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Treating restaurant wastewater using a combined activated sludge-contact aeration system

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Abstract: *The combined activated sludge/contact aeration (AS/CA) system proposed herein involves both suspended and attached microorganisms. In an experiment over 7 days, and at 8 hr hydraulic retention time (HRT), the AS/CA system was able to treat restaurant wastewater of fluctuating quantity and quality, and reduce the standard deviations of COD and BOD_5 from 115.8 and 158 to 40.5 and 8.8mg/l, respectively. In a twenty-four hour experiment, the standard deviation of COD fell from 188.9 to 23.8mg/l, showing a strong tolerance of environmental changes. In an analysis of composite samples collected over 1 day, the AS/CA effluent had 57.8mg/l COD (84% removal rate), 21mg/l BOD_5 (87% removal rate), 12mg/l SS (86% removal rate), 6mg/l oil and grease (O and G) (90% removal rate), and a true color of 1 (80% removal rate). Denaturing Gradient Gel Electrophoresis (DGGE) analysis was performed on sludge samples taken from three treatment systems: the activated sludge system, the contact aeration system and the AS/CA system for comparison. The results showed that the AS/CA system contained higher microbe quantity and diversity.*

Key words: *Oil and grease, Combined activated sludge, Contact aeration system, Spike loading, DGGE*

Introduction

The quality of restaurant wastewater varies with the type of food served, for example, Japanese, European buffet, Western and Chinese. Both the pollutant load and in particular oil content increase in the order of the food listed. Furthermore, wastewater quality can also vary greatly over the course of a day. Hence, a biological system intended for use to treat such wastewater, must be able to withstand different magnitudes of quality and quantity spike loading.

Since the quantity and quality of restaurant wastewater can fluctuate widely, a large equilization tank would be needed. However, most restaurants are situated in urban surroundings where space is very constrained. Hence, most restaurants use physical and chemical means for treating their wastewater. This leads to the discharge of chemical sludges into the sewage system with possibly high operating costs.

Most restaurants are small operations. Thus, the initial investment and operating cost for wastewater treatment must be kept low. The electrocoagulation process, for example, consumes the aluminum electrodes at 17.7 g/m^3 to 106.4 g/m^3, and the power requirement is approximately 1.5 KW h/m^3 (Chen *et al*., 2000). Thus these make the electrocoagulation process costly. Although conventional biological treatment processes have lower operating costs, they require larger land space, and are poor in treating high O and G concentrations. Their average O and G removal rate is just 20~30%. It has been noted the maximum O&G concentration activated sludge systems can efficiently decompose is 30mg/l (Nakajima *et al*., 2000).

The combined activated sludge/contact aeration (AS/CA) system proposed in this study combines suspended and attached microbes to provide a longer food chain and more complex biophase (Chen and Lo, 2003). This is to enhance the removal of COD, O and G and true color. The system is also expected to exhibit increased tolerance to spike loading, and would require a smaller land area. The biodiversity of a microbial consortium can be examined, through DGGE analysis and polymerase chain reaction (PCR) techniques which can amplify DNA material extracted from microbes (Fotiadis *et al*., 2002). Each type of microbe has its own set of 16S-rDNA, and by extracting a sample's 16S-rDNA and matching its amount and characteristics, to known microbes, the amount and types of microbes present in a population can be determined (Liu *et al*., 2002).

Materials and Methods

The restaurant's wastewater is pretreated with a CPI O&G separator. The average number of diners at the restaurant is 500, and the average quantity of wastewater is $50m^3/d$, which equates to $0.1m^3$of wastewater per person per meal. The equalization tank is just $1m^3$ and odor is a minor issue, because the AS/CA system is an aeration system and the substrates were decomposed into CO_2 and H_2O. The wastewater collector was long open channel (20m) middle the kitchen, and the equalization tank could issue hot air. The temperature was indicated in Table 3.

The reaction tanks were ordered as follows: one activated sludge tank, one contact aeration tank and one settling tank. Table 1 lists the effective volume. Fig. 1 shows the process flow chart. The equipment used included: a metering pump, sludge recycling pump, four blowers, and 13.5 litre of biological contact filters (Table 2 lists details of contact filter), a DO controller, a pH controller, an ORP controller, and a MLSS

Table – 1: Measurements of the effective volumes of each reaction tank.

