

Treatment of brewery wastewater by pilot scale upflow anaerobic sludge blanket reactor in mesophilic temperature

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In this study, treatment of brewery wastewater by pilot scale upflow anaerobic sludge blanket (UASB) reactor in mesophilic phase was investigated. UASB reactor was achieved with brewery wastewater to an organic loading rate (OLR) of 7 kg COD/m³-d at 12 m/d upflow velocity with a hydraulic retention time (HRT) of 3.5 day, and chemical oxygen demand (COD) removal efficiency of 95% with a methane yield of 0.30 m³ CH₄/kg COD_{removed}. At an OLR 0.20 kg COD/m³-d, sludge concentration was increased and reached even 70000 mg/l at the end of 6th month. At the end of experiment, a granular sludge with good settling properties was produced.

Keywords: Brewery wastewater, Methane yield, Performance, SVI, UASB reactor

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Introduction

Anaerobic digestion has been one of the oldest and most common methods for sludge management, due to its potential for stabilization of large volume of sludge at a low cost, low biomass production, high destruction rate of pathogens and generation of methane as an energy source¹. Anaerobic processes have become viable for the treatment of high-strength industrial wastewater. Modern anaerobic processes based on high rate reactors as the upflow anaerobic sludge reactor blanket reactor (UASB) or anaerobic filter (AF) have been successfully applied for treatment of industrial wastewaters². Studies are reported on treatment of various substrates examining a few operational conditions while assessing the benefits of high rate digestion over conventional digester³⁻⁵.

In the food industry, the brewing sector holds a strategic economic position with the annual world beer production exceeding 1.34 billion hectoliters in 2002⁶. Beer is the fifth most consumed beverage in the world behind tea, milk and coffee, and it continues to be popular drink consumption at 23 l/person-y⁷. In effective beer production plants, the polluting load of

wastewater can be taken as 5-6 kg BOD₅/m³-beer and ratio⁸ of BOD₅/COD is assumed to be 0.67. COD concentration of a wastewater⁹ that is to be efficiently treated in terms of anaerobic process should not fall below 2000-2500 mg/l. Therefore, high COD content of beer production industry wastewaters makes them especially suitable for processes based on anaerobic technology¹⁰.

In this study, treatment of brewery wastewater by pilot scale UASB in mesophilic temperature and start-up problems are investigated.

Materials and Methods

UASB Reactor

Hybrid reactor, made of plexiglas (active volume, 30 l), has internal diam of 14 cm, and height 200 cm (Fig. 1). Reactor is fed throughout screen equally distributed along its base, oriented to achieve a tangential feeding, in order to enhance homogenization. Upflow velocity (UV) in the reactor was controlled by effluent recirculation flow rate (2-4 times the influent flow rate) corresponding to 0.1-0.8 m/h of UV. The reactor was placed in a water bath at 35±1°C using temperature controller. Temperature was maintained at optimum values for the anaerobic bacteria within a range of 35±1°C. The pH value was controlled by automatic addition of 1 N NaOH and 1 N HCL.

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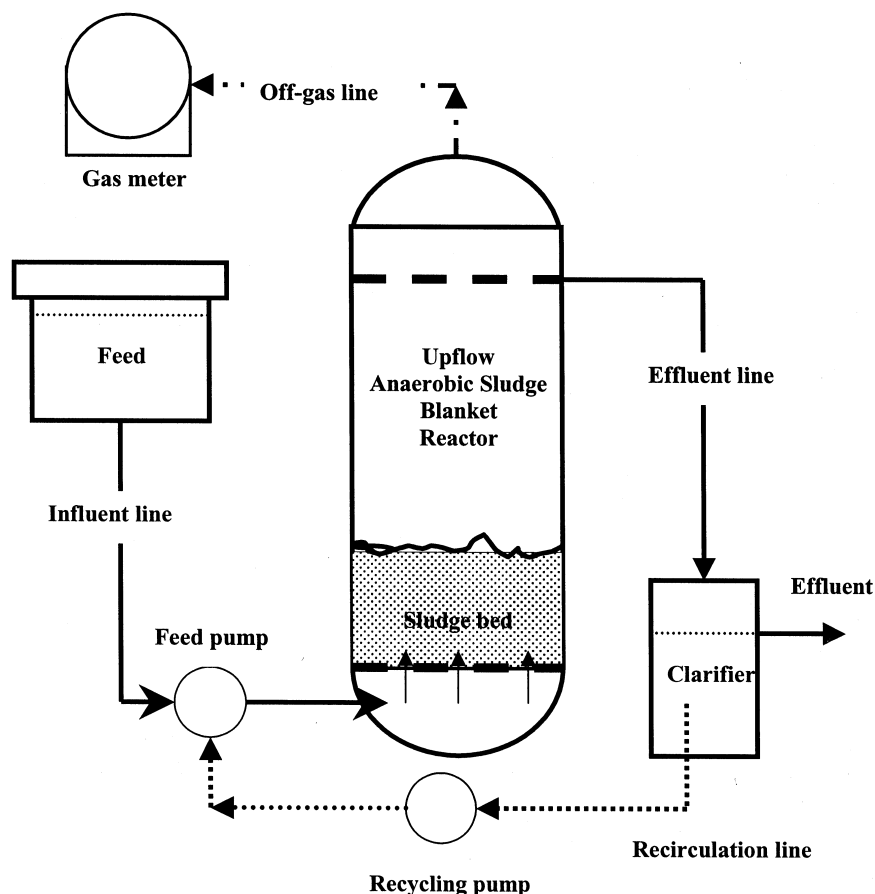


