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Prefermentation to overcome nutrient limitations in food processing wastewater: Comparison of pilot- and bench-scale systems

Zhongda Xu, George Nakhla *

Department of Chemical and Biochemical Engineering, The University of Western Ontario, London, Ontario, Canada N6A 5B9

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Abstract

A bench- and a pilot-scale anaerobic/aerobic system were evaluated for the treatment of high strength tomato-processing wastewater. The pilot-scale anaerobic tank achieved better prefermentation of organic carbon and nitrogen than the bench-scale system, although overall system performance was comparable with more than 99% SBOD removal and 97% SCOD removal. Hydraulic retention time (HRT) and temperature effects were studied in the bench-scale system. Increase of anaerobic HRT from 0.25 day to 0.5 day favored prefermentation and a better effluent quality was achieved, as demonstrated by reduction in TSS concentrations from 66 mg/L to 24 mg/L, SCOD from 103 mg/L to 78 mg/L and SBOD from 8 mg/L to 6 mg/L, respectively. Specific oxygen uptake rate (SOUR) increased from 0.15–0.23 mg O_2/mg VSS day at 25 °C to 0.67–1.24 mg O_2/mg VSS day at 32 °C. Settling characteristics deteriorated from sludge volume index (SVI) of 24–131 mL/g at 25 °C to 115–173 mL/g at 32 °C. Sludge yield decreased from 0.14 g VSS/g COD at 25 °C to 0.098 g VSS/g COD at 32 °C.

Keywords: Anaerobic/aerobic system; Tomato-processing wastewater; Prefermentation; HRT effect; Temperature effect

1. Introduction

Although anaerobic processes have been successfully applied for the treatment of various food processing wastewaters from slaughterhouses [1], cannery and meat processing [2], and vegetable processing [3], they are not typically considered capable of meeting final discharge requirements [4] and anaerobic/aerobic treatment is employed to assess the potential of anaerobic technologies to meet discharge requirements. Successful treatment of meat-processing wastewater using UASB followed by rotating biological contactors (RBC) was demonstrated [5] with overall pollutant removal efficiencies >90%. In such applications, low soluble nutrient concentrations, typical of high strength food processing wastewaters can limit anaerobic treatment efficiency, and hence solublization of nutrients by anaerobic hydrolysis is beneficial.

Hydraulic retention time (HRT) is an important variable in any biological treatment system particularly anaerobic treatment processes. Enhanced anaerobic biodegradability of dairy wastewater was observed with the increase in HRT from 4 h to 24 h [6] and was attributed to increased acidification. The performance of a laboratory-scale mesophilic acidogenic reactor treating dairy wastewater demonstrated that the highest degree of acidification and the rate of acid production were 56% and 3.1 g/L day at 12 h HRT [7]. Increase of HRT resulted in a decrease of propionate: acetate ratio in the acidogenic stage and digestion stage in a continuous anaerobic digestion system [8]. Maharaj and Elefsiniotis [9] revealed that the volatile fatty acids (VFA) and soluble COD (SCOD) concentrations and specific production rates reached their highest values at HRT of 30 h and 25 °C. Similarly, Guerrero et al. [10] confirmed that, during the treatment of organic acids and proteins, maximum acidification and VSS removal rates were at HRT of 12–24 h.

Temperature has mixed effects on the net VFA production. While net production usually increases with temperature [11], the maximum specific substrate utilization rate constant (k) also increases [12]. Masse and Masse [13] also found that COD removal efficiency and methanogenic activity increased when temperature increased from 20 °C to 25 °C and 30 °C in anaerobic sequencing batch reactors treating high strength slaughterhouse wastewater. Generally aerobic sludge settleability deteriorates with increasing temperature [14] with the sludge volume index (SVI) increasing from 110 mL/g at 15 °C to 540 mL/g at 35 °C, and higher effluent TSS levels [15].

* Corresponding author. Tel.: +1 519 661 2111x81376; fax: +1 519 850 2921.
E-mail address: gnakhla@eng.uwo.ca (G. Nakhla).

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It is apparent that despite numerous studies, the impacts of anaerobic HRTs and temperature on nutrient-deficient industrial wastewater treatment cannot be generalized and appear to be both system and wastewater specific. Thus, a bench-scale anaerobic/aerobic was constructed and used to investigate the treatment of high-strength tomato-processing wastewater generated from Sun-Brite Canning Ltd., Ruthven, Ontario as well as for comparison with the pilot-scale anaerobic/aerobic system in the field.

