TREATMENT OF TANNERY WASTEWATER BY INTERMITTENT CYCLE EXTENDED AERATION SYSTEM

Truong Trong Danh, Nguyen Dinh Tri, Nguyen Tan Phong

Ho Chi Minh City University of Technology (VNU HCM)

ABSTRACT

A continuous-flow sequencing batch reactor known as the intermittent cycle extended aeration system – sequencing batch reactor (ICEAS – SBR) was used to investigate the treatability of the tannery wastewater. A model made from poly acrylic with a capacity of 20 liters was utilized to evaluate COD and nitrogen removal while the loading rate increased up to 2.0 kg COD/m^3.day. The polyvinyl alcohol (PVA) media was used to compare with the non-media condition. At the loading rate of 1.5 kg COD/m^3.day with or without media, the removal efficiency was 83.57% and 79.17% COD, 54.01% and 43.33% TKN, 51.48% and 41.72% TN, respectively. It proved that PVA media helped increasing the removal efficiency. However, because of high concentration of the influent suspended solid and low C/N ratio input, the removal efficiency was not quite high.

***Keywords**: ICEAS, PVA, tannery wastewater*

1. INTRODUCTION

Tannery wastewater is a source of many environmental impacts. Tannery productive cycle includes a series of chemical treatments using several different chemicals such as surfactants, acid and metal organic dyes, natural or synthesis tanning agents, sulphonated oils, salts, etc. [1]. Due to a wide range of chemicals and their low biodegradability, the biological treatment of tannery wastewater is difficult and complicated. It is stated that sequencing batch reactor (SBR) is an effective system for COD removal in tannery wastewater [2]. Moreover, a low effluent nitrate concentration could be obtained in suitable COD/TKN ratio condition [3].

A modification of the SBR process is the intermittent cycle extended aeration system – sequencing batch reactor (ICEAS – SBR), which is operated on the principle of continuous influent as in the conventional activated sludge process, but has intermittent effluent withdrawing which is similar to the SBR system. ICEAS – SBR offers the advantages of easy operation and flexibility [4]. Many research proved ICEAS – SBR having high removal efficient in sewage wastewater [5-7], but its treatability in high concentration wastewater is not studied thoroughly.

On the other hand, the moving bed is usually used in order to enhance treatability of the system. The moving bed sequencing biofilm batch reactor (MBSBBR) is a combination of the SBR process and the moving bed batch reactor (MBBR) process. Some studies pointed that MBSBBR saw higher treatability than SBR [8-9]. This process is proved flexible, reliable and easy-to-operation (no clogging problems, little suspended solid in the reactor, easy to settle or decant) [10]. Similarly, the combination of ICEAS – SBR and MBBR, intermittent cycle extended aeration system – moving bed sequencing batch reactor (ICEAS – MBSBR), would have these advantages too. In this study, polyvinyl alcohol (PVA) gel was used to carry the bacteria with an effective surface area 2,554 m^2/m^3. It is claimed that bacteria which is growing inside the beads do not slough off in clusters and are protected from predation in the micro-scale pores of the PVA gel [11]. PVA gel traps the bacteria inside, it may boost the COD and nitrogen removal by increasing the bacteria concentration and creates the anoxic condition inside the gel. The objective of this study is to investigate the treatability of tannery wastewater by ICEAS with PVA used as biomass carrier.

2. MATERIALS AND METHODS

2.1. Raw wastewater, seed sludge

Raw tannery wastewater was collected at the first sedimentation tank (after the coagulation and flocculation) of wastewater treatment plant of Dang Tu Ki Company located at Le Minh Xuan Industrial Park, Binh Chanh District, Ho Chi Minh city. Compositions and properties of wastewater were represented as pH: 6.7 – 8.0; COD: 2,000 – 2,500 mg/L; SS: 850 – 1,000 mg/L; NH_4^+-N: 400 – 500 mg/L; TN: 500 – 600 mg/L; TP: 1 – 2 mg/L. The ICEAS influent was used at the suitable dilution ratio raw tannery wastewater. Seed sludge was taken from wastewater treatment plant of VISSAN Company, Binh Thanh District, Ho Chi Minh city. Seed sludge was light brown, well-settled with SVI being 92 and MLVSS/MLSS ratio being 0.70.

