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TREATMENT OF MONOSODIUM GLUTAMATE FERMENTATION WASTEWATER WITH ANAEROBIC BIOLOGICAL FLUIDIZED BED PROCESS

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ABSTRACT

This study is to explore the feasibility of the treatment of the MSG Fermentation wastewater by AFBBR (Anaerobic Biologial Fluidized Bed Reactor) Method, and intends to solve the serious pollution problem of MSG industry by the advantages of AFBBR Method. The results show that the wastewater BOD removal efficiency is very high due to this treatment. When the organic loading is below 14.0 kg-BOD/m^3.day, the BOD removal efficiency can reach 90% or more. Since the wastewater contains the undissolvable difficult biodegradation organic matter, the COD removal efficiency only reaches 65% maximum. The methane content in biogas can achieve 80.8%. When the digestion temperature is 35°C, biogas production per kg is maximum 367.8 l. The treatment results indicate if the organic loading is in the range of 10.1-31.1 kg-COD/m^3.d, and the operation condition is appropriate, we will get a very good digestion efficiency, i.e. the feasibility of this method for MSG Fermentation Wastewater Treatment is very high.

KEYWORDS

Monosodium glutamate fermentation wastewater; AFBBR; fluidized bed; anaerobic process.

INTRODUCTION

Monosodium glutamate (MSG) industry is one of the important fermentation industries in Taiwan. The COD concentration of MSG fermentation waste liquor is as high as 300,000 to 400,000 mg/l. So far, an economic, effective treatment process for the treatment of MSG wastewater has not yet been developed. Anaerobic digestion process has been shown to be a reasonable, feasible technology for treating high strength wastewater. Today, it is even deemed to be one of the methods to save some energy. Since anaerobic fluidized bed reactor (AFBBR) has some advantages, such as its ability to retain large biomass concentration (Tseng, 1985) and to provide high specific surface aera (Copper, 1980;Tseng ,1985), this study examined the feasibility of the use of AFBBR as a pretreatment in treating MSG fermentation wastewater.

EXPERIMENTAL METHOD

Treatment facilities

The AFBBR was constructed from a poly-acrylic column (3.5 cm I.D., 100 cm in length) jacketed with a 7.0 cm I.D. column (Figure 1). The reactor was main-

tained at 28°C or 35°C by passing water through the jacket. The media of fluidized bed consisted of activated carbon with a particle diameter of 0.46-0.594 mm.
The sedimentation jar consisted of a 1.0 l filter jar, for separating and sedimentation of bioparticles.
A Master - Flex tubing pump was used to recycle the wastewater at 10 - 1000 ml/min.

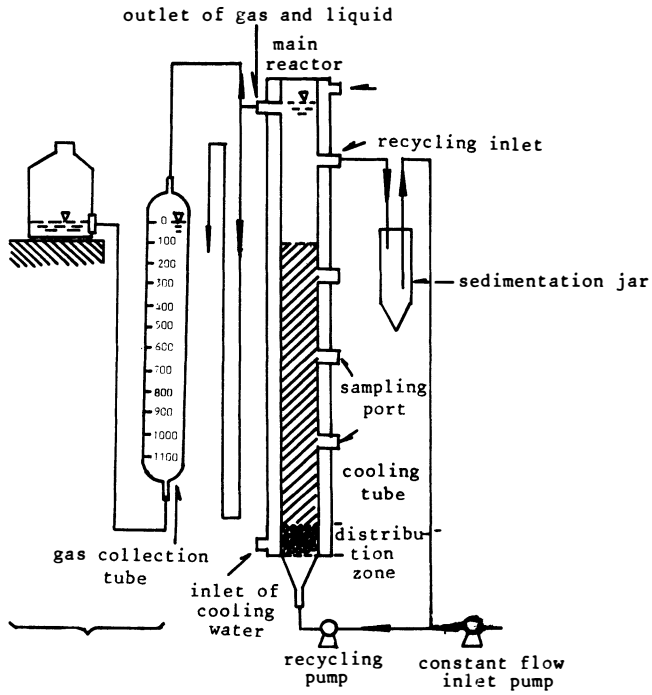

Fig. 1. Anaerobic fluidized bed reactor and process scheme.

MSG Fermentation Waste Liquor

The MSG waste liquor was provided by the Wei-Chuan Co., Taipei, R.O.C.. After dilution, the diluted wastewater had a pH of 6.5 - 7.5. During the period of normal operation, the influent COD concentration was 5,000, 10,000, and 15,000 mg/l, respectively. The MSG fermentation wastewater quality is shown in Table 1.

