Treatment of Food Processing Industrial Effluent Using Coagulation and Sequential Batch Reactor

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ABSTRACT

The performance of combined treatment processes, namely coagulation and Sequential Batch Reactor (SBR) to treat effluent from food processing industry was evaluated. The experimental study was conducted in a batch mode using pilot-scale reactor. The parameters used in assessing the treatment system were BOD_5, COD and SS. The optimum amount of chemicals for the coagulation process ranges from 20 mg/L to 80 mg/L for coagulant and 60 mg/L to 220 mg/L for polymer while the optimum pH ranges from 5.5 to 7.0. The compliance of Standard A of the Environmental Quality Act was met using the combined process with SBR retention time of 6 hours.

INTRODUCTION

Unlike domestic wastewater, the characteristics of industrial wastewater are rather complex and vary from time to time in term of flow and strength. As an industry may produce several products, each of the product manufacturing processes produces wastewater of different volume and composition. Only small number of industrial plants operate continuously that generate wastewater of non-varying characteristics while majority of industries do not operate 24 hours a day and do not attempt to produce either product or effluent continuously or consistently [1]. Due to these variations and also to the complexity of chemicals that are used in the manufacturing processes, in many cases, more than one treatment process is needed in order to treat the wastewater to the acceptable quality.

In this study, the feasibility of treating effluent from a food manufacturing industry was evaluated. The industry consists of several manufacturing plants which include beverage, poultry processing, canned food, snack food, and sauce plants. The generated wastewater contains colloidal solids, colouring compounds, suspended solids, oil, and grease. As many alternatives are available, the study focus on the possibility of using coagulation and conventional SBR to treat the wastewater. The objective is to remove the organics and suspended solids (SS) from the wastewater so as to comply with either Standard A or Standard B (Table 1) as stipulated by the Department of Environment (DOE), Malaysia [2]. The parameters of concern in the study include COD, BOD_5, and SS.

Table 1 DOE standards with respect to the evaluated parameters.

Parameters	**Standard A** (mg/L)	**Standard B** (mg/L)
COD	50	100
BOD_5	20	50
SS	50	100

MATERIALS AND METHODS

Samples for the study were taken from a nearby food manufacturing industry while the coagulant and polymer were obtained from a chemical supplier. Chemicals that were used for analytical work were of reagent grade and the analytical work were conducted based on the standard procedures [2].

The study was conducted in two stages. The first stage was to determine the optimum amount of chemicals and pH to be used in the coagulation process while the second was to determine the effectiveness of the whole treatment system (coagulation + SBR) by varying the SBR hydraulic retention time (HRT).

Optimisation of the chemicals and pH for the coagulation process was conducted using typical jar test procedures. The dose of coagulant and polymer tested ranged from 20 mg/L to 220 mg/L, each, while the pH tested ranged from 5.5 to 8.5. Study on the SBR was conducted using a pilot scale reactor. The reactor is 1 m high with a diameter of 0.4 m and total filled volume of 85 L. The microorganisms in the SBR were acclimatised for about one and half month within which the mixed liquor suspended solids (MLSS) reached about 3000 mg/L. Throughout the study, MLSS and dissolved oxygen (DO) content in the SBR were maintained not to be less than 3000 mg/L and 3 mg/L, respectively.

Once the SBR was ready, the whole treatment system was put into test. The raw wastewater was pretreated with coagulation process using a pilot mixer (40 L) and was then fed into the SBR with a filling time of about 2 hours. The performance of the system was studied for different SBR retention times (i.e. 15, 30, 60, 120, 240, 360 and 480 minutes) with settling time of 2 hours. At least two trials were conducted for each retention time in order to get representative results.

RESULTS AND DISCUSSIONS

The characterisics of the raw wastewater during the study period is given in Table 2. The wastewater can be characterised as containing high organic content, colloidal in nature and acidic.

Table 2 Raw wastewater characteristics obtained during the study period.

Parameter	Concentration Range
pH	4 – 5.5
Biochemical Oxygen Demand (BOD_5)	200 – 2500 mg/L
Chemical Oxygen Demand (COD)	600 – 6000 mg/L
Suspended Solids (SS)	50 – 1300 mg/L

Separation Process

Results for jar test study are given in Tables 3 to 5. Based on percentage of COD removed, with the variation of raw wastewater quality, the optimum amount of coagulant ranged from 20 mg/L to 80 mg/L. The optimum pH ranged from 5.5 to 7.0 while the optimum amount of polymer ranged from 60 mg/L to 220 mg/L. On average, the highest percentage of removal was achieved using coagulant dose of 80 mg/L, pH 6.5, and polymer dose of 180 mg/L. During the jar test study. average percentage of COD removal varied from 72% to 82% following the addition of chemicals and pH adjustment.