Reaction tank	Dimension cm	Effective volume liter	Material
Activated sludge tank	30L×30W×32H	27	Acrylic
Contact aeration tank	30L×30W×32H	27	Acrylic
Settling tank	30ø×32H	19	Acrylic

Table – 2: Details of contact filter

Type	Type	Demensions mm	Density (kg/m^3)	Surface area (m^2/m^3)	Void space (%)	pcs/m^3
Double ball	2''	50×44	60	155	96	12000

Table – 3: Test results of 24 hr mixed water samples from each tank after 8 hr of HRT.

	COD (mg/l)	BOD (mg/l)	Suspended solids (SS) (mg/l)	Oil and grease (mg/l)	True colour	NO_2^--N (mg/l)	NO_3^--N (mg/l)	NH_4^+-N (mg/l)	T (ºC)	pH
Influent	356	165	88	62	5	29	1.3	4	19	6.5
Effluent from activated Sludge	210	82	35	18.6	2	32.5	1.8	3.8	18	6.9
Effluent from contact Aeration tank	78	36	20	12	1	39.7	2.6	3.3	18	6.9
Effluent from settling tank	57.8	21	12	6	1	41	2.7	2.8	17	7
Effluent standard	–	50	50	10	–	–	50	10	35	6~9
Total removal %	84	87	86	90	80	–	–	–	–	–

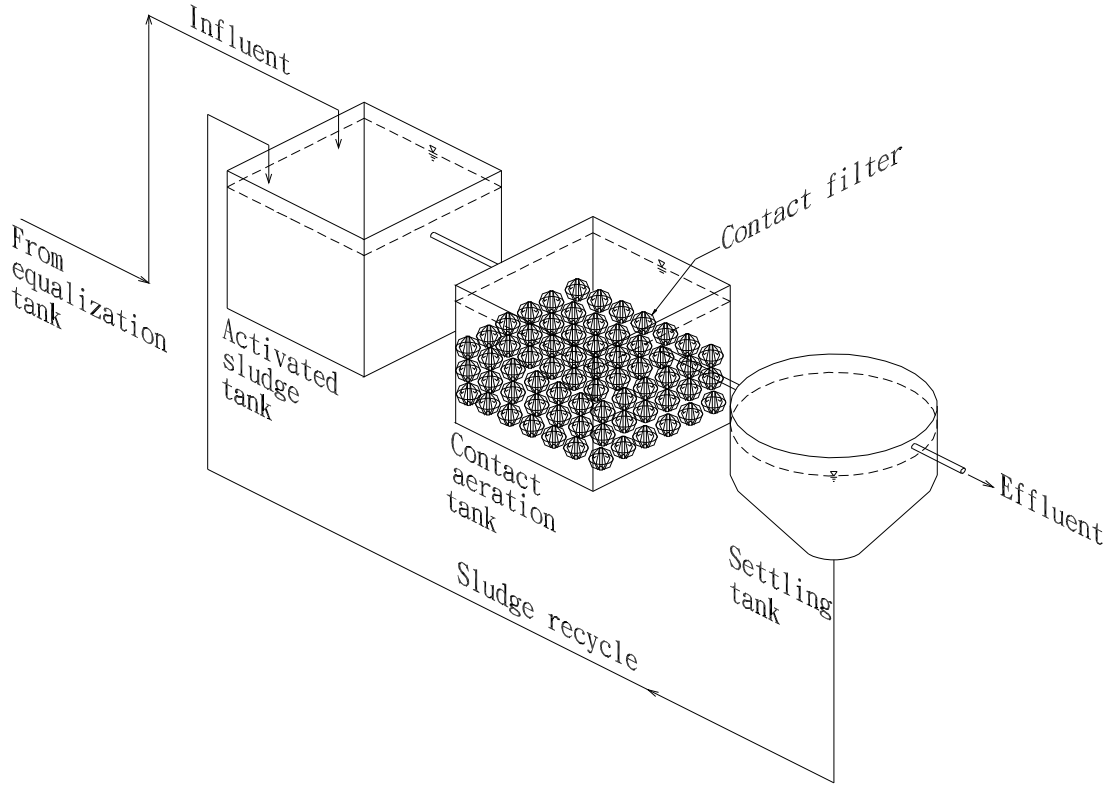


Fig. 1: 3D experimental flow chart.

