

Identification and Optimization Key Parameters for Anoxic Denitrification and Deodorization of a Novel A2/O Process

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Abstract— The performance and the characteristics of anoxic digestion of a laboratory scale A2/O were investigated for denitrification and deodorization. Key parameters such as; reflex ratio, dissolve oxygen (DO) and nitrogen load were studied to optimize chemical oxygen demand (COD), total nitrogen (TN), ammonia (NH₄-N), threshold odor number (TON) and sulfide removal in anoxic tank. The reflex ratios of 100%, 200% and 150% were optimal for summer, winter and spring, respectively. Optimum TON removal efficiency was 92% in summer, 93% in winter and 90% in spring. The TON value increased linearly with the concentration of sulfide. By increasing of influent DO the removal efficiency of TON and sulfide increased whereas denitrification process decrease. The system characteristic is high anoxic digestion for denitrification and deodorization.

Index Terms—A2O, Anoxic Digestion, BNR, Denitrification, Deodorization, TON, Wastewater

1 INTRODUCTION

With the increase of population, the physical and chemical aspect of water quality has also become a cause of concern as wastewater from different sources pose a high risk [1]. Worldwide, adequate sanitation and access to safe water is a big problem for billions of peoples [2], [3]. Acceptable quality of freshwater is the key for vital socio-economic functions. However, with expansion of industrial and agricultural activities led to widespread degradation of freshwater resources [4]. Therefore, need to control the level of pollutants entering receiving waters from point sources is of great importance [5].

Sewage wastewater is organic in nature contain nutrient compounds (e.g., nitrogen and phosphorus) [6], [7]. These nutrients can cause eutrophication into receiving freshwater bodies. There are number of wastewater treatment methods have been developed for biological nutrient removal (BNR) process. Anaerobic/anoxic/oxic (A2O) process generally includes a denitrification phase carried out by facultative heterotrophic microorganism in anoxic tank. In A2O processes, after anaerobic digestion sewage develop heavy odor which can lead to secondary pollution if not effectively managed [8]. Odor emissions can lead to psychological stress, loss of appetite, insomnia and irrational behavior [9]. Strongest odors of wastewater were derived from H₂S, SO₂, ammonia (NH₃), dimethyl sulfur (DMS) and benzyl mercaptan (alphenoluenthiol) [10].

Minimization of odor emissions from sewage treatment works is one of the most significant challenges to the water industry [11]. This paper mainly focuses on anoxic digestion of wastewater. Anoxic digestion mainly used for denitrification and deodorization from wastewater after anaerobic digestion.

2 MATERIAL AND METHODS

2.1 Reactor Setup

A lab-scale A2/O setup consisted of ABR (anaerobic baffled reactor), anoxic tank and oxic unit. Anoxic tank was constructed from PVC material with dimension 0.2 m long, 0.2 m wide and 1.0 m high with 32 L effective volume (Fig. 1). The device was equipped with DN10 outlets at different heights. Two peristaltic pumps were used to adjusted flow rates.

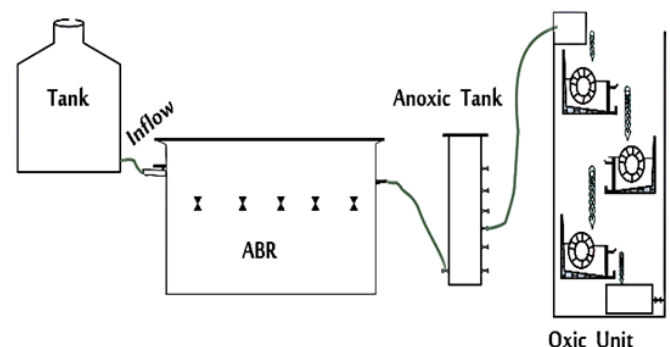


Fig. 1: Schematic diagram of A2O system

2.2 Experimental Procedure

The anoxic reactor was the part of A2O system. The experimental setup had been running for whole year. Air temperature during the summer, autumn and winter seasons was 25 – 35 °C, 15 – 20 °C and 3 – 12 °C respectively. Two inflows sim-

