Treatment of High-Strength Domestic Wastewater in Anaerobic, Aerobic and Anoxic Fed-Batch Process System

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Abstract For treatment of high-strength domestic wastewater, this study explores a fed-batch bioprocess system consisting of anaerobic (AD), aerobic (AER) and anoxic (ANX) processes in this order and each run at 24 h hydraulic retention time (HRT) and 0.8 g COD/L/d in the first bioreactor. The largest COD removal occurred in the anaerobic process, followed by the aerobic process. The overall removal in the last 6 cycles with three bioprocesses in series, was 1,222.19± 213.14 mg/L or average 83.82 ± 9.73% based on influent levels. Of this COD removed, 546.15 ± 102.00 mg/L (ca. 38%) was removed in the AD, while 541.37± 227.13 (ca. 37%) was removed in the aerobic bioreactor. Biogas production accounts for 64.48±27.83% of the COD removed in the AD process. Much of the ammonia-N removal occurred in the aerobic bioreactor (84.08 ± 18.95% of the influent NH3-N to the aerobic bioreactor). The amount (mg/L) of nitrate-N removed in the ANX process via denitrification is 36.0 ± 33.6 mg/L, which is 63.0 ± 30.4% of influent nitrate-N to the anoxic bioreactor.

Keywords: ammonia, biogas, biological, methane, nitrate

1. Introduction

Domestic wastewater causes eutrophication of receiving bodies of water. Simple-operation treatment systems are needed. With low-water use systems, domestic wastewater may have higher levels of organic matter (COD) and N levels. In the Philippines, conventional or completely mixed activated sludge process (AS), membrane bioreactors (MBR), moving bed bioreactors, sequencing batch reactors (SBR)(Dutta & Sarkar, 2015) are the most commonly used treatment for domestic wastewater. Process combinations involved anoxic and aerobic processes only, in one or two bioreactors. Achieving effluent standards and high operational costs using these systems remain a challenge.

Biological nitrogen removal occurs simultaneously with other biological processes that removes COD. The removal of N requires carbon source, which can be obtained from the organic matter present in the wastewater. In this study, for a high-concentration domestic wastewater (DWW), the treatment includes anaerobic digestion (AD), aerobic (AER) and anoxic (ANX) processes. AD removes much of the COD, AER converts ammonium to nitrate, and ANX converts nitrate to nitrogen gas. All these were done in fed-batch mode. Unlike in SBR, which undergoes intermittent changes in process conditions, fed-batch bioreactors in series can allow high population of microbial consortia, each focusing on a particular treatment role as each reactor is run at consistent oxygen conditions. Other advantages of fed-batch system are cited by Kargi & Pamukoglu (2003).

2. Materials & Methods

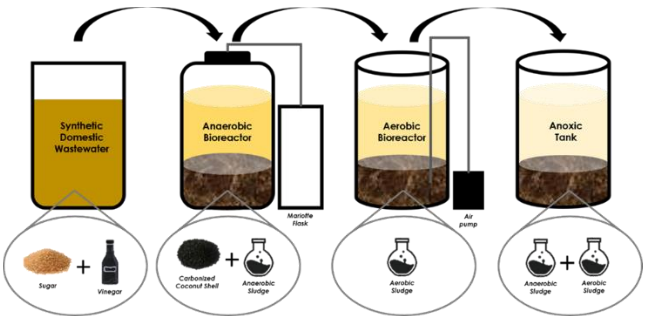

Figure 1. Experimental setup of the anaerobic, aerobic and anoxic Processes in Fed-Batch Bioreactor Mode (3 bioreactors of 6L each): anaerobic AD (R1), aerobic AER (R2) and anoxic ANX (R3). Every 12 h, wastewater (3L) is withdrawn from each bioreactor before feeding with 3L new influent wastewater from the preceding bioreactor. Aeration rate was 1.53 ml/s. Anoxic bioreactor stirring 320 rpm. Carbonized coconut shell as immobilization matrix in the R1 (AD), which was fed at 0.8 gCOD/L/d. Each bioreactor has 2.5 – 4 g/L MLSS.

Influent (model wastewater) was prepared using a mixture of water, sugar, vinegar, NH_4Cl, Na_2CO_3, micronutrients to ca. 800 mg/L COD level. Inoculum were 33% of reactor volume, which for R1-AD included carbonized coconut shell as microbial immobilization matrix (6.6% of reactor volume), buffalo manure (13.2%) and sludge from anaerobic reactor (13.2); activated sludge (33%), 1:1 mixture of aerobic sludge and anoxic sludge from exiting bioreactors (33%), for AD, AER and ANX bioreactors, respectively. COD, ammonia-N and nitrate-N were done according to standard methods (WEF & APHA 2005).

