

Performance of upflow anoxic bioreactor for wastewater treatment

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ABSTRACT: Laboratory scale studies were conducted in an up-flow anoxic bioreactor (UFAB) using synthetic fertilizer wastewater for ascertaining the denitrification efficiency. The performance of the reactor was compared using ethanol and tapioca starch as the carbon source. The initial $\text{NO}_3\text{-N}$ concentrations (50-250 mg/L) and hydraulic retention time (HRT, 12-24 h) were varied to evaluate the COD and $\text{NO}_3\text{-N}$ removal. The results from this study shows that ethanol gave very good denitrification efficiency (78-98%) compared to tapioca starch (68-96%).

Key words: Denitrification, tapioca wastewater, up-flow anoxic bioreactor, HRT

INTRODUCTION

Nitrogen is one of the principal nutrients of concern in treated wastewater discharges. The increased use of nitrate ($\text{NO}_3\text{-N}$) fertilizers and discharge of partially treated industrial wastes to rivers leads to exceedingly high $\text{NO}_3\text{-N}$ levels in rivers and groundwater. High levels of $\text{NO}_3\text{-N}$ are a major contributing factor in the problem of eutrophication of water bodies. The drinking water standard set by the European Economic Community (EEC) for $\text{NO}_3\text{-N}$ is 50 mg/L, while 44 mg/L was set by the U.S. Environmental Protection Agency (USEPA). Nitrogen removal can be effectively accomplished by biological processes involving the nitrification and denitrification steps. Abu-Ghararah, 1996 investigated the influence of type of carbon source and $\text{NO}_3\text{-N}$ loading on the denitrification process of $\text{NO}_3\text{-N}$ contaminated drinking water in an anoxic static bed column. $\text{NO}_3\text{-N}$ loading in the range 0.240 -1.30 Kg $\text{NO}_3\text{-N}/\text{m}^3\cdot\text{day}$ was investigated. The results of the study have shown that the system should be operated at a maximum $\text{NO}_3\text{-N}$ loading of 0.45 Kg $\text{NO}_3\text{-N}/\text{m}^3\cdot\text{day}$ to treat waters having a $\text{NO}_3\text{-N}$ concentration of 500 mg/l to the allowable effluent $\text{NO}_3\text{-N}$ and $\text{NO}_2\text{-N}$ concentrations. Bilanovic, *et al.*, 1999 studied denitrification under high nitrite concentration in fed-batch mode. Methanol, sodium acetate and effluent from anaerobic digesters were compared as carbon

sources. A maximum nitrite removal rate was found to be 0.486 g $\text{NO}_3\text{-N}/\text{g VSS}\cdot\text{day}$. Nitrite accumulated initially but its concentration decreased with time and reached zero when acetate or other effluents were used as carbon source. Up-flow anoxic bioreactors (UFAB) are biological systems that have proved to achieve high denitrification rates under controlled operating conditions. The main objective of the present study is to evaluate the COD and $\text{NO}_3\text{-N}$ removal efficiency using HRT and influent $\text{NO}_3\text{-N}$ concentration as the independent variables.

MATERIALS AND METHODS

Experimental

The laboratory scale anoxic up-flow bioreactor used in this study is shown in Fig. 1. It was made of acrylic cylinder (100 mm ID*1100 mm height) having 8 lit capacity. Polyurethane foams in the form of 30 mm cubes were used as packing material which serves as supporting media for the micro-organisms in the reactor. The packed bed height was 64.5 cm. The reactor had perforated plates to hold the packing firmly. The perforations in the plate also ensured uniform distribution of influent wastewater through the reactor bed. The influent synthetic wastewater moved upward through the packed bed with different velocities based on hydraulic retention time (HRT). Along the reactor length, two taps were provided at heights of 23 cm and

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44.5 cm from the base which served as sampling ports. The final effluent was collected after the substrate had moved through the complete packed height of 64.5 cm. The CO_2 and CH_4 gases were collected through outlet tap in tubes by the downward displacement of water. The substrate was fed into the reactor continuously by a variable speed peristaltic pump.

