Scientia Iranica, Vol. 10, No. 3, pp 346–349
© Sharif University of Technology, July 2003

SCIENTIA
IRANICA

Research Note

Study of Hydraulic and Toxic Shocks in Two Anaerobic-Aerobic MBBRs Used for Nitrification and Denitrification

S. Jonoud[1] and M. Vossoughi*

Pilot Moving Bed Biofilm Reactors (MBBRs) fed on synthetic wastewater, were used in order to study nitrification and denitrification of high concentration wastewater. To investigate the stability of the nitrification and denitrification process in moving bed biofilm systems, a hydraulic shock and a toxic shock were applied to the system. These two systems showed high stability and process efficiency did not change significantly, in spite of intensive variation during the applied shocks.

INTRODUCTION

It has been proved that common methods of biological treatment have not the necessary performance for nitrogen removal. In biofilm processes, in which Sludge Retention Time (SRT) and Hydraulic Retention Time (HRT) are separated, nitrifying bacteria have enough time to nitrify ammonia (NH_4) in the absence of high COD in wastewater and, consequently, the carbonaceous bacteria have low ability for competition. Also, biofilm processes have proved to be more reliable than suspended systems for organic carbon and nitrogen removal without some problems of suspended growth systems [1]. Moving bed biofilm reactors are new biofilm systems with packings moving along the height of the reactor. The attached biomass increases the sludge retention time. About 80% of treatment processes are achieved by attached biomass.

The carriers are shaped to maximize growth by protecting the biofilm from abrasion [2]. This structure increases the stability and strength of the system against various changes, probable fluctuations or shocks [3]. The moving bed biofilm process was developed about 10 years ago by the Norwegian company Kaldnes Miljiteknologie, in cooperation with SINTEF, a Norwegian research organization [4,5].

The basic idea behind the MBBR was to have a continuously operating, non cloggable biofilm reactor with no need for backwashing, with a low head-loss and a high specific biofilm surface area [6,7]. To study the effect of intensive shocks on the nitrification and denitrification process in MBBR, two shocks, firstly hydraulic and secondly toxic, were applied. Both hydraulic retention time and toxic substances are effective parameters on the nitrification and denitrification process efficiency. The system which becomes stable quicker, is easier to control and is more reliable and stable.

MATERIALS AND METHODS

Two pilot anaerobic-aerobic MBBRs were used in this study in a pre-denitrification (Pre-DN) mode. The process is based on the biofilm principle and the biofilm bed consists of a small medium of small plastic elements. The plastic elements ($\rho = 0.9$ gr/cm^3) are about 13 mm long and 13.5 mm in diameter. The elements have corrugated walls to provide a high specific surface area. Both reactors were filled 65% in volume, providing a specific surface area equal to 192.5 m^2/m^3.

As shown in Figure 1, two series anaerobic-aerobic reactors were operated in pre-DN mode to study the effect of shock loads on the efficiency of the reactors. Pre-DN mode was chosen, in order not to have extra expense in adding an external carbon source to provide the high C/N ratio for the denitrification process.

This configuration also helps to reduce the flow of influent COD to the nitrification reactor that causes high rate nitrification. The recycling flow rate was

---

[1] *Department of Chemical and Petroleum Engineering, Sharif University of Technology, Tehran, I.R. Iran.*

* *Corresponding Author, Department of Chemical and Petroleum Engineering, Sharif University of Technology, Tehran, I.R. Iran.*

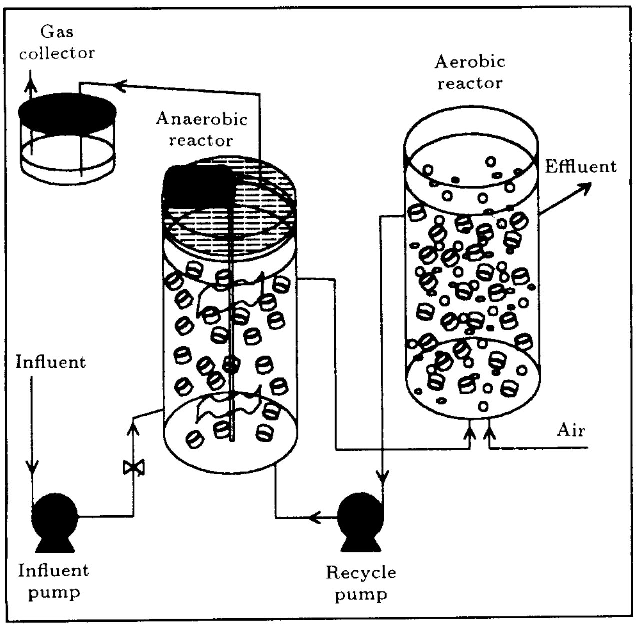

Figure 1. The experimental system of two pilot anaerobic-aerobic MBBRs used in this work.