2.2. Reactor and operation

A 20-litre polyacrylic reactor were manufactured with dimensions 500 x 80 x 500 (L x W x H) (mm). A baffle was installed to divine the reactor to 2 parts: the pre – reactor and the main reactor with the ratio 1:4 (Figure 1). With the implementation of the baffle, the mixing between the pre – reactor and the main reactor generated during the decanting phase could be prevented. In addition, this baffle could eliminate the mixing in the reactor during the settle phase while the inlet is flowing in. An air pump and several diffusers provided required air and the DO was kept remaining 4 – 5 mg/L in the aeration phase. A mixing was used to create the anoxic condition with DO < 0.5 mg/L.

The reactor was operated at a hydraulic retention time (HRT) of 12 hours and a 40 L/day continuous flow. The cycle time was 8 hours including 7 hours for reacting, 0.5 hours for settling and 0.5 hours for decanting phase. The reacting phase consisted 2 hours of aeration then 3 hours of mixing and then 2 hours of aeration. All items in the process operated automatically and were controlled by timers.

The study was operated at different organic loading rates (OLRs): 0.5; 1.0; 1.5; 1.5 and 2.0 (with PVA) (kg COD/m^3.day). The mixed liquor suspended solid (MLSS) concentration of the seed sludge was approximately 3000 mg/l; pH in the tank varied from 6.5 to 7.5. In the second part of the study, PVA gel was added to 10% reactor volume (2 L).

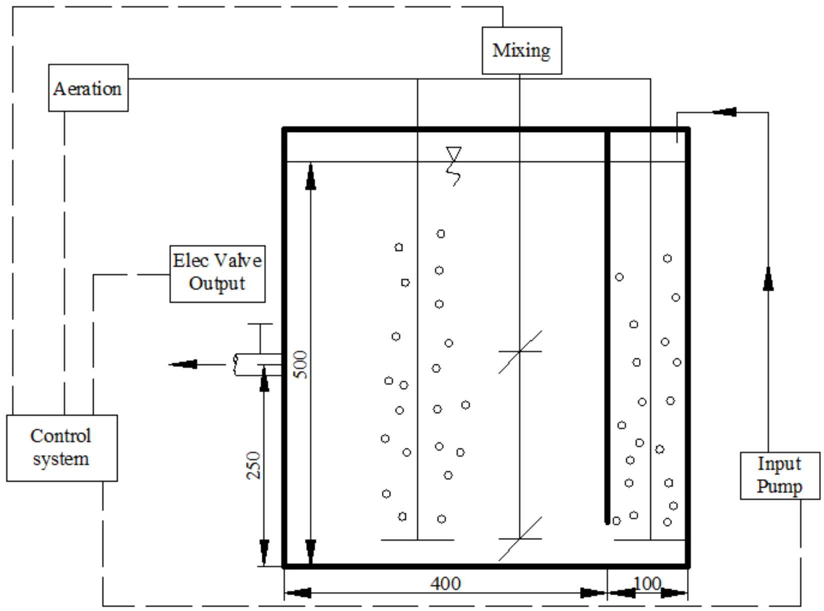

***Figure 1**: Schematic structure of ICEAS reactor.*

2.3. Analytical methods

The samples were collected at the influent and effluent positions of the reactor. The parameters of wastewater such as pH, COD, SS, TKN, NH_4^+-N, NO_2^--N, NO_3^--N, TN were analyzed according to Vietnam National Standards and Standard Methods for the Examination of Water and Wastewater (APHA, Eaton DA, and AWWA) at the Laboratory of Environmental Engineering, Faculty of Environment and Natural Resources, Ho Chi Minh City University of Technology (HCMUT). Biomass concentration was assessed at the last days of each organic loading rate.