Media composition

The synthetic fertilizer wastewater compositions as shown in Tables 1 and 2 were used in this study, Menoud, *et al.*, 1999. Tapioca starch slurry and ethanol were used as carbon sources.

Table 1: Synthetic fertilizer wastewater composition

Sl.No	Constituent	Composition
1	Glucose	1000 mg/L
2	NH_4NO_3	80 mg/L
3	KH_2PO_4	30 mg/L
4	K_2HPO_4	15 mg/L
5	Nutrient solution	1 mL

Table 2: Composition of nutrient solution

Sl.No	Chemical	Composition (g/L)
1	$\text{MgSO}_4 \cdot 7\text{H}_2\text{O}$	90
2	$\text{CaCl}_2 \cdot 2\text{H}_2\text{O}$	6
3	$\text{FeCl}_3 \cdot 6\text{H}_2\text{O}$	1.5
4	$\text{MnCl}_2 \cdot 4\text{H}_2\text{O}$	6.5
5	$\text{ZnSO}_4 \cdot 7\text{H}_2\text{O}$	1.7
6	$\text{CuCl}_2 \cdot 2\text{H}_2\text{O}$	0.1
7	$\text{CoCl}_2 \cdot 6\text{H}_2\text{O}$	1.9
8	$\text{NiSO}_4 \cdot 6\text{H}_2\text{O}$	6.5
9	H_3BO_3	0.1
10	$\text{Na}_2\text{MoO}_4 \cdot 2\text{H}_2\text{O}$	0.6
11	Yeast extract	1

Start up and acclimatization

Cow dung slurry of 8 L was fed regularly into the reactor with 24 h HRT for a period of about 4 weeks. Additionally, 500 mL of a mixture of sludge from a previously operated bioreactor and domestic sewage in equal proportion were also seeded for fast biofilm development. The pH of the cow dung slurry and sludge mixture was adjusted to 7.5 using sodium bicarbonate. After 4 weeks the cow dung slurry mixture was replaced by synthetic fertilizer wastewater at a rate of 10 % by volume in every 48 h till the cow dung slurry mixture was reduced to zero volume. The acclimatization step took 33 days for obtaining steady state removal of COD (40%) and biofilm development.