TABLE 1 Quality of the MSG Fermentation Wastewater.

Analytical item	Concentration(mg/l)
COD:	
Total	288,000-317,000
Soluble	252,000-266,000
BOD_5	
Total	113,000
Soluble	83,000-94,000
SS	35,000-49,000
TKN	23,945-29,580
NH_3-N	14,470-19,755
Cl^-	85,300
$SO_4^=$	40,435
pH	3.3
Total phosphate	1,694
Volatile acid	36,400-39,100
COD:TKN:P	100:8.8:0.56
BOD_u/COD	0.70
BOD_5/BODu	0.53

Operation Condition

The system was operated at 35°C and at 28°C. Four hydraulic retention times (HRT) applied were 3, 6, 9, 12 hr, respectively.

RESULTS AND DISCUSSION

BOD Removal Efficiency

Figures 2, 3 show that a BOD removal efficiency of > 90% could be achieved at a HRT of 12 hr irrespective of the influent COD concentration (5,000, 10,000, and 15,000 mg/l) and the digestion temperature (at 35°C and 28°C), indicating satisfactory performance of the AFBBR in treating the MSG wastewater.

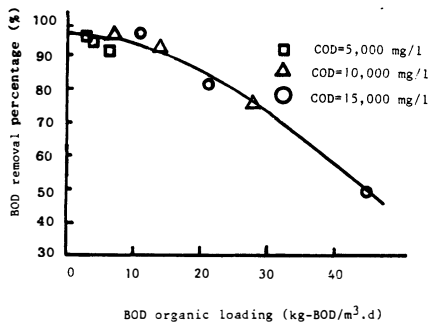

Fig.2. Effect of BOD volume loading on BOD removal percentage at 35°C

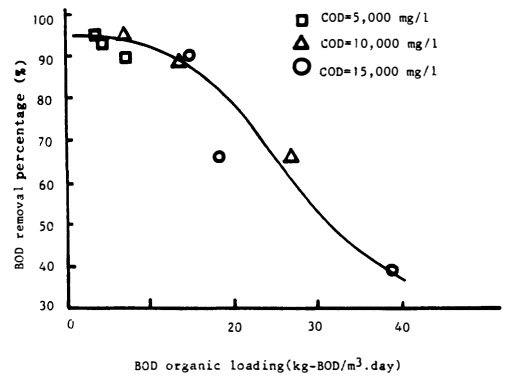

Fig.3. Effect of BOD volume loading on BOD removal percentage at 28°C

Figures 2 and 3 show the effect of organic volume loading on BOD removal at 35°C and at 28°C, respectively. When organic volume loading was in the range of 3.21-42.73 kg-BOD_5/m^3.day, BOD removal rate decreased as organic volume loading was increased; both curves were flat and nearly horizontal at low organic loading, and went downward rapidly as organic loading was increased. In addition, at high organic loading, the system gave a higher BOD removal efficiency at 35°C than at 28°C. The results indicated that both increase in organic loading and decrease in digestion temperature did not exert significant influence on BOD removal at low organic loading to the reactor. Consequently, when treating MSG wastewater at 35°C , organic loading should be maintained at < 21.0 kg-BOD_5/m^3.day to achieve a BOD removal of > 80%. Whereas, when at 28°C, organic loading should be maintained at < 14.5 kg-BOD_5/m^3. day to achieve the same BOD removal efficiency. The results also indicated that, at the same organic loading, as both influent concentration and HRT increased, so did the BOD removal in terms of % . The results were consistent with the research of Brochardt (1971). The slight decrease of BOD removal rate was because some methanogenic bacteria had been washed out due to high hydraulic loading.

Figures 4 and 5 show the effect of influent concentration on the correlation between BOD removal and HRT at 35°C and at 28°C, respectively. BOD removal rate in both cases decreased as HRT decreased and as influent concentration was increased. It was also found that the effect of HRT on BOD removal rate depended on influent concentration. The lower the influent concentration the less significant the effect of HRT on BOD removal rate; the higher the influent concentration was, the more significant the effect of HRT. However, at an HRT of 12 hr, the BOD removals at each temperature were almost the same and all were > 90%, indicating that the effects of the influent concentration and of the digestion temperature on BOD removal at this HRT was minimal. As a consequence, it is apparent that HRT is one of the most important factors during practical treatment.