3. Results & Discussion

The effluent COD level increases as influent concentration increases (data not shown). In the first 6 cycles, at influent COD of 564.07±128.81 mg/L, the effluent after the ANX process had very low to negligible levels. Thus, lower final effluent COD levels are expected for raw wastewaters of lower COD level. The average COD removal gradually increased in all bioreactors from the first 6 cycles to the fourth 6 cycles (fig. 2). This gradual increase signifies increasing population of microorganisms in the bioreactors. The largest COD removal occurs in the anaerobic process, followed by the aerobic process. The overall removal in the last 6 cycles was , i.e., with three bioprocesses in series, was 1,222.19± 213.14 mg/L or average 83.82 ± 9.73% based on influent levels. Of this COD removed, 546.15 ± 102.00 mg/L was removed in the AD, while 541.37± 227.13 was removed in the aerobic bioreactor. Biogas production accounts for 64.48±27.83% of the COD removed in the AD process. The rest of the removed COD must have been used for microbial growth.

The effluent NH_3-N level generally follows the fluctuations in the influent levels, i.e., it becomes higher when the influent concentration is higher (data not shown). As expected, much of the ammonia-N removal occurred in the aerobic bioreactor (84.08 ± 18.95% of the influent NH3-N to the aerobic bioreactor). The amount (mg/L) of nitrate-N removed in the ANX process via denitrification is 36.0 ± 33.6 mg/L, which is 63.0 ± 30.4% of influent nitrate-N to the anoxic bioreactor. Ammonia-N was further reduced in the anoxic bioreactor (fig. 2). Comparing the sum of the ammonia-N and nitrate-N levels in the effluent of AER to that of ANX shows 55.8 ± 42.0 mg/L removal in ANX, which is 65.83 ± 22.84% NH3-N+NO3-N removal. The standard NH3-N was not achieved yet but cycle 19-24 shows an improving trend. Nevertheless, further process enhancement at this low N level may be easier to achieve than in high-N wastewater, e.g., bio-augmentation or a second aerobic process.

Overall, the system with a total HRT of 72 hours has a promising performance. The anaerobic, aerobic, and anoxic reactors within the fed-batch system achieved COD removal efficiencies of 36.0%, 50.5%, and 49.0%, respectively, contributing to an overall system efficiency of 87.5%. NH_3-N removal efficiencies were 25.5%, 73.9%, and 50.3% in the respective reactors, leading to an overall fed-batch system efficiency of 92.55%. The anoxic reactor demonstrated a significant role in nitrogen removal, achieving a NO_3-N removal efficiency of 72.6%. The anaerobic reactor produced an average of 450.03 ml of biogas per gram of COD removed.

4. Conclusions

This study has shown a promising performance of a wastewater treatment system that requires low electrical energy usage, has low C emissions and energy recovery from waste.

5. Acknowledgement

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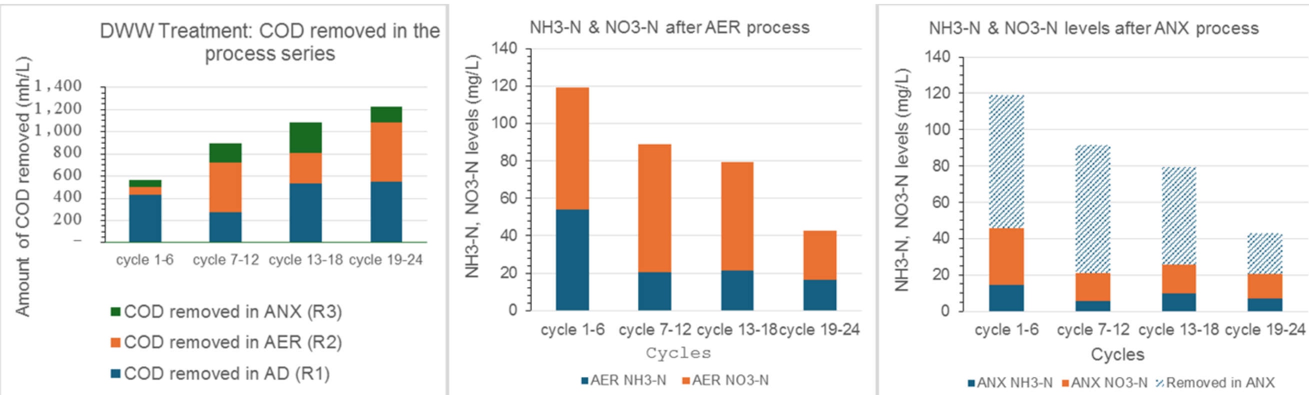

Figure 2. COD, ammonium+nitrate N removal in the fed-batch bioreactors in series: anaerobic AD (R1), aerobic AER (R2) and anoxic ANX (R3)

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