

Effects of water purity on interfacial adhesion

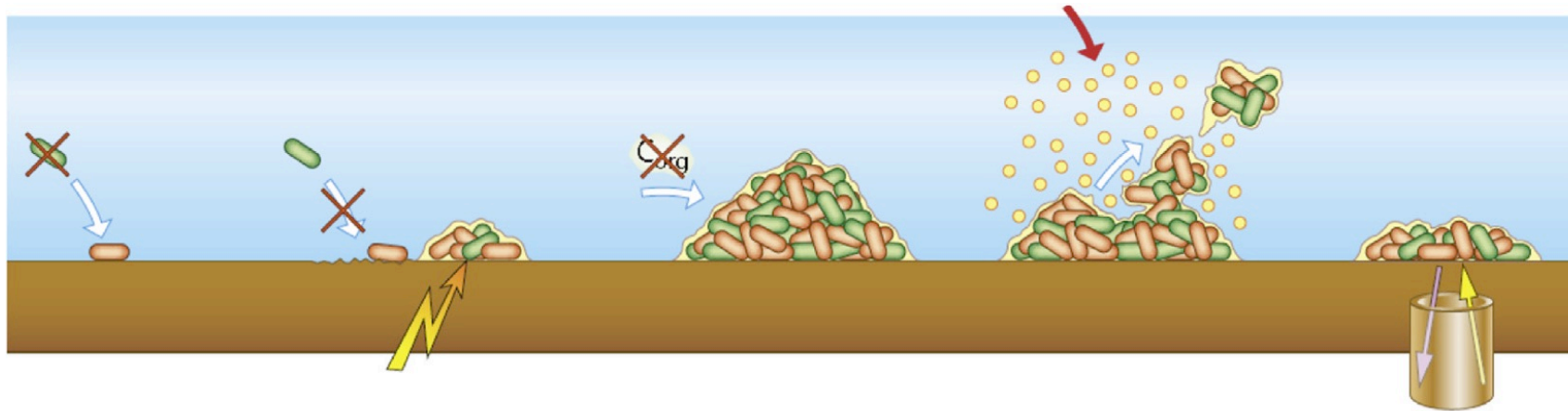
Legionella workshop 2023

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How to remove legionella biofilms from a surface?



Disinfection methods:

- Thermal
- Chemical
- Physical

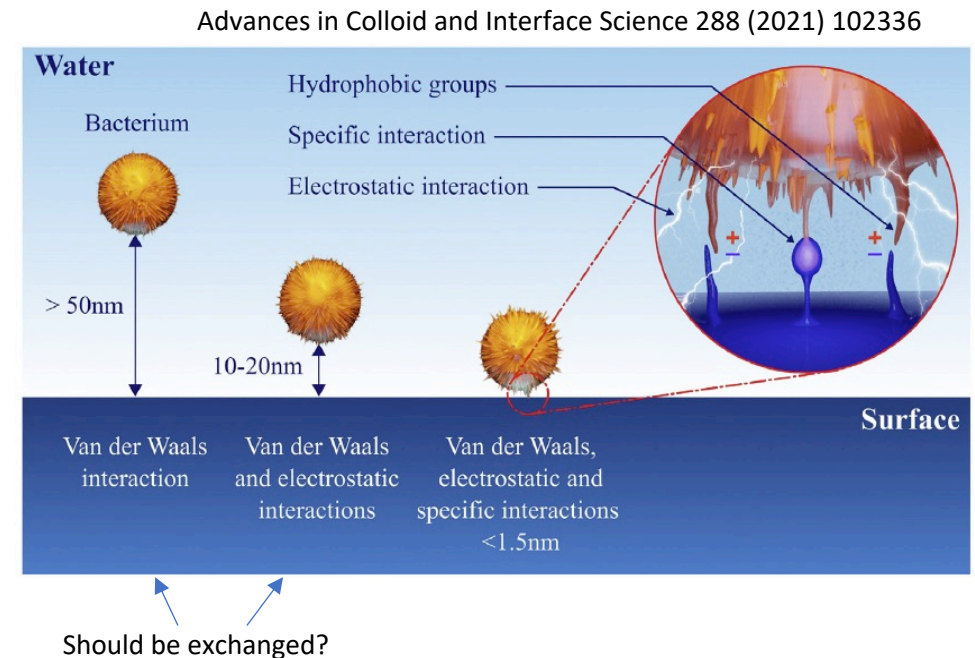
“However, these treatments generally do not result in total elimination of the bacterium, and after a lag period, recolonization occur as quickly as the treatments are discontinued”.

Front. Cell. Infect. Microbiol. 8:38.

