Treatment of slaughterhouse wastewater using an activated sludge/contact aeration process

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Abstract This study combines a two-phase biological treatment system of activated sludge/contact aeration process by adding biological contact filters into the rear sector of the activated sludge aeration tank of the slaughterhouse wastewater treatment plant. This system keeps the advantages of complete mixing of substrates and microorganisms and flexible operation of the activated sludge process, and increased biological phase, less sludge, process stability and good settleability of sludge of the contact aeration process. This system could avoid the defects of sludge bulking, increased sludge production and difficult operation of the activated sludge process, and system clogging and rigid operation of the contact aeration process. Because suspended microorganisms are flowing into the contact aeration system, which then degrade or suspend within the biological contact filters after being adsorbed by the fixed biological film, on which partial bio-solids will act as seeding microorganisms. Suspended microorganisms and the dropped biological film will settled in the secondary settling tank, then reflux into the activated sludge aeration tank. The partial dropped biological film will decompose in the activated sludge aeration tank to achieve the function of decreasing sludge. Large specific gravity and good settling ability of biofilm sludge will provide better effluent quality. It has been proven through a practical experiment at a slaughterhouse wastewater treatment plant in Taiwan, that the activated sludge process effluent COD value of 150–200 mg/L and SS value of 80–100 mg/L were decreased to around 40 mg/L and 22 mg/L, respectively, after changing its system to the two-phase biological treatment system of activated sludge/contact aeration process.
Keywords Activated sludge; contact aeration; slaughterhouse wastewater; two-phase biological system

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Introduction

With limited available land space in Taiwan cities, it is of vital importance to devise wastewater treatment facilities that are environmentally friendly, economically viable and technologically efficient, while at the same time able to meet the requirements of the increasingly stringent environmental regulations. The COD and SS effluent standards of slaughterhouse wastewater in Taiwan were revised from 200 mg/L and 100 mg/L to 150 mg/L and 80 mg/L, respectively, from 1998. Because of the limitation of existing wastewater treatment space, the treating facilities and the process must be improved to get a better efficiency of the treatment.

There are four different processes which are often used for treating wastewater from slaughterhouses (Johns *et al*., 1995; Manjunath *et al*., 2000): 1. anaerobic treatment + activated sludge; 2. anaerobic treatment + contact aeration; 3. activated sludge + chemical coagulation; and 4. contact aeration + chemical coagulation. The disadvantages of the first two systems are that they require a relatively large area for the construction of the anaerobic processing unit. The last two systems involving chemical coagulation have the disadvantage of a large requirement for chemical usage, and would also produce a greater quantity of sludge.

In this study, an activated sludge aeration system was converted to an activated sludge/contact aeration system, by adding biological contact filters into the rear section of the activated sludge aeration tank. This adjustment did not require extra land space, but did effectively lower the BOD and SS of the effluent. The treatment system also became more manageable and stable as a result, since the diversity and complexity of the biological phase was significantly increased.

AS/CA process

The activated sludge system is the most widely used biological treatment process for treating various types of wastewater. The advantages of the activated sludge process are the thorough mixing of substrates, flexibility in its operation, and low installation cost. However it has drawbacks such as sludge bulking, excess sludge production, and demanding operation and maintenance.

The contact aeration process is an improvement on the activated sludge process, whereby biological contact filters are put into the activated sludge basin so that suspended microorganisms flocculate on the filters and become biofilms. Its advantages are that it has a more diverse biological phase, less sludge, and better settling of sludge. It also has its disadvantages like clogging, rigid operation, and additional cost in purchasing the biological contact filters (Nakajima *et al.*, 2000).

The wastewater treatment system used in this study is a combination of activated sludge and contact aeration systems, as shown in Figure 1. It has a diverse and complex biological phase, which has a higher efficiency in removal of organics, and combines the advantages of both processes: thorough mixing of substrates, flexible operation, less sludge, better sludge settling, less chance of clogging, and better effluent quality. Compared to an activated sludge system, activated sludge/contact aeration would require additional spending in purchasing of the biological contact filters, but it would use fewer biological contact filters than the conventional contact aeration system.