3. RESULTS AND DISCUSSION

***Table 1:** Some average constituent values in different OLRs*

Constituent (mg/l) (Average)	Organic loading rate (kg COD/m^3.day)				
	0.5	1.0	1.5	1.5 (PVA)	2.0 (PVA)
COD influent	252	506	767	752	1014
COD effluent	23	83	161	123	235
TKN influent	55	116	195	194	249
TKN effluent	16	58	110	89	136
NO_3^- influent	0.15	0.4	0.39	1.09	0.48
NO_3^- effluent	15.73	8.71	1.12	2.44	0.83
TN influent	56	117	196	195	248
TN effluent	35	72	114	95	137
COD/NH_4^+ in ratio	5.25	5.01	4.51	4.50	4.67

Figure 2 shown the COD removal efficient in different OLRs. The COD removal efficient reduced when the OLR increased. In the OLR 1.5 kg COD/m^3/day, it could be seen the PVA gel helped to increase the COD removal efficient. It helped to reduce the COD effluent by 23% (from 161 to 123 mg COD/L, Table 1). However, the media only had a minor role in the COD removal.

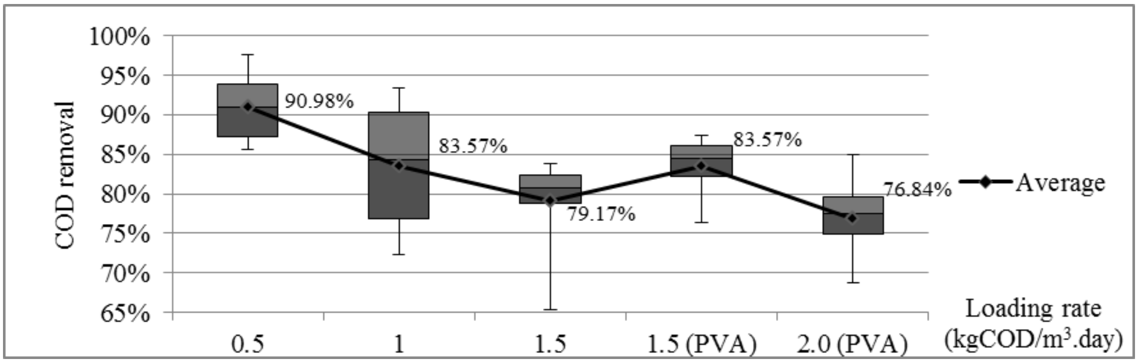

***Figure 2**: COD removal efficient in different OLRs (0.5; 1.0; 1.5 and 1.5; 2.0 with PVA gel).*

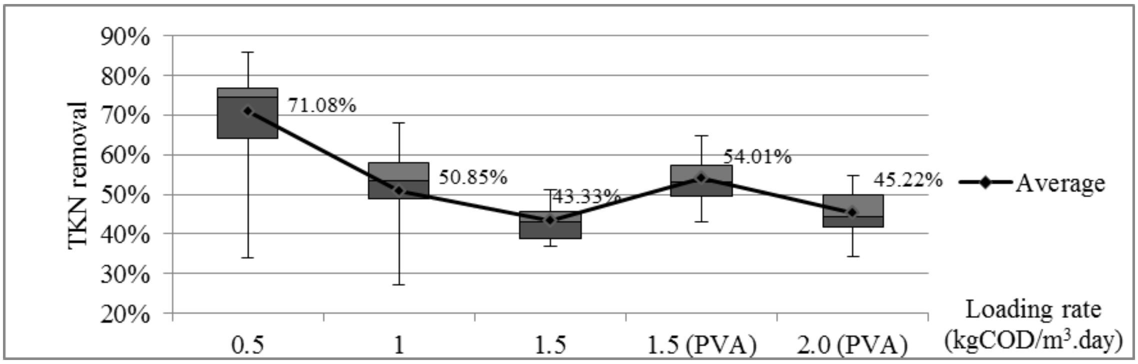

***Figure 3**: TKN removal efficient in different OLRs (0.5; 1.0; 1.5 and 1.5; 2.0 with PVA gel).*

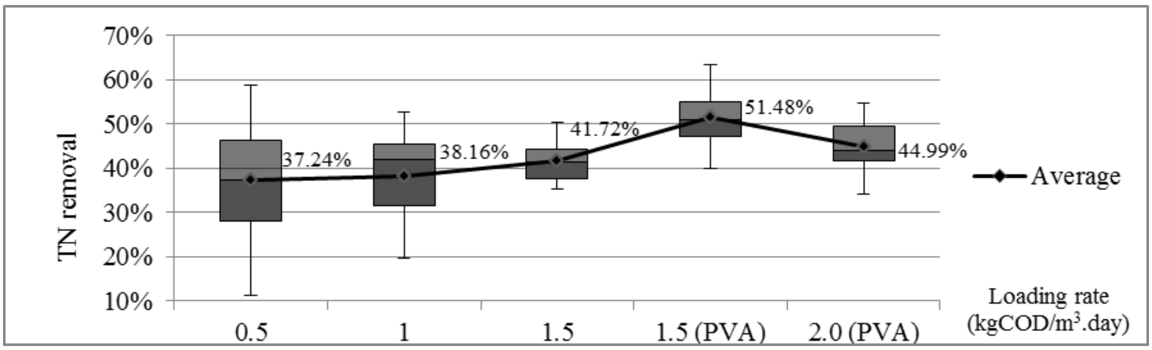

***Figure 4**: TN removal efficient in different OLRs (0.5; 1.0; 1.5 and 1.5; 2.0 with PVA gel).*

Fig. 3 and 4 represented the TKN and TN removal efficient. When the OLR increased, the TKN removal efficient decreased, similar to the COD removal, whereas the TN removal efficient increased. It could be explained as: High COD and TKN influent had negative effects on the aerobic sludge, so it leads to the declined of the COD and TKN removal efficient. However, their negative effects on the anaerobic sludge were not much. Moreover, the higher COD influent was a reason of the increase of TN removal efficient according by the following equation:

$$CH_2O + 0.711\ NO_3^- + 0.069\ NH_4^+ + 0.232\ HCO_3^- + 0.011\ H^+$$

