



Role of Surface Roughness on Reversible Primary Minimum Interactions: Implications for Colloid Attachment and Detachment

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An understanding of and ability to predict the fate and transport of colloids in porous media are of great importance in many environmental and industrial applications. In this study, the extended-DLVO theory accounting for nanoscale surface roughness was employed to calculate interaction energy parameters such as the magnitude of primary energy minimum ($\Phi_{(10 \text{ min})}$), the height of energy barrier against primary minimum attachment ($\Delta\Phi_a$), and the height of energy barrier against detachment from the primary minimum ($\Delta\Phi_d$). Packed-bed column and batch experiments were also conducted to examine effects of solution chemistry and flow velocity on the attachment and detachment processes of colloids. Theoretical analysis was employed to qualitatively explain the experimental observations of colloid attachment and detachment processes in porous media. It was demonstrated that the density and height of nanoscale roughness on the solid surfaces of porous media significantly influenced the interaction energy parameters and would subsequently affect the colloid attachment and detachment processes. Specifically, theoretical analysis indicated that the values of $\Delta\Phi_a$ and $\Delta\Phi_d$ notably decreased when nanoscale surface roughness was considered in the calculations. It was predicted that, under bulk unfavourable conditions at low to moderate solution IS, colloid attachment in the primary minimum may occur in some localised locations on the solid surface. However, nanoscale surface roughness yields a much weaker primary minimum interaction compared with that of smooth surfaces. The detachment of the colloids attached in the primary minimum was found to increase with decreasing IS and increasing pH due to the impact of nanoscale roughness of the solid surfaces on the values of $\Delta\Phi_a$. The results suggest that changes in chemical conditions caused the disappearance of the detachment energy barrier for only a fraction of the attached colloids in the primary minimum.