about 1400 ml/h to maintain an adequate concentration of N-NO_3 in the anaerobic reactor. Specification of pilot-plant MBBRs are given in Table 1. Characteristics of feed during all experiments are shown in Table 2, all analyses were carried out according to Standard Methods [8].

A water lock is located higher up than the denitrification reactor and exiting biogas from the anaerobic reactor passes through a water column and exits from the water lock to prevent air entering the anaerobic reactor. The movement is caused by aeration in the aerobic version of the reactor and by a mechanical stirrer in the anoxic version. Experiments were carried out to study the effects of hydraulic and toxic shock on effluent COD, NO_3 and NH_4.

Table 1. Specification of the MBBRs system.

Item	Specification
Reactor	
Volume	9 lit
Dimension	Diameter: 14.5 cm, height: 54 cm
Impeller	
Diameter	10 cm
Shaft height	48 cm
Electro motor	DC, 5 Amp, 40 volt
Media	
Filling ratio	60%
Aeration for nitrification	coarse bubble
Feeding tank	
Volume	50 lit

For this purpose, during one of operation days when COD, NH_4 and HRT were 2000 mg/lit, 600 mg/lit and 24 h, respectively, the hydraulic retention time was suddenly changed to 8 h for one h. After applying this shock, data were taken each h.

To apply toxic shock, phenol was added to molasses in the feed as a carbon source. During this operation, COD and NH_4 were 1800 and 600 mg/lit and the HRT was held at 24 h. During feeding with phenol, everything was kept constant, but the COD was changed to 2500 mg/lit. Like the hydraulic shock after toxic shock, effluent COD, NH_4, NO_3 and anaerobic effluent NO_3 were measured.

RESULTS AND DISCUSSION

In Figures 2 to 4, the concentration of COD, NH_3-N and NO_3-N in the effluent of the aerobic reactor after hydraulic shock are shown. Although the hydraulic retention time during shock load was one third of normal operation, it did not affect on the system efficiency significantly. It can be seen that all the

Table 2. Characteristics of synthetic wastewater and experimental arrangement during shock loads.

Item	Concentration	Item	Concentration
NH_4(mg/lit)	100-200	$CuSO_4$(mg/lit)	2
NO_3(mg/lit)	0-10	NaCl (mg/lit)	0.7
$FeCl_3$(mg/lit)	0.4	COD (mg/lit)	1000-2000
$MgSO_4$(mg/lit)	3		
Shock Load	**Item**		**Experimental Arrangement**
Hydraulic shock	COD(mg/lit)		2000
	NH_4(mg/lit)		600
	HRT(h), ordinary operation		24
	HRT(h), shock load operation		8
Toxic shock	COD(mg/lit) with molasses		1800
	COD(mg/lit) with phenol		2500
	NH_4 (mg/lit)		600
	HRT(h)		24

parameters reach to their lowest degree in a short time at about 20 h and then remain approximately constant.

In Figure 5, the change of concentration of NO_3-N in the effluent of the anaerobic reactor is shown. The results obtained after toxic shock are different from those obtained after hydraulic shock.

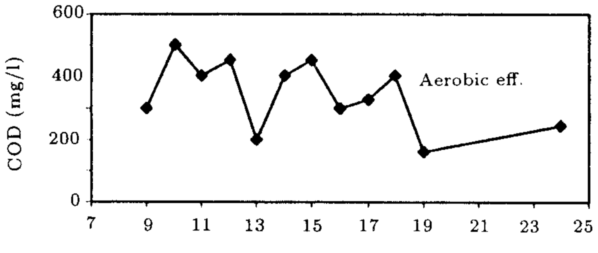

Figure 2. COD concentration profile after hydraulic shock.

