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APPENDICES

Appendix A Experimental Data of Effect of Nutrient Ratio.

1. COD Method

Table A-1 COD values and percent removal of biodiesel wastewater added nutrients at COD loading rate 0.10 and 0.60 kg/m³d (Average of COD influent was 524 mg/L)

Day	COD Effluent at COD loading rate 0.10 kg/m ³ d (mg/L)	% removal of COD loading rate 0.10 kg/m ³ d	COD Effluent at COD loading rate 0.60 kg/m ³ d (mg/L)	% removal of COD loading rate 0.60 kg/m ³ d
1	133.7	74.49	314.76	48.87
2	124.46	76.25	276.73	55.05
3	122.07	76.71	222.94	63.79
4	96.36	81.61	207.42	66.31
5	97.41	81.41	200.91	67.37
6	93.41	82.18	179.70	70.81
7	89.67	82.89	209.16	66.03
8	75.94	85.51	203.90	66.88
9	76.21	85.46	205.84	66.57
10	63.33	87.92	196.39	68.10
11	56.14	88.72	199.65	67.57
12	51.14	90.24	193.24	68.61
13	52.77	89.93	-	-
14	54.78	89.55	-	-
15	49.75	90.51	-	-

Table A-2 COD values and percent removal of the control at COD loading rate 0.10 and 0.60 kg/m³d (Average of COD influent was 650 mg/L)

Day	COD Effluent at COD loading rate 0.10 kg/m ³ d (mg/L)	% removal of COD loading rate 0.10 kg/m ³ d	COD Effluent at COD loading rate 0.60 kg/m ³ d (mg/L)	% removal of COD loading rate 0.60 kg/m ³ d
1	263.01	59.55	428.25	34.14
2	226.14	65.22	377.78	41.90
3	215.69	66.83	358.03	44.94
4	221.98	65.86	362.77	44.21
5	236.66	63.61	343.78	47.13
6	188.47	71.02	306.43	52.88
7	219.84	66.19	351.32	45.97
8	195.57	69.93	306.80	52.82
9	167.12	74.30	344.13	47.08
10	162.20	75.06	336.47	48.26
11	157.63	75.76	379.16	41.69
12	179.90	72.33	316.82	51.28
13	182.38	71.95	305.59	53.01
14	196.62	69.76	357.30	45.05
15	207.85	68.04	310.97	52.18
16	204.95	68.48	328.28	49.52

2. TOC Method

Table A-3 TOC values and percent removal of biodiesel wastewater added nutrients at COD loading rate 0.10 and 0.60 kg/m³d (Average of TOC influent was 146 mg/L)

Day	TOC Effluent at COD loading rate 0.10 kg/m ³ d (mg/L)	% removal of COD loading rate 0.10 kg/m ³ d	TOC Effluent at COD loading rate 0.60 kg/m ³ d (mg/L)	% removal of COD loading rate 0.60 kg/m ³ d
1	92.83	20.41	143.50	1.67
2	88.15	24.43	145.30	0.43
3	90.96	220.02	136.37	6.55
4	84.41	27.63	137.10	6.05
5	94.48	19.00	139.60	4.34
6	91.20	21.81	123.27	15.53
7	87.39	25.08	124.43	14.73
8	91.14	21.86	131.23	10.07
9	89.04	23.66	132.87	8.95
10	88.61	24.03	120.83	17.20
11	85.75	26.48	132.10	9.48
12	86.92	25.48	123.10	15.64
13	91.46	21.59	-	-
14	79.47	31.87	-	-
15	75.33	35.42	-	-

Table A-4 TOC values and percent removal of the control at COD loading rate 0.10 and 0.60 kg/m³d (Average of TOC influent was 161 mg/L)

Day	TOC Effluent at COD loading rate 0.10 kg/m ³ d (mg/L)	% removal of COD loading rate 0.10 kg/m ³ d	TOC Effluent at COD loading rate 0.60 kg/m ³ d (mg/L)	% removal of COD loading rate 0.60 kg/m ³ d
1	155.73	3.53	159.57	1.15
2	157.97	2.14	153.27	5.05
3	155.90	3.43	157.03	2.73
4	156.65	2.96	151.20	6.34
5	152.83	5.33	153.97	4.62
6	152.83	5.33	157.10	2.68
7	151.03	6.44	141.23	12.51
8	140.47	12.98	157.07	2.70
9	135.80	15.88	143.57	11.06
10	135.03	16.35	151.63	6.07
11	138.70	14.08	141.10	12.59
12	136.40	15.51	144.03	10.78
13	142.03	12.02	147.80	8.44
14	142.87	11.50	143.33	11.21
15	141.33	12.45	140.73	12.82
16	138.07	14.47	143.60	11.05

3. MLSS Method

Table A-5 MLSS and F/M ratio of the biodiesel wastewater added nutrients at COD loading rate 0.10 and 0.60 kg/m³d

Day	COD loading rate 0.10 kg/m ³ d		COD loading rate 0.60 kg/m ³ d	
	MLSS (mg/L)	F/M ratio	MLSS (mg/L)	F/M ratio
4	1,270	0.06	840	0.49
8	1,655	0.05	950	0.43
12	1,575	0.04	1830	0.23
15	1,785	0.04	-	-

Table A-6 MLSS and F/M ratio of the control at COD loading rate 0.10 and 0.60 kg/m³d

