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Study of hydrolysis and acidification process to minimize excess biomass production

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Abstract

In this paper, a new wastewater treatment process has been presented to minimize excess biomass production in which both excess sludge digestion and wastewater treatment are conducted simultaneously in the system. The process is modification of conventional activated sludge process with insertion of two facultative basins in the sludge return line. The excess biomass in the aeration tank is recirculated to the first facultative tank. It was observed that: (1) The amount of excess biomass is reduced to nearly aero when 5.95 g/day excess sludge is recirculated from the aeration tank to the first facultative tank at COD_{Cr} loading of 2.31 kg/m^3 day. A biomass experiment of 1000 mg/L was maintained at 2.31 kg-COD_{Cr}/m^3 day without drawing excess sludge for 6 months of experiment period. Inert organic substances did not seem to accumulate. The effluent quality has been well below the discharge limit. (2) On the basis of infrared spectroscopy proved that dye molecule in wastewater were firstly absorbed on the sludge, and then the bond energy of was gradually weakened and decomposed and eliminated lastly.

Keywords: Activated sludge treatment; Hydrolysis and acidification; Excess biomass minimization

1. Introduction

Through the long and continuous history of the activated sludge process, it has been proved efficient and economic ways for the treatment of dyeing wastewater. As the result of wide application and utilization of the process, excess sludge production has been presenting a serious problem for the operator to dispose of. Owing to the fact that excess sludge production has been considered as an inevitable drawback inherent to the activated sludge processes, and the failure of sludge minimization in the extended aeration process, many efforts have devoted on the sludge treatment after withdrawal of excess biomass from the activated sludge process, such as sludge digestion and dewatering. Recently, incineration and/or sludge melting process landfilling or agriculture have been taken into consideration to solve the problem. But because of the decrease of cultivable land and the care for human health, the sludge must undergo a further handling before it can be used in agriculture. The final removal of sludge is very difficult and costly; so people are more interested in a biological treatment process that can reduce the output of sludge [1].

In the recent years, many papers have introduced a series of methods of reducing excess biomass production in activated sludge biological treatment system [2–8]. Unfortunately, in most papers on the subject, the cost of using such schemes was ignored.

This study evaluates an innovative approach to minimize excess sludge production in the activated sludge process, in which both excess sludge digestion and wastewater treatment

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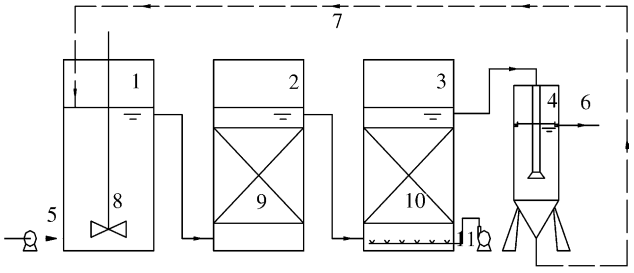


Fig. 1. Experiment apparatus: (1) 1# hydrolysis and acidification reaction tank; (2) 2# hydrolysis and acidification reaction tank; (3) aeration basin; (4) sedimentation basin; (5) inflow; (6) effluent water; (7) excess sludge; (8) rabbler; (9) hydrolysis filler; (10) aeration filler; (11) aerator pipe.

are conducted simultaneously in the system. The schematic diagram is shown in Fig. 1. The process consists of two facultative basins and an aeration tank. In this process, excess sludge is recirculated from the aeration tank to the first facultative basin. The hydrolysis and acidification in the facultative basins enhances the biological degradability of the sludge and turns excess sludge into liquid, which is decomposed in a subsequent aeration basin. In the system, the production of excess biomass minimizes and the cost enhance is not large. The effluent quality has been well below the discharge limit.

The change of organic compound in different pools is analyzed by infrared spectroscopy. The results of studies indicate that the dye molecules in wastewater were firstly absorbed on the sludge, and then the bond energy of the some structure in the organic compound was weakened by different tank treatment. It is in disposed to being decomposed and eliminated lastly.

2. Materials and methods

2.1. Experiment set-up

A continuous flow experimental apparatus is illustrated in Fig. 1. The process consisted of two 15.6 L rectangular facultative basins and a 15.6 L rectangular aeration tank. Three tanks made of transparent PVC material. The fillers were directly hanged in the second facultative tank and aerobic tank. The three reactors were run for over 6 months under identical conditions to reach steady state. The influent waste was fed to the reactor at an average rate of 25 mL/min.

