Free Energy of Adhesion of Nitrifying Bacteria to Limestone and Basalt

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Keywords: *adhesion, surface properties, thin-layer wicking, contact angle*

Any surface in contact with a biological fluid is a potential target for microbial cell adhesion. In this process, the surface properties of both interacting bodies, like surface charge and surface free energy play an important role. Surface energy considerations enable the computation of the free energy of adhesion between two surfaces - the thermodynamic model. According to this model, bacterial adhesion will be favoured if the process itself causes the free energy to decrease, $\Delta G^{IF} = \Delta G^{LW} + \Delta G^{AB} < 0$, where LW means Lifshitz-van der Waals interactions (apolar) and AB stands for Lewis acid-base interactions (polar).
To determine the surface free energy components of a solid, contact angles of three different liquids (for which apolar and polar components are known) need to be measured. However, when the solid material is in a particulate form an alternative technique "Thin-Layer Wicking" has to be used [1]. In the present study the two methods were compared by determining the free energy of interaction between nitrifying bacteria and supporting materials (basalt and limestone) when immersed in liquid medium (Table 1).

Although the absolute values of ΔG^{IF}_{132} obtained by both techniques were different, the tendency observed was the same. From the data presented in Table 1 it is clear that although adhesion is not thermodynamically favourable ($\Delta G^{IF}_{132} > 0$), adhesion of both bacteria to limestone would be more auspicious than adhesion to basalt.

Table 1 Interfacial free energy of adhesion (ΔG^{IF}_{132}) between nitrifying bacteria (1) and support materials (2), immersed in water (3), in mJ/m^2, at 20 ºC

Interaction	Contact angle			Thin-layer wicking		
	ΔG^{LW}	ΔG^{AB}	ΔG^{IF}	ΔG^{LW}	ΔG^{AB}	ΔG^{IF}
Nitrosomonas/W/L	-0.93	17.67	16.73	-1.20	9.39	8.19
Nitrosomonas/W/B	-0.61	27.21	26.60	-1.20	12.94	11.75
Nitrobacter/W/L	-0.93	24.22	23.29	-1.37	14.13	12.76
Nitrobacter/W/B	-0.61	36.73	36.12	-1.36	19.43	18.07

The higher hydrophobicity of limestone and the establishment of Ca^{2+} bridging can be possible explanations for this fact. The differences observed on the absolute values can be related to the porosity of the material plates in the thin-layer wicking method. Although the plates are prepared with very small particles and a high concentration of solids, there are some pores remaining among the particles, which are responsible for an increase in liquid spreading. Furthermore, limestone and basalt used in this technique were submitted to a previous dehydration by heating and the same procedure was not followed in contact angle measurements, which imply a different degree of surface hydration.

[1] van Oss, C.J., Biofouling, 4, 25-35, 1991.