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Soil Air Water

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Research Article

Effect of the Organic Matter to Ammonia Ratio on Aerobic Granulation during 4-Chlorophenol Degradation in a Sequencing Batch Reactor

The influence of the chemical oxygen demand (COD)/N ratio on the performance of a granular sequencing batch reactor (SBR) system degrading 4-chlorophenol (4CP) was evaluated. Two SBR were operated under the same conditions, but with two different COD/N ratios, 150 and 20. It was observed that successful granule formation was obtained when activated sludge was initially acclimated to 4CP without using a co-substrate, and then hydrodynamic pressure selection was used to generate granules. Removal efficiencies of 4CP were >99.7%, and the specific degradation rates were up to 87 mg 4CP/(mg volatile suspended solid) per hour. It was found that nitrogen limitation had no effect on the removal efficiencies of 4CP and on the specific degradation rates. However, the results indicated that under nitrogen-limited conditions, higher granule sizes and a denser biomass were promoted.

Keywords: Aerobic granules; COD/N ratio; Extracellular polymeric substances; SBR; Wastewater treatment

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1 Introduction

Aerobic granulation has been investigated because of its advantages compared with classical flocculation for activated sludge processes. The advantages of granules compared to flocs include higher settling velocities, higher biomass retentions, stronger inter-microbial structures and higher resistances to inhibitory and toxic waste materials [1, 2]. The phenomenon of aerobic granulation is a mechanism whereby microorganisms form biofilms without carrier materials [3]. Microbial aggregation occurred by cell-to-cell attachment through cell surface receptors such as protein–saccharide or protein–protein interaction [3]. Liu and Tay [4] proposed that the granulation follows four steps: (1) Microbe-to-microbe contact to form aggregates by hydrodynamic, diffusion, gravity, and/or thermodynamic forces; (2) Initial attraction to form aggregates by physical, chemical, or biochemical forces; (3) Microbial forces to form aggregates by biological glue like cellular clustering and secretion of extracellular polymeric substances (EPS), and (4) Hydrodynamic shear force to stabilize the three-dimensional structure of the granule. Granulation has been observed to arise from the exposure of biomass to environmental stresses, including both physical stresses such as hydrodynamic shear [5, 6] and chemical stresses such as changes in nutrient concentrations and organic loads, the presence of toxic substances and the lack or limitation of some essential nutrients, such as nitrogen or phosphorus [7, 8].

Aerobic granulation has been observed in sequencing batch reactor (SBR) processes applied to treat municipal wastewaters and some industrial wastewaters containing inhibitory compounds [8–10]. The SBR technology employs five well-defined phases: fill, react, settle, draw, and idle. This operation mode can produce a selection pressure on biomass production and, the rapid fill and draw phases, accompanied by feast-famine periods favor the formation of aerobic granules [8].

Chlorinated phenolic compounds such as monochlorophenols can be found at high concentrations in petrochemical, pharmaceutical, and wood preservation effluents and wastewaters [10, 11]; therefore, 4-chlorophenol (4CP) has been used as a model compound for studying the acclimation of the microorganisms to degrade inhibitory compounds in SBR processes [12]. SBR processes are also an appropriate technology for obtaining aerobic granulation [13]. It has been demonstrated that the aggregation of microbial cells as granules increases the protection of a microbial community against high toxic compound concentrations [14]. For that reason, combining SBRs with granule formation is a promising technique for treating highly toxic industrial inhibitory wastewaters [15].

One of the parameters that can affect granule formation in wastewater is the nitrogen content, particularly the ammonia-nitrogen content. It was demonstrated that high cohesiveness of aggregates is induced under high C/N ratios [16]. Yang et al. [7] reported that aerobic granules cultivated with ethanol and a chemical oxygen demand (COD)/N-$NH4^+$ ratio (COD/N) of 20 (100:5) had four times the diameter of those cultivated with a COD/N ratio of 3.3 (diameter 0.5 mm). The stressful condition induced by nitrogen limitation promotes the increase of polysaccharide production [17], which is

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Abbreviations: **B-EPS**, bound EPS; **COD**, chemical oxygen demand; **4CP**, 4-chlorophenol; **EPS**, extracellular polymeric substance; **F-EPS**, free EPS; **PN**, protein; **PS**, polysaccharide; **SBR**, sequencing batch reactor; **Sv**, settling velocity; **SVI**, sludge volumetric index; **VSS**, volatile suspended solid