Adhesion of biofilms to surfaces

Steps:

- Formation of conditioning layer
- Reversible adhesion
 - DLVO: electrostatic, van-der Waals forces
 - Non DLVO forces (steric, hydration etc.)
- Irreversible adhesion
 - Interfacial tension, work of adhesion
- Population growth



Surface chemistry approach: adhesion and interfacial tension

Adhesion free energy

$$(\Delta G_{adh}^{\circ})' = \gamma_{sm} - \gamma_{sl} - \gamma_{ml}$$

γ_{sm} , γ_{sl} and γ_{ml} are:

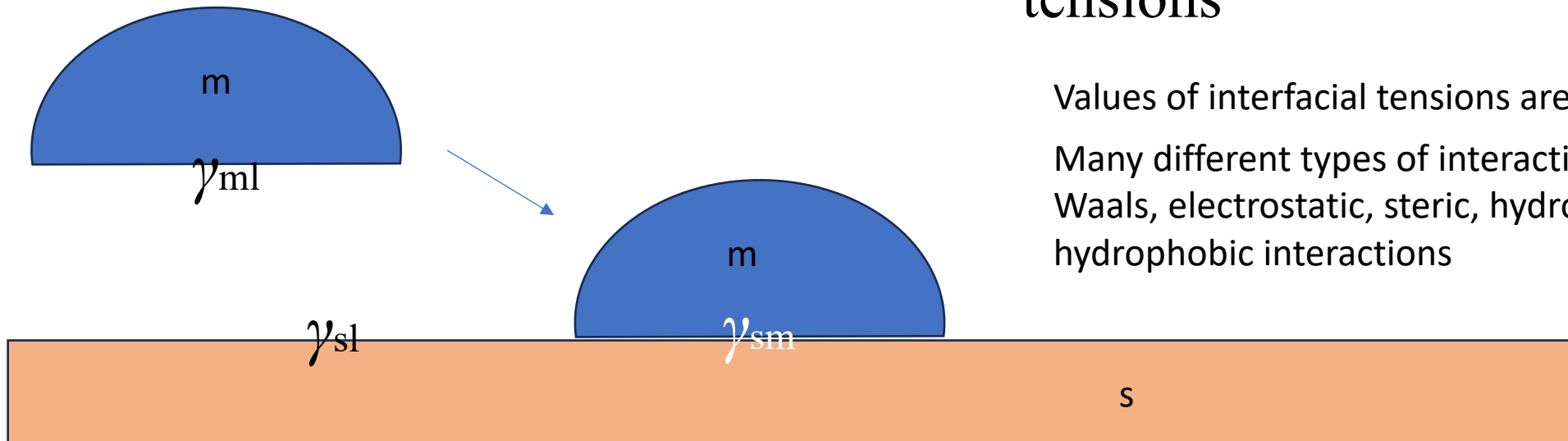
Solid – bacteria,

Solid – liquid,

Bacteria – liquid interfacial tensions

Values of interfacial tensions are usually unknown...

Many different types of interactions, including van der Waals, electrostatic, steric, hydrogen bonding, hydrophobic interactions



Legionella bacteria are negatively charged

Table 1 Cell surface hydrophobicity and zeta potential of *Legionella pneumophila* serogroup 1 strain Philadelphia

Lifecycle	Relative hydrophobicity (%)	Zeta potential (mV)
Lag phase	28.83 (± 3.77)	-26.02 (± 1.07)
Exponential phase	33.37 (± 4.21)	-26.52 (± 3.12)
Stationary phase	45.14 (± 2.91)	-25.17 (± 2.02)



Size: around 1 micron

<https://www.rki.de/>

The duration of lag, exponential and stationary phases was 5, 13 and 6 h, respectively.

