Impact of lipopolysaccharide on flocculation of bacterial suspensions conditioning with polyethyleneimine polymers

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Bacterial sludge generated by wastewater treatment is commonly conditioned by adding either polymers of high molecular weight or ferric chloride. After the dewatering stage, more than 70% of water remains in the sludge. The physico-chemical processes underlying the interaction between the conditioner and the sludge remains poorly documented in literature. In this study, we investigate the destabilization mechanisms of bacterial dispersions against aggregation induced by the presence in the medium of cationic polyethyleneimine (PEI) polymer of various molecular weights. Additionally, the impact of the presence/absence of the lipopolysaccharide (LPS) surface structure at the periphery of the bacteria was analyzed.

For this purpose, Schewanella oneidensis MR1 was selected because of the varying length of the LPS polysaccharidic chain in response to growth temperature [1], which allows for examining the influence of the LPS chain on conditioning. Measurements of optical density, electrophoretic mobility, and aggregates size were carried out. Observations by TEM and AFM further rendered possible the evaluation of the bacterial surface status after contact with conditioning cationic polymer added at various concentrations.

Figure 1. a) Aggregation of the bacteria. b) Lysis of the bacterial membrane after contact with PEI.

For the bacteria with short LPS polysaccharidic chain and PEI of moderate molecular weight (10000-60000 Da), the cationic polymer is adsorbed at the bacterial membrane, which ultimately results in bacterial aggregation (Figure 1a). Upon significant increase of PEI concentration in medium (>3-4 mg l⁻¹), lysis of the bacterial membrane is inferred from both electrokinetics and AFM (Figure 1b). For larger molecular weights (750 000 Da, corresponding to realistic conditions in wastewater treatment), a severe lysis of bacterial membrane is observed, even at low PEI-concentration. For the bacteria with longer LPS polysaccharidic chain at the periphery and PEI of moderate molecular weight, polymer adsorbs at LPS surface structure. For increasing PEI concentration, this adsorption is accompanied by LPS deterioration that yields to bacterial aggregation due to steric destabilization. Additionally, PEI adsorption ultimately leads to inner membrane lysis and the latter takes place at lower PEI concentration with increasing PEI molecular weight.

Altogether, this study clearly highlights that despite the known function of LPS as protective barrier for membrane integrity, addition of PEI systematically conducts to deterioration of cell membrane. This induces a release of small size fragments of bacterial origin in the suspension, which likely affects the quality of sludge dewatering.