Although highest average percentage of removal was obtained using polymer dose of 180 mg/L, acceptable amount of COD removal ($\geq$ 70%) occurred throughout the polymer doses. Thus, for economic reason, lower coagulant and polymer doses (than the optimum ones) could be used in the actual treatment process. During the second stage study, the pretreatment of raw wastewater prior to SBR was carried out using 80 mg/L dose of coagulant and polymer, each, at pH 7.

Table 3 Percentage of COD removal following coagulant addition.

Run #	Initial COD (mg/L)	mg/L coagulant										
		20	**40**	**60**	**80**	**100**	**120**	**140**	**160**	**180**	**200**	**220**
		Percentage of Removal										
1	854	53	67	73	85	25	51	44	23	86	30	52
2	3380	53	48	54	59	45	46	30	54	59	45	56
3	2685	88	80	78	68	78	50	84	79	71	86	78
4	1020	64	65	70	74	68	71	61	53	67	61	62
5	1870	67	70	49	64	58	55	54	58	64	49	53
Average		65	66	65	70	55	55	55	53	69	54	60

Highest removal percentage obtained in a run trial

Table 4 Percentage of COD removal following coagulant addition and pH adjustment.

Run #	Initial COD (mg/L)	pH						
		5.5	**6**	**6.5**	**7**	**7.5**	**8**	**8.5**
		Percentage of Removal						
1	3380	72	65	69	65	67	70	63
2	2515	-	67	69	66	64	67	-
3	2685	70	64	63	71	66	67	65
4	1730	61	67	64	54	59	55	55
5	1020	65	87	89	80	70	81	58
6	1870	64	61	81	82	60	73	76
Average		66	69	73	70	64	69	65

Highest removal percentage obtained in a run trial

Table 5 Percentage of COD removal following coagulant addition, pH adjustment and polymer addition.

Run #	Initial COD (mg/L)	mg/L polymer										
		20	**40**	**60**	**80**	**100**	**120**	**140**	**160**	**180**	**200**	**220**
		Percentage of Removal										
1	854	75	75	92	83	79	87	83	84	91	80	84
2	3380	64	73	74	74	65	72	-	74	65	72	71
3	2515	68	68	51	60	52	60	61	63	-	72	64
4	2685	65	65	58	67	70	68	67	68	66	68	71
5	1730	69	68	86	76	81	72	79	84	85	68	70
6	1020	-	86	83	81	80	75	93	87	87	83	94
7	1870	93	93	86	93	94	95	95	96	95	94	95
Average		72	75	76	76	74	76	80	79	82	77	78

Highest removal percentage obtained in a run trial

Although highest average percentage of removal was obtained using polymer dose of 180 mg/L, acceptable amount of COD removal ($\geq$ 70%) occurred throughout the polymer doses. Thus, for economic reason, lower coagulant and polymer doses (than the optimum ones) could be used in the actual treatment process. During the second stage study, the pretreatment of raw wastewater prior to SBR was carried out using 80 mg/L dose of coagulant and polymer, each, at pH 7.

SBR Process

As reported in previous studies [4], the SBR has been used to treat a variety of wastewater either in combination with other processes or as a single treatment process. A summary of several SBR studies is given in Table 6. In general, better than 90% organic removal efficiencies are reported.

Table 6 Summary of SBR performance studies[1].

Type of Wastewater	**Influent** (mg/L)	**F/R/S/D/I**[2] (hour)	**BOD Removal** (%)
1. Dairy	2000[3]	8/10/6(S+D)/0	90
2. Settled sewage	140	2.9/0.7/0.7/0.7/1.0	95
3. Landfill leachate	2300[4]	10/12/1/0.5/0.5	89
4. Hazardous wastes	1440[4]	10/10/2/2(D+I)	81
5. Raw sewage	268	17.2(F+R)/0.83/0.37/0	98
6. Raw piggery	1075	3/16/1/0.5/3.5	98
7. Anaerobically pretreated piggery	269	3/16/1/0.5/3.5	83
8. Oleochemical	1200[3]	4/6/6/1/0	92
9. Palm oil refinery	1800	3/17.5/3/0.5/0	94

[1] Adapted from [4]
[2] F = FILL; R = REACT; S = SETTLE; D = DECANT; I = IDLE
[3] based on COD
[4] based on TOC

Results for the SBR treated wastewater in this study are given in Tables 7 to 9 and is illustrated in Figure 1. As shown in Table 7, depending on the initial COD concentration, the treated COD ranged from 708 mg/L (HRT = 15 min) to 15 mg/L (HRT = 6 hours). During the study, the SBR treated wastewater almost complied with Standard B at HRT of 4 hours. At 6-hour retention time, the treated wastewater complied with Standard A with average COD of 15 mg/L (average of five trials). Percentage removal of the system ranges from from 73.8% at HRT of 15 minutes to 99.2% at HRT of 8 hours. Significant increase in COD removal could be observed at HRT of 4 hours.

