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pH regulation of alkaline wastewater with carbon dioxide: A case study of treatment of brewery wastewater in UASB reactor coupled with absorber

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Abstract

Studies were carried out with carbon dioxide absorber (CA) to evaluate the usage of carbon dioxide (CO_2) in the biogas as an acidifying agent by Up-flow Anaerobic Sludge Blanket (UASB) reactor. Investigation on the 5 l absorber revealed that ratio of brewery wastewater (BW) flow rate to biogas flow rate of 4.6–5.2 was optimum for minimum consumption of CO_2 for acidification. The acidified BW after the absorber was treated in UASB reactor with optimum organic loading rate (OLR) of 23.1 kg COD/m^3/day and hydraulic retention time (HRT) of 2 h. UASB reactor exhibited good performance with respect to reduction of chemical oxygen demand (COD) and methane yield. The implications of the present study on the full scale anaerobic reactor of medium scale brewery revealed that sufficient cost savings could be made if CO_2 in the biogas or CO_2 that was being wasted (let out to the atmosphere) can be used instead of sulfuric acid (H_2SO_4) for pH control.

Keywords: Acidifying agent; Carbon dioxide; Brewery wastewater; Biogas; HRT; OLR; UASB; Absorber

1. Introduction

The brewing process employs a number of batch-type operations in processing raw materials to the final beer product and produces large quantities of wastewater, typically 3–12 l of wastewater for every litre of beer produced (Luc Fillaudeau et al., 2006). The quality of brewery effluent depends on various processes that take place within the brewery (Driessen and Vereijken, 2003). In general, brewery effluents are easily biodegradable (BOD/COD ratio is in the range of 0.6–0.7) and amenable for anaerobic treatment (Leal et al., 1998; Parawira et al., 2005; Driessen and Vereijken, 2003; Hanqing Yul and Guowei Gu, 1996; Etheridge and Leroff, 1994). Anaerobic treatment is applied successfully for the treatment of brewery effluent in laboratory, pilot and full scale with a variety of reactor configurations (Parawira et al., 2005; Speece et al., 2001; Hanqing Yul and Guowei Gu, 1996; Etheridge and Leroff, 1994). The pH of brewery effluent varies in the wide range of 4.5–12 (Karl Ockert, 2002; Charles, 2001). The wastewater obtained from brewing operation is acidic whereas the wastewater obtained from caustic operation is alkaline (Briggs et al., 2004; Karl Ockert, 2002). Most of the breweries provide buffer tank (pH Equalization tank) before the anaerobic reactor so that wastewater generated in different operations of the brewery can be made to uniform pH. Even after mixing, pH of the combined wastewater in the buffer is alkaline since two thirds of the wastewater from the brewery is alkaline (Luc Fillaudeau et al., 2006). Therefore, acids (sulfuric acid or hydrochloric acid) are used to maintain the pH in the range of 7–7.5 for feeding to the anaerobic reactor (Cronin and Lo, 1998). The addition of acids led to the

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formation of sulfide and added to the cost of the effluent treatment operation. The reactor performance deteriorates, if the sulfide concentration is in the range of 200–250 mg/l (Gangagni Rao et al., 2003; Sawyer and McCarty, 2000) due to the inhibition of the mixed cultures of anaerobic microbial consortia. Carbon dioxide (CO_2) is abundantly produced in breweries during fermentation and it is used in the final stage of beer production for flavour and excess is vented to the atmosphere (David Willison, 2006). If this can be utilized in the buffer tank to reduce the pH of wastewater prior to the anaerobic reactor, the cost of the acids and negative affects of sulfide can be avoided. Alternatively, if the brewery is having anaerobic effluent treatment plant (ETP), biogas generated in the anaerobic reactor can also be used for pH reduction. In one study CO_2 (Lom, 1977) is used for neutralization of alkaline brewery wastewater. However, there are no reports in the literature regarding the usage of CO_2 as an acidifying agent in the buffer tank prior to the anaerobic step. Hence, in the present study, the pH of the brewery wastewater was regulated with CO_2 and anaerobic treatment of the same was studied in the UASB reactor.

2. Methods

2.1. Wastewater

The brewery wastewater (BW) was obtained (approximately 200–3001 per week) from United Breweries (UB), Hyderabad, India. The BW was collected from buffer tank in which pH was in the range of 9–12. The physicochemical characteristics of the BW were determined and shown in Table 1. All the chemicals used during the experiments were of A R grade.

2.2. Inoculum

Sludge obtained from an anaerobic lagoon was used as the inoculum for seeding the reactor. Volatile suspended solids (VSS) of the sludge were 27.66 kg/m^3 and the methanogenic activity was 0.21 kg CH_4-COD/kg VSS/day. The sludge was acclimatized with BW for three weeks under anaerobic conditions as a result of which, the VSS of the sludge increased to 33.63 kg/m^3 and the methanogenic activity rose to 0.26 kg CH_4-COD/kg VSS/day.

Table 1
Characteristics of brewery wastewater

Parameter[a]	Brewery wastewater
pH	3–12
Temperature	18–40 °C
COD	2000–6000
BOD	1200–3600
VFA	1000–2500
Phosphates as PO_4	10–50
TKN	25–80
TS	5100–8750
TSS	2901–3000
TDS	2020–5940

[a] All parameters except pH and temperature are in mg/l.

2.3. Analysis

The physicochemical characteristics of the wastewater were determined as per standard methods (APHA, 1998). The characteristics of the inlet and outlet viz., COD, pH, alkalinity and volatile fatty acids were determined daily during the reactor operation. The volume of the biogas produced and its composition were estimated using Orsat apparatus (APHA, 1998). The washout of the microbial cells in the reactor outlet was estimated following the procedure of Gangagni Rao and Bapat (2006).

2.4. Experimental set up

The experimental set up (Fig. 1) consisted of peristaltic pump, centrifugal pump, feed tank, absorber, buffer tank, UASB reactor and biogas holder. Absorber was made of

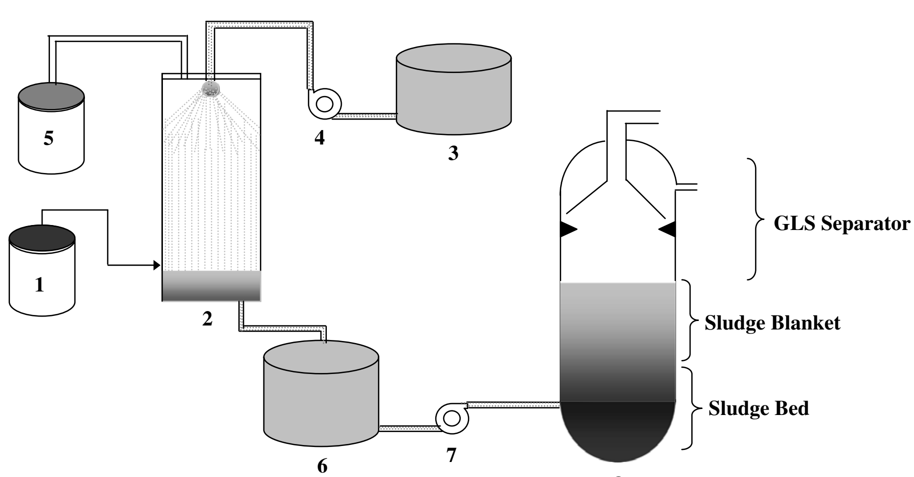

Fig. 1. Experimental set-up: (1) Biogas holder, (2) absorber, (3) feed tank, (4) centrifugal pump (5) methane gas holder (6) buffer tank, (7) peristaltic pump and (8) UASB reactor.