Effect of micro aeration on anaerobic treatment of sulphate and ammonia rich wastewater

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ABSTRACT – Microaeration is a stratergy applied during anaerobic conversion to improve treatment efficicency. The objective of this study is to investigate the effect of microaeration on a combined effect of sulphate and ammonia present in latex wastewater. Wastewater obtained from skim latex processing plant contains high ammonia content apart from high sulphate oncentration. the latex wastewater was treated anaerobically in two sequential anaerobic reactors with two treatment steps and the reactors were semi continuously fed with hydraulic retention time(hrt) of 14 days. After 7 weeks of operation first reactor was microaerated using an oxygen permeable polymeric membrane. during micro aeration of latex wastewater sulphate and ammonia removed by sulphur reducing ammonium oxidation(srao) mechanism. Micraeration result in cod recduction enhancement by 24% in during first treatment step.

Keywords: Microaeration; Latex wastewater; anaerobic digestion; Hydrogen sulphide; Ammonia

INTRODUCTION

Micro aeration is a technique strategy which has a growing attention among the researchers as a method to overcome several drawbacks of the anaerobic digestion process such as low hydrolysis rate, release of toxic/corrosive hydrogen sulphide and instability at high organic rates (OLR). (Nguyen & Khanal, 2018) Micro aeration can be simply defined as dosing small amount of air to the anaerobic digester while maintaining the anaerobic conditions.(Krayzelova et al., 2015) Air or oxygen can be dosed either one time, in pulse mode or continuously at different stages of the anaerobic digestion process as a pretreatment, during digestion or post digestion. (Girotto et al., 2018) During anaerobic digestion of sulphate-rich wastewater, hydrogen sulphide is generated via dissimilatory sulphate reduction, which is not only inhibit methanogens but also causes corrosion of pipes and other metal parts, and hence need to be removed from both aqueous and gaseous phases. (Krayzelova et al., 2015)Latex wastewater also rich in sulphate. Hence high hydrogen sulphide content can be expected in the biogas during the anaerobic digestion. However latex wastewater also consists of a high ammonia content. In the presence of ammonia in the system, production of hydrogen sulphide in the system has reduced. (Dai et al., 2017)Similar conclusions are given drawn by (Fdz-Polanco, 2001). The mechanism suggested by them is the Sulphur reducing ammonium oxidation (SRAO) process given by Equation 1.

$$NH_4{}^+ + \frac{1}{2}\,SO_4{}^{2-} \rightarrow \frac{1}{2}\,N_2 + \frac{1}{2}\,S + 2H_2O \qquad (1)$$

When interactions between ammonia and sulphate are further studied, (Fdz-Polanco et al., 2001a) suggested another mechanism of ammonia and sulphate interactions. That is sulphide removal via denitrification (Equation 2).

$$S^{2-} + \frac{1}{2}\,NO_2{}^- \rightarrow N_2 + 3S + 4H_2O \qquad (2)$$

Micro aeration of an anaerobic reactor should be done under controlled conditions. because over aeration beyond the oxygen consumption and anti-oxidation capacities of facultative bacteria can cause detrimental effects on strict anaerobes (Xu et al., 2014). In a two staged reactor configuration, when one reactor is microaerated, the risk of inhibiting methanogens would be minimal (Xu et al., 2014). Thus, a two staged reactor configuration was used in the experiment. Previous studies have not evaluated effect of micro aeration in the context of removing both ammonia and sulphide present in the latex wastewater. Thus, the objective of this research is to find the impact of micro aeration on anaerobic treatment of latex wastewater in a two staged reactor set up and its effect on simultaneous hydrogen sulphide and ammonia removal.

METHODOLOGY

The substrate used in the experiment was wastewater obtained from a skim latex processing factory. The inoculum was obtained from the anaerobic reactor of the wastewater processing plant of the same factory. Characterization results of substrate and inoculum are shown in Table 1 and Table 2.

Table 1. Characterization results of substrate

	TS(mg/l)	TSS(mg/l)	VSS(mg/l)
Substrate	61280	36660	16620
Inoculum	83760	1226	826.67

Table 2. Characterization results of inoculum

Substrate COD	3600 mg/l
Substrate pH	7
Substrate total ammonia	(450-600) mg/l

The reactor configuration used for the experiment was two staged reactor configuration where the substrate was treated in two sequential reactors (R_1 and R_2). Two 1L glass bottles under anaerobic condition served as two reactors in the treatment process. Two identical experimental setups were used with same configuration where one served as blank or control. This control reactor set up was not micro aerated.