- Note: most surfaces are negatively charged too
- Repulsion

Colloid chemistry approach: colloidal stability: DLVO and disjoining pressure

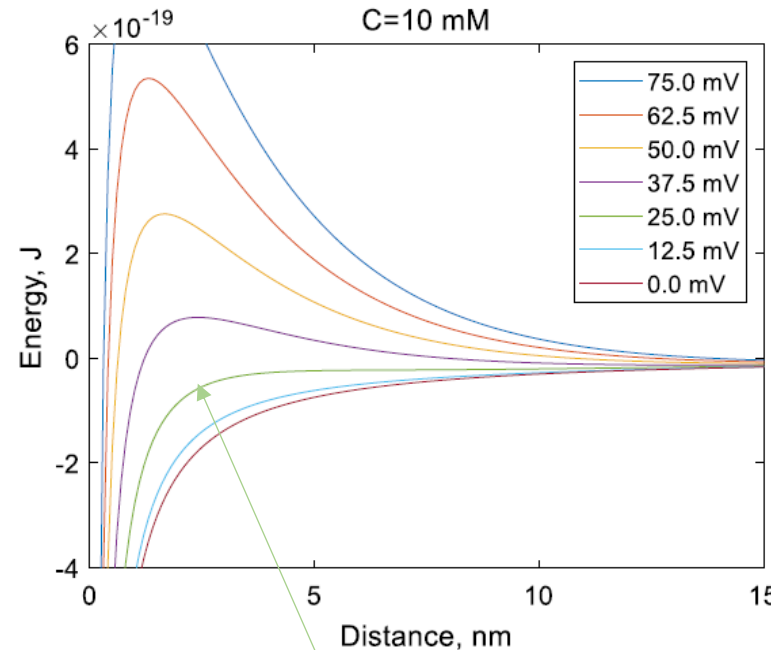
DLVO: Derjaguin-Landau-Verwey-Overbeek

$$V_R = \frac{32\pi\epsilon a k^2 T^2 \gamma^2}{e^2 z^2} \exp[-\kappa h_d]$$

$$\gamma = \frac{\exp\left[\frac{ze\psi_d}{2kT}\right] - 1}{\exp\left[\frac{ze\psi_d}{2kT}\right] + 1}$$

$$V_A = -\frac{A}{12} \left[\frac{1}{x(x+2)} + \frac{1}{(x+1)^2} + 2 \ln\left(\frac{x(x+2)}{(x+1)^2}\right) \right]$$

$$x = h_d / 2a$$

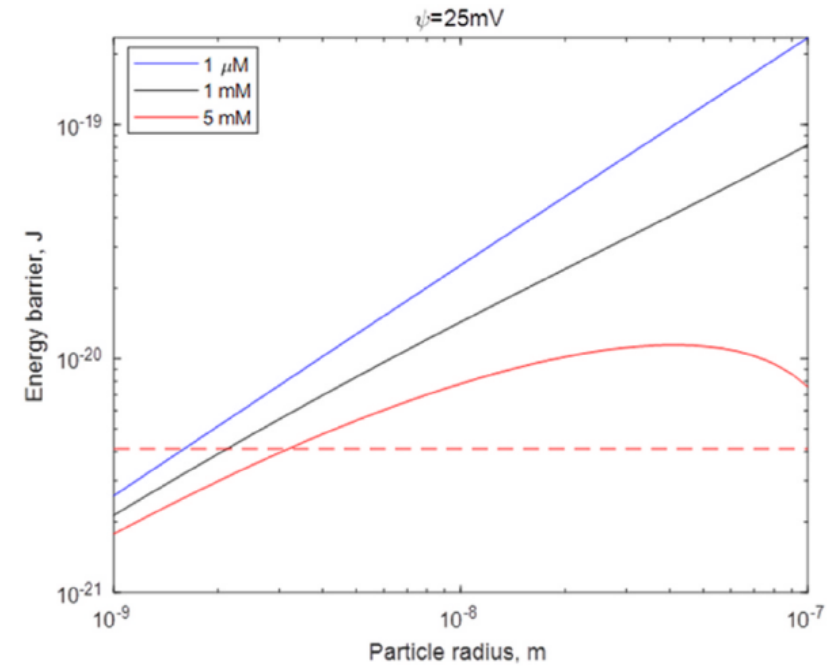
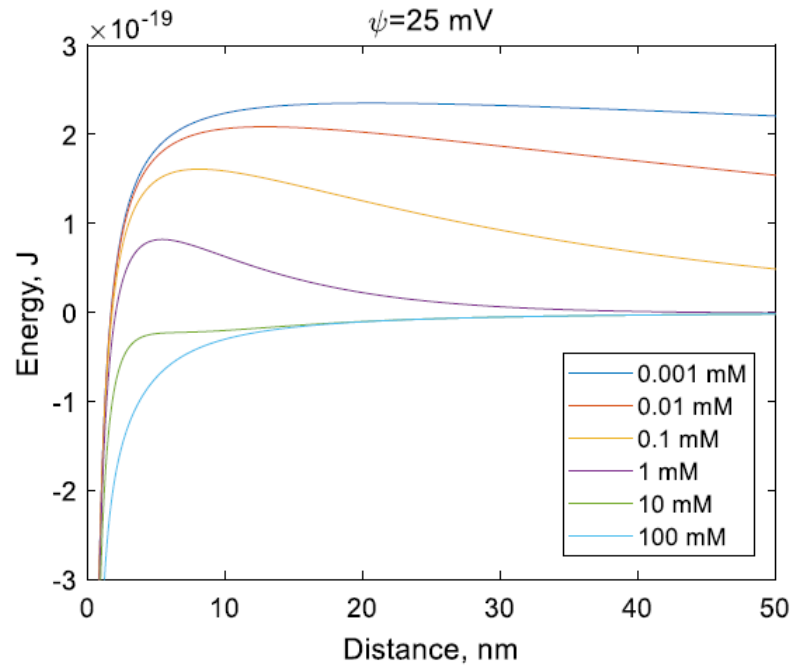


- No charge: van der Waals forces case strong attraction
- Charge cases repulsion (electrostatic stabilisation)

