NITROGEN REMOVAL OF TEXTILE WASTEWATER BY COMBINED ANAEROBIC-AEROBIC SYSTEM

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Abstract

The discharges of textile wastewater containing nitrogen to the environment are undesirable because these nutrients accelerate eutrophication. Further problems occur because certain forms of nitrogen (ammonia, nitrite, and nitrate) are toxic to aquatic life or may lead to diseases in those who drink water contaminated with these compounds. A combined anaerobic-aerobic system was operated continuously for the treatment of textile wastewater. Cosmo balls were used to function as growth media for microorganisms in an anaerobic reactor, and activated carbon in the aerobic one. Effect of pH, dissolved oxygen, and organic changes in nitrification and denitrification processes was investigated. The results indicated that 85% ammonia nitrogen, 80%COD, and 65%BOD removal efficiencies could be obtained. Dissolved oxygen, pH were shown to have only slight influences on the nitrification process.

Keywords: Anaerobic, aerobic, cosmoball, nitrification, denitrification

Introduction

Nitrogenous pollutants from domestic and industrial wastewaters are responsible for promoting the eutrophication effect in ponds and lakes (Tchobanoglous and Burton, 1991). Thus, the removal of nitrogen compounds from wastewater is of increasing importance. Biological nitrogen removal involves two successive processes, i.e. nitrification and denitrification. The nitrification transforms ammonia to a more oxidized nitrogen compound such as nitrite or nitrate, which is then converted to nitrogen gas in the subsequent denitrification process (Kuenen and Robertson, 1988). These two processes are usually carried out in different reactors because the nitrification occurs under aerobic conditions while the denitrification prevails in the absence of oxygen (Hong *et al*., 1999). However, the two processes are complementary in many ways i.e. the former produces nitrite or nitrate, which is a reactant in denitrification, and reduces the pH that is raised in denitrification, while the latter generates the alkalinity that is required in nitrification (Chen *et al.,* 1998; Menoud *et al.,* 1999).

To develop a simple and efficient nitrogen removal system, a combined anae robic-aerobic system with Cosmo balls to function as growth media for microorganisms in the anaerobic system, has been used in this study to overcome the disadvantages of individual unit processes. In this study, the effectiveness of the combined anaerobic-aerobic processes to treat textile wastewater was discussed in terms of nitrogen removal.

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Materials and Methods

Textile Wastewater Source

The industrial wastewater used was collected from a textile factory located in the Balakong, Selangor State, Malaysia. The various waste streams from the wash down of the chemicals from bleaching, printing and dyeing processes were collected and combined in a storage tank. Since the combined wastewater was in the alkaline pH range (8.7 - 10.8), the pH was adjusted to around neutral mark by adding a concentrated solution (96% w/w) of sulfuric acid (H_2SO_4), prior to feeding into the bioreactors, in order to minimize any potential toxic and /or inhibitory effects on the biomass (Wongwikraw, 2000; Yamasmit, 2000). To enable the Wastewater Treatment model to run on a continuous basis, a collection of more than an 8 day retention time was built to allow for the routine discharges from the system occasionally. Wastewater characterization was done for the textile wastewater used for experimental practice (Table 1).

Experimental Set-up

A laboratory scale for a combined anae robic-aerobic system was designed and set up to investigate the effects of nitrogen removal (Figure 1). The anaerobic reactors made of PVC transparent with a diameter of 30 cm and height of 30 cm, the total working volume of the reactor was 18 litres. The reactor was filled up with Cosmo balls to function as the growth media for microorganisms in the system, and a total of 2-liter active sludge from palm oil mill was collected and fed into the reactor.

