Evaluation of process performance of UASB-DHS system treating high concentration industrial wastewater containing ethylene glycol

Nagaoka University of Technology ○(学)ChoolakaHewawasam, (学)Takahiro Watari, (学)Kyouhei Kuroda, (正)Akinobu Nakamura,(正)Masashi Hatamoto, (正)Takashi Yamaguchi
Kure National Collage of Technology (正)Daisuke Tanikawa
Tokai Rubber Industries LTD (非)NanakoFujii, (非)FuminoriYoneyama, (非)Osamu Wakisaka

1. Introduction

Upflow Anaerobic Sludge Bed (UASB) wastewater treatment systems represent a proven sustainable technology for a wide range of very different industrial effluents[1]. Highlights of UASB include high organic loading rates (OLR), lower operational costs, and energy recovery in the form of methane. Further to that UASB reactor is preferred especially in treating highly polluted industrial wastewaters owing to its high COD removal capacity [2]. Ethylene glycol is an organic compound primarily used as a raw material in the manufacturing industry. It is often used in the synthesis of raw materials such as polyethylene fiber and production of anti-freeze solutions.In addition to that several industrial wastewaters such as rubber product manufacturing contain high concentration of ethylene glycol. However a few studies on anaerobic treatment of wastewater containing ethylene glycol have been documented. But these have been on relatively low concentrations of glycol under low temperature conditions. Ethylene glycol has high biodegradability in aerobic and anaerobic conditions [3]. However, it is usually treated by conventional aerobic processes such as activated sludge system. Lately our research group has been developing a combination of anaerobic - aerobic system consisting of UASB and Down-flow Hanging Sponge (DHS) as a low-cost wastewater treatment system [4].As such in this study, a combination of UASB and DHS reactors was applied for treatment of industrial wastewater containing high concentrations of ethylene glycol.

2. Materials and Methods

2.1 Characteristics of Wastewater

In this study, industrial wastewater containing 8% ethylene glycol and 2% propylene glycol discharged from a rubber production unit was used. The influent of the reactor was prepared by diluting raw wastewater to the appropriate COD concentration using tap water. Its alkalinity was adjusted using 1.0 g-$NaHCO_3$/g-COD of sodium bicarbonate. The COD: N: P ratio was adjusted to 100:10:1 using ammonium chloride and dipotassium hydrogen phosphate. The wastewater was stored at 7˚C.

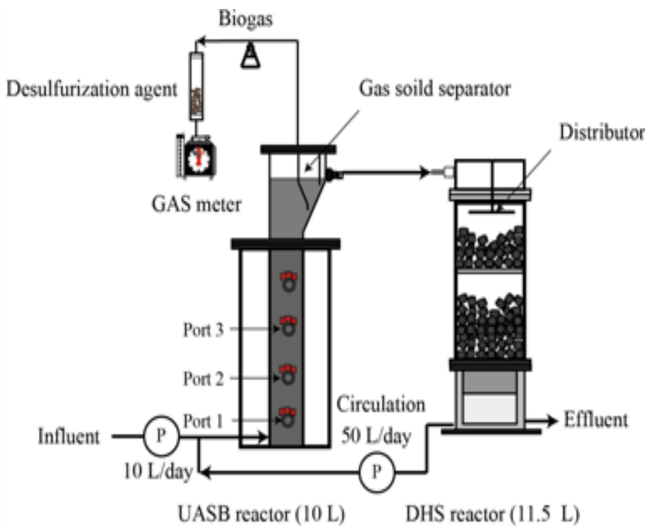

Fig. 1 System diagram of proposal system

2.2 System description and Operational conditions

Fig. 1 shows a schematic diagram of the proposed treatment system, which consisted of UASB and DHS reactors. The UASB reactor (height: 90 cm) was equipped with a gas solid separator. It had a working volume of 10 L. It was seeded with mesophilic granular sludge obtained from another UASB reactor treating wastewater from the food industry.
The DHS reactor was equipped with a distributor and had a

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連絡先〒940-2188 新潟県長岡市上富岡町 1603-1 TEL. 0258-47-1611 E-mail.ecoya@vos.nagaokaut.ac.jp

height of 80 cm. Each of Square sponge cubes (dimensions: 30 mm × 30 mm × 30 mm) were covered from a plastic net ring which was used as media. The reactor volume and working volume of the DHS reactor were 11 L and 5.7 L, respectively. The reactors were placed in a temperature-controlled (35˚C) room.

