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Effects of pH adjustment by parawood ash and effluent recycle ratio on the performance of anaerobic baffled reactors treating high sulfate wastewater

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ABSTRACT

The objective of this study was to compare the performance of anaerobic baffled reactor (ABR) treating concentrated rubber latex wastewater under different pH adjustment substances and recycling ratios (R). Two ABRs, one received wastewater pretreated with NaOH and the other with ash, were operated at 35 °C under identical HRTs from 10 to 1.25 d. Results show that both ABRs had highest COD and sulfate removal efficiencies at HRT 10 d (averaged 82.71% and 96.16% of ABR-NaOH, and 80.77% and 96.60% of ABR-Ash, respectively), where majority of the influent COD and sulfate were removed by the first compartment of the ABR at all conditions tested. Increasing R (0, 0.3 and 0.5) raised the hydraulic loading on the system and resulted in a drop of organic removal efficiency and methane yield. Translocation of sulfate reducing bacteria and methanogens in the ABRs caused by increased organic loading and effluent recycle is discussed. The results show great potential of parawood ash as a pH adjustment substance for acidic wastewaters.

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1. Introduction

Rubber (*Hevea brasiliensis* Muell. Arg.) is one of the leading economic crops of many southeast Asian countries. Its latex from the rubber tree can be transformed and used to produce natural rubber, which is a basic component of various products we depend upon. Since year 1991, Thailand has been the number one producer of natural rubber in the world (Thailand Office of Industrial Economics, 2006) accounting for 2,952,000 tons or approximately 30 percent of the total world production in 2005 (Rubber Research Institute of Thailand, 2006). Of such figure, about 20 percent of the country's rubber production is preprocessed into concentrated rubber latex. Concentrated rubber latex industry is a major source of environmental pollutions in Thailand, particularly in the lower south region where most concentrated latex factories are located. The distinct characteristics of wastewater from this industry is its high organic, ammonia nitrogen and sulfate concentrations. This is because large amount of ammonia is used for preserving rubber latex while the sulfuric acid (H_2SO_4) is required for recovering rubber particles in a waste stream. Through this acid coagulation, the liquid left after rubber coagulate was removed, so-called serum, is rich in organic substance. This wastewater is also highly acidic with a pH of 3.6–4.7. Improper management of this wastewater could cause various air and water pollutions (Bunyakan et al., 2004; Boonreongkaow et al., 2002; Agamuthu, 1999). The treatments that have been widely applied in concentrated latex industry are natural pond system and aerated lagoon, both are open systems. These systems are not able to consistently produce effluents that can comply with the industrial effluent standards, and also generate malodorous hydrogen sulfide gas caused by an anaerobic decomposition of sulfate-rich wastewater. This circumstance had often caused complaint from nearby communities. Therefore, anaerobic close system becomes an attractive choice because it can prevent gas emission, requires low energy input for operation, and the organic pollutant converted to methane gas can be used readily as fuel. Suitable anaerobic technology for this wastewater is needed.

Since sulfate reducing bacteria (SRB) activities and the subsequent sulfide production are inevitable in anaerobic treatment of sulfate-rich wastewater, optimization of the treatment was shifted toward managing the production of hydrogen sulfide either together with or in separate from methane production. For the single reactor combined sulfate removal and methane production scheme, there are a few methods presented. Dilution of the influent by effluent or sulfate free water could alleviate inhibitory effects in anaerobic reactor by lowering the H_2S concentration in the bacterial aqueous habitat down to the point where methanogens can be active (Fox and Venkatasubbiah, 1996). In the stage separation scheme, a.k.a. two-stage sulfidogenic–methanogenic

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configuration, a sulfidogenic reactor intended for biological reduction of sulfate to hydrogen sulfide is located as a front reactor. Sulfate is removed from the wastewater before going into the second stage for methane production. Provided that there is enough COD for sulfate reduction in the first stage, the excess COD will enter the subsequent methanogenic stage (Speece, 1996). Sulfidogenesis in combination with acidogenesis reportedly occurred in their first stage at pH 6 where sulfate removal ranged from 86 to 92% at sulfate concentration of 1000 mg/L and COD:sulfate ratios of 10 and 5. This phenomenon prompted subsequent methanogenesis in the second stage.

Many reactor configurations have been applied to constitute the two-stage systems including upflow filters, CSTRs, UASB, and fluidized bed reactors (Lens et al., 1998). In this setup, it is important that sulfate and sulfide have to be removed in the first stage to allow efficient methanogenesis in the second stage. Anaerobic baffled reactor (ABR), a high-rate anaerobic bioreactor, is a single reactor configuration with compartmentalization within which could employ the benefits of a stage separation scheme. With the compartmentalized configuration, it is able to keep the biomass in the reactor for a long period of time (long solids retention time; SRT) independent of the hydraulic retention time (HRT), and resilient to hydraulic and organic shock load (Manariotis and Grigoropoulos, 2002). Moreover, the compartmentalization of the bacteria may provide the opportunity to separate sulfate reduction and methanogenesis longitudinally down the reactor. However, with plug flow characteristics, high substrate loading in the front part of the reactor can lead to the accumulation of volatile fatty acid (VFA) and a concomitant decrease in pH, affecting its efficiencies in pollutant removals. High strength wastewater is more likely to expose sensitive bacteria in front compartments to toxic levels of inorganic and organic compounds (Boonpaty, 1998; Barber and Stuckey, 1999; Hutñan et al., 1999; Baloch et al., 2007; Yu et al., 2002). To lessen such negative effects, dilution of incoming wastewater can be accomplished by effluent recycle (Smith et al., 1996; Kennedy and Barriault, 2005). Additionally, the addition of a recycle stream could also alleviate the problem of low pH caused by high levels of VFA at the front part of the ABR reactor (Baloch et al., 2007).