Table 3. Reactor identification

	Reactor 1 (R1)	Reactor 2 (R2)
Experimental apparatus (E)	R1E(micro aerated)	R2E
Control apparatus (C)	R1C	R2C

Initially R_1 reactors were acclimated and taken up to the full volume. Then, R2 reactors were inoculated and fed with the effluent from R1 reactors. Reactors were operated by feeding 200 ml of liquid semi-continuously. Similar feeding cycles were followed throughout the experiment for both experimental and control apparatus. The hydraulic retention time (HRT) of reactors were 14 days. Effluent sample and gas sample collection for all reactors were initiated from week 5.

In this experiment Reactor 1 (R1) of the experimental apparatus (R1E) was micro aerated in the pulse mode from week 8 with oxygen dosing rate of 0.4736 mg/day. An oxygenator which is used in medical applications was used to transfer oxygen to the reactor. "Oxygenator" contains a polymeric membrane (PDMS) which transfer oxygen from the environment to a stream which pass through the equipment. A recycling stream from the reactor was send through the equipment and fed back to the reactor. Initially the "Oxygenator" was characterized to find the oxygen transfer rate of the equipment. The oxygen transfer rate of the equipment was found as 1.6575 mg/l/min.

pH and ORP of the reactors were monitored throughout the experiment. ORP was measured offline. Samples were taken out of the reactor with a minimum contact with the environment and ORP was measured using an ORP meter. Sulphate and nitrate concentrations of the liquid effluent samples were measured by ionometric method. And the hydrogen sulphide and ammonia concentration of the gas were measured by an ambient air quality meter (GasAlertMicro 5/PID/IR).

RESULTS AND DISCUSSION

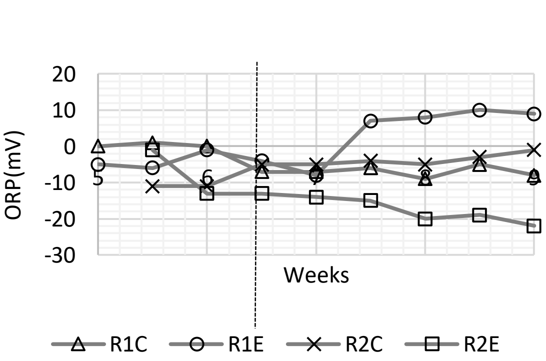

Figure 3. ORP results

Although micro aeration has increased the ORP value of the liquid in R1E , it has not negatively affected the R2E. And when the ORP values of the reactors are compared with the control reactors that were under anaerobic conditions, it can be concluded that all the reactors were maintained under anaerobic condition even after micro aeration. The sulphate concentration of both rectors of experimental set-up (R1E and R2E) have reduced after micro aeration (Figure 2). Two methods can be suggested for the reduction in sulphate concentration. Either sulphate reduction to hydrogen sulphide by Sulphur reducing Bacteria(SRB) (Krayzelova et al., 2015) has enhanced or Sulphate has reduced to elemental Sulphur.

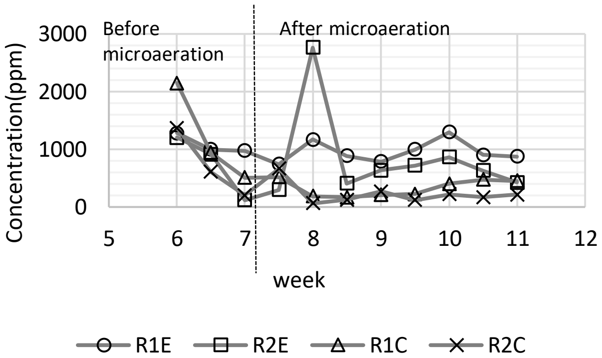

Figure 4. Liquid phase sulphate analysis

However, hydrogen sulphide concentration in gas phase shows reduction due to micro aeration (Figure 3). Similar reduction of hydrogen sulphide in gas phase has observed by (Khanal & Huang, 2006) after introducing micro aeration during anaerobic treatment of sulphate rich wastewater.