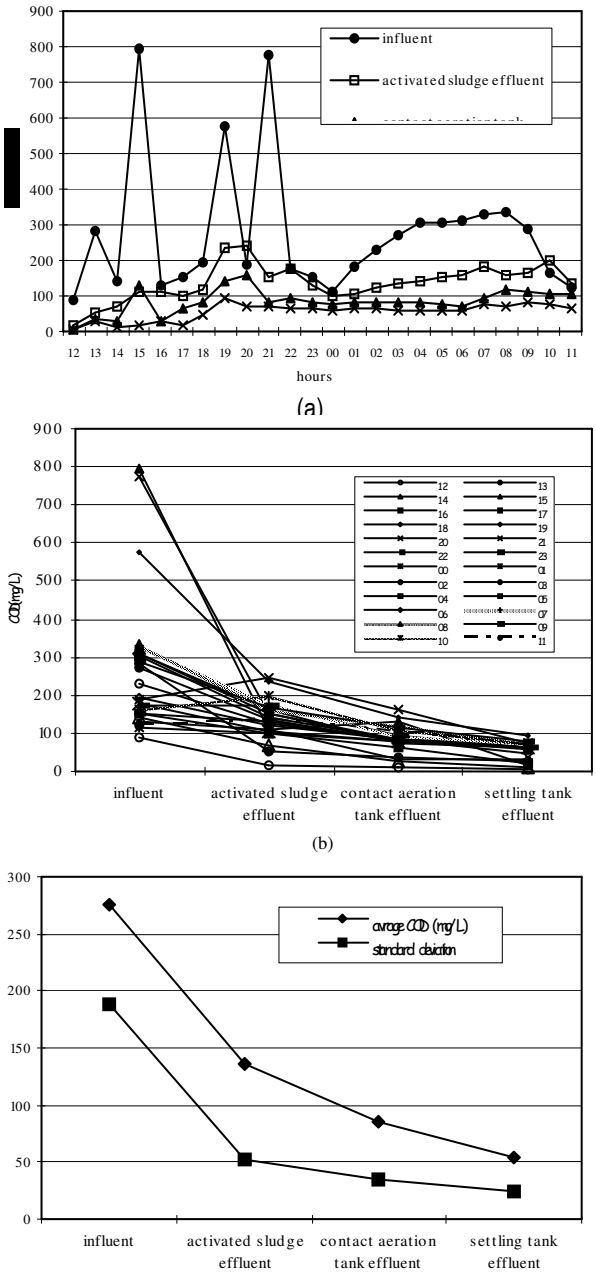


Fig. 2: (a) COD of reaction tanks (24hr samples).
(b) Concentration diagram of COD (24hr samples).
(c) Standard deviation and average COD of reaction tanks (24hr samples).

controller. ORP meter can monitor the degree of chemical and biological reaction, and control the condition of aeration advanced. We can use it to control the nitrification and denitrification process precisely, and get the high efficiency.

Because the low-power blower supply the DO concentration is not enough, and the high-power one is too much, we used the two low-power blowers in each bioreactor to independently adjust the DO concentration to 1.5 mg/l.

