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Reduction of sludge generation by the addition of support material in a cyclic activated sludge system for municipal wastewater treatment

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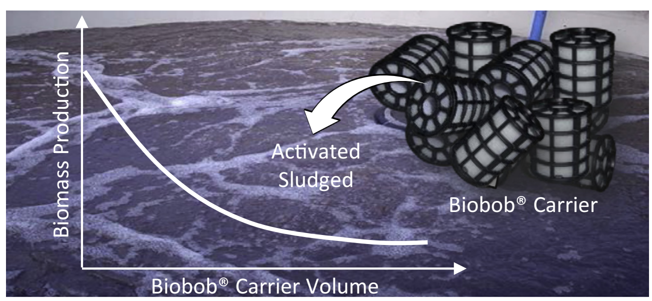
HIGHLIGHTS

- The addition of Biobob® carrier decreases the MLVSS concentration.
- The addition of Biobob® carrier decreases the waste sludge production.
- The Yobs reduces 36% with support material volume ratio of 18%.
- The addition of Biobob® did not affect system performance for COD and TSS removal.
- The nitrification was improved by 24% with 18% (v/v) carrier.

GRAPHICAL ABSTRACT



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ABSTRACT

An innovative biomass carrier (Biobob®) was tested for municipal wastewater treatment in an activated sludge system to evaluate the pollutant removal performance and the sludge generation for different carrier volumes. The experiment was carried out in a pilot-scale cyclic activated sludge system (CASS®) built with three cylindrical tanks in a series: an anoxic selector (2.1 m^3), an aerobic selector (2.5 m^3) and the main aerobic reactor (25.1 m^3). The results showed that by adding the Biobob® carrier decreased the MLVSS concentration, which consequently reduced the waste sludge production of the system. Having 7% and 18% (v/v) support material in the aerobic reactor, the observed biomass yield decreased 18% and 36%, respectively, relative to the reactor operated with suspended biomass. The addition of media did not affect the system's performance for COD and TSS removal. However, TKN and TN removal were improved by 24% and 14%, respectively, using 18% (v/v) carrier.

1. Introduction

To remove organic matter and nutrients (nitrogen and phosphorus), many municipal wastewater treatment stations have been designed as sequencing batch reactors (SBR) with a cycle format (Cycle Activated Sludge System – CASS) in the last two decades. The combination of aerobic and anoxic conditions enables nitrification and denitrification in a single reactor, creating advantages such as lower energy demand, smaller reactor volume and better control of sludge bulking (Callado and Foresti, 2001; Lim et al., 2011; Valdivia et al., 2007). However, most of the municipal wastewater treatment plants in operation have faced difficulties with sustainability, mainly because of the high costs of treatment (the demand for energy and chemicals for the dewatering process) and disposal (to a landfill or agricultural field) of the biological sludge generated.

Several studies have been developed in order to decrease the sludge amount after its generation, improving the digestion and dewatering processes. The feasibility of waste activated sludge reducing and resourcing by 2-step alkaline fermentation was investigated by Gao et al. (2011). The system was operated at room

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temperature (23–35 °C) and with total hydraulic retention time of 3.1 d. The result showed that 42.1% of waste sludge was reduced and 19.7% was acidified into volatile fat acids (the liquor can be used as carbon source for heterotrophic denitrification). Zhu et al. (2012) evaluated the usage of forward osmosis to the simultaneous thickening, digestion and dewatering of waste activated sludge. After 19 days of operation, the total reduction efficiency of MLSS was 63.7%, increasing the MLSS concentration from 7 g L^{-1} to 39 g L^{-1} in the system.

The digestion and dewatering processes for biological sludge treatment have been extensively studied in the last years. However, less attention has been paid to the development of processes to decrease the sludge generation. The biomass production is influenced by the structures of microbial communities in wastewater treatment systems, which are affected by influent wastewater characteristics and treatment process (Hu et al., 2012).

One way to decrease the biomass production is to increase the biomass concentration in the reactors and to apply the same volumetric organic loading rate (VOLR) and hydraulic retention time (HRT), causing the substrate to be the limiting factor in the metabolism of the microorganisms (Metcalf and Eddy Inc, 2003). This result can be achieved by increasing the sludge retention time (SRT) in the reactors, thus decreasing the food-microorganism ratio (F/M) and increasing endogenous metabolism. However, in a suspended growth biomass process, this approach is limited by the solid separation system capacity (the capacity of the clarifiers, flotators, membrane filters, etc.) because of the high concentration of mixed liquor suspended solids in the reactors (MLSS). Alternatively, biomass production can be decreased by adding biomass carrier to the reactors, provided that part of the biomass grows attached to an inert support, which promotes increased biomass concentration and SRT.

