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Enhanced immobilization of extracellular DNA in ferrihydrite–bacterial biomass conjugates: adsorption and spectroscopic mapping insights

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Extracellular DNA (exDNA) is a common component of environments such as soil or sediments. It plays a crucial role in the functioning of microorganisms by facilitating horizontal gene transfer and biofilm formation. The behavior and reactivity of exDNA in environmental settings may be governed by interactions with mineral phases and organic matter. For example, in organic-rich settings, exDNA may form complexes with other biomolecules and simultaneously react with mineral surfaces.

To investigate such a complex system, we examine the influence of bacterial lyase (BL) on exDNA adsorption onto ferrihydrite, a common soil mineral with a high specific surface area. BL is a complex mixture of biomolecules, including polysaccharides, proteins, and phospholipids. Each of these biomolecules may form complexes with exDNA or be adsorbed onto the ferrihydrite surface, thereby influencing exDNA adsorption mechanism. First, exDNA adsorption experiments onto ferrihydrite were conducted in the presence of varying BL concentrations. This was followed by zeta potential, Fourier Transform Infrared Spectroscopy (FTIR), and scattering-type Scanning Near-Field Optical Microscopy (s-SNOM) analysis.

Results indicate that exDNA adsorption capacity increases with increasing BL concentration across entire investigated concentration range. This is accompanied by the changes of zeta potential of the particles. After exDNA adsorption at low BL loading, the zeta potential of ferrihydrite particles decreases. However, with further BL increase, the zeta potential of particles in the system begins to increase. At low BL content in the system, exDNA and other biomolecules, e.g., polysaccharides, are co-adsorbed onto the ferrihydrite, lowering the zeta potential. With increased BL concentration, enhanced protein incorporation occurs at the ferrihydrite surface, increasing zeta potential. The co-adsorption of proteins, phospholipids, and polysaccharides on the ferrihydrite is indicated by FTIR results, as specific bands related to these biomolecules occur. However, spectroscopic mapping by s-SNOM highlights the key role of proteins, implying their co-occurrence with exDNA bands. These findings provide insights into the processes underlying exDNA adsorption onto mineral matrices, potentially influencing fate of genetic information in the environment.

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