$$\rightarrow 0.429\ C_5H_7NO_2 + 0.798\ CO_2 + 0.161\ N_2 + 0.635\ H_20$$ [12]

However, it saw a decline in TN removal during the OLR 2.0 kg COD/m^3/day. The NO_3^- effluent in this OLR was still lower than the previous OLR (this meant that denitrification efficient in this OLR still increased) but the NO_3^- proportion in TN was too low. So, that was the reason why, in the OLR 1.5 and 2.0kg/m^3/day, we assumed that TN removal efficient was equal to the TKN removal efficient and these two declined when the OLR increased. So that, since the denitrification efficient in the OLR 1.5 and 2.0kg/m^3/day was too high while the TKN efficient was low, the aeration time should be increased whereas the mixing time should be decreased.

On the other hand, PVA gel helped to increase the TN and TKN removal efficient too. However, the gel only contributed a small role (reduced TKN effluent from 110 to 89 mg TKN/L, TN effluent from 114 to 95 mg TN/L).

The low initial C/N ratio (6.3) was not relevant to NH_4 removal [13]. Since the COD/NH_4^+ ratio average of this research is in the range of 4.5 – 5.25, so the average TKN removal efficient was not high (from 43% to 54%). However, in the OLR 0.5 kg COD/m^3/day, the average TKN removal efficient was 71%, it could be explained as a small TKN amount was adsorbed in the sludge and helped to boost the TKN removal efficient. Furthermore, since the influent suspended solid was quite high (900 mg/l), inorganic solid was accumulated in the reactor and it lead to the decline of COD and nitrogen removal.

In order to enhance the performance, initial C/N ratio should be increased by adjusting the external carbon source (for example: methanol or acid acetic) and resolve the high influent suspended solid problem. In addition, this experiment used the diluted raw wastewater, it needs to have another experiments using the non – diluted raw wastewater.