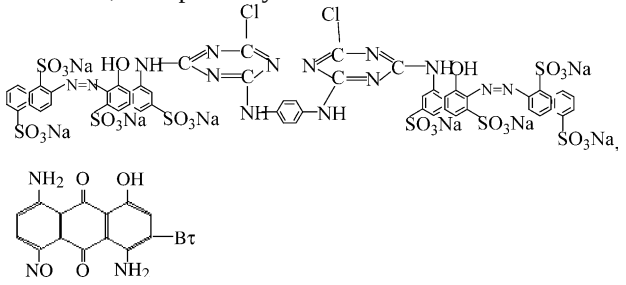
Table 2
Synthetic wastewater quality

[COD] (mg L^{-1})	980–1050
[SS] (mg L^{-1})	70–95
pH	8–9
Color (times)	~500

2.1.1. Water in Lab

Synthetic dyeing wastewater was used in the experiment. The composition and concentration of the wastewater are shown in Table 1.

The structural information of the Reactive Dye Red HE-7B and Disperse Blue 2BLN, which are containing in synthetic wastewater, is respectively:



The synthetic dyeing wastewater quality is shown in Table 2.

3. Methods and instrument

All analyses were made according to the PR China Standard methods. IR spectroscopy was made in Thermo Nicolet Corporation.

MLSS or SS (g/L): mixed liquor suspended solids.
MLVSS or VSS (g/L): mixed liquor volatile suspended solids.

4. Result and discussion

4.1. The analysis of excess biomass decrement

After experiment start-up COD_{Cr} concentrations was about 1000 mg/L. The speed of influent water was 25 mL/min, namely HRT was 10 h in every reactor tank and total HRT is 30 h in system. After test steady running the production of excess biomass is about 300 mL/day and excess biomass is not recirculated. Water content of excess biomass is 98.3 percent and the yield of dry sludge is 5.1 g/day. When

Table 1
The composition and concentration of simulated wastewater

	Composition				
	Reactive Dye Red HE-7B	Disperse Blue 2BLN	Glucose	Phosphate natrium	Urea
Concentration (g/L)	~0.3	~0.1	~20	~1	~1

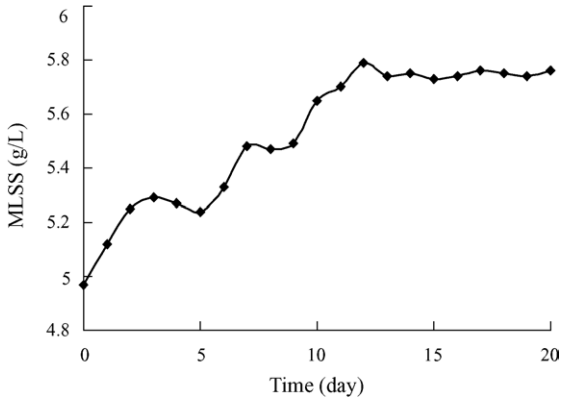


Fig. 2. MLSS concentrations in the first facultative tank.

excess biomass was recirculated MLSS concentrations in the first facultative tank were determined and are shown in Fig. 2.

In Fig. 2, MLSS concentration is 4.96 g/L before excess biomass recirculation (0 day). After excess biomass recirculated MLSS concentrations in the first facultative tank increased gradually and kept up about 5.76 g/L at last. It illuminates that there is the phenomenon of excess biomass accumulation from the first day to the 12 day after excess biomass recirculated to the first facultative tank. After 12 days, the balance was achieved between the amount of inverse excess biomass and hydrolyzed excess biomass in reactor tank. When excess biomass was recirculated continually they did not be accumulated. The results show that the first facultative reactor tank has the ability of hydrolysis and acidification excess biomass and can efficiently realize excess biomass decrement.

4.2. The analysis of VSS/SS

In the course of excess sludge recirculated VSS to SS ratios are determined so as to understand the effect of inverse sludge on sludge active and evaluate whether inert organic substances accumulated in the reactor tank.