Table 1. Characteristics of Textile Wastewater used in the present study

Parameter	Value
pH	7.0
COD (mg/l)	500 ± 50.4
BOD_5 (mg/l)	188 ± 15.2
TSS (mg/l)	64 ± 8.5
VSS (mg/l)	56 ± 4.2

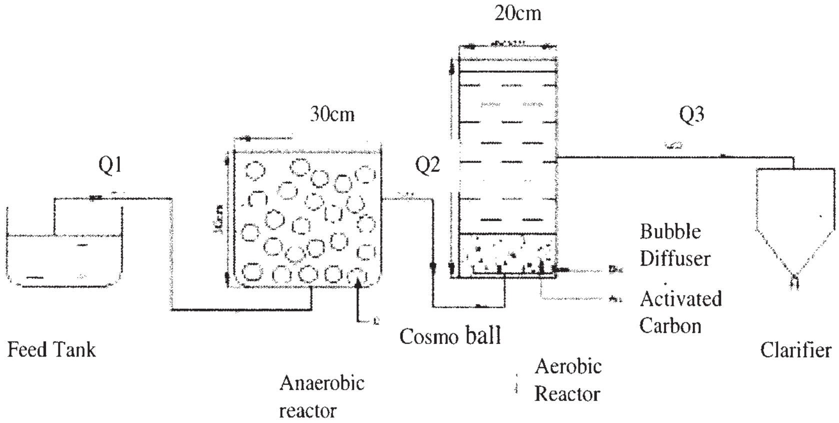

Figure 1. Schematic drawing of combined anaerobic- aerobic system

An aerobic reactor was made of PVC transparent with a diameter of 20 cm and height of 48 cm. The reactor was fed by 1 l sewage sludge, and then was followed by a clarifier tank and feed with effluent from the anaerobic reactor. Air was providing via diffuser at the bottom of the aerobic reactor. The study was carried out in four different hydraulic retention times: 24, 18, 12, and 8 respectively, with the operating conditions divided into 4 phases shown in Table 2. Each of the phases lasted for 14 days in order to allow biomass flocs to develop inside the reactors for biodegradation of the influent organic substrate.

Feeding Method

The first load of textile wastewater with organic loading rate (OLR) 1 kg COD/l/d was fed into the anaerobic reactor on 1st week and continued till the end of 2nd week. The influent COD was kept almost constantly (500 mg/l) throughout the entire 14-day period. The OLR was subsequently increased to 2 kg COD/l/d in Week 3 to Week 4. On Week 5 to Week 6, the OLR was further increased to 3 kg COD/l/d and finally raised up to 4 kg COD/l/d for Week 7 to Week 8 to complete the 4 OLRs in this study. The OLR is corresponding to the HRT of 24, 18, 12, and 8 h respectively. The incremental increase of OLR was made after steady state conditions (SSC) were attained. The growth of new cells is offset by the death of old cells. The SSC were considered to occur when the treated COD concentrations were constant for a period of 3 - 4 days.

Analytical Method

Liquid effluents were analyzed according to Standard Methods for Examination of Water and Wastewater (APHA, 1998). The following parameters were determined: pH, Chemical Oxygen Demand (COD), Biochemical Oxygen Demand (BOD), Volatile Suspended Solid (VSS), Total Suspended Solid (TSS), Ammonia,

Table 2. Operating Conditions of the Combined Anaerobic-Aerobic reactor

Parameter	Phase I	Phase II	Phase III	Phase IV
Period day-Continuous	1-14	15-28	29-42	43-63
HRT (Hrs)	24	18	12	8
OLR ($kg/m^3/d$)	1	2	3	4
Flow rate (liter/d)	18	24	36	54