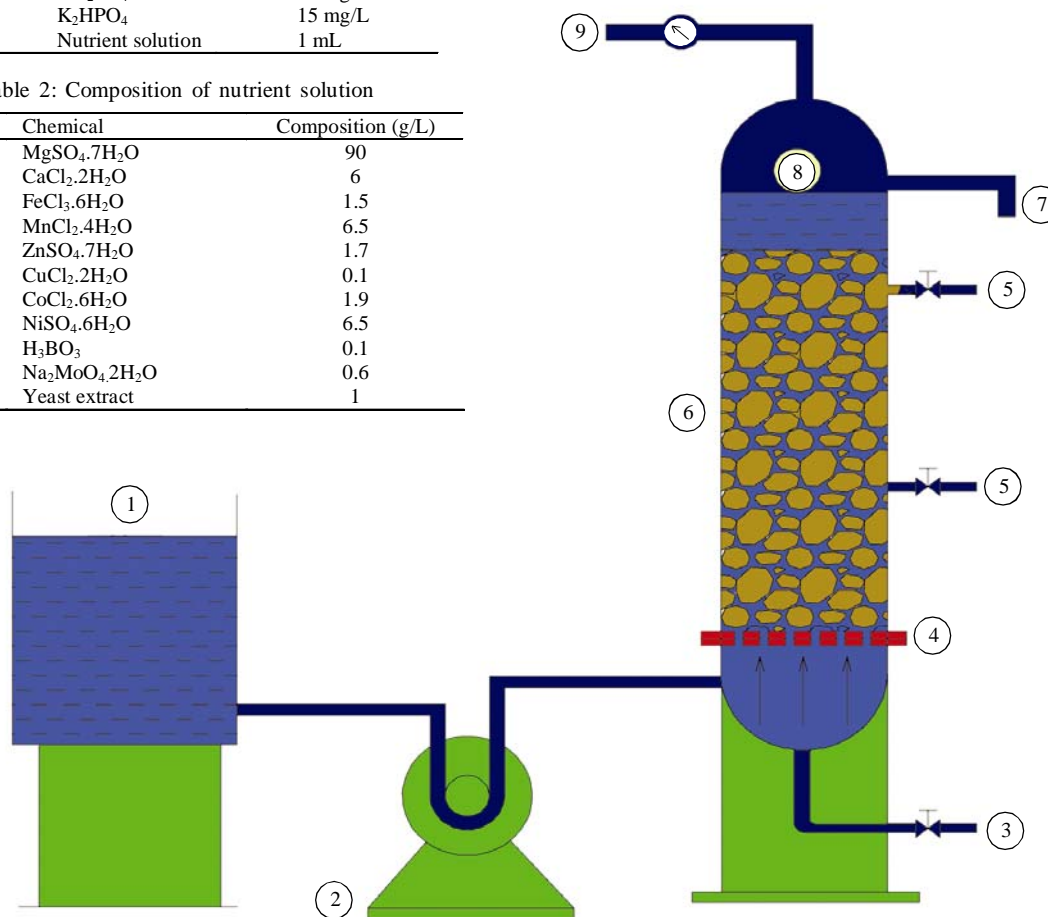


Fig. 1: Schematic of the experimental UFAB (1) Synthetic wastewater; (2) Peristaltic pump; (3) Draining port; (4) Perforated plate; (5) Sampling port; (6) Filter media; (7) Effluent outlet; (8) Liquid hold-up; (9) Gas collection and measurement

Experimental procedure

The required composition of synthetic fertilizer wastewater was prepared to a volume of 8 L and passed into the bioreactor at the required flow rate (0.66, 0.44, 0.33 L/h) with the help of a peristaltic pump. After acclimatization, during continuous experiments the influent $\text{NO}_3\text{-N}$ concentration was gradually increased in steps of 50 mg/L. 16 gm of tapioca starch powder was added to 8 litres of synthetic fertilizer wastewater. Similarly when carbon source was changed to ethanol, 6.25 mL of ethanol was added to 8 litres of synthetic fertilizer wastewater. These amounts were taken by determining the COD values of tapioca starch and ethanol. The dissolved oxygen values were maintained in the range of 0.6 to 1 mg/L. The HRT was varied between 12-24 h, while the $\text{NO}_3\text{-N}$ concentrations were between 50-250 mg/L depending on the carbon source. COD and $\text{NO}_3\text{-N}$ analysis were performed according to the procedure outlined in Standard Methods (APHA, 1992).

RESULTS

To understand the denitrification performance in UFAB using two different carbon sources, a synthetic wastewater of a known composition was fed to the bioreactor. During the start-up period the pH of the influent and effluent was monitored and was found to be fluctuating in a normal way (7-7.8). 33 days of acclimatization was considered sufficient for the bioreactor based on the results. During this period, glucose was used as the carbon source. A near steady state was observed in % COD removal for about five days (Fig. 2) following which regular experiments were performed to monitor the effect of HRT and influent $\text{NO}_3\text{-N}$ concentration on COD and $\text{NO}_3\text{-N}$ removal. Fig. 3 shows the percentage $\text{NO}_3\text{-N}$ nitrogen and COD removal efficiency variation with influent $\text{NO}_3\text{-N}$ concentration when tapioca starch was used as carbon source and HRT was 24 hours. As the influent concentration of $\text{NO}_3\text{-N}$ nitrogen increases (50 to 150 mg/L) the $\text{NO}_3\text{-N}$ nitrogen and COD removal efficiencies decreased.