Fig. 3 and Table 3 show the changes of VSS to SS ratio in the first facultative tank. It is seen that VSS to SS ratios

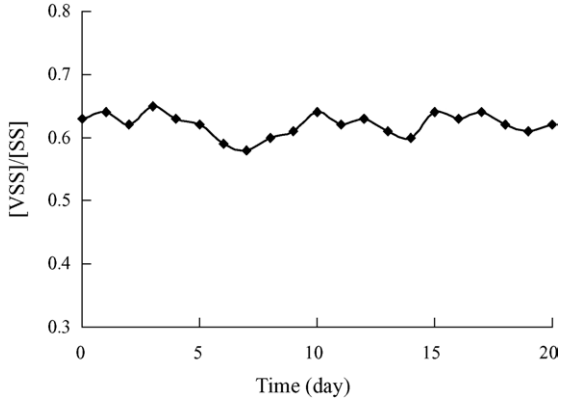


Fig. 3. Change of VSS to SS ratio in the first facultative tank.

Table 3
Result of VSS and SS in the first facultative tank

Time (day)	Items		
	SS ($g\,L^{-1}$)	VSS ($g\,L^{-1}$)	VSS/SS
0	4.96	3.14	0.63
1	5.12	3.27	0.64
2	5.25	3.26	0.62
3	5.29	3.45	0.65
4	5.27	3.31	0.63
5	5.24	3.26	0.62
6	5.33	3.16	0.59
7	5.48	3.19	0.58
8	5.47	3.27	0.60
9	5.49	3.35	0.61
10	5.65	3.63	0.64
11	5.7	3.55	0.62
12	5.79	3.64	0.63
13	5.74	3.52	0.61
14	5.75	3.47	0.60
15	5.73	3.66	0.64
16	5.74	3.63	0.63
17	5.76	3.70	0.64
18	5.75	3.56	0.62
19	5.74	3.51	0.61
20	5.76	3.58	0.62

rested about 0.61. The results prove not only living body cells in sludge were hydrolyzed but also a majority of the other involatile solid in sludge effectually was hydrolyzed. The residual non-biodegradable solid particles discharged the reactor tank under hydraulic washout. The inverse excess biomass were completely decomposed and not accumulated. The activity of hydrolyzed sludge was not affected. Inert organic substances did not seem to accumulate.

The control train was operated at constant operational conditions so as to determine the best inverse sludge ratio (R). The influent contained about 1000 mg/L of COD_{Cr}. The wastewater was treated at the temperature 25 °C and HRT 10 h in every reactor tank. The inverse excess biomass was gradually increased after MLSS concentrations stabilization.

In the experiment, the most inverse sludge amount is 350 mL/day. Because the recirculation of excess biomass advanced organic load in the aeration tank and enhanced the production of excess biomass in the system. When there are inverse sludge the most inverse sludge amount is the bigger than excess biomass discharge amount before excess biomass recirculated.

In Fig. 4 and Table 4, the results showed that MLSS concentrations increased whenever inverse sludge amount 50 mL, but MLSS concentrations could achieve balance after 5 or 6 days. When excess biomass entirely was recirculated MLSS concentrations in the first facultative reactor tank

Table 4
The different inverse sludge amount and inverse sludge ratio

	Inverse sludge amount (mL/day)					
	100	150	200	250	300	350
R (10^{-1})	2.86	4.29	5.71	7.14	8.57	10.00

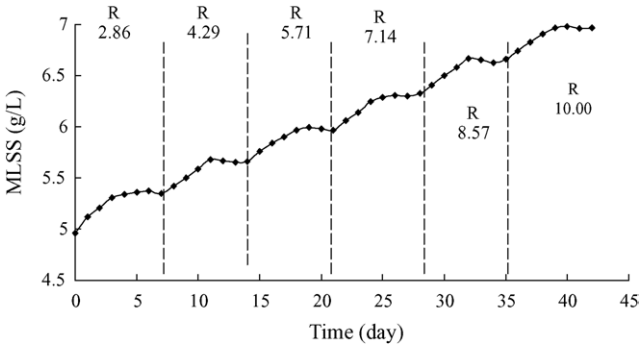


Fig. 4. Change of MLSS concentrations at different *R*.

attained a balance on about 6.97 g/L at last. It proves that the hydrolysis of excess biomass is a complex and slow biochemistry process and need quite long residence time. Because excess biomass could be degraded by hydrolysis acid production bacteria and could not appear the phenomenon of sludge continually accumulated. Even if all production excess biomass in the system were returned to the F_1 reactor tank ($R = 1$) MLSS concentrations could attain the balance, the amount of inverse excess biomass was almost equal to the amount of hydrolyzed excess sludge. This illuminates that the entire wastewater treatment system has quite big sludge disposal load and can realize excess biomass hardly emission.