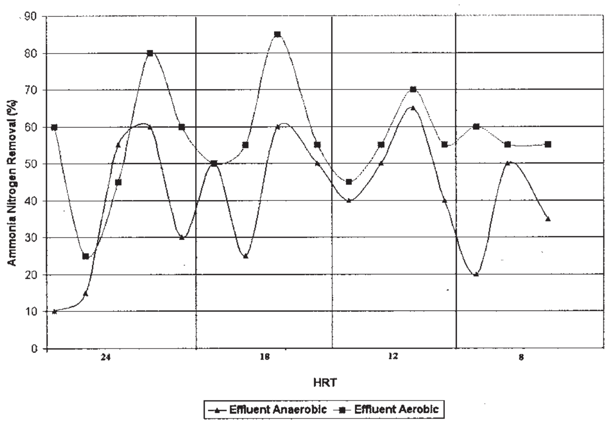

Figure 2. Effect of HRT on the removal of ammonia in the combined system

Nitrate, and Nitrite. Dissolved oxygen in the aerobic reactor was measured using an Ingold Transmitter (4300) and a polarographic electrode (Bernet *et al.,* 2000).

Results and Discussions

Combined System Acclimation

For most industrial wastewaters, an acclimation period is necessary in order to gradually expose the microbial community to the potentially inhibitory or toxic organic compounds present. This allows for the development of appropriate enzyme-producing genes that are essential to induce biodegradation (Chin *et al.,* 2002; Metcalf and Eddy, 2003). In this study, the feeding pattern, which followed (described in feeding method), appeared to be successful. It should be noted that despite the relatively low biodegradability potential of the wastewater used, acclimatized biomass was able to remove a much higher amount of organic matter.

Total Nitrogen Removal

In phase I where the HRT was around 24 and OLR applied was 1 kg COD/m3/d, anaerobic reactor achieved removal efficiency of 60%, while the aerobic system achieved 80% NH_4-N removal (Figure 2). In phase II the HRT was reduced to 18, and the OLR increased to 2 kg COD/m3/d, anaerobic reactor kept the previous value of removal efficiency (60%), while the aerobic reactor reached 85% in removal efficiency of NH_4-N. The result from phases (III-IV) indicated that any further decrease in the HRT with the increase of OLR, result in the gradual reduction in the removal efficiency of the both reactors (Figure 2).

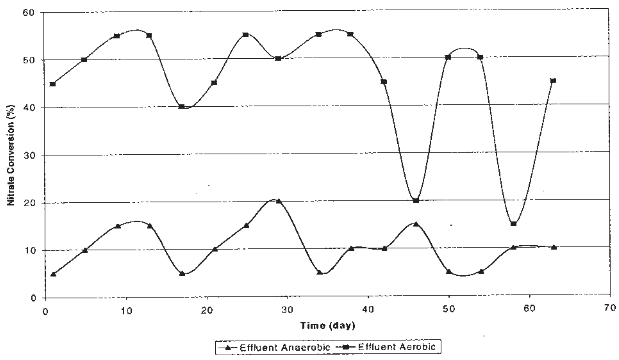

Figure 3. Nitrate Conversion during the treatment process

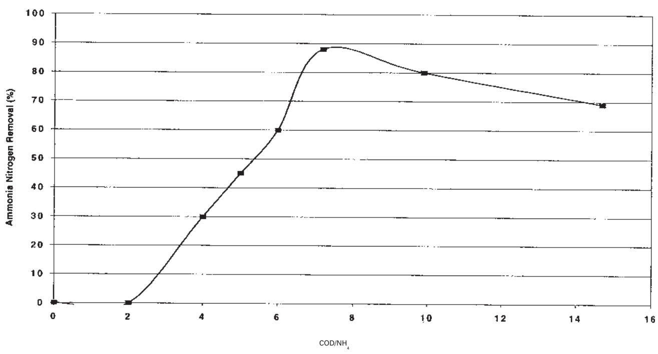

Figure 4. The relation of COD/NH_4 Ratio and NH_4-N removal (%)

The average NH_4-N removal rate was high about (85%) in the aerobic system when compared with the anaerobic system, which achieved only (60%) as in Figure 2. It was found that the final treated effluent in the aerobic system was low when compared with that in the anaerobic system. This was due to the nitrification process, which had occurred, in the aerobic system. The nitrification process was not 100% completed due to the high organic load, and the time needed for the regeneration of biofilm was too short to allow adequate colonization of nitrifying bacteria to occur (Macro *et al.,* 1997). Also the aeration time was too short to allow the completion of 100% nitrification process.