As shown in Table 8, the BOD_5 of the treated wastewater ranges from 675 mg/L to less than 10 mg/L. Compliance of Standard B was observed at 2-hour HRT. However, possibly due to the contents of the wastewater, further reduction of BOD_5 could not be achieved until 4-hour HRT. At 4-hour HRT, BOD_5 was reduced to 20 mg/L and thus, complied with the Standard A. Increasing the HRT further reduced the BOD_5 to less than 10 mg/L. Percentage removal of BOD_5 ranges from 63.7% to 99.1%. Similar to COD, significant BOD_5 reduction was observed when the HRT was extended to 4 hours. Removal percentage of greater than 97% was observed at HRT of 4 hours and greater.

Table 7 Removal of COD following coagulation and SBR treatment.

SBR HRT (min)	Average COD (mg/L)		% Removal
	Raw	SBR treated	
15	2700	708	73.8
30	3000	228	92.4
60	1612	311	80.7
120	2623	291	88.9
240	4835	103	97.9
360	926	15	98.4
480	3603	30	99.2

Table 8 Removal of BOD_5 following coagulation and SBR treatment.

SBR HRT (min)	Average BOD_5 (mg/L)		% Removal
	Raw	SBR treated	
15	1860	675	63.7
30	2540	87	96.6
120	700	175	75.0
240	2160	20	99.1
360	330	< 10	> 97.0
480	666	11	98.3

Results for SS are shown in Table 9. With raw SS value ranges from 183 mg/L to 1350 mg/L, the treated water complies with Standard A even at 15-minute retention time. Thus, SS is not considered as a limiting factor in the design of the treatment system. Although chemically treated wastewater was not analysed for SS, from its appearance, removal of SS could be achieved by using the coagulation process.

CONCLUSION

The feasibilty of treating food manufacturing industrial effluent using coagulation and SBR to the standard set by the DOE was evaluated in the study. With respect to the considered parameters (i.e. BOD_5, COD, and SS), the combination processes were found to be adequate in fulfilling the requirements.

For coagulation, the optimum chemicals concentration ranges from 20 to 80 mg/L and from 60 mg/L to 220 mg/L for coagulant and polymer, respectively. The optimum pH ranges from 5.5 to 7.5. With respect to the tested parameters, compliance with Standard B was achieved at SBR HRT of 4 hour while full compliance with Standard A was achieved at SBR HRT of 6 hours.

Table 9 Removal of SS following coagulation and SBR treatment.

SBR HRT (min)	Average SS (mg/L)		% Removal
	Raw	SBR treated	
15	720	20	97.2
30	892	45	95.0
60	443	26	94.1
120	1350	23	98.3
240	-	17	-
480	183	12	93.4

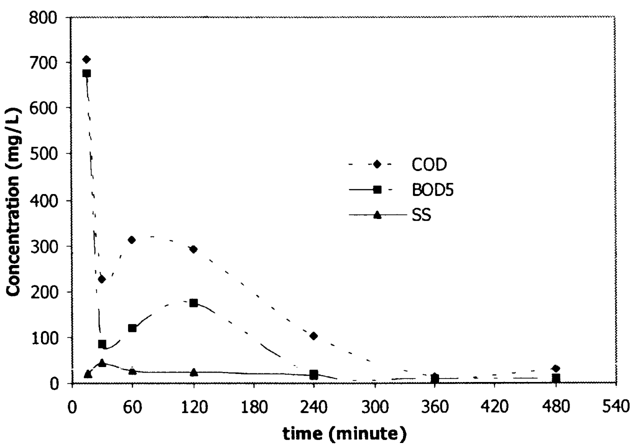

Figure 1 Profile of SBR treated wastewater.

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REFERENCES

[1] Barnes, D., Forster, C.F., Hrudey, S.E.(Editors), *Surveys in Industrial Wastewater Treatment: Food and Allied Industries (Volume 1),* Pitman Publishing Limited, 1984.

[2] *Akta Kualiti Alam Sekeliling 1974 (Akta 127) dan Peraturan-peraturan,* International Law Book Services, 1991.

[3] *Standard Method for the Examination of Water and Wastewater*, 18th Edition, APHA, AWWA and WER, 1992.

[4] Wun-Jern, N., *Sequencing Batch Reactor (SBR) Treatment of Wastewater,* Environmental Sanitation Reviews, Vol. 28, September 1989.