Materials and methods

The experiment of this study was conducted on a wastewater treatment plant of a slaughterhouse in Taiwan. The wastewater treatment plant includes an oil separation tank, an equalization tank, two activated sludge tanks, three contact aeration tanks, a settling tank and a sludge thickening tank. Table 1 shows the details of the plant design and its hydraulic retention time. Table 2 shows the contact filter details (330 m^3).

Figure 2 shows the process diagram of the treatment plant. Other equipment used include an automated bar screen, a solid-liquid separation machine, two submersible wastewater pumps, two blowers, two scrapers, a suite of sludge dewatering units, and two sludge pumps.

At the beginning of the study, a field investigation was performed to establish the control and operation parameters. Improvement schemes were devised according to the structural and functional limitations of the existing wastewater treatment plant. After the alteration, monthly measurements of pH, temperature, COD, BOD, SS, oil and grease, and true colour of the influent and effluent were taken for analysis. Results were analyzed and compared.

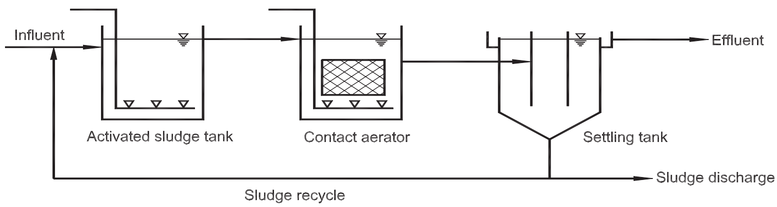

Figure 1 Activated sludge/contact aeration combination system

Table 1 Details of wastewater treatment plant and its hydraulic retention time (2000 CMD)

Unit	Quantity	Structure	Measurement L*W*H	Volume m^2	HDT hour
Equalization tank	1	RC	23 m*10 m*2.2 m	506	6.4
Activated sludge tank	2	RC	12 m*4 m*3.5 m	336	4.0
Contact aeration tank	2	RC	12 m*4 m*3.5 m	660	7.9
	1	RC	12 m*6 m*4.5 m		
Settling tank	1	RC	10 mØ*3 m	236	2.8

Table 2 Details of contact filter

Type	Material	Specific surface area m^2/m^3	Porosity %	Unit hole area cm^2	Measurement L×W×H cm	Thickness mm
Honeycomb	Endure strike against, High density, Limpid PVC	120	99.4	20	120×64×64	0.2–0.4

Results and discussion

Tables 3 and 4 show statistics of influent and effluent qualities measured over a period of fifteen months, respectively. All of the effluents measured complied with the 1998 effluent standards. The average removal efficiency for COD, BOD and SS was 96%, 97% and 95%, respectively.

Figures 3 and 5 show the monthly variation of influent and effluent COD and BOD, respectively. Figures 4 and 6 are the frequency distributions of COD and BOD values. The average COD and BOD values were 39.8 mg/L and 18.8 mg/L, respectively. More than 50% of the COD values were lower than 30 mg/L, and more than 50% of BOD values were below 15 mg/L. This suggests that the combined system is a stable system, and that its buffering capacity can well accommodate the variation of the influent quality of the slaughterhouse. Furthermore, when wastewater was drawn from the equalization tank to the bioreactor, the impact of high substrate concentration can be quickly mitigated through rapid mixing. Since the first two activated sludge reactors did not have the biological contact filters, the influent could diffuse rapidly and the concentration of the substrates was

Table 3 The characteristics of influent measured over a fifteen month period

	Range	Average	Standard deviation
pH	6.2~8.4	7.6	0.6
Temperature (°C)	25~30.9	27.6	2.2
COD (mg/L)	700~1400	1,018	211
BOD (mg/L)	590~991	737	118
SS(mg/L)	137~500	311	104
Oil and grease (mg/L)	27~92	54	23
True color	90~400	194	102

