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ORIGINAL ARTICLE

Research on soybean protein wastewater treatment by the integrated two-phase anaerobic reactor

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Abstract The start-up tests of treating soybean protein wastewater by the integrated two-phase anaerobic reactor were studied. The results showed that the soybean protein wastewater could be successfully processed around 30 days when running under the situation of dosing seed sludge with the influent of approximately 2000 mg/L and an HRT of 40 h. When the start-up was finished, the removal rate of COD by the reactor was about 80%. In the zone I, biogas mainly revealed carbon dioxide (CO_2) and hydrogen (H_2). Methane was the main component in the zone 2 which ranged from 53% to 59% with an average of 55%. The methane content in biogas increased from the zone I to II. It indicated that the methane-producing capacity of the anaerobic sludge increased. It was found that the uniquely designed two-phase integrated anaerobic reactor played a key role in treating soybean protein wastewater. The acidogenic fermentation bacteria dominated in the zone I, while methanogen became dominant in the zone II. It realized the relatively effective separation of hydrolysis acidification and methanogenesis process in the reactor, which was benefit to promote a more reasonable space distribution of the microbial communities in the reactor. There were some differences between the activities of the sludge in the two reaction zones of the integrated two-phase anaerobic reactor. The activity of protease was higher in the reaction zone I. And the coenzyme F_{420} in the reaction zone II was twice than that in the reaction zone I, which indicated that the activity of the methanogens was stronger in the reaction zone II.
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1. Introduction

The amount of the wastewater containing soybean protein is huge in Chin, with the great development of the soybean protein (Su and Yu, 2005). Soybean protein wastewater is the high organic wastewater, which contains organism, nitrogen and phosphorus (Bao et al., 2009). Therefore, it is crucial to develop an innovative appropriate anaerobic reactor for treating soybean protein wastewater.

Most of the treatment studies on soybean protein processing wastewater have focused on aerobic and membrane technology (Su and Yu, 2005). However they have the shortages

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such as sludge yield, membrane pollution and high cost, which restrict the utilization of pond treatment system. It is regarded that anaerobic biological treatment technology is the most efficient method to deal with the high concentration of organism wastewater, which can also gain biomass energy (Maroun and Fadel, 2008; Hong and David, 2007a,b; Barber and Stuckey, 1999). Therefore, it is crucial to develop an innovative appropriate anaerobic reactor for treating and gaining biomass energy from soybean protein wastewater.

Although, a lot of anaerobic reactors such as upflow sludge blanket reactor (UASB), anaerobic filter (AF), and anaerobic continually stirred tank reactor (CSTR) have been developed, the two-phase anaerobic process has many advantages compared to those anaerobic reactors. The process of anaerobic decomposing organic substrate can be simplified into two phases of acid production and the methane production (Yu et al., 2014). The microbial activity is directly influenced by the temperature in the anaerobic reactor (Speece, 1996; Barber and Stuckey, 1999; Angenent et al., 2002). The two-phase anaerobic technology which improved separation of phases (acidogenic and methanogenic) possessed stable and high removal rate, and stronger ability to resist impact load than common anaerobic devices. The literature survey shows that it lacks on the anaerobic treatment of soybean protein wastewater by the two-phase anaerobic technology. Therefore, the purpose of this study is to determine the feasibility for treating soybean protein wastewater by a laboratory-scale the two-phase anaerobic technology.

In order to provide theoretical guidance and technical reference for engineering application about the integrated two-phase anaerobic reactor, this paper not only investigated the efficiency of treating soybean protein wastewater, but also elucidated the microbial phase in the reactor during the experiments.

2. Materials and methods

2.1. Devices

The integrated two-phase anaerobic reactor was made by UPVC, which was cylindrical with the effective volume of 60 L. It was divided into two anaerobic reaction zones, whose volume was about 20 L and 40 L, respectively. The soybean protein wastewater entered into the anaerobic reaction zone I by uniform water distribution system, through the inlet pipes which were placed at the bottom of reactor. The effluent entered into anaerobic reaction zone II through the down flow weir which was placed at the top of the baffle plate. The outlet pipe was at the bottom of the anaerobic reaction zone II. The reactor was equipped with three phase separators. The anaerobic reaction zone I was equipped with auto stirring device and auto heating apparatus. The sludge was discharged through the mud pipe placed at the bottom of the reactor. The methane production was measured by the wet-type gas flow meter. The operating temperature of the reactor was maintained constant at 30 °C by the auto heating apparatus in the anaerobic reaction zone I. The reactor was wrapped with insulating sponge, aiming at reducing the loss of heat. The soybean protein wastewater was pumped into the reactor in the way of continuous feeding by peristaltic pump. The integrated two-phase anaerobic reactor is shown in Fig. 1.

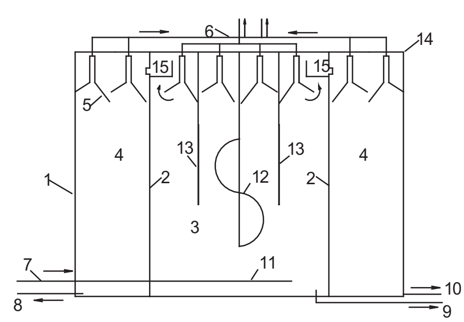
2.2. Wastewater and the seed sludge characteristic

The soybean protein wastewater used in this research was taken from a local soybean protein productive company, and the wastewater quality is shown in Table 1. The average chemical oxygen demand (COD) was about 8500 mg/L, and the biochemical oxygen demand (BOD)/COD value was about 0.6. The soybean protein wastewater was diluted using tap water to required concentration.

The seed sludge was taken from the upflow anaerobic sludge blanket (UASB) in a local foodstuff wastewater treatment plant. The ratio of mixed liquor volatile suspend solid (MLVSS) to mixed liquor suspend solid (MLSS) was about 0.7 in seed sludge. The quantity of the seed sludge in the reaction was 30 g MLVSS/L. The hydraulic retention time (HRT) of this reactor was 40 h.

2.3. Analytical methods

Analysis of COD, total nitrogen (TN), total phosphorus (TP), MLVSS, suspended solids (SS), and pH were conducted in accordance with standard methods (China, 2004). The amount of collected gas was determined by the wet corrosion gas meter (Changchun Automobile Filter Co., Ltd.). The biogas composition (CH_4, CO_2 and N_2) was analyzed using gas



1tank、2 inner diaphragm、3 the anaerobic reaction zone Ⅰ、4 the anaerobic reaction zone Ⅱ、5 separator、6 discharge pipe、7 inlet pipe、8 outlet pipe、9 sludge pipe、10 sludge pipe、11 water distributor、12 spiral stirrer 、13 heater、14 support post、15 overflow weir

Figure 1 Schematic diagram of the integrated two-phase anaerobic reactor.

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