4.3. Analysis of the effluent quality

When the reactors were run to reach steady state analysis of the influent and effluent water quality is shown in Table 5 on 1 day.

In Table 5, it can be seen that the effluent quality has been well below the discharge limit. It proved that the process cannot only realize to minimize excess sludge production but also can guarantee the effluent quality.

Table 5
The influent and effluent water quality

	[COD] (mg L^{-1})	[SS] (mg L^{-1})	pH	Color (times)
Influent	1035	90	8.7	512
Effluent	91	26	7.3	32

4.4. Organic compound analysis on sludge by IR spectroscopy

In every reactor tank, the absorption organic compounds on sludge were analyzed by infrared spectroscopy. Figs. 5–8 are the series of infrared spectrograms and show the structure change of the absorption organic compounds on sludge. The samples were dry sludge cake in different reactor tank.

1# spectrogram—dry sludge cake came from the first facultative tank;
2# spectrogram—dry sludge cake came from the second facultative tank;
3# spectrogram—dry sludge cake came from the aeration tank;
0# spectrogram—dry sludge cake came from the sedimentation tank.

From infrared spectrograms (Figs. 5–8), it is seen that:

1. In the range of 2000–1000 vibration frequency there are some characteristic infrared groups frequency. This is explained by that some structure organic compounds,

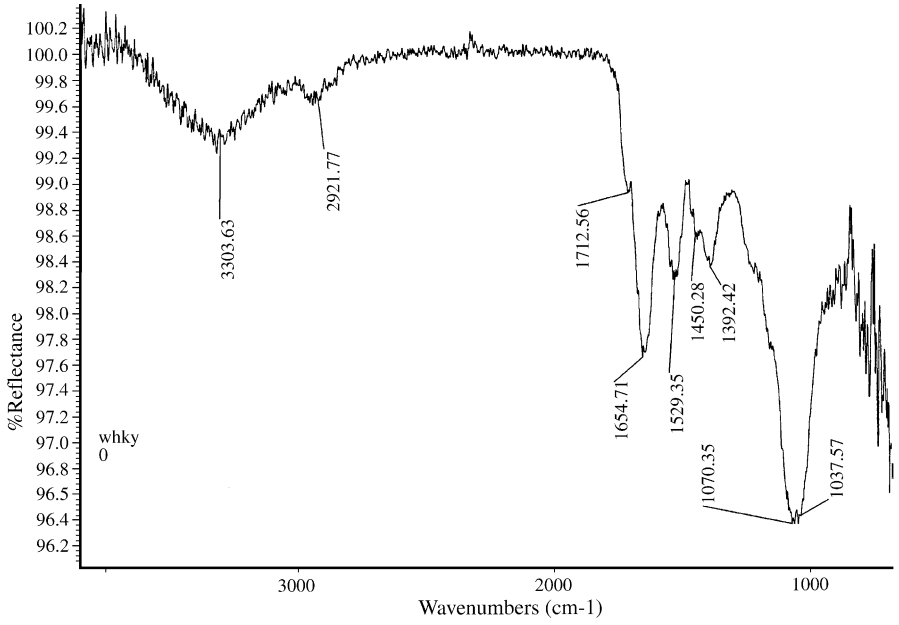


Fig. 5. 0# spectrogram—dry sludge cake came from the sedimentation tank.

