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Anaerobic-aerobic granular system for high-strength wastewater treatment in lagoons

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Abstract. This study aimed at determining the treatability of high-strength wastewater (chemical oxygen demand, COD > 4000 mg/L) using combined anaerobic-aerobic granular sludge in lagoon systems. The lagoon systems were simulated in laboratory-scale aerated and non-aerated batch processes inoculated with dried granular microorganisms at a dose of 0.4 g/L. In the anaerobic batch, a removal efficiency of 25% was not attained until the 12th day. It took 14 days of aerobic operation to achieve sCOD removal efficiency of 94 % at COD:N:P of 100:4:1. The best removal efficiency of sCOD (96%) was achieved in the sequential anaerobic-aerobic batch of 12 days and 2 days, respectively at COD:N:P ratio of 200:4:1. Combined anaerobic-aerobic lagoon system can achieve efficient and cost effective treatment for high-strength wastewater in lagoon systems.

Keywords: biological wastewater treatment; dried granular microorganisms; high-strength wastewater; lagoon systems; sequential anaerobic-aerobic treatment

1. Introduction

Industrial wastewater, typically referred to as high-strength wastewater, is a major source of water pollution due to its elevated organic content. High-strength wastewaters are characterized by chemical oxygen demand (COD) concentrations greater than 4000 mg/L (Chan et al., 2009; Hamza et al., 2016). The effluents of these industries need to undergo pretreatment followed by biological treatment to remove the organic matter. However, conventional biological treatment processes fail to stabilize high-strength wastewater to regulatory limits. Aerobic treatment processes are not economically feasible for the treatment of high-strength wastewater. Anaerobic processes suffer from low bacterial growth rate, high sensitivity to toxic loadings, fluctuations in environmental conditions, and require post treatment to bring the water quality within regulations.

Lagoons have been widely used for wastewater treatment. Lagoons are large shallow basins enclosed by earth embankments in which wastewater is treated using entirely natural processes involving both algae and bacteria (Mara 2004). The activities of autotrophic, phototrophic, and heterotrophic microorganisms are employed to remove wastewater pollutants (Shpiner et al. 2009). Lagoons offer the advantages of being very simple to construct, having low capital, operational and maintenance (O&M) costs, and exhibiting good resistance to hydraulic and organic shock loads (Mara 2003; Mara 2004). The

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major disadvantage of the technology is the large land requirement. However, where space is not a constraint, lagoon systems remain attractive processes (Orupold et al. 2000).

Lagoon systems have been employed to treat high-strength wastewaters (Rakkoed et al. 1999; Rajbhandari and Annachhatre 2004; Arbeli et al. 2006; Shpiner et al. 2009). Anaerobic Lagoons followed by facultative lagoons are typically used to provide the required treatment (US EPA 2002). The pathways for pollutants removal in lagoon systems are sedimentation and biodegradation (Rajbhandari and Annachhatre 2004). However, the treatment efficiency for high-strength wastewater in lagoons is limited to only 60% (US EPA 2002).

The structure of microorganisms responsible for biodegradation plays an important role in the treatment process. Since lagoons employ naturally-occurring microorganisms, the removal efficiency is limited to that offered by flocculent sludge. To enhance the performances of biological treatment processes, a novel biotechnology - granulation - has emerged. Granules are aggregates of microorganisms that form through microbe-to-microbe self-immobilization in the absence of any biocarrier (Beun et al. 1999; Liu and Tay 2004). Granular sludge offers distinctive advantages such as dense and strong microbial structure, high biomass retention time, tolerance to toxicity and resistance to shock loading when compared to suspended cultures (Ergüder and Demirer 2005; Adav et al. 2008; Maszenan et al. 2011). These granules are dense microbial communities containing millions of organisms per gram of biomass (Tay et al. 2009), which individually are not capable of completely degrading wastewaters, but complex interactions among the resident species can achieve rapid treatment of wastewater (Liu and Tay 2002; Liu and Tay 2004).

However, the cultivation of granules is carried out in an upflow reactor that requires controlled loading and operational strategy; and it is influenced by a variety of factors such as reactor start-up, seed sludge, substrate composition, organic loading rate, feeding strategy, reactor design and hydrodynamics, settling time, exchange ratio and aeration intensity (Tay et al. 2001; Liu and Tay 2004; Adav et al. 2008; Show et al. 2012a). These conditions do not apply to lagoons. Dried granules can provide a practical solution for commercial and industrial applications due to the convenient storage and handling, in addition to making the process entirely passive.

The present work investigated the application of dried granules (proprietary engineered granular microorganisms - EGMs) in treating high-strength wastewater in lagoon systems under aerobic and sequential anaerobic-aerobic conditions. It has been hypothesized that the effluent of anaerobic treatment contains solubilized organic matter suitable for subsequent aerobic treatment because of its reduced organic strength and enhanced amounts of nitrogen and phosphorus (Chan et al. 2009; Chan et al. 2012).

2. Materials and methods

2.1 Experimental design and operation

5 L jars were used as batch reactors to depict the lagoon system in aerobic, anaerobic and sequential anaerobic-aerobic operations. Mechanical mixers were employed to provide gentle mixing of the wastewater. Air was supplied into the aerated batch through fine-pore ceramic diffusers. The jars were covered to minimize losses by evaporation. A schematic diagram of the aerobic and the anaerobic system is shown in Fig.1. Dry EGMs, provided by Acti-Zyme (Hycura) (Fig.2), were applied at doses of 0.2 and 0.4 g/L. Acti-Zyme EGMs are bio-augmentation products that include over six billion microbes and enzyme per gram. Energy Dispersive Spectroscopy (EDS) analysis showed that EGMs are composed of 60-65% (wt) carbon, traces of sodium, silica, calcium, magnesium, aluminium, potassium and iron oxides. The experiment was conducted at room temperature (21 ±2°C). The reactors were operated without pH control.

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