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ultaneously drained into the anoxic tank from the anaerobic reactor and the other from the oxic unit. ABR received water directly from storage tank. The ABR treated water then diverted to anoxic tank. The flow ratio from the oxic unit to that from the anaerobic reactor is called the reflux ratio. This ratio determines the DO concentration, carbon source and nitrate quantity in the anoxic tank, which are both parameters that affect the denitrification and deodorization process [12]. Therefore, the reflux ratio is one of the most significant parameters affecting the anoxic treatment. Different parameters were investigated at different reflex ratios. During autumn and spring season temperature range was similar hence considered single season.

2.3 Analytical Methods

Chemical oxygen demand (COD), ammonia ($\text{NH}_4^+\text{-N}$), total nitrogen (TN), sulfate and hydrogen sulfide (H_2S) were analyzed according to standard methods [13]. Dissolved oxygen (DO) and pH were analysed by DO200 and PH100 probes (YSI), respectively.

3 RESULT AND DISCUSSION

3.1 Reflex Ration impact on COD, $\text{NH}_4^+\text{-N}$ and TN removal

Four different sets of reflex ratio were adjusted during all seasons. 25% , 50% , 100% , 150% for summer; 100% , 150% , 200% , 250% for summer; and 50% , 100% , 150% , 200% for spring and autumn. The removal efficiencies of COD, $\text{NH}_4^+\text{-N}$ and TN during study seasons are shown in Fig. 2 (a-c).

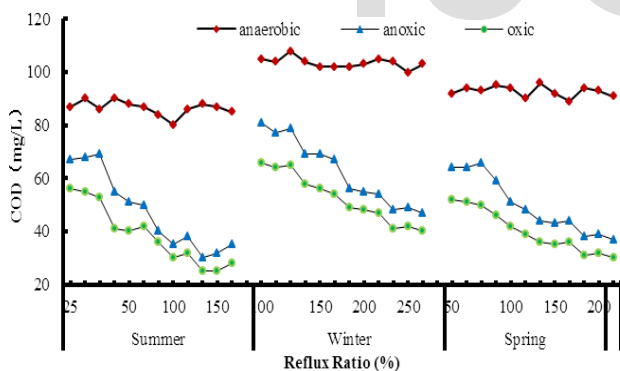


Fig 2(a): Effect of reflux ratio on COD

The average influent concentrations of COD and $\text{NO}_3\text{-N}$ were 80.2–108 mg/ l and 20–29 mg/ l from ABR influent, and 25.5–66 mg/ l and 2.1–6.2 mg/ l from oxic unit, respectively. Increasing the reflux ratio increased the contaminant removal efficiency during all seasons. At higher reflex ratio, the influence on TN removal was more significant than that for the removal of COD and $\text{NH}_4^+\text{-N}$. TN removal in anoxic was largely dependent on the concentration of $\text{NO}_3\text{-N}$, which was mainly back from the oxic unit [14].