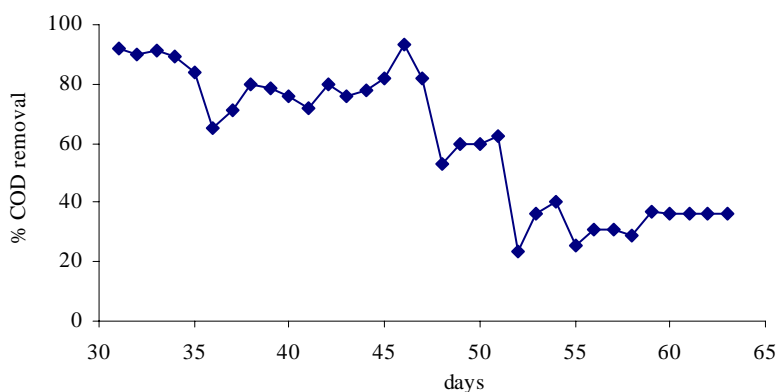


Fig. 2: Start up and acclimatization of anoxic bioreactor

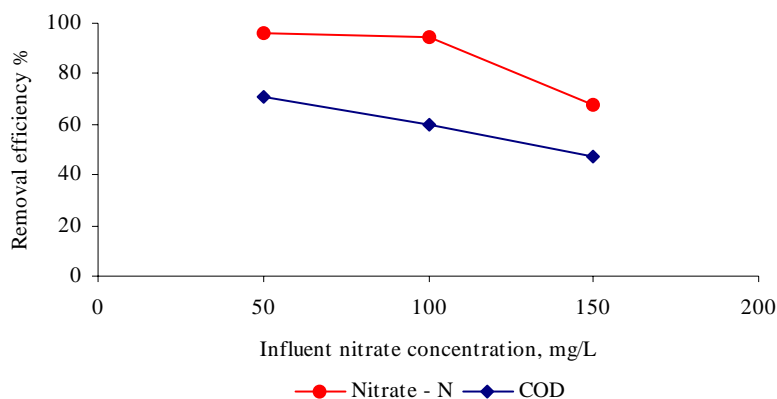
Fig. 3: Effect of Influent $\text{NO}_3\text{-N}$ concentration on Removal efficiency
(Carbon source: Tapioca starch, HRT: 24 h)

Fig. 4 shows the $\text{NO}_3\text{-N}$ and COD removal efficiency variation with influent $\text{NO}_3\text{-N}$ concentration when ethanol was used as carbon source and HRT was 24 h. As the influent concentration of $\text{NO}_3\text{-N}$ nitrogen increases (50 to 250 mg/L) the $\text{NO}_3\text{-N}$ nitrogen and COD removal efficiency decreased. Rajapakse and Scutt, 1999 investigated the treatment of synthetic wastewater (by dissolving NaNO_3 in tap water) using methanol as the carbon source. Their results reveal that, as influent $\text{NO}_3\text{-N}$ nitrogen concentration increased, denitrification efficiency decreased. This tendency is similar to the present results of the synthetic fertilizer wastewater investigation carried out.

From these figures, it is evident that ethanol yields better denitrification efficiency compared to tapioca starch. When tapioca starch was used as carbon source and influent concentration increased from 100 to 150

mg/L, $\text{NO}_3\text{-N}$ nitrogen removal efficiency drastically reduced by 26.6 %, whereas when ethanol was used as the carbon source $\text{NO}_3\text{-N}$ nitrogen removal efficiency is just reduced by 3.35 %. In the case of tapioca starch as carbon source, it has to undergo hydrolysis as well as acid production stages before it becomes an alcoholic compound. But ethanol being a direct alcohol acts quickly and serves as a ready carbon source. Probably this is the reason for the enhanced efficiency in the case of ethanol as carbon source. The $\text{NO}_3\text{-N}$ nitrogen and COD removal efficiency variation with HRT when tapioca starch and ethanol were used as carbon source and influent $\text{NO}_3\text{-N}$ concentration was 50 mg/L is shown in Figs. 5 and 6 respectively. It can be seen that the denitrification efficiency and % COD removal efficiency increased with increase in HRT.

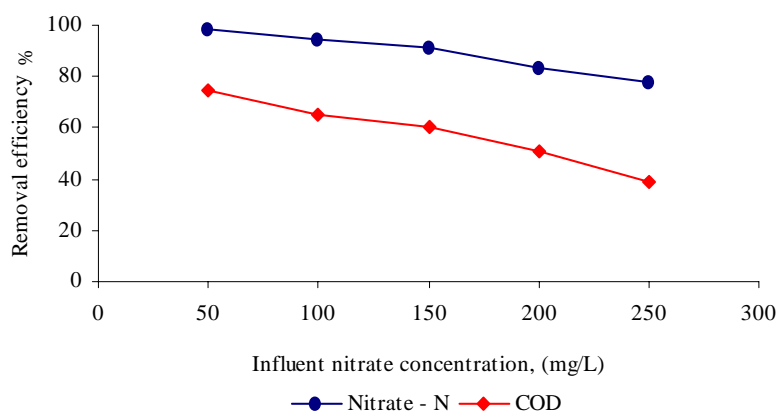


Fig. 4: Effect of influent $\text{NO}_3\text{-N}$ concentration on removal efficiency
(Carbon source: Ethanol, HRT: 24 h)