Table 4 The characteristics of effluent measured over a fifteen month period

	Range	Average	Standard deviation	Ave. removal efficiency (%)	Effluent standards
pH	6.8~7.9	7.3	0.3	–	6~9
Temperature (°C)	24~31.1	27.6	2.1	–	<35
COD (mg/L)	20.7~80	39.8	19.0	96	<150
BOD (mg/L)	7.7~39	18.8	10.3	97	<80
SS (mg/L)	5~59	22	14	95	<80
Oil and grease (mg/L)	2.3~9.2	6.6	2.1	88	<10
True color	18~66	45	14	77	<550

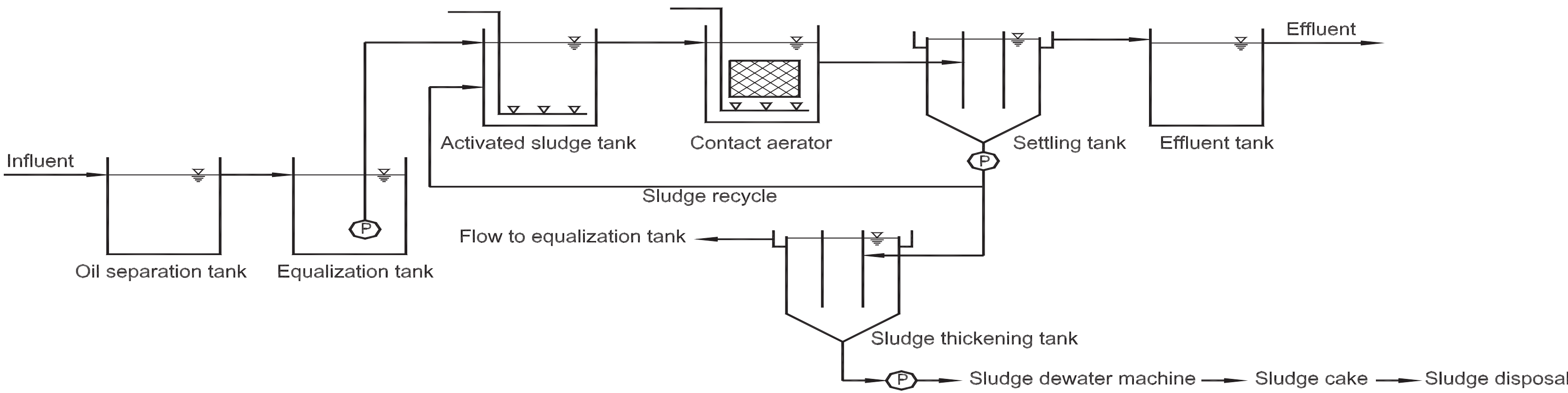

Figure 2 Process diagram of the wastewater treatment plant

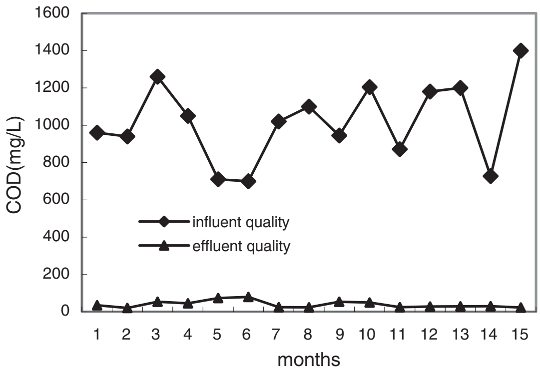

Figure 3 Monthly variation of influent and effluent COD

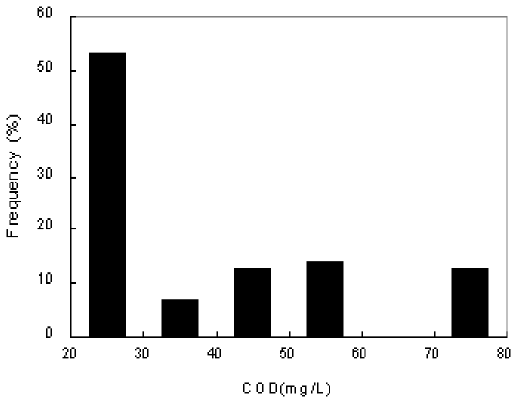

Figure 4 Frequency distribution of COD measured

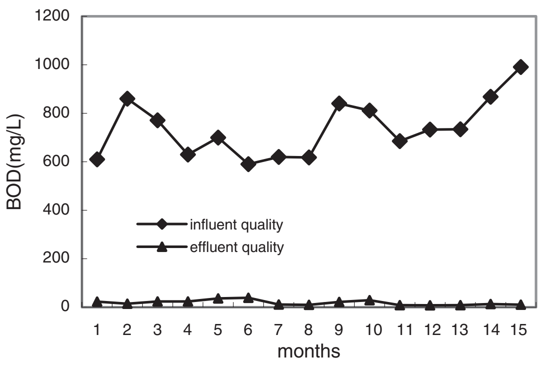

Figure 5 Monthly variation of influent and effluent BOD

swiftly lowered. Hence, after the processing in the activated sludge reactors, the substrates would not pose much impact on the biofilms when it enters the contact aeration tanks.

Before the alteration of the system, Flagellates and *Paramecium* were the dominant species found in the system under high organic loading conditions. After the alteration of the system, free swimming ciliates, stalk ciliates, Metazoa and Crustacea also appeared in the system. This indicates that the new system effectively raised the MLSS concentration, and lowered the F/M ratio of the system.

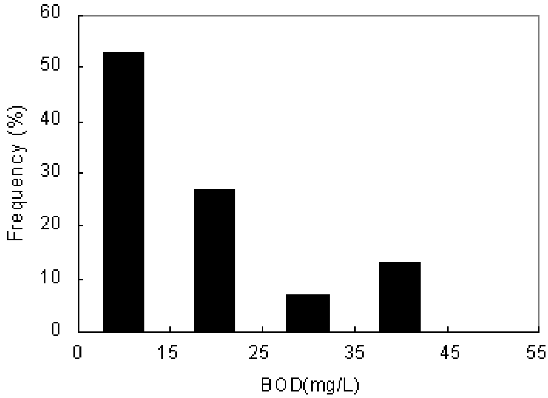

Figure 6 Frequency distribution of BOD measured