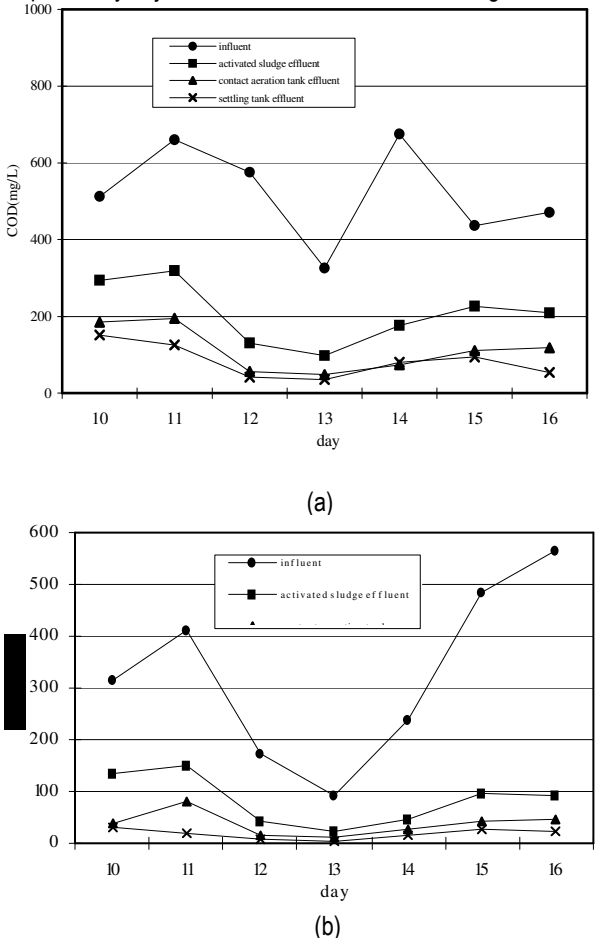


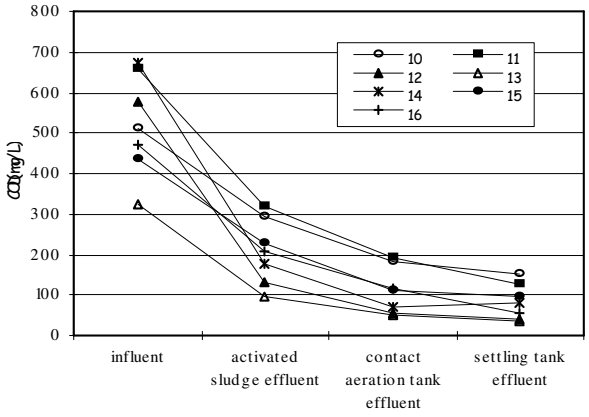
Fig. 3: (a) Fluctuation of daily COD (daily samples-7 consecutive days).
(b) Fluctuation of daily BOD (daily samples-7 consecutive days).

A AS/CA facility was constructed and trial run over two weeks. The microbial acclimation period was run over two months. The stationary period was run over one month, and that identified 24hr and 7days monitoring periods.

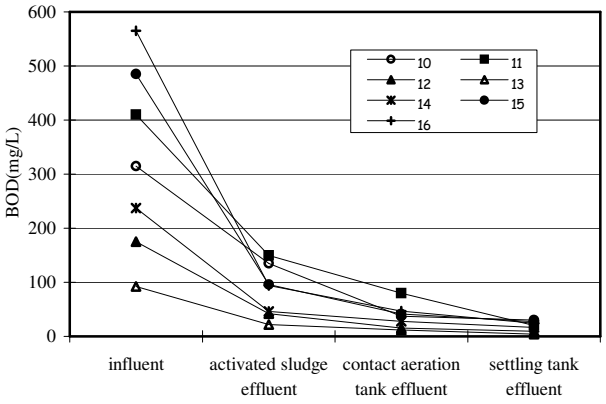
Water quality analysis: Alter operation criteria, after the system stabilized, water samples were taken from the equilibration tank, and from the discharge outlet of each tank. Analysis was conducted to obtain the pH, the temperature and the concentrations of BOD_5, $COD_{K_2C_{r2}O_7}$, SS_{total}, NH_4^+-N, O and G, and the true color, to demonstrate the treatment efficiency of the proposed system.

SEM observation: Sludge samples were taken from each reaction tank once the system stabilized. The samples were treated as follows: (1) fixation by glutardialdehyde solution; (2) flushing by phosphoric acid buffer solution, and (3) dewatering eight times with different concentrations of ethyl alcohol solutions. Microbe morphology in the activated sludge tank and

the contact aeration tank then was observed and recorded using scanning electronic microscope (SEM).

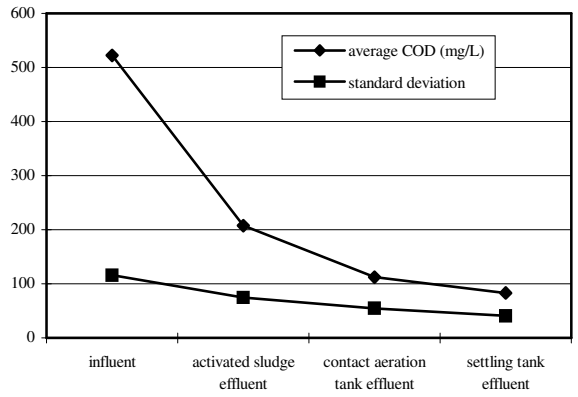


(a)

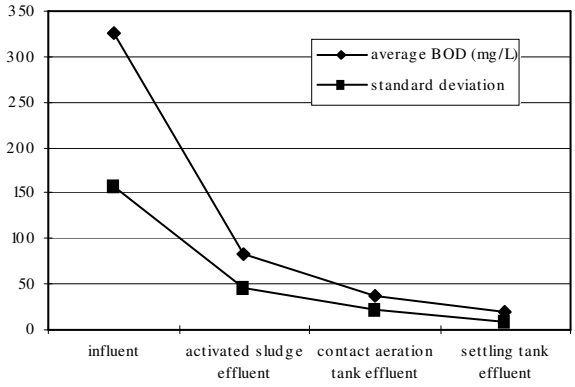


(b)

Fig. 4: (a) Concentration diagram of COD for each reaction tank (daily samples - 7 consecutive days).
(b) Concentration diagram of BOD for each reaction tank (daily samples - 7 consecutive days).