The sequencing batch biofilm reactor (SBBR), which incorporates both suspended-growth and attached-growth processes, has been studied as a promising technology for improving SBR systems. This reactor type has the following advantages (Guo et al., 2010):

(i) simple implementation; there is no need for major changes to the current reactor facilities;
(ii) no dead zones; the total liquid volume of the reactors is used;
(iii) low headloss; there is no clogging of the bed, and the backwash is not needed;
(iv) flexible operation; the treatment capacity can be gradually increased by biomass carrier addition.

The type of support material used for biofilm reactors influences their biomass adhesion and their hydrodynamics, thus affecting overall system performance. Many types of support material have been studied in the last decade, including polyurethane foam (Araujo Junior and Zaiat, 2009; Guo et al., 2010; Lim et al., 2011), plastic rings (Tawfik et al., 2010; Aygun et al., 2008), plastic plates (Rahimi et al., 2011) and ceramic rocks (Oliveira Netto and Zaiat, 2012).

Rahimi et al. (2011) compared the biomass generation in an SBR and an FBSBR (fixed biofilm sequencing batch reactor) with polypropylene plates used as a biomass support and tested these reactors for the treatment of synthetic wastewater. The observed biomass production yield (Y_{obs}) for the FBSBR was approximately 20% lower than that estimated for the SBR. For VOLR values from 0.5 to 2.5 kg COD m^{-3} d^{-1}, the Y_{obs} ranged from 0.43 to 0.28 g SS g^{-1} COD in the FBSBR and from 0.56 to 0.35 g SS g^{-1} COD in the SBR.

Biofilm reactors employing polyurethane (PU) foam as a biomass support have been shown to perform well and to simultaneously remove organic matter and nutrients (Guo et al., 2010). PU foam makes an excellent attached-growth material because of its high surficial area for biomass adhesion (approximately 5000 m^2 m^{-3}; Lim et al., 2011) and its macroporous structure, promoting a gradient of dissolved oxygen and creating aerobic and anoxic zones inside of biofilm. This condition increases nitrogen removal via a simultaneous nitrification-denitrification process (Lim et al., 2011; Guo et al., 2010). A previous study (Deguchi and Kashiwaya, 1994) reported that the nitrification and denitrification rate coefficients were 1.5 and 1.6 times higher, respectively, for a reactor containing PU foam as a carrier than for a conventional activated sludge reactor.

Valdivia et al. (2007) studied three different SBBR setups for municipal wastewater treatment, each using one of the following commercial materials as a biomass carrier: Kaldness® (q12 mm polyethylene rings), Liapor® (ceramic spheres with a diameter between 4 and 6 mm) or Linpor® (polyurethane cubes 15 mm on each side). The reactors were operated using 8-h cycles (0.5 h fill, 2 h anaerobic conditions, 5 h aerobic conditions and 0.5 h draw), and the best results were achieved using the reactor packed with Linpor®, which provided good nitrification performance and total nitrogen removal with both low and high organic loads.

The influence of PU cube size on SBBR performance was studied by Lim et al. (2011). Four SBBRs were operated with a cycle time of 24 h (0 h fill, 10 h aerobic conditions, 2 h anoxic conditions, 1.5 h settle, 1 h draw and 9.5 h idle). Each reactor received 8% (v/v) PU foam cubes, with a unit volume of 125 mL, 64 mL, 27 mL and 8 mL, keeping the same total surficial area. The total nitrogen removal increased as the size of the PU foam cubes decreased, with respective average values of 14.6 ± 0.6%, 19.1 ± 0.3%, 23.6 ± 0.5%, 30.8 ± 0.2% and 37.3 ± 1.1%. This finding can be attributed to the increasing amount of attached-growth biomass obtained as the cubes became smaller.

Despite the advantages of PU foam as a support for biomass attachment, its high compressibility and low mechanical resistance have limited its application in full-scale plants. To overcome these problems, an innovative support material, Biobob®, has been developed. Biobob® is a matrix of polyurethane foam surrounded by an external frame of polypropylene. In this paper, the experiments involving a pilot-scale sequencing batch biofilm reactor (SBBR) for municipal wastewater treatment using this new material as a biomass carrier is reported. The roles of the support material in the removal of organic matter and nutrients and in biomass generation were evaluated for different percentages of carrier in the reactor, and experiments were performed with and without the support material for comparison.

2. Methods

2.1. Pilot plant

The pilot plant was built by connecting three polypropylene cylindrical tanks in a series: an anoxic selector, an aerobic selector and the main aerobic reactor. These tanks had liquid volumes of 2.1 m^3, 2.5 m^3 and 25.1 m^3, respectively. The air for the aerobic selector and aerobic reactor was supplied by a blower and a fine-bubble tubular diffuser system. The operational sequence (fill, reaction, settling and draw) was controlled by an automated on-off system. Fig. 1 presents a basic flowchart of the pilot plant, including characteristics of the equipment and tanks.

2.2. Support material for biomass attachment

A commercial media called Biobob®, made in Brazil by Bio Proj Tecnologia Ambiental Ltda. was used for biomass support. Biobob®