When the microorganisms in the activated sludge flow into the contact aeration tank, some of them will form new biofilms on the contact filters, and some of them will remain suspended within the filters. The biofilm shed from the filters will settle in the settling tank together with the suspended microorganisms. These would then be recycled back to the activated sludge reactor, and complete the seeding function of the activated sludge system. This means that every aeration tank has both the biological phase of the suspended system and the fixed system at the same time. Under the electron microscope, various sizes of very active microbes were observed. Moreover, competition between the diverse species of microbes resulted in a significant reduction in sludge production. In the original activated sludge system, 3830 kg/day (80% water content) of sludge were produced, but after the alteration to a two-phase biological system, the sludge production was reduced to 2,200 kg/day (80% water content). Hence, it can be seen that the combined system would produce less sludge than the traditional activated sludge system.

Due to the fact that the contact aeration tank comes before the settling tank, and that the contact aeration tank is a fixed biofilm system, the biofilm shed from the filters is much larger in specific gravity than the microbes in the suspended microbe system. Moreover, most microorganisms from the activated sludge would become attached to the biofilm and be shed from the filter and settle together. Thus, the activated sludge/contact aeration system would have better sludge settling than the activated sludge system. From Figure 7 it can be seen that the effluent SS kept between 5~59 mg/L even when the influent SS fluctuated between 120~500 mg/L, meaning a 83~96% removal efficiency. It can be seen from Figure 8 that 70% of the effluent SS values measured were below 20 mg/L.

