E. coli deposition and transport in porous media: Influence of solution chemistry and bacterial surface polymers

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Recent research has demonstrated the role of bacterial surface polymers on the transport and retention of the bacteria in porous media. In this study, the influence of both bacterial surface polymer presence and solution chemistry on the bacterial deposition kinetics has been investigated. Two *Escherichia coli* strains – D21g and XL1-Blue – a mutant strain and wild-type respectively, have been used. Adhesion of these cells in the presence of potassium chloride (KCl) was studied. Additionally the adhesion kinetics of the D21g strain was evaluated in the presence of calcium chloride ($CaCl_2$) to study the impact of electrolyte valence in cell transport.

The influence of solution chemistry on the cell deposition of two *E. coli* strains has been investigated in well-controlled packed-bed column experiments. The cells were also characterized under a range of solution chemistry conditions for the viability, size, electrophoretic mobility, hydrophobicity, surface charge density, and extracellular polymeric substances (EPS) content and composition.

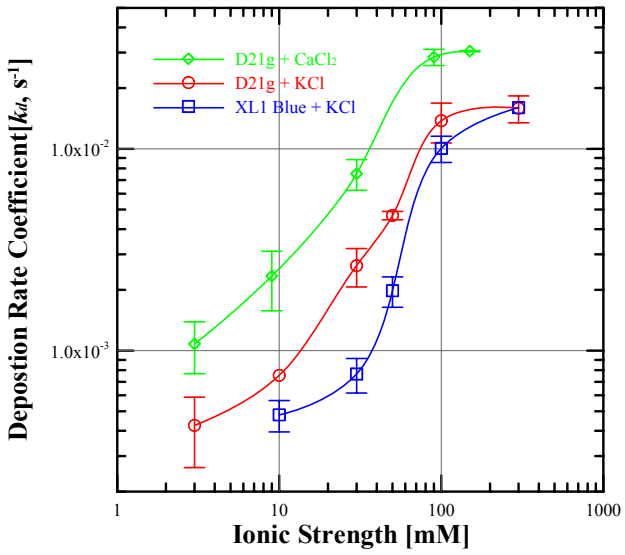

Figure 1. Deposition rate coefficient, k_d, of *E. coli* D21g and *E. coli* XL1-Blue in the packed-bed column as a function of ionic strength (KCl and $CaCl_2$). pH was unadjusted (5.6-5.8) and temperature was 25ºC.

Figure 1 shows the deposition rate coefficients as a function of ionic strength for two

cell strains at different electrolyte. Results show that the cell deposition rate and the amount of retention in the column increased with ionic strength (IS) for both *E. coli* strains, as predicted by traditional DLVO theory. The deposition rate of D21g was found to be greater than that of XL1-Blue, showing a trend which cannot be explained by cell hydrophobicity, size, or viability. However, the cell mobility corresponds with the deposition trends, as the more negatively charged XL1-Blue deposited the least suggesting that electrostatic interaction was the dominating mechanism. On the other hand, the hydrophobicity of XL1-Blue was greater than that of D21g, supported by evidence that the former cell type has the higher relative ratio of sugar to protein content in the EPS. The inconsistency between the hydrophobicity and the cell deposition rate may be explained by the fact that two *E. coli* strains were found to have relatively low and virtually negligible amount of EPS. Presumably, the distribution of the EPS may be such that these polymers may not fully cover the outer surface of the cell, and partially expose the lipopolysaccharides (LPS) and protein onto the outer membrane of the cell. Accordingly, the exposed outermembrane structures may contribute to the XL1-Blue having a higher electrophoretic mobility and hydrophobicity than D21g.

Additional experiments with D21g cells found the valence played an important role on the deposition kinetics, with the deposition rate in the presence of a divalent electrolyte ($CaCl_2$) being substantially greater than in a monovalent electrolyte (KCl). These results were also consistent with the measured mobility of the D21g cells in the two types of electrolyte solutions, with the more negatively charged cell in the KCl solution having a lower deposition rate than cells in $CaCl_2$. Based upon DLVO theory, once the electrostatic energy barrier is overcome the deposition rate should be same regardless of ion species under the same IS. However, our results show the retention and mobility of D21g cells in the presence of $CaCl_2$ were greater than those in the KCl solution over the entire region of IS. This may be attributed to the neutralization of cell surface charges in that calcium ion (Ca^{2+}) has the higher affinity with the cell surface functional groups than potassium ion (K^{+}).

Our results suggest that, for two *E. coli* strains used in this study, the dominant mechanism controlling the bacterial transport is the electrostatic interaction rather than the role of bacteria surface polymer due to the relatively small amount of EPS. In addition, the electrostatic interaction can be considered to be the main affecting factor for explaining the cell deposition trends at different electrolyte valence. Based upon this work, it is clear that future studies must account for both the electrolyte valence and the amount and composition of the EPS to fully analyze the mechanisms involved in the deposition of bacterial cells.

References

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