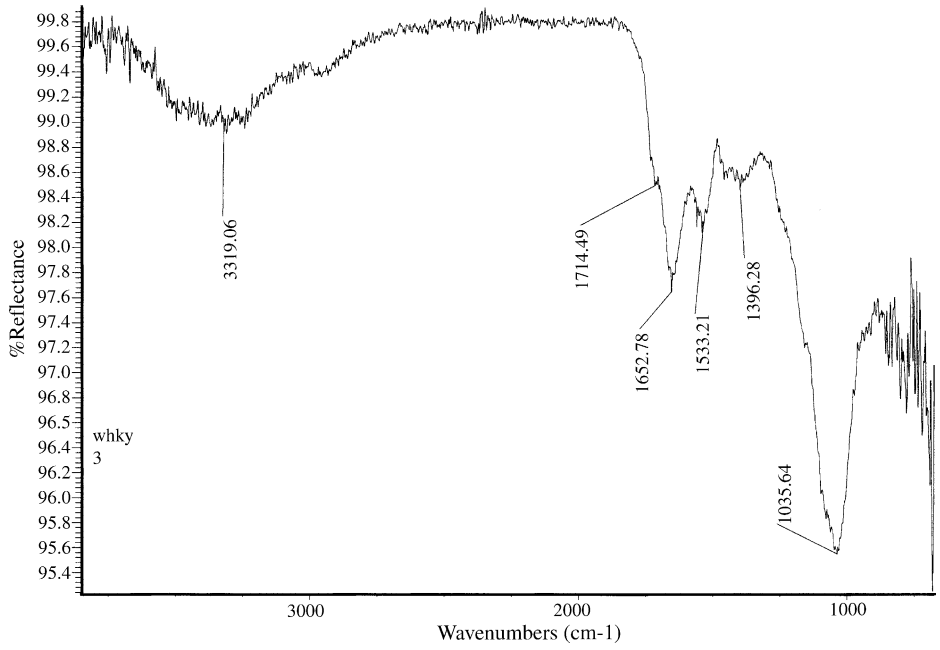


Fig. 6. 3# spectrogram—dry sludge cake came from the aeration tank.

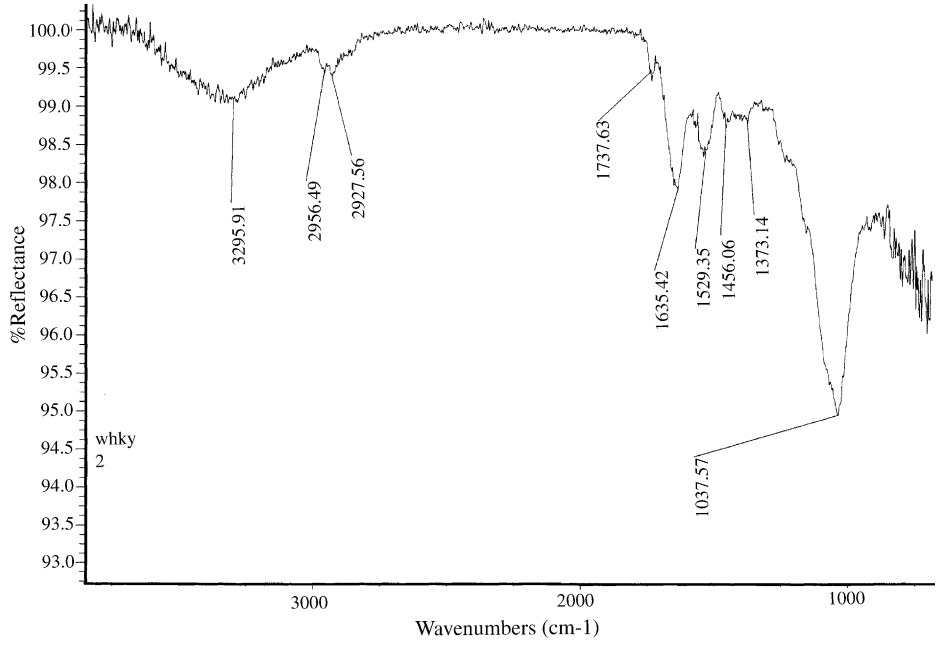


Fig. 7. 2# spectrogram—dry sludge cake came from the second facultative tank.

for example —C=C— , —C=O , —C=N— , phenyl and the substitution groups of some alkyl, were absorbed on sludge from three tanks.

2. In all spectrogram near 1530–1550 cm^{-1} there is the characteristic group frequency of C–N (aromatic nitryl). The characteristic group frequencies are listed in Table 6.

According to the formula:

$$\nu = \frac{1}{2\pi C}\sqrt{\frac{f(m+m')}{mm'}} \quad (1)$$

ν is the vibration frequency; f is the force constant, it expresses the bond intensity or bond energy. C is the velocity of light; m, m' are the atom mass [9].