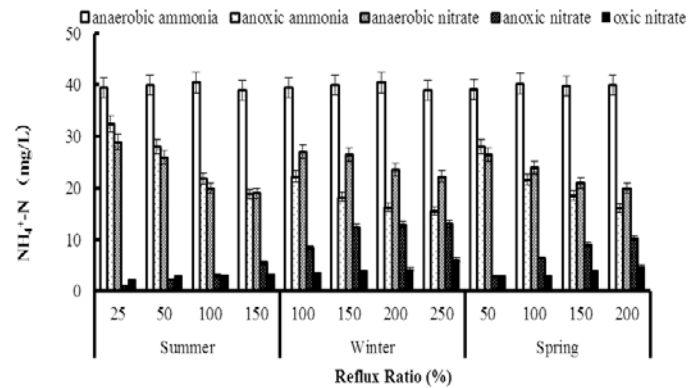


Fig 2(b): Effect of reflux ratio on $\text{NH}_4^+\text{-N}$

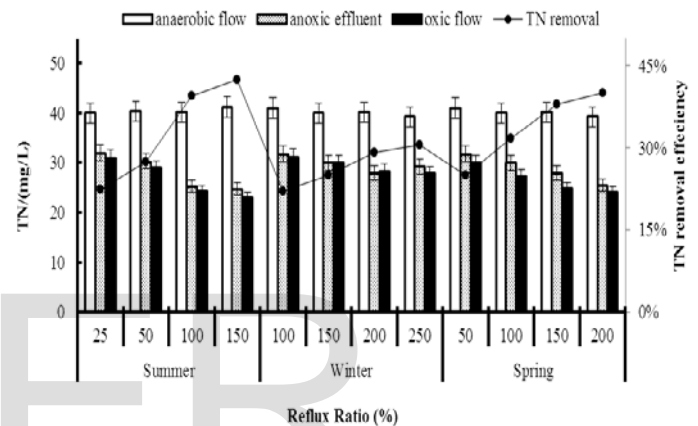


Fig 2(c): Effect of reflux ratio on TN removal

The TN removal rates were 22.5% - 42%; 22% - 30% and 25% - 40% during summer, winter and spring, respectively. During all study period at lower reflex ratio TN removal was high but when the reflux ratio increased, the increase in the TN removal efficiency was not remarkable. This result may be caused by nitrogen limitation in the anoxic zone [15]. Therefore, reflex ratio of 100% for summer, 200% for winter and 150% for spring were optimal.

3.2 Deodorization

Threshold Odor Number (TON) is refer to number of dilutions needed to reduce the concentration. Odor nuisance is a very common problem near wastewater treatment units. Odours in wastewater treatment arise mainly from the biodegradation of sewage, especially anaerobic degradation [16].

Fig. 3(a) showing the TON relationship with reflex ratios during studied seasons. TON removal reached to 92%, 93% and 90% during summer, winter and spring respectively. During all seasons at high reflex ratios removal efficiency was improved. During summer deodorization was higher as compare to spring and winter. The same trend was observed in Fig. 3(b), between reflex ratio and hydrogen sulfide. Removal efficiency was high with increase of reflex ratio, and during summer high deodorization occurred as compared to winter and spring.