25 mV: no barrier

DLVO: electrostatics: effect of water purity

- Effect of salt at 25 mV (Legionella's potential)
- Effect of size at 25 mV



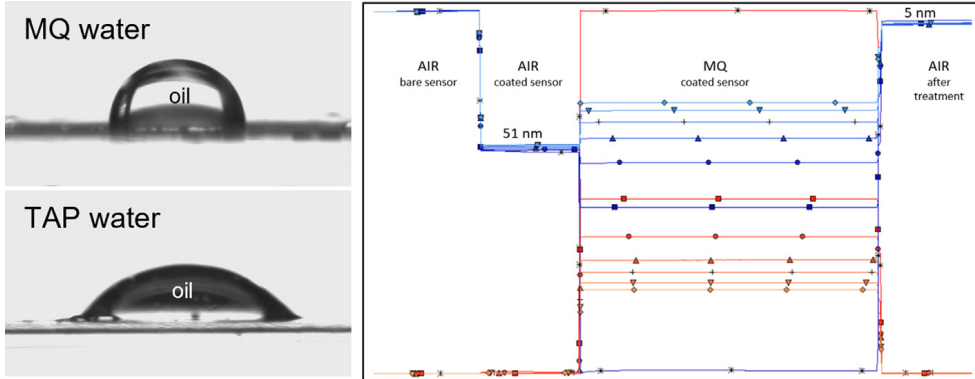
Remove bacteria by using purified water?
Not tested yet

The pure water project



Andriani Tsompu

Industrial partners: SWATAB, Sandberg Development



Ανδριανή Τσόμπου: Ελπιδοφόρα αποτελέσματα για πλύσιμο χωρίς απορρυπαντικό

Δημοσιεύτηκε πριν 10 μήνες στις
20/01/2023
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EDUCATION ▾ RESEARCH ▾ COLLABORATION AND INNOVATION ▾ ABOUT US ▾ SEARCH

Malmö University - News - Hopeful results for washing without detergent

NEWS Published: 4 January 2023

Hopeful results for washing without detergent



Ο στόχος του ερευνητικού έργου είναι η ανάπτυξη ενός επιστημονικού μοντέλου που εξηγεί τι συμβαίνει τόσο χημικά όσο και φυσικά όταν αφαιρείται η βρωμιά σε καθαρό νερό.

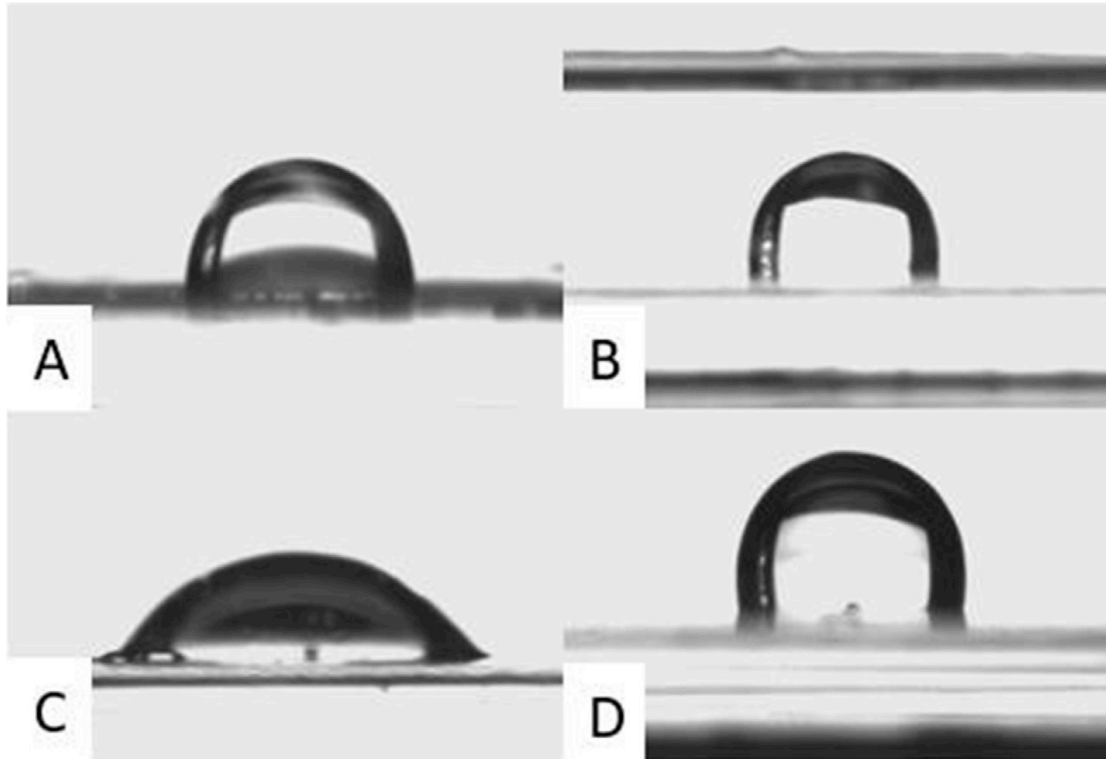
Το πλύσιμο των ρούχων μας χωρίς απορρυπαντικό θα μπορούσε να γίνει παρελθόν; Παρόλο που η έρευνα βρίσκεται στα αρχικά της στάδια, μια έρευνα για το αν το πλύσιμο ή ο καθαρισμός μπορεί να γίνει με καθαρό νερό αντί για διάλυμα απορρυπαντικού φαίνεται πολλά υποσχόμενη.