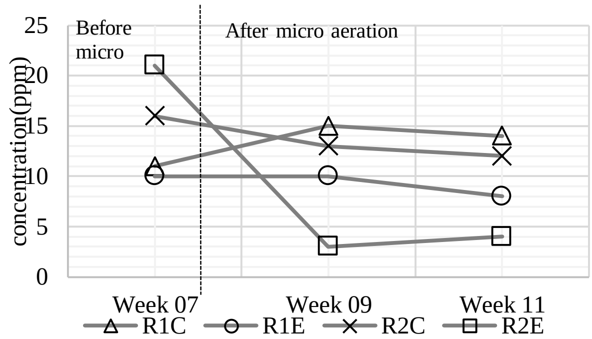

Figure 5. Gas phase hydrogen sulphide analysis

After micro aeration was introduced, Sulphur formation could be observed visually in the reactors. This indicate that sulphate reduction in liquid were observed due to reduction of sulphate to elemental Sulphur by means of equations (1) or (2)(Fdz-Polanco et al., 2001b).

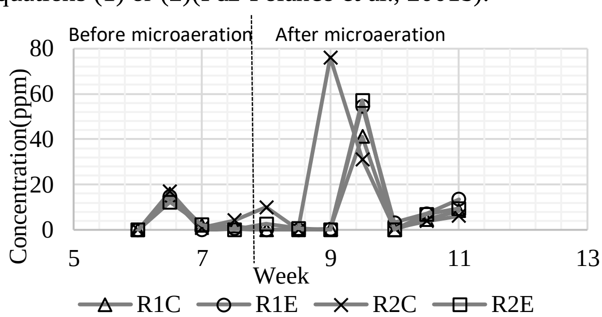

Figure 6. Liquid phase nitrate analysis

Micro aeration does not show significant effect on nitrate concentrations in the reactors(Figure 4). According to equation (1) and (2) ammonia and nitrite are the nitrogenous compounds that interact with sulphate during anaerobic treatment. Micro aeration enhances hydrolysis of protein and carbohydrate(Johansen & Bakke, 2006). Latex wastewater contains high protein content. Thus, high ammonia content should be expected in gas.

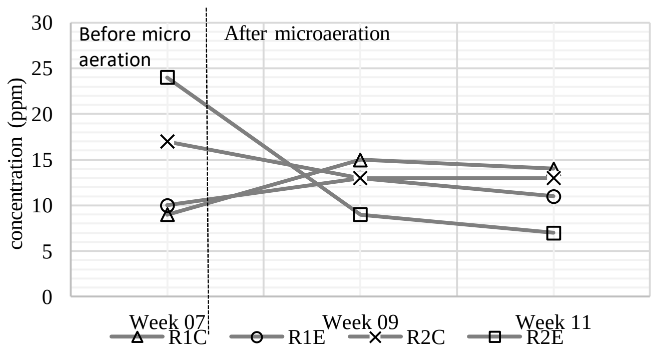

Figure 7. Gas phase ammonia analysis

However, gas phase ammonia analysis shows low ammonia content after applying micro aeration (Figure 5). Ammonia can be consumed for two reactions in a combined system of ammonia and sulphate micro aeration applied. Equation (1) shows one reaction. Ammonia can be converted to nitrite under limited oxygen concentrations by AOB(Ammonium oxidizing bacteria) under limited oxygen concentrations(Nhu Hien et al., 2017).

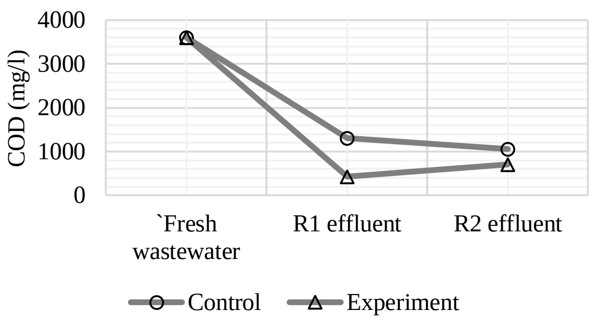

Figure 8. COD variation along the treatment process

Figure 6 shows the effect of micro aeration on COD reduction. COD reduction in R1 reactors has enhanced by 24% after micro aeration. However, in the experimental set up, COD has increases from R1 to R2. Enhancement of COD can happen due to enhancement of hydrolysis. Inorganic interference during COD experiment also can influence on that.(Boyles, n.d.) The main compounds that contribute to inorganic interference are nitrite, sulphide, ferrous and chloride.(Boyles, n.d.) However, the effect of chloride and ferrous is similar to both set ups. Reduction of hydrogen sulphide in gas phase suggest less amount in liquid phase. Thus, high concentration of nitrite in R2E can be suggested as the reason for COD enhancement.

