suffered system failures due to biofilm growth within water systems. These failures required system cleaning and filter replacement to remain functional, a solution that increases in cost and difficulty as humanity seeks to return to the moon and beyond. To prevent biofilm growth within these systems and develop cleaning and operating procedures to manage growth, tools are needed to simulate these systems on the ground.

In this work, a novel tool is developed for simulating many of the conditions found within these water systems, such as microgravity and nutrient limitation, while being able to evaluate the growth of these biofilms. This system is called the simulated microgravity biofilm reactor (SMBR). The SMBR system is designed to produce simulated microgravity while allowing biofilms to be grown and quantified. To evaluate if low-shear modeled microgravity is being produced, computational fluid dynamics simulations were conducted to understand the fluid environment within the SMBR. These simulations were then compared to results obtained using particle imaging velocimetry to experimentally capture velocity measurements from the SMBR. If too much fluid shear and mixing is present in the SMBR system, the device is not recognized as creating low-shear modeled microgravity. According to CFD simulations, the SMBR has low shear stress. Experimental PIV results validated these simulation results.

SMBR design and operational changes were evaluated for the effect on the shear stress within the SMBR. Optimized reactor designs are developed and manufactured for improved biological sensing and ease of use. The optimal SMBR designs are documented and ready to be used to develop biofilm control strategies for spacecraft wastewater systems.

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