«Στόχος μας είναι να αναπτύξουμε ένα επιστημονικό μοντέλο που εξηγεί τι συμβαίνει τόσο χημικά όσο και φυσικά όταν η βρωμιά αφαιρείται σε καθαρό νερό. για να βρείτε μια μαθηματική εξήγηση που να περιγράφει αυτές τις διαδικασίες. Όσον αφορά το πλύσιμο με απορρυπαντικά, γνωρίζουμε ήδη τι συμβαίνει, αλλά αυτή είναι μια ανεξερεύνητη περιοχή», λέει η **Ανδριανή Τσόμπου, διδάκτορας στο Τμήμα Βιοιατρικών Επιστημών του Πανεπιστημίου του Μάλμε**.

Ο Vitaly Kocherbitov επιβλέπει το έργο στο Biofilms Research Center for Biointerfaces, προσθέτει:

«Μακροπρόθεσμα, η έρευνά μας μπορεί να λύσει περιβαλλοντικά προβλήματα με τη ρύπανση του νερού που προκαλείται από απορρυπαντικά. Για να επιτύχουμε σε αυτό, πρέπει να κατανοήσουμε καλύτερα τις διαμοριακές δυνάμεις που δρουν στο καθαρό νερό».

Tap water vs purified water: adhesion of oil



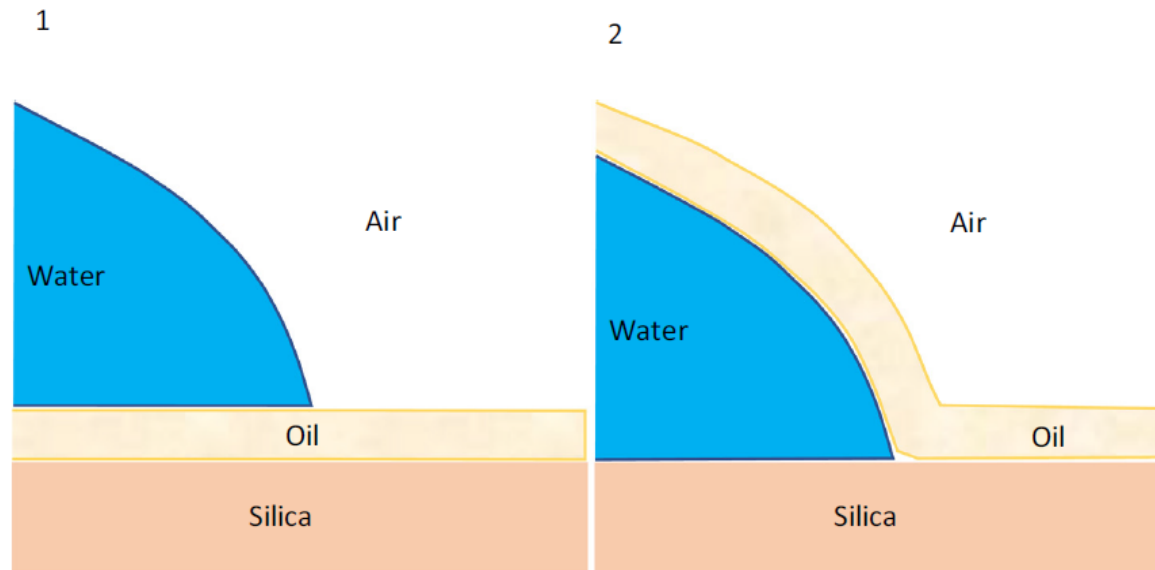
- Tap water promotes adhesion of oil to hydrophilic surfaces (case c in the figure)

Contact angle of olive oil droplet on glass surface in MQ (A), DIRO (B), TAP (C) and NaCl (D).