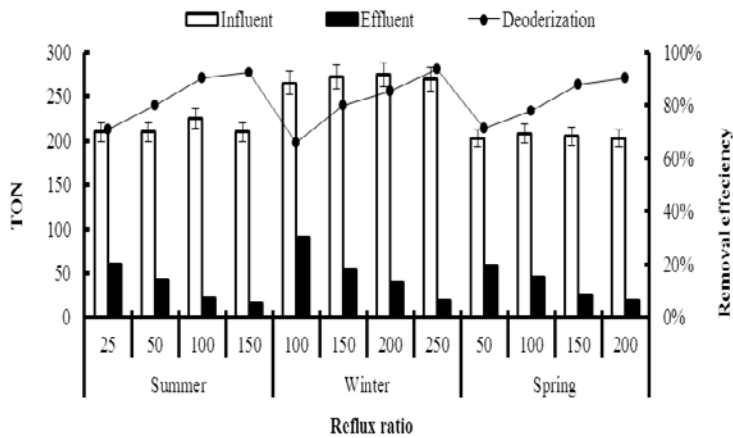


Fig 3(a): TON relation with reflex ratio

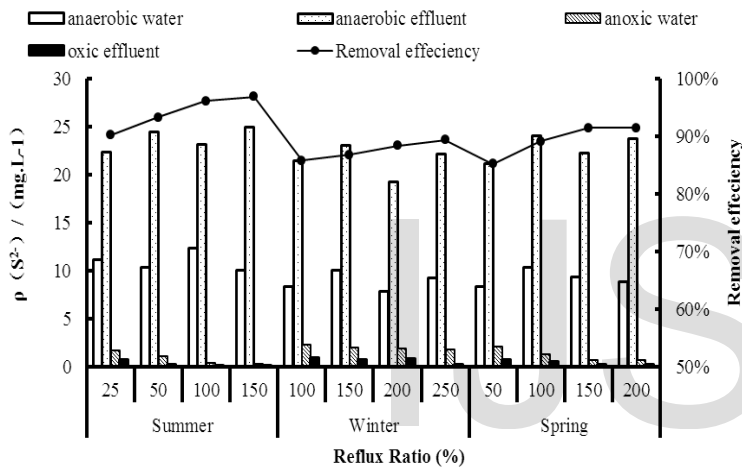


Fig 3(b): TON relation with sulfur

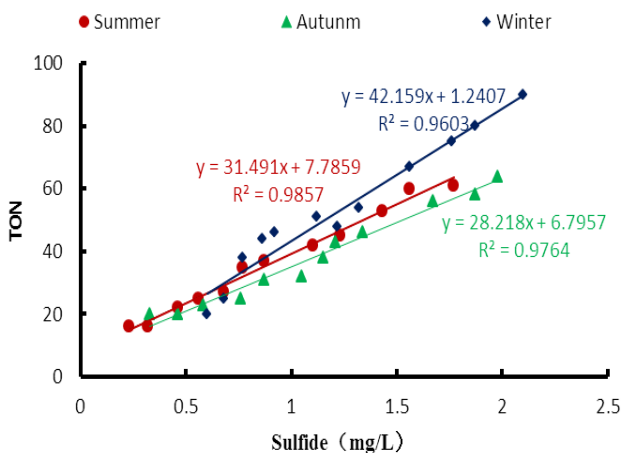


Fig. 3(c): TON and Sulfide relationship

Hydrogen sulphide gas (H_2S), sulfide (S^{2-}) and hydrogen sulfide (HS^-) are three forms of sulfides exist in wastewater.

Predominant source of odor in sewage is hydrogen sulphide (H_2S) [17]. The formation of H_2S arises from two sources: the reduction of sulphate and the desulphurisation of organic compounds containing sulphur in a reduced state [18]. The value of TON increased linearly with the concentration of sulfide (Fig. 3c) during all seasons, R_2 values are 0.9857, 0.9603 and 0.9764 during summer, winter and spring respectively.

The odor causing substances in wastewater are mostly at a very low redox potential formation [19]. The increased reflex ratios led to increased supply of nitrates and dissolved oxygen into the anoxic tank, which help to increase the oxidation-reduction potential of water can effectively inhibit the formation of odorous substances [20]. At the same time, increasing reflux ratio also helped to dilute odor causing substances.

3.3 Effect of nitrogen load and DO on sulfide and TON removal

The effects of nitrogen loading and DO on sulfide and TON removal were studied by adjusting reflex ratios (Fig. 4(a) and 4(b)). In anoxic tank reflex ratios defined the influent nitrate load and DO concentration. DO is critical factor to determining whether anaerobic or aerobic bacteria will dominate the breakdown of organic material in the wastewater. If DO concentration is in excess of 1.0 mg/L, aerobic bacteria will likely dominate the activity, particularly on the outer layers of an attached biofilm. Consequently, increased DO will reduce the production of sulfide by limiting the food reaching the anaerobic bacteria [21].

As Fig. 4(a) shows, nitrate loading significantly affect sulfide and TON removal. Both processes increased by increased of nitrate load. Initially, during all seasons when the influent nitrate load increased TON removal increased significantly as well as sulfide. But later sulfide and TON removal efficiency increased little with increased of influent nitrate, especially during summer and spring. This is because of lower temperature during winter compare to summer and spring. Low temperature during winter limits the activity of microorganism.

