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Effect of carriers on the performance of anaerobic sequencing batch biofilm reactor treating synthetic municipal wastewater

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A B S T R A C T

In this study, effects of granular activated carbon (GAC) and natural zeolite as attached carriers for microbes on anaerobic treatment of synthetic municipal wastewater were evaluated in laboratory scale anaerobic sequencing batch biofilm reactors (ASBBRs). An anaerobic sequencing batch reactor (ASBR) and three ASBBRs, individually named ASBR-1 without any carrier (control), ASBBR-2 with GAC, ASBBR-3 with zeolite, ASBBR-4 with both GAC and zeolite, were operated at 2.5 d HRT with non-fat dry milk to mimic municipal wastewater. The four reactors were successfully started up and attained steady state within two weeks of operation. Total COD and soluble COD removal efficiencies of more than 93% and 98%, respectively, were observed in the four reactors during steady-state. The average biogas productions for ASBR-1, ASBBR-2, ASBBR-3 and ASBBR-4 were 229, 246, 238 and 278 ml/d, respectively. Addition of carriers improved both the COD removal efficiency and biogas production. Apparently GAC improved COD removal efficiency and zeolite improved gas production. SEM results suggested higher number of biomass attached to GAC than zeolite.

1. Introduction

Recently anaerobic treatment of wastewater gains significant attention over aerobic treatment due to its advantages like less energy consumption (no aeration), low sludge production and possibility of energy recovery in the form of methane. Anaerobic sequencing batch reactors (ASBRs) have been considered a potential system for treatment of several types of wastewater. ASBRs containing granular biomass have been widely studied for wastewater treatment as they have advantages over continuous processes, including better solids retention, efficient operating control and absence of primary or secondary settling (Sung and Dague, 1995; Rodrigues et al., 2003; Sarti et al., 2007a,b). Like the aerobic sequencing batch reactor (SBR), the ASBR involves repetition of a cycle including five discrete steps: feed, react, settle, draw and idle. In reaction step the reactor is agitated and in third step agitation is stopped to permit the biomass sedimentation, preventing the loss of biomass with the effluent in decant step (Sarti et al., 2007a). Therefore retention of biomass in the reactor depends on sedimentation step, which in turn depends on the granulation property of the sludge. Several studies showed that ASBR could successfully treat low strength wastewater even at low temperature (Brito et al., 1997; Rodrigues et al., 2003). However the granulation is uncertain depending on the sludge characteristics. In such cases addition of carriers helps complete retention of biomass. These carriers provide solid support for the microorganisms and thereby facilitate the sedimentation process. The use of small, porous, carriers enables the reactor to retain high biomass concentrations and thereby to operate at significantly reduced hydraulic retention times (HRTs) (Montalvo et al., 2012). Retention of high biomass concentration within the reactor increases the process stability and resistance to shock loads. These systems are reported to be well suited for the treatment of wastewater containing poorly degradable compounds (Venkata Mohan et al., 2007). The attached form of microbial growth as in biofilm/fixed film systems were effective, robust and could survive in extreme environments compared to the non-attached growth (suspended growth) (Bishop, 1997). On the whole, biofilm configured systems exhibit higher substrate removal rates, greater system stability, simple to operate, could handle the shock loads, require less power, produce less sludge and the overall efficiency clearly exceeded the conventional methods of wastewater degradation (Venkata Mohan et al., 2007). Several materials have been studied till date as a

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carrier in anaerobic sequencing batch biofilm reactor (ASBBR) (Ratusznei et al., 2003; Pinho et al., 2005; Sarti et al., 2007b).

The porous and non-uniform structure of granular activated carbon (GAC) makes it suitable for using as carrier medium for anchorage of microbial cells in reactors treating wastewater. The adsorption property of GAC provides a temporary storage place for some contaminants that are in excess of the bacterial capacity to transform. The contaminant then desorbs when concentration decreases in the reactor, maintaining the feed concentration same to the bacteria. Previous study showed that GAC could retain 3.75–10 times higher biomass than other media (sepiolite, pumice, sand and anthracite) and also accumulate biomass at a faster rate during start-up (Saravanane and Murthy, 2000). GAC has been widely used as fluidized medium in anaerobic fluidized bed reactor (Kim et al., 2011; Shin et al., 2011, 2012; Yoo et al., 2012; Dutta et al., in press). However, to the best of our knowledge no reports are available on use of GAC in ASBBR.

Natural zeolite is one of the most attractive materials for wastewater treatment due to its excellent ion-exchange, adsorption property and serving as molecule sieves. Zeolite can selectively remove ammonia and other heavy metals that are toxic for microorganisms involved in anaerobic treatment. In addition, zeolite has also been proved as a good support for both aerobic and anaerobic microorganisms (Fernandez et al., 2007). Several studies have been carried out with the zeolite as support material in anaerobic fluidized reactor. The proper doses of zeolite was found to reduce the concentrations of ammonia and ammonium ion that were present in raw piggery wastewater and those produced during anaerobic degradation of proteins, amino acids and urea, thus facilitate the anaerobic digestion of piggery wastewater (Milán et al., 2003). Natural zeolite had also been used for treatment of low strength municipal wastewater in both lab-scale (2 L) and pilot scale (1000 L) ASBBR (Ratusznei et al., 2000; Sarti et al., 2006, 2007a,b).