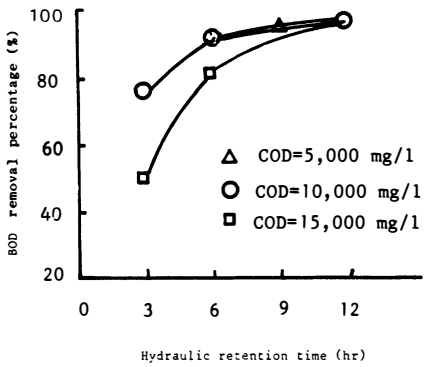

Fig.4. Effect of inf. conc. on the correlation between HRT and BOD removal percentage at 35°C

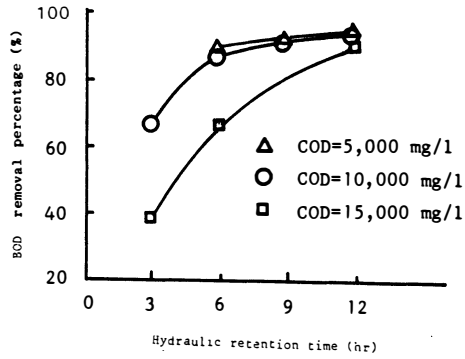

Fig.5. Effect of inf. conc. on the correlation between HRT and BOD removal percentage at 28°C

COD Removal Rate

From Table 1, the MSG wastewater had a BODu/COD ratio of 70%. Approximately 30% of the COD was not biodegradable. It was therefore predicted that COD removal rate would be lower than BOD removal rate in treating the wastewater. Figures 6 and 7 show the effect of organic leading on COD removal rate at 35°C and at 28°C, respectively. When organic loading was maintained at between 10.1 and 117.9 kg-COD/m^3. day, COD removal rate decreased as organic loading was increased. The maximal COD removal rate was merely 65%. The COD digestion efficiency also showed that satisfactory removal rate would be achieved (>60%) in treating the wastewater of each COD concentration and digestion temperature , when the system was operated at HRT of 12 hr. This could be confirmed by high BOD removal rate (>90%) achieved.

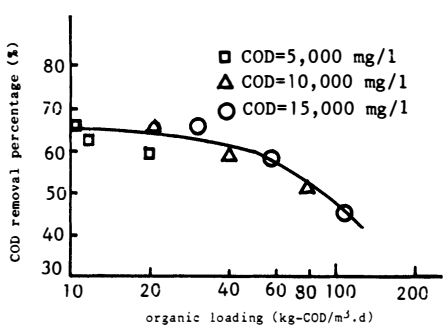

Fig.6. Effect of organic volume loading on COD removal percentage at 35°C

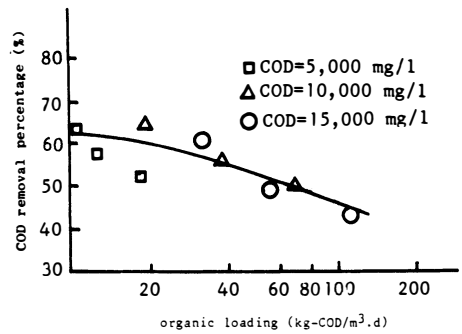

Fig.7. Effect of organic volume loading on COD removal percentage at 28°C

Figure 8 presents COD removals and temperatures for the duration of the experiment without controlling temperature at COD of 5,000 mg/l and HRT of 6 hr. Under this operation condition, COD removal rate did not have significant variation for the duration of the experiment and was in the range of 57.0%-63.4%. This range was almost the same as when temperature was under control. Hence, it is clear that, as long as the system is operated under proper conditions, AFBBR can achieve a satisfactory removal rate without controlling temperature. In addition, COD removal increased as room temperature increased.