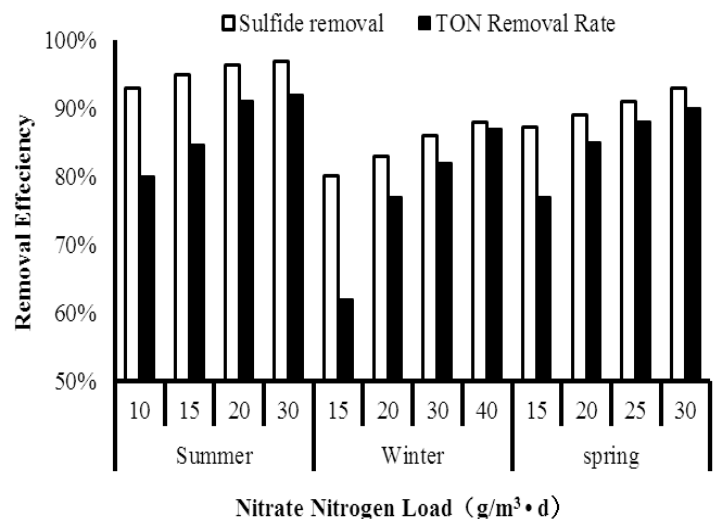


Fig. 4(a): Nitrogen load impact on removal efficiency of sulfide and TON

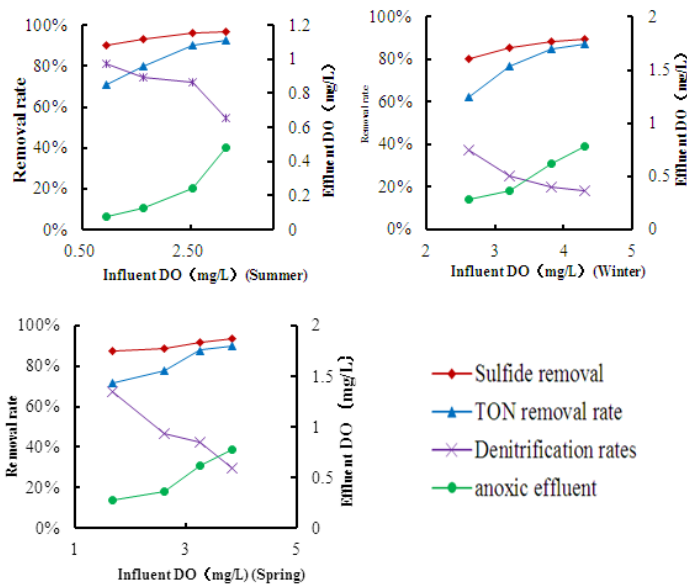


Fig. 4(b): DO impact on removal efficiency of sulfide and TON

Figure 4(b) shows the relation of DO with sulfide and TON removal. Influent DO was 0.95 - 3.15 mg/l, 2.62-3.4 mg/l and 1.68-3.83 mg/l during summer, winter and spring, respectively. The removal efficiency of sulfide and TON were 0.90-0.96% and 70-90%, 80-89% and 62-87%, 87-93% and 71-90% during summer, winter and spring, respectively. With the increased of influent DO, sulfide and TON removal efficiency also increased. Sulfide inhibition depends on the composition and components of biomass, temperature and the concentration of H_2S in the wastewater [22]. The efficiency of sulfide oxidation drops significantly at low temperatures and became inhibited below $15.6^\circ C$ (Sublette et al. 1998). In the presence of oxygen responsible bacteria in wastewater oxidise ionic sulfide species to nonodorous sulfur species. While denitrification processes reduce from 81-54%, 37-18% and 67-29% during summer, winter and spring. It was most probably that denitrification only occurred under anoxic conditions, increased in DO concentration decrease in denitrifying rate and accumulation of nitrous oxide, nitric oxide, nitrite and then nitrate [23].

4 CONCLUSION

The main findings are the following:-

- Increasing the reflux ratio increased the contaminant removal efficiency during all seasons. The optimal reflux ratios for summer, winter and spring were 100%, 200% and 150%, respectively.
- TON removal reached to 92%, 93% and 90% during summer, winter and spring, respectively. Hydrogen sulfide removal was high with increase of reflux ratio. During summer high deodorization occurred as compared to winter and spring.
- The sulfide concentration showed linear association with TON.

- Nitrate load and DO improved the removal efficiency of Sulfide and TON. Moreover, increased DO concentration decreased denitrification process.
- The system characteristic is high anoxic digestion for denitrification and deodorization.

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