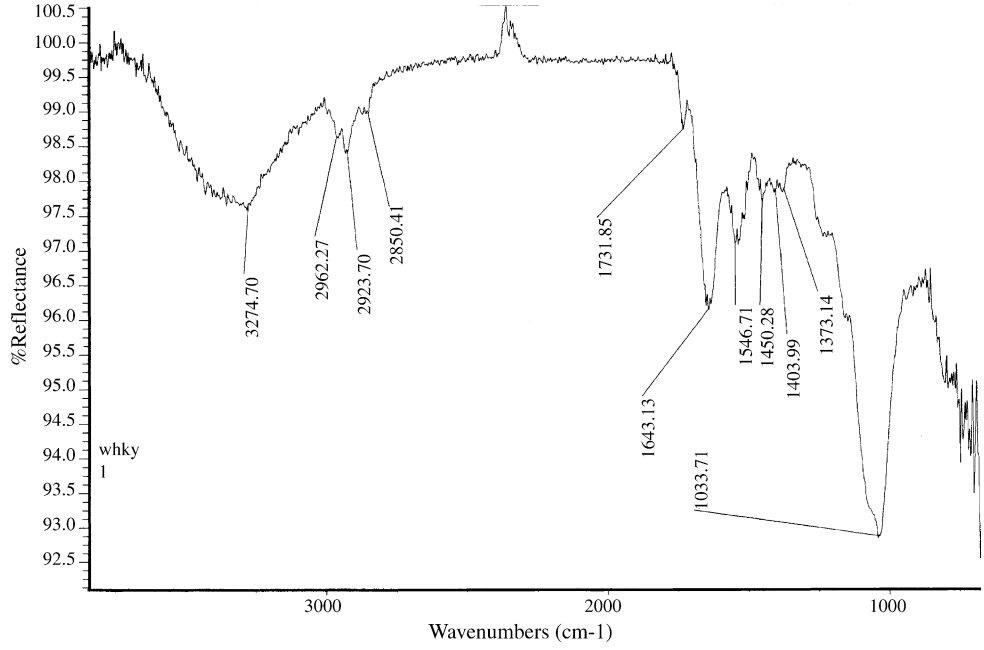


Fig. 8. 1# spectrogram—dry sludge cake came from the first facultative tank.

Table 6
The characteristic group vibration frequency

	Spectrogram			
	1#	2#	3#	0#
ν (cm^{-1})	1546.71	1529.35	1533.21	1529.35

From the formula 1, it may be seen that f is in direct proportion to ν, namely the more bigger ν is, the more bigger f is and the more strong the bond energy is. Among four spectrograms the ν in 1# spectrogram is the most biggest. It proves that the bond energy of aromatic nitryl is most strong, the sludge of absorption aromatic nitryl came from the first facultative tank. Moreover the ν in 0# spectrogram is the least. It says that the bond energy of aromatic nitryl is most infirm, the sludge of absorption aromatic nitryl came from the sedimentation tank. Consequently, it proves that the bond energy of the some structure in the organic compound is weakened by hydrolysis and acidification treatment.

3. In all spectrograms near 1700 cm^{-1} there are the characteristic groups frequency, for example $\diagdown\!\!\diagup C{=}O$, $\diagdown\!\!\diagup C{=}N-$ or phenyl. The characteristic groups frequency are listed in Table 7.

Table 7
The characteristic groups vibration frequency

	Spectrogram			
	1#	2#	3#	0#
ν (cm^{-1})	1731.85	1537.63	1714.49	1712.56

By same reason, the ν in 0# spectrogram is the least. It says that the bond energy of carbonyl or phenyl is weakened, the sludge of carbonyl or phenyl came from the sedimentation tank.

On the basis of infrared spectroscopy analysis the changed directions of dye molecule in wastewater are that dye molecules were firstly absorbed on the sludge (obvious group characteristic peak), and then the bond energy of the some structure in the organic compound was weakened by different tank treatment (the vibration frequency of characteristic peak gradually weakened). It is in favor of being decomposed and eliminated lastly.

5. Conclusion

The following conclusion is obtained through 8 month operation of a laboratory-scale facultative-facultative-aerobic activated sludge biological treatment process in which excess biomass is recirculated from aeration tank to the first facultative tank.

1. There was no excess biomass that had to be withdrawn with synthetic dyes wastewater.
2. The inverse excess biomass was completely decomposed. Inert organic substances did not seem to accumulate. The activity of hydrolyzed sludge was not affected.
3. The effluent quality has been well below the discharge limit.
4. On the basis of infrared spectroscopy analysis the dynamics of dye molecules in wastewater are that dye molecules were firstly absorbed on the sludge, and then the bond energy of the some structure in the organic compound

was weakened by different tank treatment. It is in favor of being decomposed and eliminated lastly.

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