# *Abstract*:

An understanding of factors that influence interactions of microorganisms, nanoparticles, and other colloids with surfaces is needed for many industrial and environmental applications. Approaches were developed to predict the interaction energy of colloids on surfaces with different amounts of roughness and chemical heterogeneity (spatial variability in surface charge, Hamaker constant, or contact angle), and for hollow colloids. Results reveal that nanoscale roughness fraction and height controlled the interaction between a colloid and solid surface. Furthermore, the influence of roughness on colloid interactions was found to vary with the colloid size and the solution chemistry. Roughness provided a viable alternative explanation for anomalous colloid retention and aggregation behavior that has previously been attributed to steric repulsion in the literature. Hollow colloids were found to have weaker adhesive interactions than solid colloids. Calculated adhesive interaction were used in conjunction with energy and torque balances to determine conditions for enhanced or diminished colloid retention on natural and engineered surfaces with special relevance to water treatment and remediation.