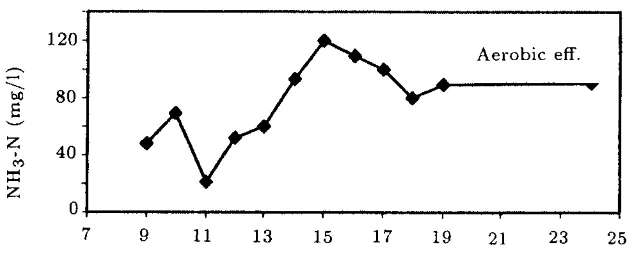

Figure 3. Amonia-nitrogen concentration profile after hydraulic shock.

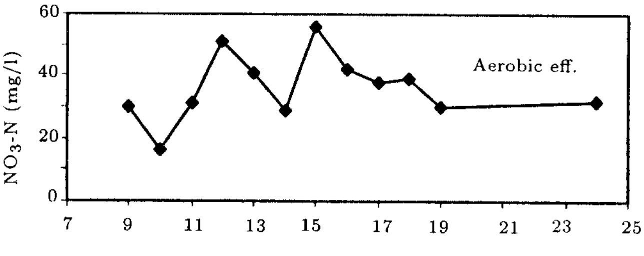

Figure 4. Nitrate-nitrogen concentration profile after hydraulic shock.

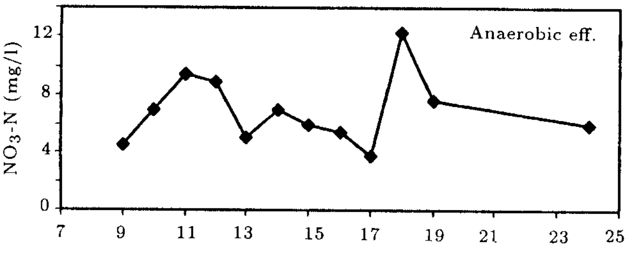

Figure 5. Evolution of concentration in the effluent of anaerobic reactor.

As can be observed in Figure 6, COD concentration increased after shock, therefore, it can be concluded that a part of the carbonaceous bacteria were damaged by toxic shock. However after about 15 h, the COD concentration decreased to 50 mg/lit.

Figures 7 and 8 show the concentration of ammonia and nitrate in the effluent from the aerobic reactor plant. In spite of the inhibiting effect of phenol on the nitrification process, the concentration of ammonia in the effluent decreases after 24 h. This result has been obtained because of the decreased ability of the bacteria, which compete with nitrifiers as mentioned before. In fact, the damaging effect of phenol on carbonaceous bacteria provides a suitable condition for nitrifiers to consume the dissolved oxygen in wastewater.

From the results mentioned above, it was ex-

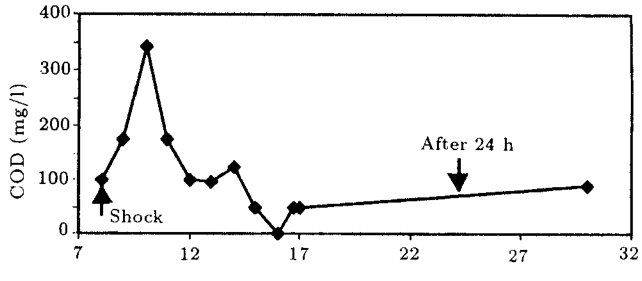

Figure 6. Concentration of COD in the effluent after toxic shock.

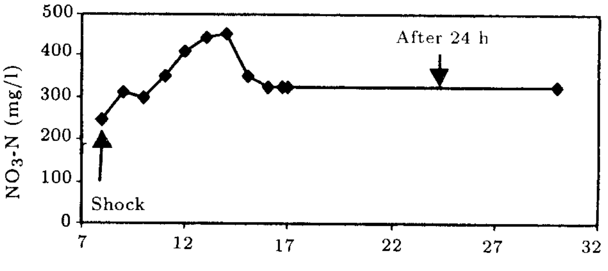

Figure 7. Concentration of NH_3-N in the effluent after toxic shock.