Figure 3 shows the conversion of nitrate for the combined treatment plant. It showed that the nitrate conversion in the aerobic system was twice as high as in the anaerobic one. This is due to the conversion of ammonia to nitrite and from nitrite to nitrate.

Influence of Organic Changes on Nitrification

Previous studies carried by Osada *et al.* (1991), showed that organic such as BOD and COD of the influent, effluent of anaerobic have great influence on the nitrification process. The result of this study shows that the removal of NH_4 increased with an increase of the organic loading materials and HRT. The COD/NH_4 ratio also has an influence on the removal and efficiencies of the Anaerobic-Aerobic process. The result of this study shows that there is no effect of ammonia removal within the range of 0 to 2.0 (Figure 4). The optimum COD/NH_4 ratio for removal of ammonia is 7.2.

Lee *et al.* (1997) reported that the amm onia removal efficiencies decreased with an increase in NH_4 loading of wastewater. The result also showed that at influent COD/NH_4 of 7.2, 9.9, and 14.7, the removal efficiencies in the combined system are 88%, 80%, and 69% respectively.

Osada *et al.* (1991) confirmed that the optimum influent COD/NH_4 ratio for nitrogen removal was around 14.0. At high influent COD/ NH_4 ratios, nitrogen removal efficiency was limited by incomplete ammonia oxidation, as the high organic load was not removed in the unaerated zone that affects the nitrification process. Although ammonia was completely oxidized for lower COD/NH_4 ratios, there was also a corresponding build-up in the nitrite and nitrate concentration due to insufficient carbon for the denitrification (Osada *et al.,* 1991).

The pH value shows a slight difference between the systems. The average pH for anaerobic and aerobic system was 7.0 and 6.9 respectively. Figure 5 reflects the influence of pH on the nitrification rate. From the graph plotted in Figure 5 it was found that there are only small changes on the nitrification rate, caused by the pH range of 6.7 - 7.8.

The optimum pH of this study is 8.3 and the nitrification rate will fall almost to zero at pH 9.6 (Figure 5). Hofman and Lees (1953) and Qassim (1999) reported that the optimum pH for nitrification was in the range of 7.2 - 8.6. The

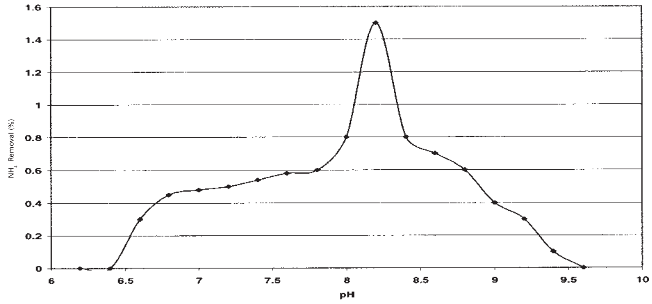

Figure 5. Influence of pH of the combined system on nitrification

nitrification practically stops when pH is below 6.3. In comparison with the results of this study, the pH obtained is still within the range of acceptation and will enhance the nitrification process.

Evaluation of Denitrification Rate

The denitrification rate varied during the 63 days of the process. The rate is largely dependent on the concentration of nitrate and volatile suspended solids on that particular day (Lee et al., 1997) (Figure 6). As can be seen in the Figure, the rate varies from 0.4 to 1.2 mg NO_3/ mg VSS.day.

Influence of Dissolved Oxygen Changes on Denitrification

Figure 7 shows the decrease of denitrification rate with the increase of dissolved oxygen concentration. It appears that the results from this study is comparable to previous one (Table 3), with the facts that the dissolved oxygen will inhibit the denitrification process, if it is present in a large amount. This is because the oxygen either represses the formation of the enzyme nitrate reductase or acts as an electron acceptor, thereby preventing the reduction of nitrate (Meyer, 1981).