Changing the interface type

A. Tsompou and V. Kocherbitov

Journal of Colloid and Interface Science 608 (2022) 1929–1941

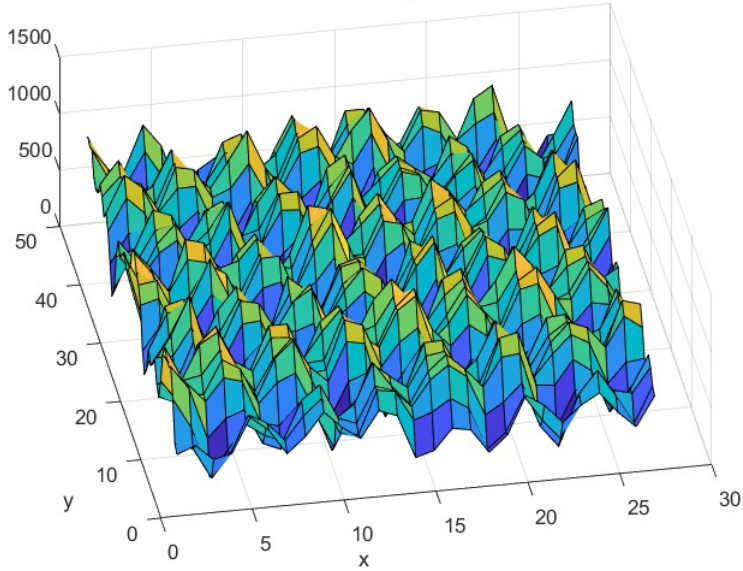


Change of
interface type
may promote
detachment

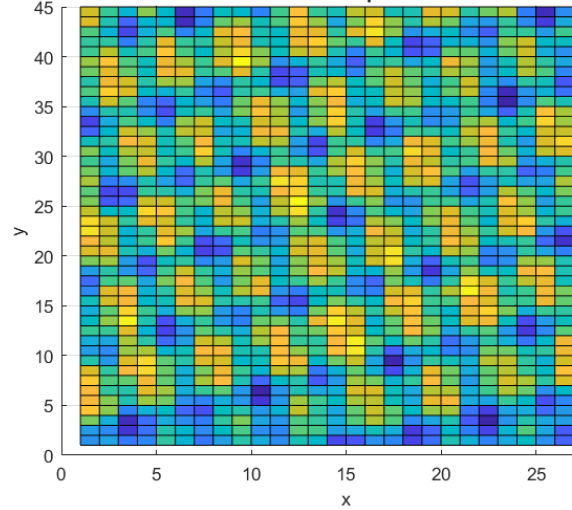
Fig. 8. Two possible ways of interactions of water with a thin oil film on a solid surface. Case 2 favors removal of oil from the surface.

Pure water project: analysis of cotton fabric

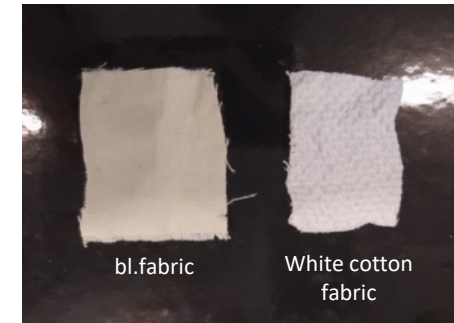
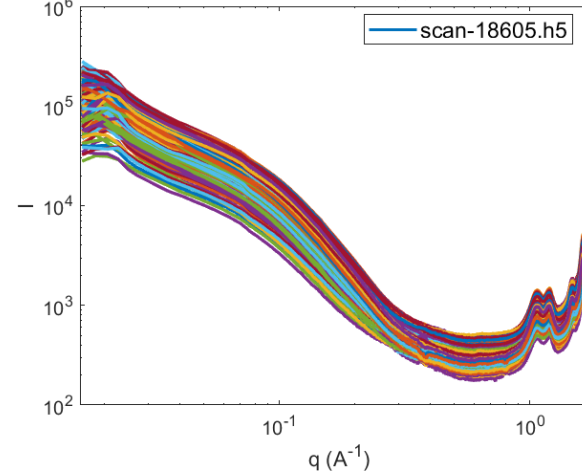
Surface plot