2.3 Analytical methods

Samples of the influent, UASB effluent and DHS effluent were collected for routine analysis. COD, TN, and TP were determined using a HACH water quality analyzer (DR-2800, HACH, US). Routine water analysis was performed as per standard methods published by Japan Sewage Works Association. Biogas production was measured by a wet gas meter (WS-1A, Shinagawa, Japan) after desulfurization. Biogas composition was analyzed using gas chromatograph equipped with thermal conductivity detector (GC-8A, Shimadzu, Japan).

3. Results and Discussion

The system was started up with an influent CODof 2,500 mg-COD/L and operated for 355 days. From days 0 to 189, the system was run for start-up and optimization of operational conditions (data not shown). Organic loading rate (OLR) was increased stepwise by increasing the influent COD (5900 ± 460, 8500 ± 1010, 13100 ± 730 mg-COD/L) at a constant HRT of 24 hours, until wash out of granular sludge from UASB reactor occurred. The COD of UASB effluent and DHS effluent were 1240 ± 850 mg-COD/L, 374 ± 254 mg-COD/L, respectively. This shows that while UASB removed most of the organic compounds, DHS removed residual organic compounds. The system achieved an average COD removal of 96.6 ± 2.7% during the entire experimental period. Such high COD removal rates may have been achieved owing to the use of wastewater containing ethylene glycol that has a high ratio of easily biodegradable organic compounds. The production of the two gases was 31.4 ± 15.5 L biogas/day and 28.8 ± 9.9 L methane/day during the entire experimental period. The rate of production of both gases increased gradually with respect to influent COD concentration. Maximum biogas and methane production were 86.4 L/day and 50.4 L/day, respectively, on day 316. Fig. 2 shows COD removal and methane recovery (based on the reduced COD) at OLRs of 8.3 (days 190-222), 9.7 (days 223-300), and 15.3 kg-COD/m^3-day (days 301-355). At OLR of 9.7 kg-COD/m^3-day, the UASB reactor achieved 90.1 ± 4.3% COD removal and 83.3 ± 33.5% methane recovery. The COD of final effluent was 453 ± 172 mg-COD/L at an OLR of 9.7 kg-COD/m^3-day. Thus, high COD removal and methane gas recovery were achieved in this study. An increase of OLR to 15 kg-COD/m^3-day resulted in the granular sludge being gradually washed out from the UASB reactor, and accumulation of propionic acids was observed. Thus, 9.7 kg-COD/m^3-day was considered the optimal OLR in this study.

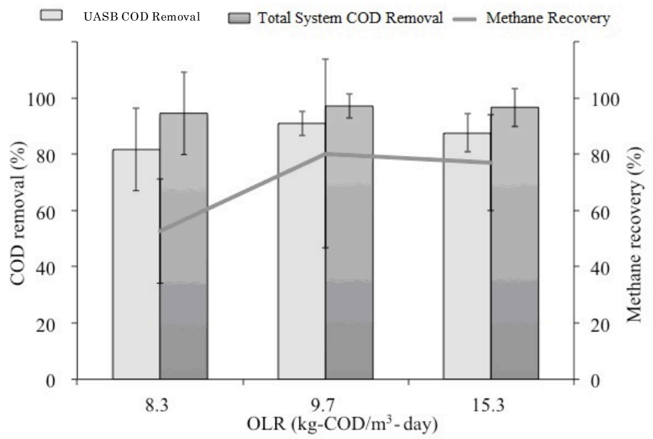

Fig. 2. COD removal and methane recovery at each OLR

Conclusion

In this study, a combined system of UASB and DHS for treatment of industrial wastewater containing ethylene glycol and propylene glycol achieved high COD removal and methane recovery during the entire experimental period. At OLR of 9.7 kg-COD/m^3-day, the UASB reactor achieved 90.1 ± 4.3% COD removal and 80.3 ± 33.5% methane recovery. Thus, this system could be proposed for the treatment of industrial wastewater containing ethylene glycol.

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