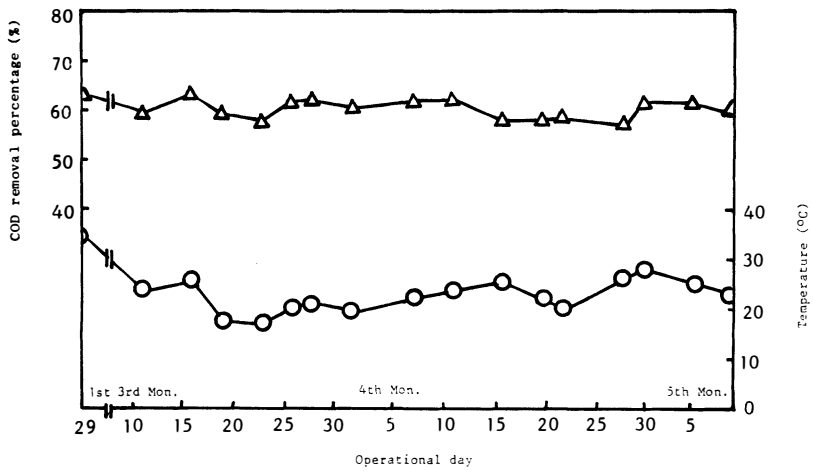

Fig.8. Relationship of COD removal percentage and temperature, without temperature control at influent COD concentration of 5000 mg/l and HRT of 6 hrs.

Biogas Production

The efficiency of anaerobic digestion can be judged from biogas production per kg of COD in Table 2. When HRT was maintained at > 6 hrs. and digestion temperature was greater than 28°C, the biogas production for each influent concentration all achieved > 250 l/kg-COD. The result demonstrated a satisfactory digestion efficency of the AFBBR.
It was also found from the experiment that methane production decreased with decreasing of HRT and with digestion temperature when HRT was maintained at 12 hr and digestion temperature was decreased to 28°C, the methane content of biogas for each influent concentration all achieved > 70%.

TABLE 2 Biogas Production of per kg COD in Various Operation Conditions.

COD Conc.	Temp.(°C)	HRT (hr)			
		3	6	9	12
5,000	35		305	314	324
	28		279	304	321
1,000	35	260	344		368
	28	162	328		346
15,000	35	256	342		365
	28	178	247		261

Note: Unit is l/kg-COD.

Other Effluent Quality and Parameters

pH. The pH value of influent ranged from 4.26 to 7.10 , and the pH value of effluent was between 7.16-7.39.

Volatile Acid. From Table 3, it is presented that the concentrations of volatile acids in effluent were much lower than that in influent, and all lower than 2,500 mg/l, indicating high digestion efficiency of the system.

TABLE 3 Average Volatile Acid Concentrations in Effluent Under Various Conditions.

COD conc.(mg/l)	Temp.(°C)	HRT (hr)			
		3	6	9	12
5,000	35		282	233	243
	28		352	278	248
	21		416	292	258
10,000	35	1245	678		465
	28	1254	712		544
	21		1024	672	536
15,000	35	2760	1278		859
	28	3228	1928		1096
	21	3798	3090		1931

Note: unit is mg/l as CH_3COOH

Sulfide. In this study, the sulfate concentration of influent increased with the increase of influent concentration. The sulfate concentration was as high as 2,400 mg-$SO_4^=$/l (1,200 mg-$S^=$/l) at influent COD concentration of 1,500 mg/l. Whereas, the maximal effluent sulfide concentration turned out to be as low as 58.8 mg-$S^=$/l, suggesting that this system was capable of removing sulfate. According to some literatures (Kao, 1985; Lin, 1985), the minimal inhibitive concentration of sulfide on methanogenic bacteria was 300 mg-$S^=$/l. Consequently, it is apparent that the concentration of sulfide in the system did not affect the performance of methanogenic bacteria.

MLSS. MLSS is given in Table 4. Biomass concentration increased as influent concentration was increased, HRT decreased and digestion temperature decreased. The MLSS was in the range of 15.27-43.33 g/l.

TABLE 4 MLSS Concentrations Under Various Conditions.

COD conc. (mg/l)	Temp. (°C)	HRT (hr)			
		3	6	9	12
5,000	35		20.7	19.1	18.4
5,000	28		22.4	20.9	18.5
5,000	21		24.2	22.2	19.5
10,000	35	30.7	34.7		15.3
10,000	28	32.6	29.2		21.0
10,000	21		31.7	27.0	20.0
15,000	35	31.0	29.7		25.0
15,000	28	35.3	30.1		24.3
15,000	21	43.3	34.9		25.2

Note: unit is g/l

Comparison of Different Anaerobic Processes for the Treatment of MSG Fermentation Wastewater

The effluent quality from systems with AFBBRs, with completely mixing process, and with upflow sludge-bed, treating MSG wastewater are respectively presented in Table 5. Due to low influent biodegradable organic concentration, the COD removal rates from these systems operated at 35°C did not have much difference, and all were about 60%. Although operated at room temperature (21°C-28°C), the fluidized-bed systems still achieved relatively high removal efficiency (55.5-61.0%). The COD volume loading to AFBBRs were found to be the highest, 1.4 times the sludge-bed system, and 10 times the completely mixing system, indicating smallest reactor volume required. This resulted in a reduction of construction cost. AFBBR was quite similar to sludge-bed reactor as to unit weight sludge loading, and, as a consequence, high total sludge concentration accounted for the main reason for the high digestion efficiency of AFBBR.