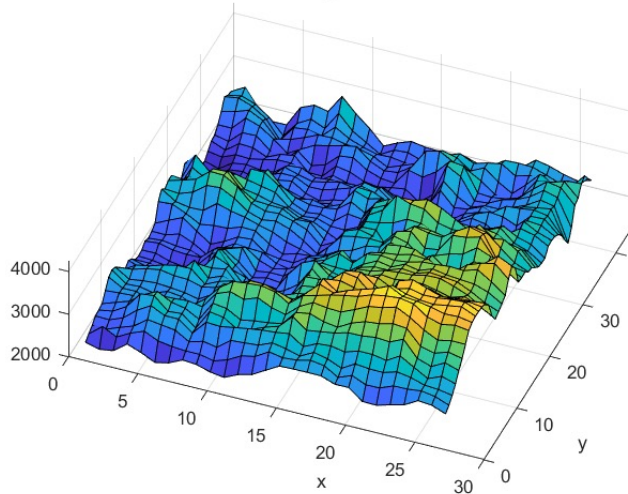
Surface plot



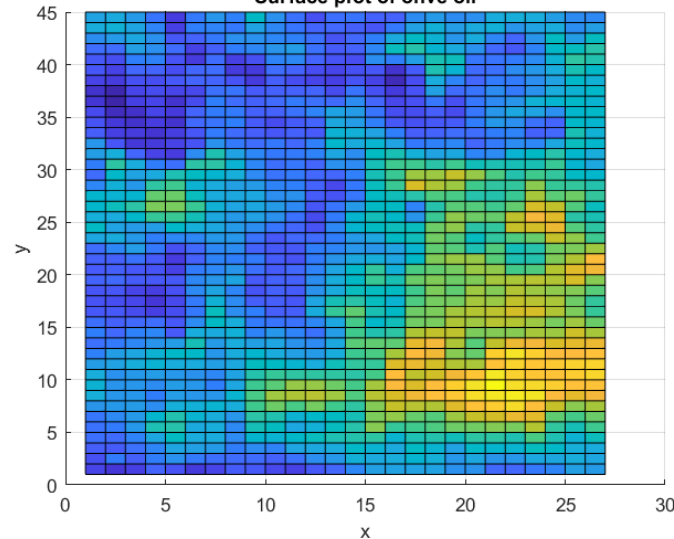
fabric with MQ



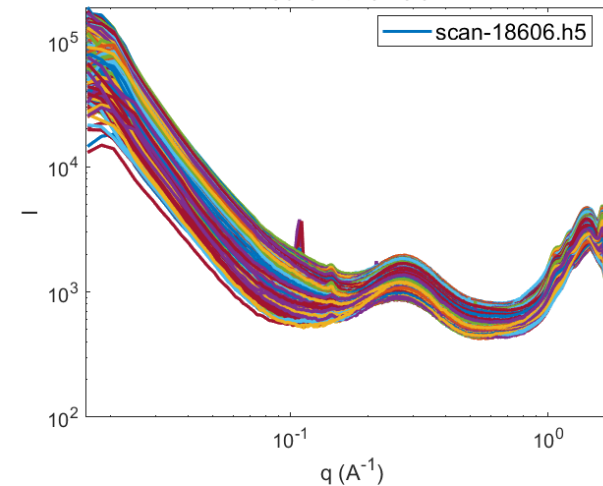
Surface plot of olive oil



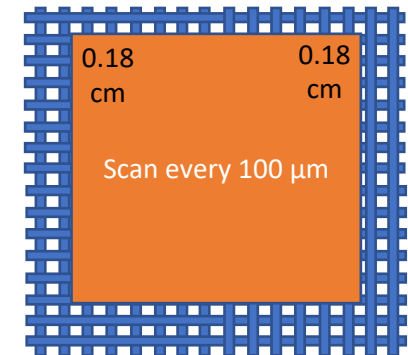
Surface plot of olive oil



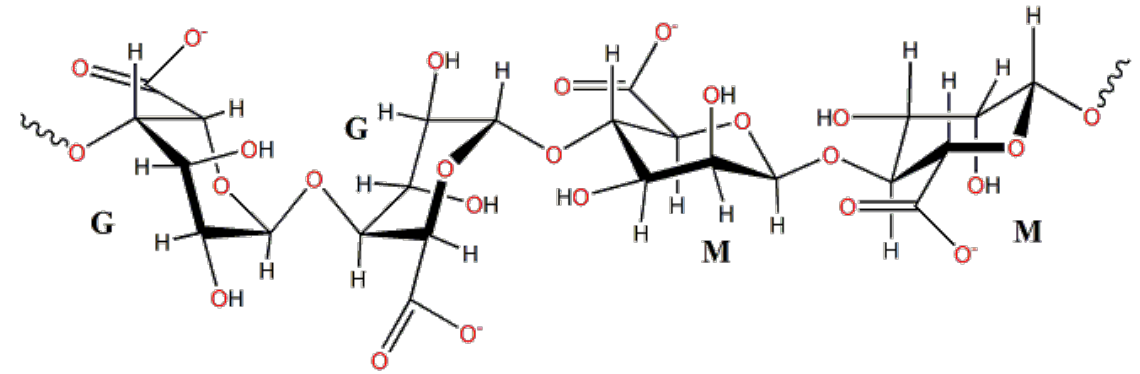
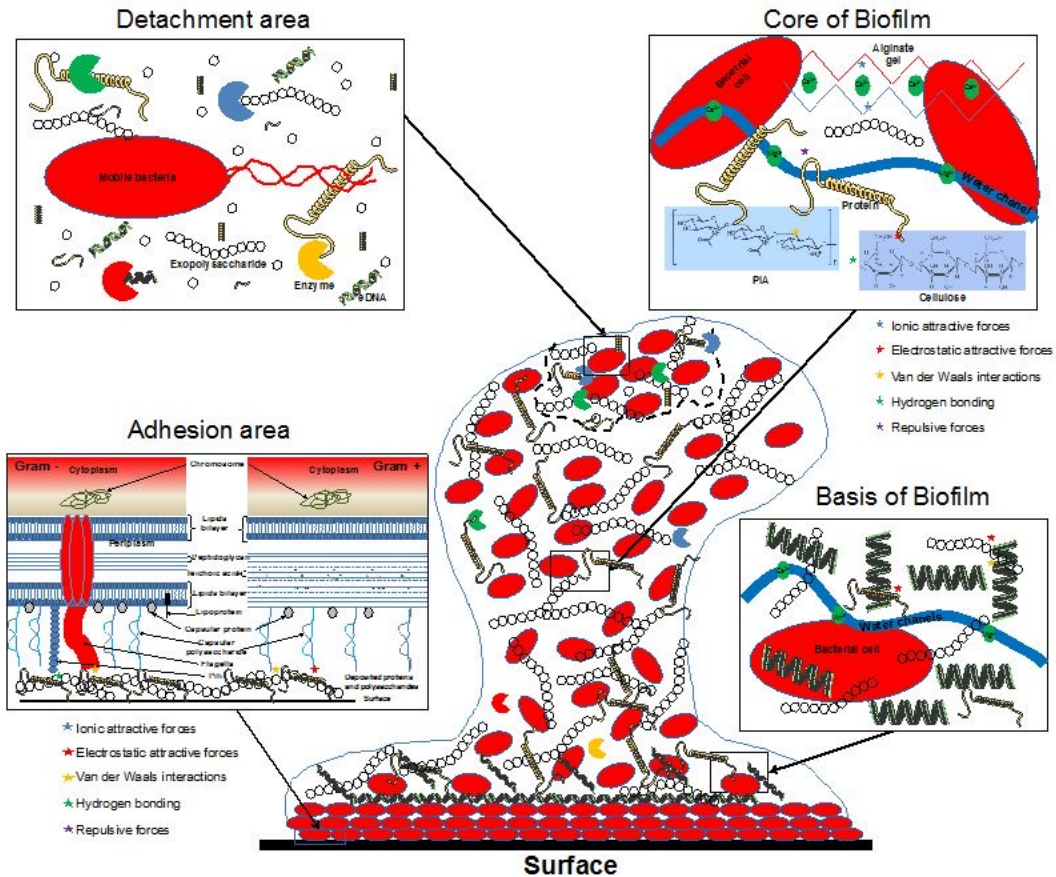
fabric with olive oil