4. CONCLUSIONS

The experimental study indicated when the OLRs increased, the COD and TKN removal efficient reduced while the TN removal efficient increased. The operation time should be adjusted in the OLR 1.5 and 2.0kg/m^3/day by increasing the aeration time and reducing the mixing time. It shown that PVA gel helped to boost the COD and nitrogen removal but the difference between the media and non – media condition was not much. Hence, comparing price and its effect, PVA is not worthy. Moreover, because of the low initial C/N ratio and high influent suspended solid, COD and nitrogen removal was not quite high. So external carbon source should be used and the coagulation and flocculation should be improved for better treatment efficiency.

REFERENCES

[1] Di Iaconi C., Lopez A., Ramadorai R., Di Pinto A.C. and Passino R. – Combined chemical and biological degradation of tannery wastewater by a periodic submerged filter (SBBR), Water Res. **36**(9) (2002) 2205–2214.

[2] Ganesh G., Balaji G., Ramanujam R.A. – Biodegradation of tannery wastewater using sequencing batch reactor - Respirometric assessment, Bioresource Technology **97**(15) (2006) 1815–1821.

[3] Carucci A., Chiavola A., Majone M. and Rolle E. – Treatment of tannery wastewater in a sequencing batch reactor, Water Sci. and Technol. **40**(1) (1999) 253–259.

[4] Khararjian H. A., Callaway W. H., Cardinal P. and Meany J. – Intermittent cycle extended aeration system (ICEAS R) for small wastewater treatment plants, Water Sci. Technol. **22**(3–4) (1990) 323–330.

[5] Chen A. C., Chang J. S. , Yang L. and Yang Y. H. – Nitrogen Removal from Sewage by Continuous Flow SBR System with Intermittent Aeration, Environmental Technology **22**(5) (2001) 553–559.

[6] Lee H., Brereton J. A., Mavinic D. S., Fiorante R. A., Oldham W. K. and Paisley J. K. – Nutrient Removal with Methanol as a Carbon Source Full-Scale Continuous Inflow SBR Application, Environmental Technology **22**(10) (2001) 1223–1235.

[7] Li Hongjing, Chen Yinguang, Gu Guowei, Liu Yandong – Phosphorous Removal in Intermittent Cycle Extended Aeration System Wastewater Treatment Plant - Effect of Temperature, Proceedings of the 2nd International Conference, Shanghai, 2008, pp.2970–2973.

[8] Kwannate Sombatsompop, Anusak Songpim, Sillapa Reabroi, Prapatpong Inkongngam – A comparative study of sequencing batch reactor and moving-bed sequencing batch reactor for piggery wastewater treatment, Maejo International Journal of Science and Technology **5**(02) (2011) 191–203.

[9] Jun-WeiLim, Poh-EngLim, Chye-EngSeng – Enhancement of nitrogen removal in moving bed sequencing batch reactor with intermittent aeration during REACT period, Journal of Chemical Engineering **197** (2012) 199–203.

[10] Giuseppe Pastorelli, Roberto Canziani, Luca Pedrazzi and Alberto Rozzi – Phosphorus and nitrogen removal in moving-bed sequencing batch biofilm reactors, Water Sci. and Technol. **40**(4–5) (1999) 169–176.

[11] Meta Levstek, Igor Plazl – Influence of carrier type on nitrification in the moving-bed biofilm process, Water Sci. and Technol. **59**(5) (2009) 875–882.

[12] C. P. Leslie Grady Jr., Glen T. Daigger, Nancy G. Love, Carlos D. M. Filipe. Biological Wastewater Treatment 3rd Edition, IWA publishing, London, UK, 2011, pp.88.

[13] Ying-Chih Chiu, Li-Ling Lee, Cheng-Nan Chang and Allen C. Chao – Control of carbon and ammonium ratio for simultaneous nitrification and denitrification in a sequencing batch bioreactor, International Biodeterioration & Biodegradation **59**(1) (2007) 1–7.

Article history:

– Received: Sep. 3.2016

– Accepted: Nov. 29.2016

– Email: *trongdanh0604@gmail.com*