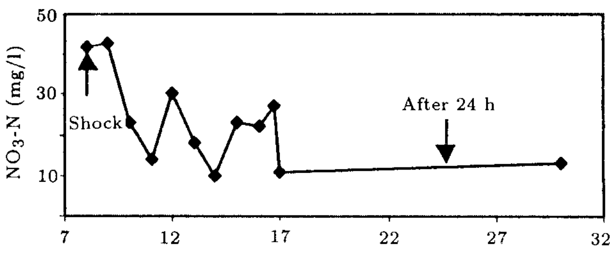

Figure 8. Concentration of NO_3-N in the effluent of aerobic reactor after toxic shock.

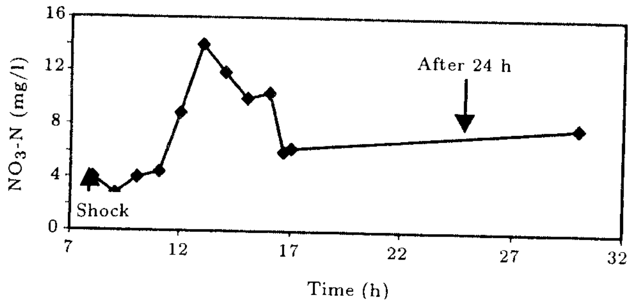

Figure 9. Concentration of NO3-N in the effluent of anaerobic reactor after toxic shock.

pected that the effluent NO_3 would increase because of the high performance nitrification that occurs in the aerobic reactor. However, it did not change from its initial amount, after becoming steady state, as shown in Figure 8.

These results can be explained by Figure 9, which shows the procedure of changes after toxic shock for the anaerobic effluent NO_3. In the denitrification reactor, there is a progressive rate for NO_3 removal that causes less anaerobic effluent NO_3 after toxic shock and, consequently, there is an approximately constant aerobic effluent NO_3, despite the increased nitrification rate.

Previously obtained results show that carbonaceous bacteria do not compete with denitrifiers, therefore, their decreased activity cannot be the reason for the increased removal rate of NO_3 in the anaerobic reactor.

It can be guessed that, probably, this high performance is because of the type of carbon source. However, it needs supplementary flask work experiments to obtain results regarding the behavior of denitrifiers against phenol as the carbon source.

CONCLUSION

Based on experiences received from the operation investigations in two anaerobic-aerobic MBBRs for nitrification and denitrification, the following conclusions may be drawn:

1. MBBRs show high stability against hydraulic shock. This is a good advantage for MBBRs in comparison with all suspended growth systems and some attached systems like RBC;
2. The nitrification and denitrification process in MBBRs get steady state in a short time after hydraulic shock, because of the presence of main bacteria in the biofilm;
3. Toxic shock applied by phenol has a damaging effect on COD removing bacteria and, therefore, effluent COD from the system does not decrease to its first amount, even after 24 h;
4. Effluent ammonia decreases after getting steady state, because, in the situation of inactivity of carbonaceous bacteria, nitrifiers can nitrify ammonia better;
5. Finally, MBBR has proven itself to be a reliable system, which is suitable in many situations without cousing serious change after flow fluctuation, even for the nitrification and denitrification process.

REFERENCES

1. Andreottola, G., et al. "Experimental comparison between MBBR and activated sludge system for the treatment of municipal wastewater", *Wat. Sci. Tech*, **41**(4-5), pp 177-185 (2000).
2. Rusten, B., et al. "Biological pretreatment of a chemical plant wastewater in high-rate MBBRs", *Wat. Sci. Tech.*, **39**(10-11), pp 257-264 (1999).
3. Hem, L.J. et al. "Nitrification in a MBBR", *Wat. Res.*, **23**(6), pp 1425-1433 (1994).
4. Odegaard, H., et al. "Small wastewater treatment plants based on moving bed biofilm reactors", *Wat. Sci. Tech.*, **28**(10), pp 351-359 (1993).
5. Odegaard, H., et al. "A new moving bed biofilm reactor-application and results", *Wat. Sci. Tech.*, **29**(10-11), pp 157-165 (1994).
6. Rusten, B., et al. "Nitrification of municipal wastewater in MBBRs", *Wat. Env. Res.*, **67**(1), pp 65-74 (1995).
7. Rusten, B., et al. "Upgrading of a biological-chemical treatment plant for cheese factory wastewater", *Wat. Sci. Tech.*, **34**(11), pp 41-49 (1996).
8. "Standard methods for the examination of water and wastewater", 18th Ed., *APHA, AWWA, WPCF*, Washington D.C., USA (1992).