Surface and colloidal mechanisms of surfactant-free cleaning

Andriani Tsompou

[1] Department of Biomedical Science, Malmö University, Malmö, Sweden
[2] Biofilms Research Center for Biointerfaces, Malmö University, Malmö, Sweden

andriani.tsompou@mau.se

Growing concerns about the environmental impact of detergents have driven interest in alternative, eco-friendly cleaning strategies, including the use of purified water. This work investigates how the properties of purified water can be used to achieve effective cleaning while minimizing the need for surfactants. We studied the removal of common oily soils, such as olive oil, from hydrophilic and hydrophobic surfaces and examined the interactions between oil, water, and cotton fabrics. In addition, the effect of purified water treatments on bacterial viability was evaluated.

For hydrophilic surfaces, the removal of thin vaseline films and thicker oil layers was studied under different temperatures and washing cycles using Quartz Crystal Microbalance with Dissipation Monitoring (QCM-D). Thin films were largely removed within two washing cycles, with higher temperatures improving removal efficiency. For thicker films, gravimetric analysis showed that the washing process could be divided into two regimes (exponential and linear), where each one is governed by different washing mechanisms and stability principles.

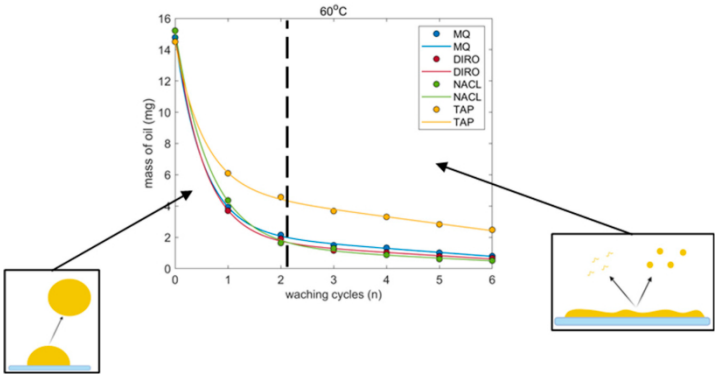
Two strategies were explored to improve cleaning on hydrophobic surfaces: pH adjustment of purified water using trace amounts of NaOH and the addition of small amounts of lipase. Both approaches significantly enhanced oil removal. Increasing the pH promotes deprotonation of fatty acids in olive oil, facilitating detachment through roll-up and reduced interfacial tension, while lipase hydrolyses olive oil into more water-soluble products that can act as natural surfactants.

Spatially resolved SAXS measurements were used to study interactions between cotton, oil, and water, revealing that these components interact with cotton at different length scales and that washing results in partial redistribution and removal of oil.

Finally, isothermal calorimetry was used to assess bacterial viability, demonstrating that repeated washing cycles and longer incubation times reduce bacterial survival.

These findings highlight the potential of purified water–based systems as a sustainable approach to cleaning with reduced reliance on conventional detergents.

Keywords:
surfactant-free, washing, cleaning, hydrophilic, hydrophobic, cotton, pure water



Average amount of olive oil remaining on the surface of glass tubes (mg) as a function of the number of washing cycles for MQ, DIRO, NaCl, and TAP at 60 ºC. The number of replicates is 3. The dashed black line indicates the change of regimes, while figures followed by arrows show the main mechanism