TABLE 5 Comparison of Various Anaerobic Processes in Treating MSG Wastewater

Process	fluidized bed			completely mixing	sludge bed
digestion temp.(°C)	35	28	21	35	35
Inf. Conc.:					
COD(mg/l)	15,000	15,000	15,000	25,000	18,000
COD removal(%)	65.5	61.0	55.5	63	60
BOD(mg/l)	5,700	5,100	5,400	11,000	10,000
BOD removal (%)	96.6	90.5	72.0	85	75
Volume loading:					
kg-COD/m^3.d	31.1	30.2	29.0	3.0	22.0
kg-removal COD/m^3.d	20.4	18.4	16.1	1.7	12.5
kg-BOD/m^3.d	10.9	9.7	10.2	1.1	13.0
kg-removal BOD/m^3.d	10.5	8.7	7.3	0.98	8.0
Sludge loading:					
kg-COD/kg-VSS.d	1.26	1.28	1.23	1.5	1.2
kg-removal COD/kg-VSS.d	0.82	0.78	0.68	1.25	0.7
kg-BOD/kg-VSS.d	0.44	0.40	0.40	0.67	0.45
kg-removal BOD/kg-VSS.d	0.43	0.36	0.29	0.6	0.38

Note: The data of completely mixing and sludge bed process are obtained from UCL, ITRI. (Juan, 1984)

CONCLUSION

1. When anaerobic fluidized-bed reactor was used to treat MSG fermentation wastewater, the optimal volume loading was at 10.1-13.1 kg-COD/m^3.day. When HRT was maintained at 12 hr, the AFBBR was able to remove, at 35°C, 65.4% of influent COD and 95% of influent BOD, and, at 28°C, 65.4% of influent COD and 91.0% of influent BOD.
2. Biogas production rate and methane content per kg of COD increased as influent concentration was increased, hydraulic retention time increased, digestion temperature was raised. When organic volume loading was < 20 kg-COD/m^3.day and digestion temperature was > 28°C, > 70% of methane content was achieved.
3. As long as the system is operated at proper pH and under proper operation conditions, the COD removal rate from the system without controlling temperature can be close to that with controlled temperature.
4. From the digestion efficiency, effluent pH, volatile acid concentration, and other operation parameters, it is apparent that AFBBR, as long as operated under proper conditions, is highly feasible for the treatment of MSG fermentation wastewater.

REFERENCES

Borchardt, J. A. (1971). "Anaerobic Phase Separation by Dialysis Technique", Anaerobic Biological Treatment Process, in Advances in Chemistry Series 105, ed., Gould, R. F. Amer. Chem. Soc. 108-125.

Copper, P. F. and Wheeldon, D. H. V. (1980), "Fluidized - and Expanded - Bed Reactors for Waste Water Treatment", Journal Waste Water Pollution Control. Vol.79.

Juan Kuo-Dong, et al. (1984). "Evaluation of Various Industrial Wastewater Pollution Characteristics and Treatment Technology--Fermentation and Starch-making Industry", Pollution Protection Series No.3, UCL, ITRI, Shin-Jwu, Taiwan, R.O.C.

Kao Jao-Fuan, et al.(1985)."Effects of Inhibitive substance on Methane Fermentation in Anaerobic Filter Process", Proc. 10th Conf. on Wastewater Treatment Technology, Republic of China, 489-500.

Lin Shihn-Yi,Ouyarng Chiaur-Huei (1985). " Operation Parameters and Utility of Biogas on Anaerobic Sludge Digestion ", report of Graduate Institute of Civil Eng. of National Jung-Yang University, Jung-Lir, Taiwan, R.O.C.

Tseng Szu-Kung, Lin Min-Ray (1985). " Treatment of High Concentration Organic Wastewater and Temperature Effects Studies by Anaerobic Biological Fluidized Bed Technology", No.112, Report of Graduate Institute of Environ. Eng. of National Taiwan University, R.O.C.