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Relationships between the conditioning film and the surface characteristics of materials in contact with drinking water A way to assess new innovative non-adhesive materials

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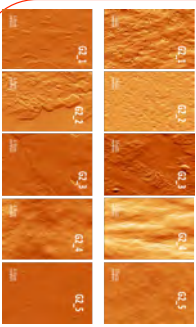
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Biofouling of any material in contact with water should begin with the attachment of a set of organic biopolymers recruited from the bulk water and forming a so-called « conditioning film ». The conditioning film is generally considered as a critical factor in biofilm initiation.

Here we describe AFM characterization of organic biopolymers and bacteria accumulated on polymeric materials after immersion in tap water for a short period of time (24 h, 20°C) under low turbulent hydrodynamic conditions.

Our study aims to address the following three questions: (i) Is there a link between the physicochemical characteristics of the surface after 24 h immersion in drinking water and the intrinsic properties of the tested materials? (ii) Can the number of attached bacteria be explained by the surface characteristics measured before or after the 24 h immersion in drinking water? (iii) Does cleaning efficiency (i.e., hydrodynamic flushing and 50 mg Cl₂/L chlorination) depend on the physicochemical characteristics of the material or/and on the organic conditioning film adhesiveness?



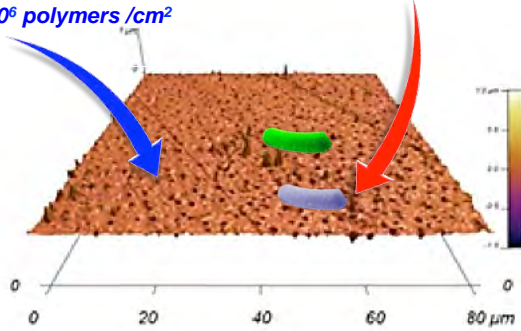
17 polymeric materials tested in the study

Roughness from 0.2 to 2,450 nm

Hydrophobic balance adhesion forces from 0.2 to 17nN

POLYMERS in 24 hours
 More than 1×10^6 polymers /cm²

BACTERIA in 24 hours
 from zero to 2×10^4 /cm²



Regression and correlation analyses were performed on a data set including 12 to 54 assays and 14 variables (number of bacteria, density of polymers, forces of detachment of the polymers, etc.).

- The hydrophobicity of the material (T0-Hi-surf) was positively correlated with the accumulation of hydrophobic polymers (T24-Ho-Fpol) on the surface examined.

$$T24-Ho-Fpol = 0.02 \times T0-Hi-surf + 0.08 \quad P = 0.004$$

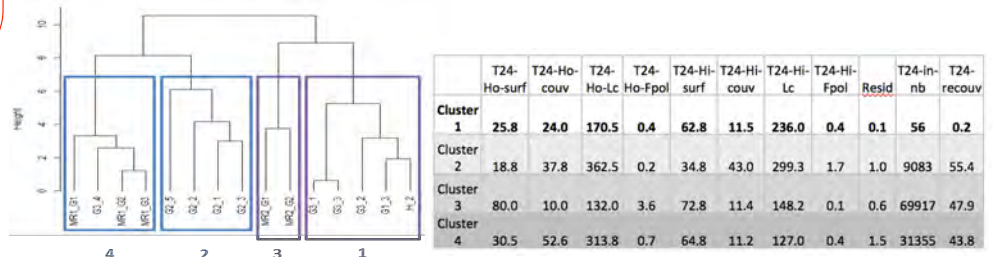
- The number of attached bacteria was not linked to the intrinsic physicochemical characteristics of the materials (i.e., before immersion in water); however, the bacterial density (T24-recouv) was positively correlated with both the adhesion forces (T24-Ho-Fpol and T24-Hi-Fpol) and the density of polymers (T24-Ho-couv and T24-Hi-couv) forming the conditioning film.

$$T24-recouv = 0.90 \times T24-Ho-couv + 0.53 \times T24-Hi-couv + 19.0 \times T24-Ho-Fpol + 16.2 \times T24-Hi-Fpol - 32.6 \quad P = 0.0001$$

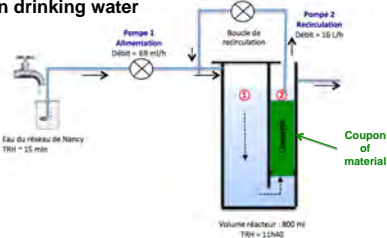
- The fraction of residual bacteria (Resid) (i.e., after surface cleaning) was shown to be positively correlated with polymer adhesion forces (T24-Hi-Fpol).

$$Resid = 0.60 \times T24-Hi-Fpol + 0.16 \quad P = 0.014$$

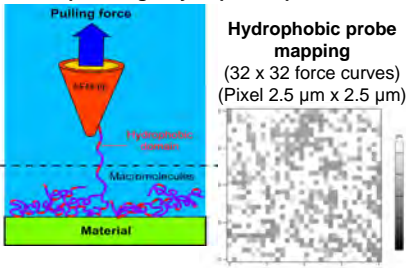
Furthermore, cluster analysis (k-means and hierarchical cluster analysis) was performed on the whole data set (i.e., on the 17 materials), after 24 h immersion in drinking water. Statistical analysis allowed different classes of materials to be identified objectively. Thus, the materials with the best anti-biofilm properties for use in drinking water systems (cluster 1) were characterized by low conditioning film (T24-Ho-surf and T24-Ho-couv), low bacterial colonization (T24-in-nb), and easy cleanability (Resid).



Immersion of coupons for 24 hours in drinking water

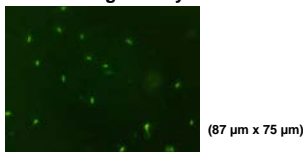


Scheme of chemical force spectroscopy technique using a hydrophobic probe



Hydrophobic probe mapping (32 x 32 force curves) (Pixel 2.5 µm x 2.5 µm)

In situ counting of adhered bacterial cells (72 h) after staining with Sybr II



(87 µm x 75 µm)

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