As mentioned, since concentrated rubber latex wastewater is highly acidic, it is unsuitable for anaerobic bacteria in the reactor. Therefore, pH adjustment is not only required to render pH toxicity to an optimal range of 6.5–7.6 (Rittmann and McCarty, 2001; Sawyer et al., 2003; MetCalf and Eddy, 2004) but also to increase the wastewater buffer capacity. The pH adjustment can be achieved by an addition of alkali chemical, typically calcium carbonate or sodium hydroxide. With a large volume of wastewater produced daily from this industry, cost of these chemicals is an obvious disincentive for a long-term chemical pH adjustment. An alkali material, parawood ash, that is a solid waste from para firewood boilers in industrial plants is abundantly available in the region. This ash is typically disposed in large amount in the neighborhood surrounding the factories, causing serious environmental problem, soil pollution in particular, due to its high alkali. Recycling of this ash to increase the productivity of the widespread acid soils and to improve chemical soil fertility of the agricultural soils has been reported (Voundi Nkana et al., 1998, 2003; Amirfakhri et al., 2006). Nonetheless, application of wood ash for wastewater pH adjustment to improve the treatment efficiency has not been studied.

The objectives of this study were first to investigate the effects of two different alkali materials, NaOH and parawood ash, used in the pH adjustment of the influent wastewater on the performance of the ABR in treating the concentrated latex wastewater. And second is to examine the applicability of effluent recycling as to improve the performance of ABR treating the concentrated rubber latex wastewater. Results of this study could provide information necessary to a more sustainable waste management for rubber industry in a long term by way of co-management of acidic wastewater and alkali solid waste simultaneously.

2. Methods

2.1. Reactors configuration

To evaluate the treatment efficiency of the concentrated rubber latex wastewater, two acrylic anaerobic baffled reactors (ABRs) were constructed in this study (Fig. 1). The reactor design is a rectangular shape with internal vertical baffles alternately hanging and standing to make the upward–downward flow channels. These baffles divided the bioreactor into 4 equal size compartments. Each reactor is 60 cm × 30 cm × 32 cm ($W \times L \times H$), with a total effective working volume of 23 L. This arrangement provides mixing effect and promotes contact between the wastewater and anaerobic sludge at the base at each upward flow (Setiadi et al., 1996).

Wastewater was stored in a feed tank and fed to the reactor by a variable-speed peristaltic pump (Masterflex, Cole-Parmer Instrument Co., Chicago, Illinois). In effluent recycling mode, the effluent was pumped from an effluent holding tank. Biogas production was measured daily by water displacement gas meter while the biogas sample was collected from a balloon for composition analysis (Fig. 1). The reactors were heated by wire electric heater to maintain the temperature at 35 ± 1 °C. The experimental setup was located in the laboratory at the Faculty of Environmental Management, Prince of Songkla University.

2.2. Wastewater and inoculum

Concentrated rubber latex wastewater was obtained from an equalization pond of the wastewater treatment system of Chalong Latex Industry Co. Ltd., while parawood ash was collected from a boiler of Safeskin (Tunglung) Co. Ltd., Songkhla Province, Thailand, and dried at 103–105 °C until constant weight. The pH of the wastewater was adjusted by adding parawood ash and 6 N NaOH to 7.6 ± 0.1 (Srisuwan et al., 1998) and stored at 4 °C until required. High pH of the influent could help raise the pH of the overall system ensuring sufficient buffer capacity of the anaerobic system. It is

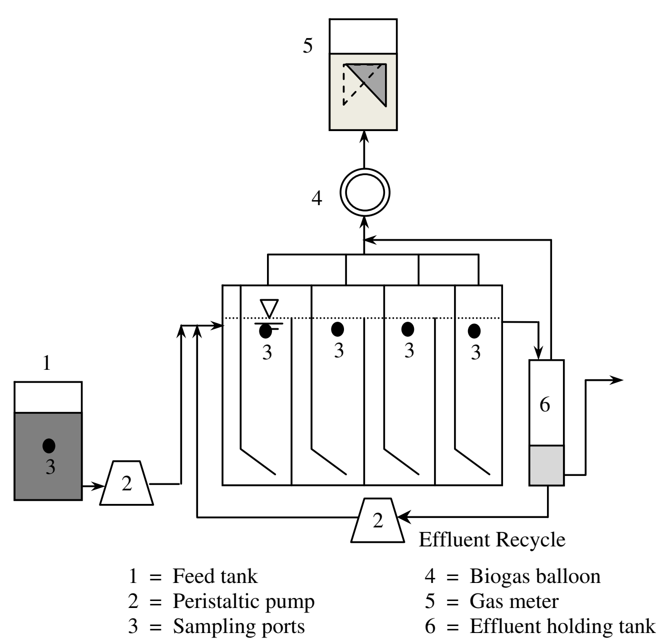

Fig. 1. Schematic diagram of the anaerobic baffled reactor in this study.

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