(a)



(b)

Fig. 5: (a) Mean and standard deviation of COD for each reaction tank (daily samples - 7 consecutive days).
(b) Mean and standard deviation of BOD for each reaction tank (daily samples - 7 consecutive days).

DGGE analysis: DGGE was used to analyze the biological phase. DNAs were extracted from the sludge samples taken from each tank, after which various chemicals were added to breakdown chemically the cell walls. Using physically quick freezing method procedure, rapid shaking bath warm up to destroy the cell wall, and put the sample into a centrifuge to separate the proteins, polysaccharide, and DNA material. Then using several other chemicals to stimulate PCR' and amplify the amount of DNA material. Finally electrophoresis and silver staining were used to complete the DGGE experiment.

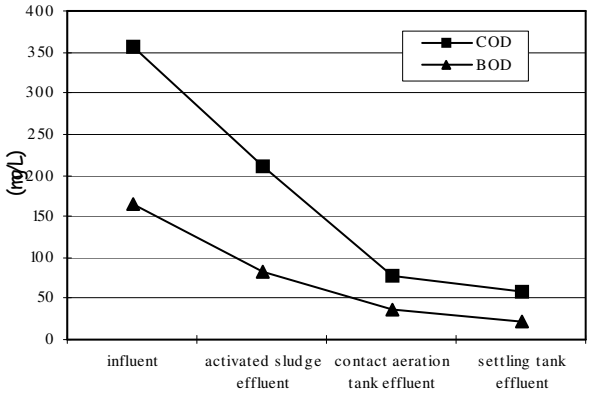
Biological content analysis: The changes in the amount of suspended and attached microorganisms in the activated sludge tank and contact aeration tank were monitored at a maintained sludge recycle rate of 0.3.

This study investigates whether the effluent with highly variable influent quality, which is treated by the AS/CA process with 8hr HRT, would comply with the regulation standards. The removal of O&G and true color, the stability of the system, and the growth of microbes in the different reaction tanks are also examined. The results are then compared to those obtained using a conventional single activated sludge system and a conventional single contact aeration system. These three, AS, CA or AS/CA systems were under the same operating condition as follows: (1) HRT: 8hr; (2) Sludge recycle rate: 30%, and (3) Influent substrates.

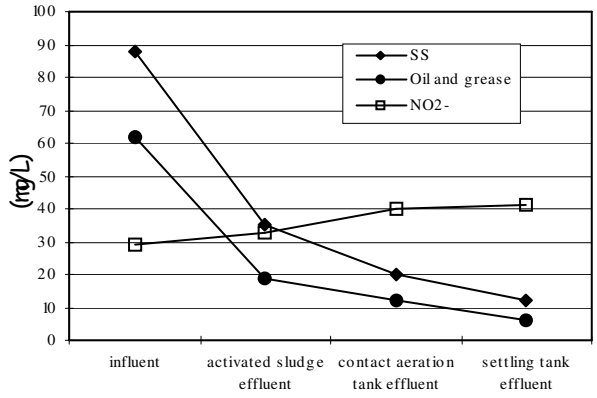
Results and Discussion

Figs. 2 (a) and (b) shows that the COD value of the wastewater fluctuated considerably over a twenty-four hour period, but after passing through the first reaction tank (activated sludge tank), the disparity was significantly reduced and the COD value significantly lowered. Two observations became even more significant as the wastewater pass through the second reaction tank. After the settling tank, the quality of effluent was even better, and the change in water quality was

minimal, and the standard deviation of COD dropped from 188.9 to 23.8mg/l. This indicates that the system's buffering capacity for spike loading was high. The system achieved an average 75% removal rate for COD, from 275.3 to 54.7mg/l.