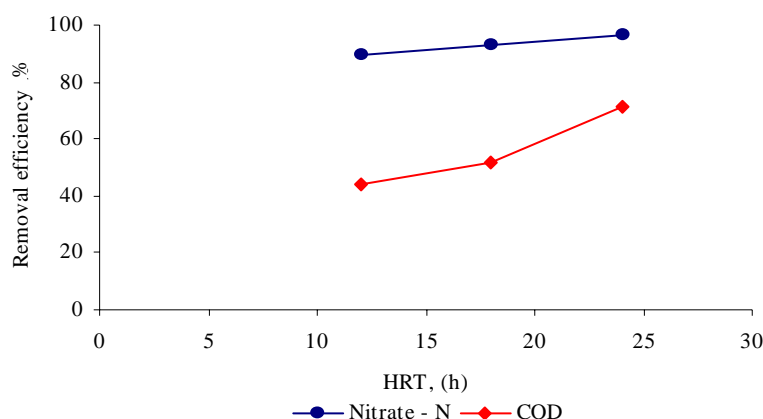


Fig. 5: Effect of HRT on removal efficiency
(Carbon source: Tapioca starch, Influent $\text{NO}_3\text{-N}$ concentration: 50 mg/L)

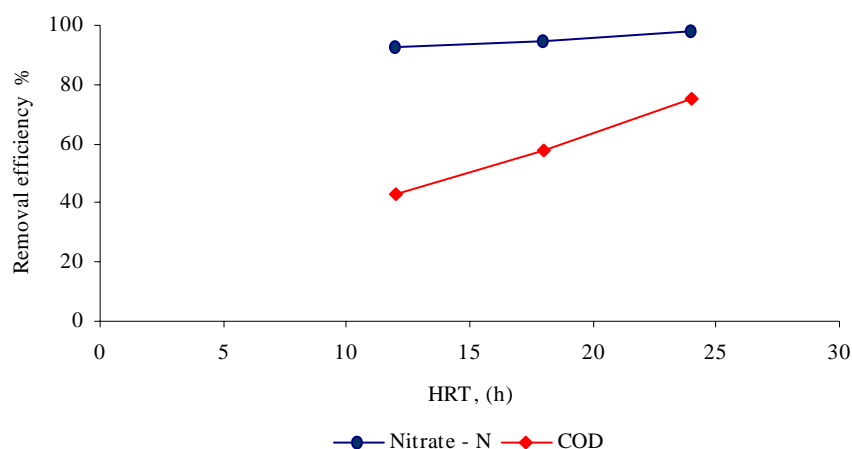


Fig. 6: Effect of HRT on removal efficiency
(Carbon source: Ethanol, Influent $\text{NO}_3\text{-N}$ concentration: 50 mg/L)

DISCUSSION AND CONCLUSION

An increase in $\text{NO}_3\text{-N}$ concentration in the influent (50 to 250 mg/L) decreases the $\text{NO}_3\text{-N}$ removal efficiency in UFAB. When tapioca starch was used as the carbon source, denitrification efficiency reduced from 96.4 to 68 % while the denitrification efficiency reduced from 98.2 to 78 % when influent $\text{NO}_3\text{-N}$ nitrogen concentration increased from 50 to 250 mg/L for ethanol. With increase in HRT, denitrification efficiency increases irrespective of type of carbon sources. But at minimum HRT of 12 h (taken in this study) ethanol yields better denitrification efficiency of 92.4 % compared to tapioca starch of 89.5 % at same influent $\text{NO}_3\text{-N}$ concentration of 50 mg/L. The results from this study can be applicable for treating tapioca and ethanol laden wastewater in field applications.

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