Fig. 1—Schematic configuration of UASB reactor (no legend)

Wastewater Characteristics

The wastewater, provided from a local beer production factory in Istanbul, contained: COD, 870-5065; BOD, 350-4200; $\text{NH}_3\text{-N}$, 1.12-5.0; TKN, 13-50; $\text{PO}_4\text{-P}$, 1.75-7.20; suspended solids, 190-970; oil and grease, 45-90; and alkalinity (as CaCO_3), 290-550 mg/l; pH 5-11.2.

Seed Sludge

UASB reactor was seeded with an inoculation sludge taken from an UASB reactor treating industry effluent. Due to granular characteristics of the sludge, filtration could not be accomplished. Therefore, total solids (TS) and total volatile solids (TVS) parameters are used. TVS/TS of seed sludge is approx 96 percent.

Analytical Methods

The parameters were measured on a regular, yet different frequency basis: (i) Biogas production, influent/effluent soluble and total COD, daily; and (ii) Effluent pH, alkalinity, volatile fatty acids (VFAs) and suspended solids (SS), twice weekly. COD, SS,

pH and alkalinity test were conducted in accordance with Standard Methods¹¹. Biogas production rate was measured by wet gas meter (Ritter TG05 drum type gas meter).

Reactor Operation

The pilot reactor, where the start up and granulation studies were carried out with UASB, was settled in brewery and reactor was fed with beer wastewaters. Experimental studies continued for 6 months to start up, inoculation sludge (8l) was taken from a UASB settled in a fermentation products plant. Since desired results could not be obtained with this inoculation sludge (biomass conc, 1350 mg/l), a new sludge (conc, 1900 mg/l), was taken from the UASB settled in a different reactor and added in the reactor. No other inoculations were used till the end of the experimental study.

Since the beer industry wastewaters are poor in nutrients, NH_4Cl and KH_2PO_4 are added to wastewater entering the reactor in order to provide the C/N/P ratio (300/5/1). Feeding solutions are prepared

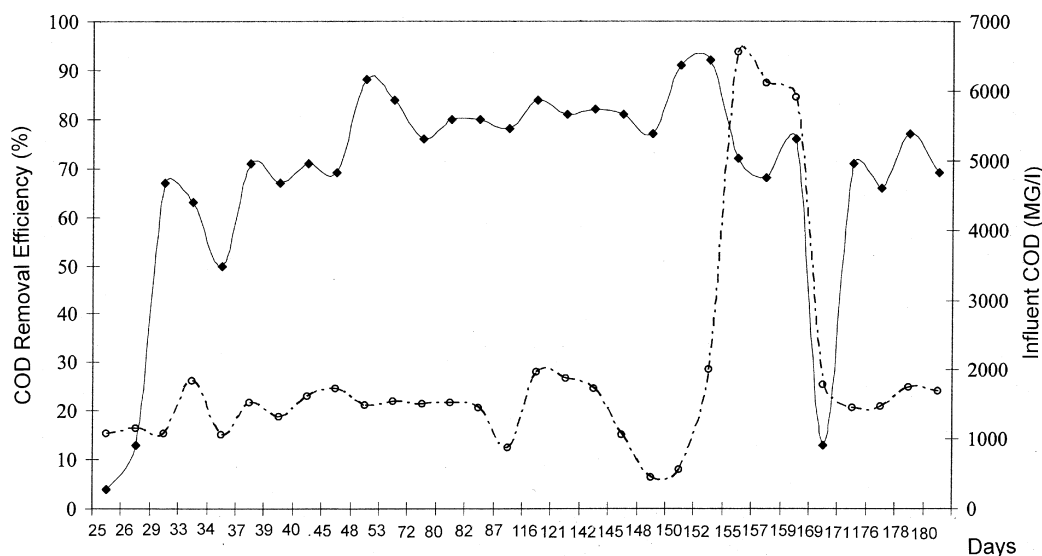


Fig. 2—COD removal efficiency (v) against influent COD (O) throughout the study

daily and diluted with municipal wastewater. Besides, system was fed with NaHCO_3 (conc, 3.3 g/l) to provide enough alkalinity in reactor kept at a given temperature (35-37°C) and pH (6.9-7.2).