In the present study, the effect of addition of zeolite and GAC individually and combined was evaluated for treatment of synthetic municipal wastewater in ASBBR on COD removal efficiency and gas production.

2. Materials and methods

2.1. Anaerobic sludge

The anaerobic sludge used in this study was collected from municipal wastewater treatment plant in Linkao, Taiwan. One hundred milliliter anaerobic sludge was sieved to remove big particles then washed with buffer solution (0.14 g/L KH_2PO_4 and 0.75 g/L K_2HPO_4) before inoculating. MLSS and MLVSS of the sludge were in between 2600 and 3000 mg/L and 2000–2500 mg/L, respectively. The food to microbe ration was in the range of 0.4–0.5 for all four reactors. After inoculation, the ASBBR was sparged with argon gas to maintain anaerobic condition.

2.2. Carrier used

In this study natural zeolite and GAC were employed as carrier materials to support the anaerobic biomass. The natural zeolite used in this study was of 10 to 30 mesh size with the porosity of 0.2 to 1, hardness of 3 and density of 2.1 g/cm^3 approximately. The chemical composition (%, w/w) of the zeolite used were H_2O 4.98%; P_2O_5: 0.03%; K_2O: 1.99%; CaO: 2.49%; MgO: 0.24%; SiO_2: 66.1%; Fe_2O_3: 2.57%; Al_2O_3: 11.91%; NaO: 1.72%. The GAC used in this study was of 10–30 mesh size with specific surface area, bulk density and specific gravity of 500–1000 m^2/g, 0.85 g/cm^3 and 2 g/cm^3, respectively.

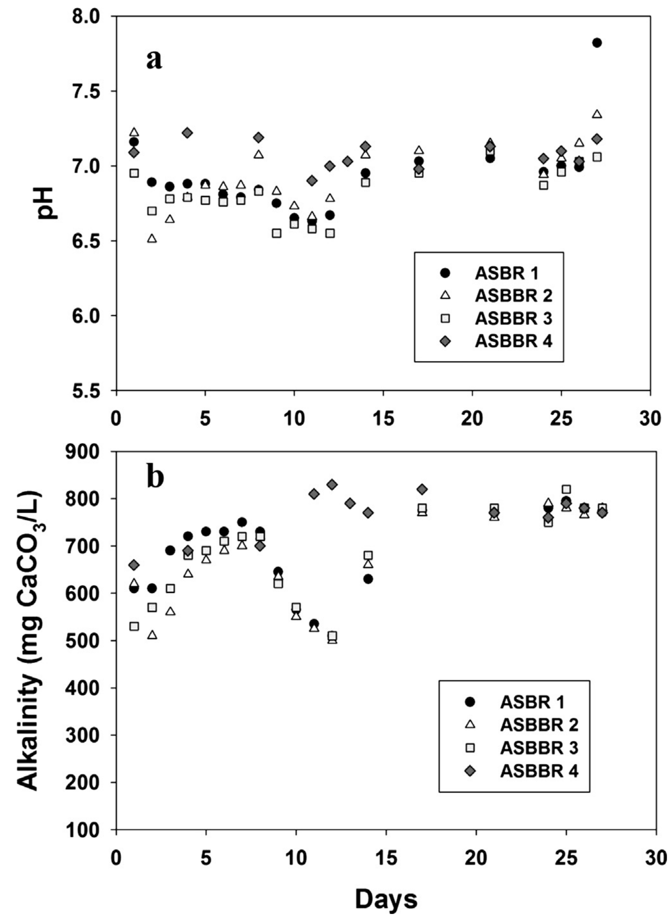

Fig. 1. Profiles of (a) pH and (b) alkalinity in ASBR and ASBBRs.

2.3. Set up and operation of anaerobic sequencing batch bioreactor (ASBBR)

The bench-scale reactors with 1 L of working volume were used in this study. Total four reactors were set up, individually named ASBR-1 without any carrier (control), ASBBR-2 with GAC, ASBBR-3 with zeolite, ASBBR-4 with both GAC and zeolite. Each reactor contained 100 ml of sludge and 100 ml of carriers (except ASBR-1). Reactors were operated at 35 °C and 2.5 d HRT with 24 h cycle at organic loading rate (OLR) of 400 g/m^3 d with influent COD concentration of 1000 mg/L. Each cycle consisted of 0.2 h for feeding, 23 h for reaction, 0.5 h for settling and 0.25 h for decanting time. Mixing was provided by shaker at 140 rpm.

2.4. Wastewater

A synthetic wastewater having a chemical oxygen demand (COD) concentration of approximately 1000 mg/L was prepared with non-fat dry milk (830 mg/L), sodium acetate (600 mg/L), yeast extract (40 mg/L), KH_2PO_4 (44 mg/L), $KHCO_3$ (600 mg/L) and NH_4Cl (191 mg/L). The initial pH was in between 7.3 and 7.5.

2.5. Analytical procedures

Organic matter concentration (measured as COD) for both filtered and non-filtered samples, bicarbonate alkalinity concentration were measured according to procedures given in Standard Methods (APHA, 1998). pH of the effluent sample was measured by