(a)



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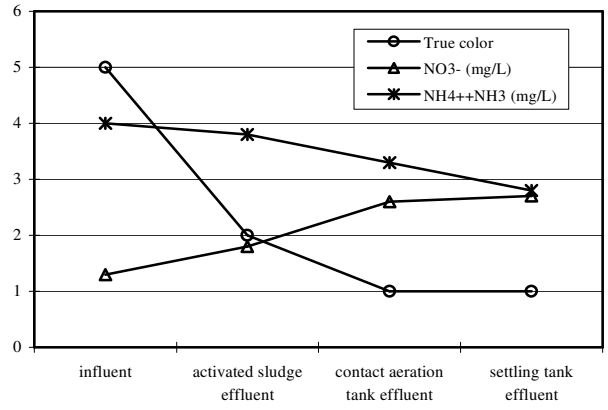
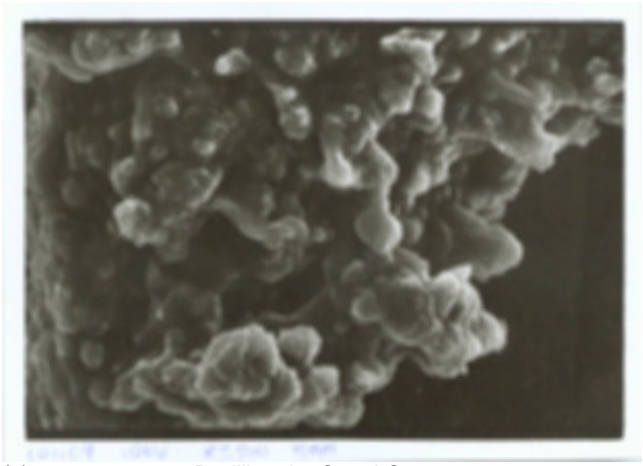


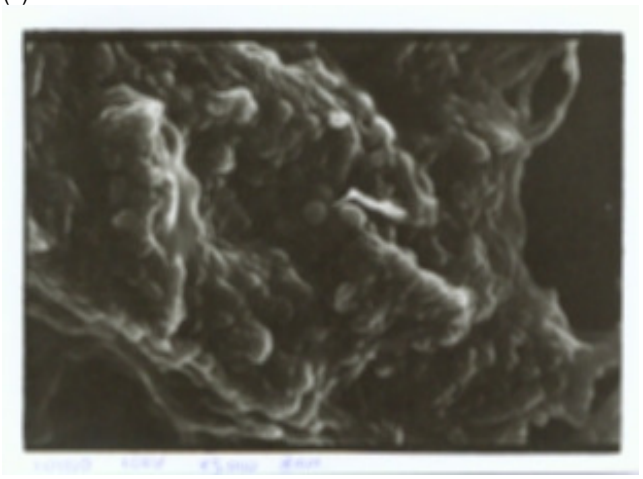
(c)

Fig. 6: (a) COD and BOD of each reaction tank (24 hr mixed sample).
(b) SS, oil and grease and NO_2^--N concentrations of each reaction tank (24 hr mixed sample).
(c) True color, NO_3^--N and NH_4^+-N concentrations of each reaction tank (24 hr mixed sample).

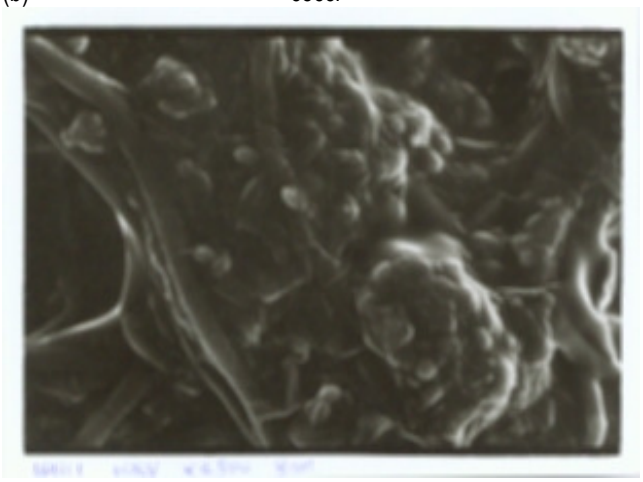
Fig. 2(c) shows the decrement of COD, and that most COD are treated in the first reaction tank. These results suggest that the combined AS/CA system's microbes are very active and can rapidly consume the substrates.



(a) Bacilli under O and G



(b) cocci



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