Highly concentrated substrates in the activated sludge system were fully mixed, diluted

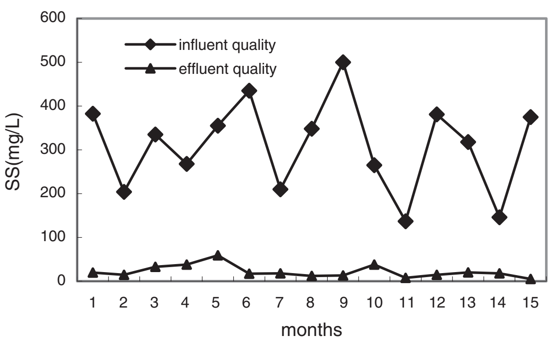

Figure 7 Monthly variation of influent and effluent SS measured

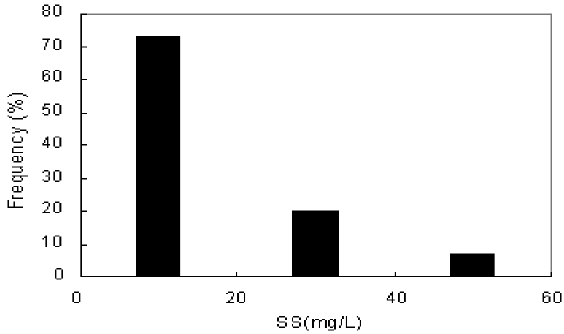

Figure 8 Frequency distribution of SS measured

and decomposed. Thus when the substrates reach the contact aerators, they would be of low concentration and would not cause the formation of excess biofilm, which would clog the contact filters.

The removal efficiency of true color is shown in Figure 9, where the effluent's average true color was reduced to 45 with a removal efficiency of 77%. The effluent's average oil and grease concentration reduced to 6.6 mg/L, with a removal efficiency of 88% as shown in Figure 10.

After various adjustments, the best operating conditions were found as follows:

1. Activated sludge MLSS – 3,200 mg/L
2. Contact aeration MLSS – 5,000 mg/L
3. Activated sludge SVI – 81
4. F/M ratio – 0.34 kg BOD/kg MLSS
5. Sludge residence time – 9.94 days
6. Sludge recycle rate – 30%

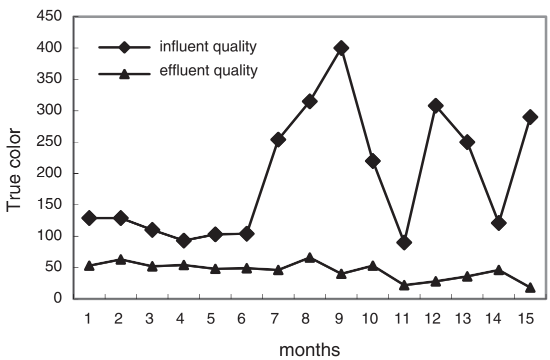

Figure 9 Monthly variation of true color measured

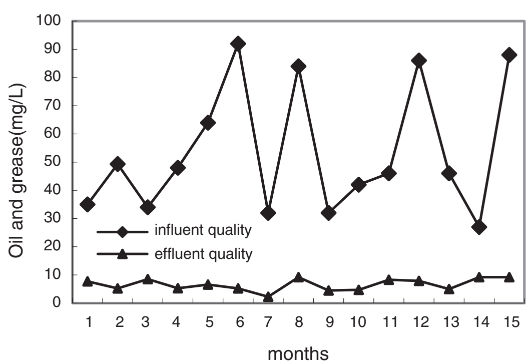

Figure 10 Monthly variation of oil and grease measured

Conclusions

Due to the increasingly stringent effluent standards and increasing industrial production, the production of wastewater and its concentration has been increasing. It is necessary to improve the existing facilities to raise the treatment efficiency, and increase treatment capacity. Improving the efficiency and capacity of an existing treatment plant without structural reconstruction, is an increasingly important task. The schematic of activated sludge/contact aeration system examined in this study provides a convenient and economical option. The efficiency of an activated sludge system can be improved by adding in some contact filters and, in effect, combines the activated sludge system and contact aeration system into one system. Unlike the activated sludge system which would require extra aeration tanks, and unlike the contact aeration system which requires biological contact filters in every aeration tank, the activated sludge/contact aeration system can enhance the efficiency and capacity of an existing wastewater treatment plant of a slaughterhouse with minimal resources and work.

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