Influence of pH on Denitrification Rate

Figure 8 shows the optimum pH of the combined system for the denitrification rate, which is 6.6 - 7.2, and the rate of denitrification was reduced with increasing pH.

As stated by Qasim (1999), the effect of pH on the nitrification is not significant if the denitrification is carried out when the ranges of pH are between 6.5 - 8.0. The optimal pH for the denitrification varies according to the types

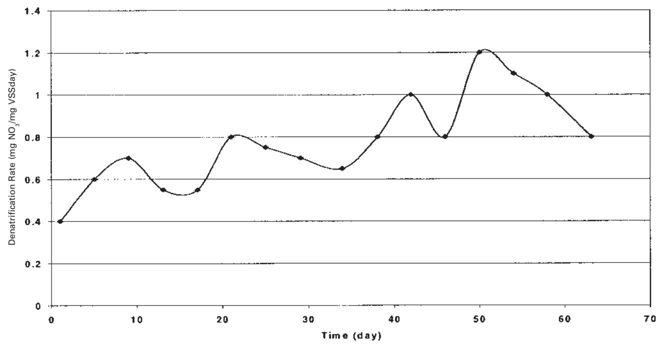

Figure 6. Denitrification rate over the time

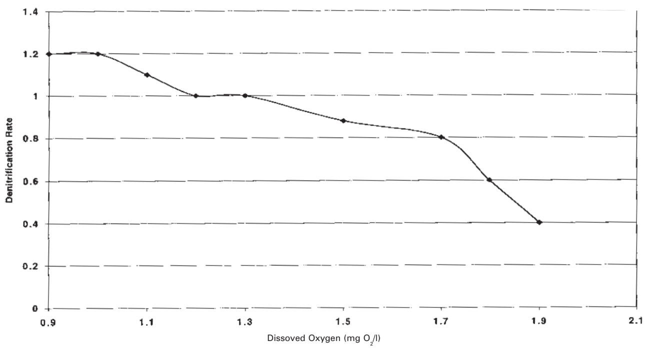

Figure 7. Influence of Dissolved oxygen on denitrification

of organisms present but in general a neutral or slight alkaline condition is suitable. Metcalf and eddy (1991) have also indicated the optimal pH between 7 and 8 with different optimums for different bacterial populations. However, the range of pH value used for the denitrification has varied from 7.0 to 7.5 (USEPA, 1975).

Organic Removal

Figures 9 and 10 shows the removal efficiency of BOD and COD in the anaerobic and aerobic reactors during the different HRT. It was observed that the removal rate of the both parameters (COD, BOD) in the aerobic system was higher when compared with that in the anaerobic system. In this study the anaerobic system achieves final BOD removal value of 40% in the effluent, while 65% removal for the effluent in the aerobic system (Figure 9). In anaerobic system, the COD removal achieved in the effluent was 50% whereas the value of 75% in the aerobic system (HRT = 8) (Figure 10).

Effect of Organic Loading on the Effluent Quality

The overall COD removal efficiency in anaerobic unit was in the range of 20 - 80% with average 45% for 24 - 12 h HRT. The maximum removal was obtained as 80% at HRT 24. Supportive activity of aerobic unit in COD removal was more significant compared to anaerobic one. It significantly enhanced the COD removal and higher COD removal efficiency 85% was observed in HRT 24 (Figure 10). This result of COD and BOD removal is in the same line with that obtained by Kapdan and Sabiha (2003).