Results and Discussion

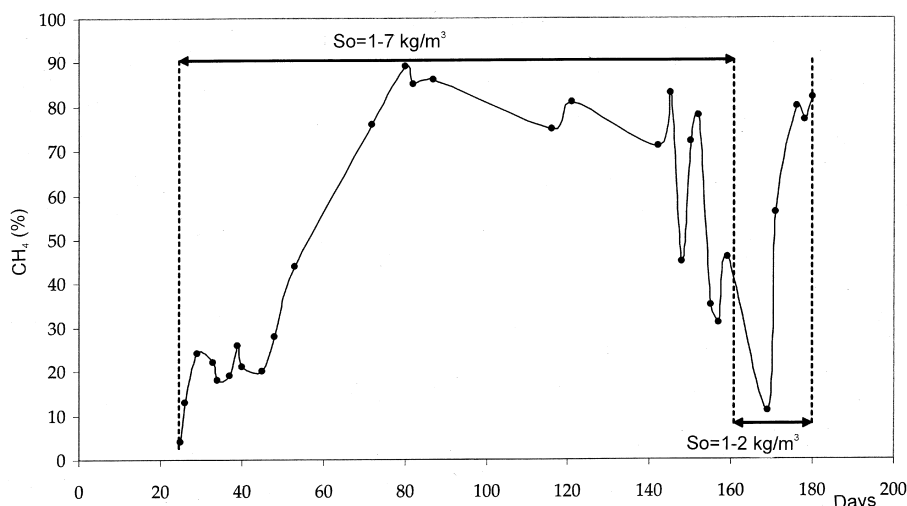
UASB reactor was fed with wastewater at an organic loading rate (OLR) of 0.3 kg COD/m³-d with a hydraulic retention time (HRT) of 1.3 days. Overall linear UV was determined 0.1 m/h (2.4 m/d). Influent COD concentration was kept 1000-2000 mg/l in the first 3 months. The hybrid reactor performed well at an OLR of 0.3 kg COD/m³-d, when maximum COD (91-92 %) removal efficiency was achieved after 152 days (Fig. 2).

OLR was increased progressively after the third month, reaching 7 kg COD/m³-d at the end of 6 months. While COD efficiency was 4 percent in the first 25 days, it increased with time (60% in the 30th day, 80% on 50th day, and 90% on 150th day). As long as the environmental conditions were controlled, COD removal efficiency was stabilized (80-90%). Meanwhile, failures (like failure of the circulation pump) during the experimental studies caused the efficiency to drop (13%), but efficiency was recovered (80%) within a week after failures eliminated.

Depending on the increase in OLR, HRT also changes. UASB reactor was initiated with HRT of 1.3 days, however since desired COD removal efficiency was obtained, depending on the reduced OLR, HRT was increased to 3.5 days. Later, OLR was progres-

sively increased and at the same time the HRT was decreased to 0.5 days (12 h). Methane yields changes throughout the study (Fig. 3). As OLR was increased, amount of the gas produced also increased. In addition, the formed gas provided the mixing of reactor content by suddenly elevating the sludge bed. The mixing was observed to be better in the sludge cover than in the sludge bed. Therefore, UV was increased from 0.1 m/h (2.4 m/d) to 0.5 m/h (12 m/d) to improve performance of the reactor.

This resulted in an increase in COD removal efficiency from 60 percent to 90-95 percent with a methane yield of 0.25-0.30 m³ CH₄ / kg COD_{removed}. Consequently, OLR was increased (7 kg COD/m³-d) and even in this situation, it was possible to obtain COD removal efficiency of 95 percent. Performances of the various reactors treating brewery wastewater have been investigated in many studies. Anderson *et al*¹², operated pilot-plant study on the anaerobic fluidized-bed reactor (AFBR) for treatment of brewery wastewater. They stated that higher COD removal efficiency (>75%) was observed at an OLR of 8.9 kg COD/m³-d. The OLR was increased (>14 kg COD/m³-d) and a COD to methane conversion of 87 percent was achieved, while Herrmann & Janke¹³ reported maximum COD removal efficiency (87 %) at relatively lower OLR, 9.3 kg COD/m³-d, with brewery wastewater as the primary substrate, cofermentation of two commonly found flavonoids (rutin and hesperidin) using two-stage anaerobic digester.

Fig. 3—Methane yields (λ) throughout the study

Second part of this study is effect of granulation on COD removal efficiency in UASB reactor. Sludge concentration in the reactor, which was 1900 mg/l at the start up conditions, was decreased to 500 mg/l at the end of 40th day; by addition of new inoculation sludge and reduction of OLR (0.20 kg COD /m³-d), sludge concentration has increased and reached even 70000 mg/l at the end of 6th month. At this point, sludge volume index (SVI) was measured as 11 mg/l. Although classic SVI changes depending on the biomass concentration, value of 11 mg/l is possible to be evaluated as perfect.

Conclusions

UASB reactor with brewery wastewater achieved an OLR of 7 kg COD/m³ per day at the 12 m/d upflow velocity with a HRT of 3.5 day, and the COD removal efficiency of 95 percent with a methane yield of 0.30 m³ CH₄/kg COD_{removed}. OLR could be increased progressively up to 10-15 kg COD /m³-d and at the same time HRT could be decreased to 0.5 days (12 h). As OLR was increased, amount of CH₄ produced also increased. At the end of the study, a granular sludge (70.000 mg/l) and SVI (11 mg/l) was produced.

Acknowledgement

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