Increase in nitrite concentration proves that ammonia consumption in the nitrification process during micro aeration. Ammonia concentration in gas phase also has reduced which suggest less ammonia in the liquid phase. This result is similar to the results obtained by (Nhu Hien et al., 2017). Thus, it can be suggested that the simultaneous removal of ammonia and sulphate compounds has happened by means of equation (2). Thus, it can be concluded that SRAO is the simultaneous removal mechanism of sulphate and ammonia.

CONCLUSIONS

This study conducted to investigate the effect of micro aeration on sulphate and ammonia rich wastewater during anaerobic digestion suggest that simultaneous removal of both ammonia and sulphate can be achieved by micro aerating first reactor during the treatment of wastewater in a two staged reactor set up. This study suggest that simultaneous removal happen by the SRAO mechanism.

REFERENCES

Botheju, D., & Bakke, R. (2011). Oxygen effects in anaerobic digestion—A review. http://dx.doi.org/10.2174/1876400201104010001

Boyles, W. (n.d.). Technical Information Series, Booklet No. 9. 24.

Dai, X., Hu, C., Zhang, D., Dai, L., & Duan, N. (2017). Impact of a high ammonia-ammonium-pH system on methane-producing archaea and sulfate-reducing bacteria in mesophilic anaerobic digestion. Bioresource Technology, 245, 598–605. https://doi.org/10.1016/j.biortech.2017.08.208

Fdz-Polanco, F. (2001). New process for simultaneous removal of nitrogen and sulphur under anaerobic conditions. Water Research, 35(4), 1111–1114. https://doi.org/10.1016/S0043-1354(00)00474-7

Fdz-Polanco, F., Fdz-Polanco, M., Fernández, N., Urueña, M. A., García, P. A., & Villaverde, S. (2001a). Combining the biological nitrogen and sulfur cycles in anaerobic conditions. Water Science and Technology, 44(8), 77–84. https://doi.org/10.2166/wst.2001.0469

Fdz-Polanco, F., Fdz-Polanco, M., Fernández, N., Urueña, M. A., García, P. A., & Villaverde, S. (2001b). Combining the biological nitrogen and sulfur cycles in anaerobic conditions. Water Science and Technology, 44(8), 77–84. https://doi.org/10.2166/wst.2001.0469

Girotto, F., Peng, W., Rafieenia, R., & Cossu, R. (2018). Effect of Aeration Applied During Different Phases of Anaerobic Digestion. Waste and Biomass Valorization, 9(2), 161–174. https://doi.org/10.1007/s12649-016-9785-9

Johansen, J.-E., & Bakke, R. (2006). Enhancing hydrolysis with microaeration. Water Science and Technology, 53(8), 43–50. https://doi.org/10.2166/wst.2006.234

Khanal, S. K., & Huang, J.-C. (2006). Online Oxygen Control for Sulfide Oxidation in Anaerobic Treatment of High-Sulfate Wastewater. Water Environment Research, 78(4), 397–408. https://doi.org/10.2175/106143006X98804

Krayzelova, L., Bartacek, J., Díaz, I., Jeison, D., Volcke, E. I. P., & Jenicek, P. (2015). Microaeration for hydrogen sulfide removal during anaerobic treatment: A review. Reviews in Environmental Science and Bio/Technology, 14(4), 703–725. https://doi.org/10.1007/s11157-015-9386-2

Nguyen, D., & Khanal, S. K. (2018). A little breath of fresh air into an anaerobic system: How microaeration facilitates anaerobic digestion process. Biotechnology Advances, 36(7), 1971–1983. https://doi.org/10.1016/j.biotechadv.2018.08.007

Nhu Hien, N., Van Tuan, D., Nhat, P. T., Thi Thanh Van, T., Van Tam, N., Xuan Que, V. O. N., & Phuoc Dan, N. (2017). Application of Oxygen Limited Autotrophic Nitritation/Denitrification (OLAND) for anaerobic latex processing wastewater treatment. International Biodeterioration & Biodegradation, 124, 45–55. https://doi.org/10.1016/j.ibiod.2017.07.009