Table 3. Influence of Dissolved oxygen on denitrification from previous studies compared with present study

Author	DO Concentration (mg O_2/l)
Henze and Harremoes (1983)	Below 0.5
Van Haute *et al.* (1981)	0
Harremoës *et al.* (1998)	> 6.4
Lee et al. (1997)	0.3-1.5
Qasim (1999)	0.1-0.2
Present Study	**0.9-2.0**

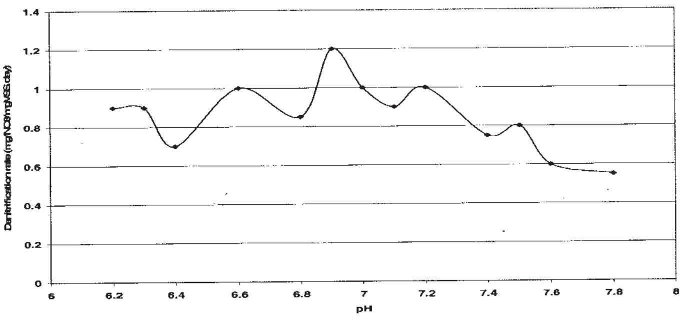

Figure 8. Influence of pH of the combined system on denitrification

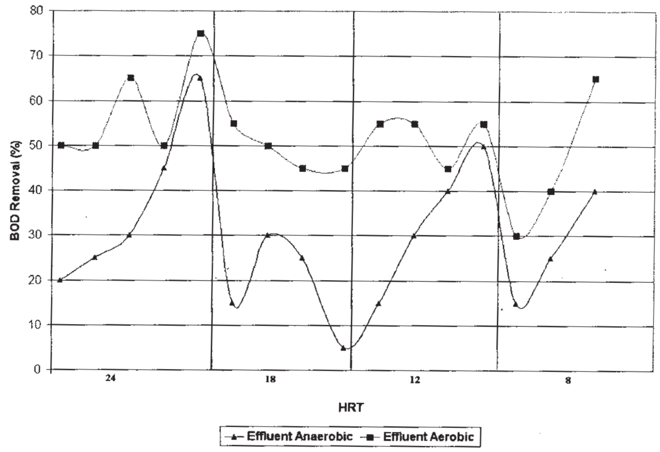

Figure 9. Effect of HRT on BOD removal of the combined system

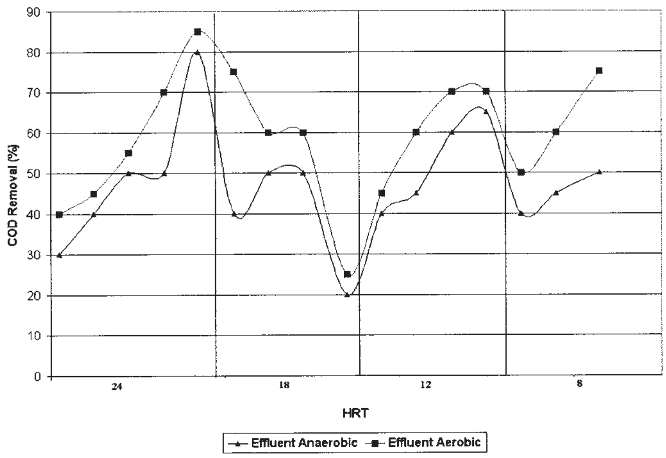

Figure 10. Effect of HRT on BOD removal of the combined system

Conclusions

The application of combined an aerobic-aerobic system for the treatment of ammonia nitrogen in the textile wastewater is acceptable. This system require the control of different factors, which affect the process, dissolved Oxygen (DO) is being one of the most important constraints to be considered. The presence of O_2 as electron acceptor in the water makes the inorganic nitrogen removal decrease, and increases the concentration of nitrite. This negative effect is increased with the rise in DO concentration and varies depending on the nature of the electron donor applied in the process.

The maximum removals of NH4-N, BOD, and COD, were 85%, 65%, and 75%, respectively. Dissolved oxygen, pH was shown to have only slight influences on the nitrification process. The optimum pH for Nitrification and denitrification is 8.3 and 6.8 respectively. The optimum COD/NH4 ratio for the removal of ammonia was found to be around 7.2.

The removal efficiencies of COD and BOD in the aerobic reactor are high than in the anaerobic one.

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