2. Materials and methods

2.1. System setup

The detailed setup of the bench-scale anaerobic/aerobic biological wastewater treatment system is shown in Fig. 1a. The system was composed of a 75 L influent storage tank with a heavy-duty high-torque mixer (Arrow 2000, Arrow Engineering Co. Inc., Hillside, NJ), a 5 L polyvinyl chloride (PVC) anaerobic tank with a mixer mounted on the top, a 10 L PVC aeration tank with a mixer on the top and copper coil air diffuser immersed in the mixed liquor, and an 8 L PVC clarifier. Two immersion heaters with dial temperature controller (Cole-Parmer short rod 5.5 in. *L*, 500 W and short rod 5 in. *L*, 1100 W, Labcor Technical Sales Inc., Montreal, Que.) were put into the anaerobic and aerobic tank to increase the liquid temperature to 32 ± 2 °C. Internal recirculation ratio R_1 (from aeration to anaerobic) of $3Q$ and R_2 (return activated sludge (RAS), from clarifier to anaerobic) of $2Q$ were employed while influent flow rate (Q) was set to 10 L/day in Periods II–IV. Three adjustable peristaltic pumps (MasterFlex L/S, Labcor Technical Sales Inc., Montreal, Quebec) with L/S 14 and L/S 16 tubings were applied to control

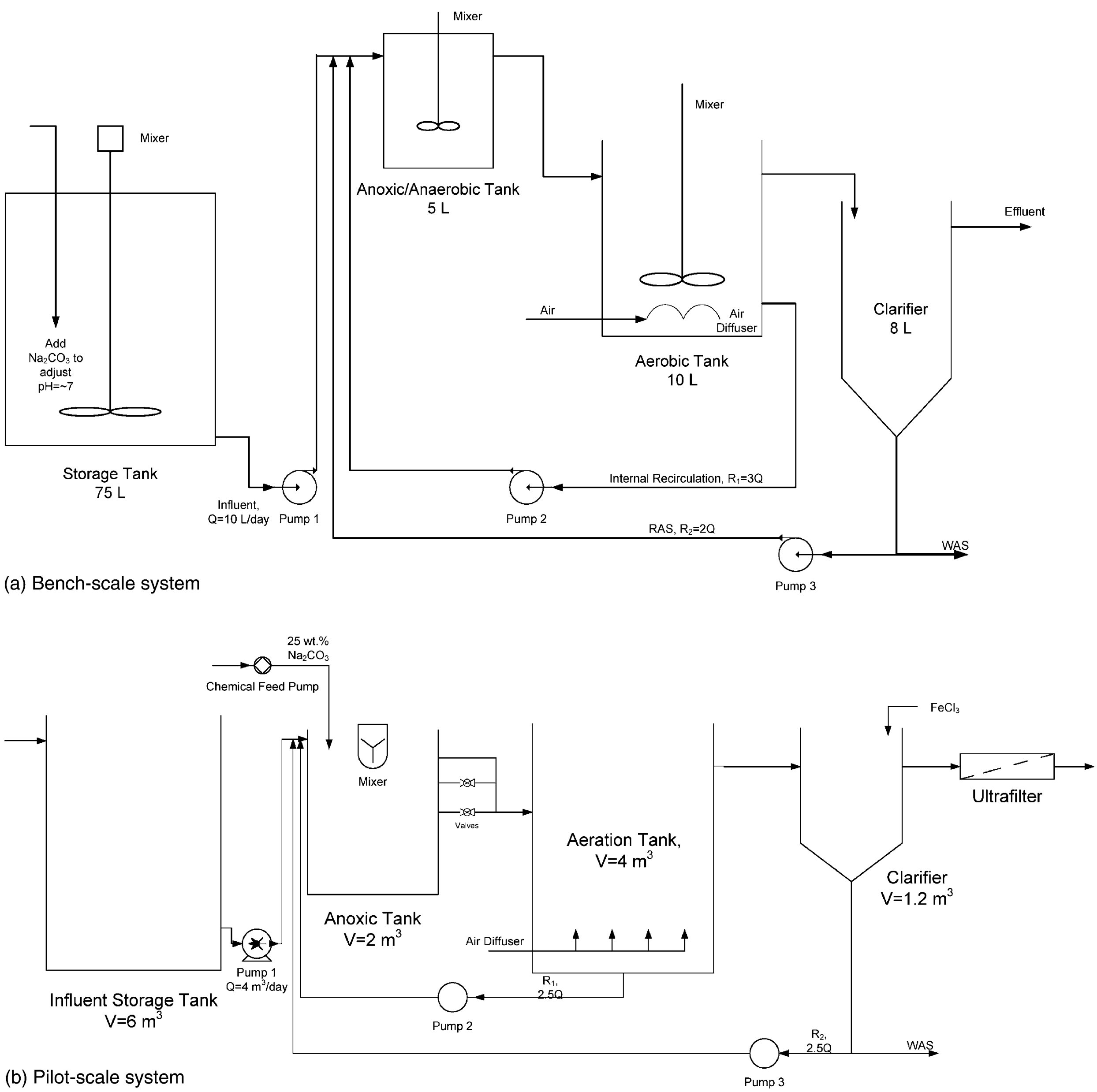

Fig. 1. Schematic diagram of bench- and pilot-scale anaerobic/aerobic biological wastewater treatment systems.