0.25 cm

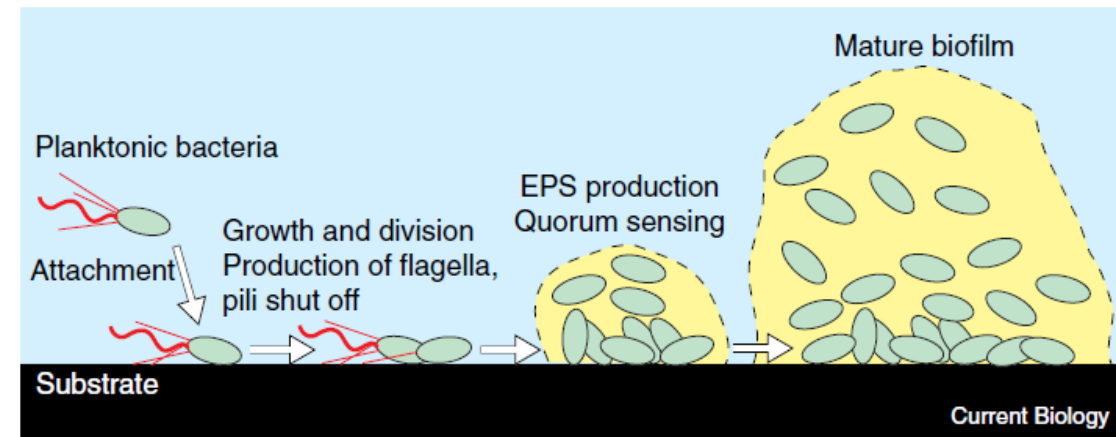


Effects on polysaccharide matrix



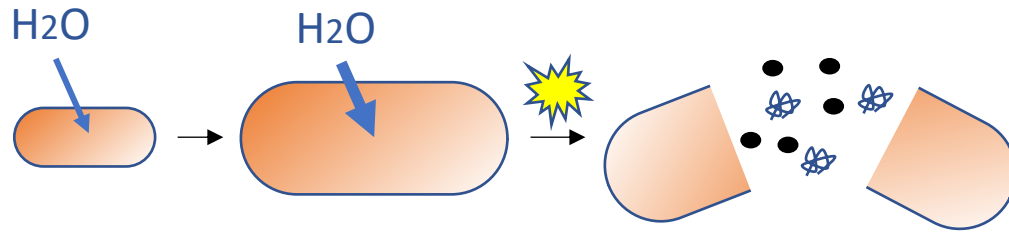
Polysaccharide matrix is formed by charged polymer chains

Removal of salts would result in increased repulsion and potentially can “open up” structure



Osmotic pressure

Can purified water promote extreme absorption of water and cause a burst of bacteria?



More ideas to test....

Thank you!