Day	COD loading rate 0.10 kg/m ³ d		COD loading rate 0.60 kg/m ³ d	
	MLSS (mg/L)	F/M ratio	MLSS (mg/L)	F/M ratio
4	820	0.09	1170	0.25
8	1,130	0.07	910	0.38
12	780	0.10	1100	0.30
16	1,090	0.07	1140	0.28

$$F/M \text{ ratio} = \frac{(COD_{in} - COD_{out}) \times \text{Flow rate}}{\text{Amount of bacteria} \times \text{Volume of aeration tank}}$$

4. Effluent SS Method

Table A-7 Effluent SS of the biodiesel wastewater added nutrients at COD loading rate 0.10 and 0.60 kg/m³d

Day	COD loading rate 0.10 kg/m ³ d	COD loading rate 0.60 kg/m ³ d
4	32	112
8	60	132
12	44	113
15	60	-

Table A-8 Effluent SS of the control at COD loading rate 0.10 and 0.60 kg/m³d

Day	COD loading rate 0.10 kg/m ³ d	COD loading rate 0.60 kg/m ³ d
4	86	145
8	102	160
12	80	157
16	83	112

Appendix B Experimental Data of Effect of COD Loading Rate.

1. COD Method

Table B-1 COD values and percent removal of dilute biodiesel wastewater (Average of COD effluent of COD loading rate 0.05 and 0.075 kg/m³d were equal to 632.97 mg/L, COD loading rate 0.10 kg/m³d was equal to 524.08 mg/L, COD loading rate 0.20 and 0.40 kg/m³d were equal to 591.09 mg/L, and COD loading rate 0.60 kg/m³d was equal to 615.65 mg/L)

Day	COD loading rate 0.05 kg/m ³ d		COD loading rate 0.075 kg/m ³ d		COD loading rate 0.10 kg/m ³ d		COD loading rate 0.20 kg/m ³ d		COD loading rate 0.40 kg/m ³ d		COD loading rate 0.60 kg/m ³ d	
	COD (mg/L)	% removal	COD (mg/L)	% removal	COD (mg/L)	% removal	COD (mg/L)	% removal	COD (mg/L)	% removal	COD (mg/L)	% removal
1	66.96	89.42	77.80	87.71	133.70	74.49	181.53	69.29	181.29	69.33	314.76	48.87
2	50.18	92.07	75.03	88.15	124.46	76.25	131.72	77.72	185.49	68.62	276.73	55.05
3	81.91	87.06	80.69	87.25	122.07	76.71	137.98	76.66	167.44	71.67	222.94	63.79
4	56.35	91.10	77.40	87.77	96.36	81.61	126.21	78.65	185.13	68.68	207.42	66.31
5	68.75	89.14	71.02	88.78	97.41	81.41	140.21	76.28	194.21	67.14	200.91	67.37
6	93.21	85.27	97.95	84.53	93.41	82.18	84.44	85.71	189.90	67.87	179.70	70.81
7	87.62	86.16	63.49	89.97	89.67	82.89	79.87	86.49	135.33	77.11	209.16	66.03
8	75.36	88.09	64.00	89.89	75.94	85.51	71.99	87.82	102.47	82.66	203.90	66.88
9	76.88	87.85	71.70	88.67	76.21	85.46	41.51	92.98	65.60	88.90	205.84	66.57
10	69.72	88.99	80.88	87.22	63.33	87.92	58.68	90.07	67.33	88.61	196.39	68.10
11	77.52	87.75	76.04	87.99	56.14	88.72	58.00	90.19	54.51	90.78	199.65	67.57
12	69.93	88.95	77.38	87.78	51.14	90.24	55.37	90.63	87.57	85.19	193.24	68.61
13	64.06	89.88	59.11	90.66	52.77	89.93	71.07	87.98	72.35	87.76	-	-
14	57.65	90.89	53.57	91.54	54.78	89.55	-	-	-	-	-	-
15	54.74	91.35	57.59	90.90	49.75	90.51	-	-	-	-	-	-
16	51.56	91.85	69.39	89.04	-	-	-	-	-	-	-	-
17	54.01	91.47	57.13	90.97	-	-	-	-	-	-	-	-

2. TOC Method

Table B-2 TOC values and percent removal of dilute biodiesel wastewater (Average of TOC effluent of COD loading rate 0.05 and 0.075 kg/m³d were equal to 144.15 mg/L, COD loading rate 0.10 kg/m³d was equal to 116.64 mg/L, COD loading rate 0.20 and 0.40 kg/m³d were equal to 146.98 mg/L, and COD loading rate 0.60 kg/m³d was equal to 145.93 mg/L)

Day	COD loading rate 0.05 kg/m ³ d		COD loading rate 0.075 kg/m ³ d		COD loading rate 0.10 kg/m ³ d		COD loading rate 0.20 kg/m ³ d		COD loading rate 0.40 kg/m ³ d		COD loading rate 0.60 kg/m ³ d	
	TOC (mg/L)	% removal	TOC (mg/L)	% removal	TOC (mg/L)	% removal	TOC (mg/L)	% removal	TOC (mg/L)	% removal	TOC (mg/L)	% removal
1	105.77	26.63	97.29	32.51	92.83	20.41	130.87	10.96	116.87	20.49	143.50	1.67
2	94.81	34.23	91.80	36.32	88.15	24.43	125.73	14.46	123.20	16.18	145.30	0.43
3	98.52	31.65	98.87	31.41	90.96	22.02	126.27	14.09	114.53	22.08	136.37	6.55
4	102.34	29.00	97.83	32.13	84.41	27.63	132.00	10.19	105.90	27.95	137.10	6.05
5	103.98	27.87	99.10	31.25	94.48	19.00	96.05	34.65	104.33	29.02	139.60	4.34
6	102.65	28.79	97.16	32.60	91.20	21.81	95.81	34.81	99.36	32.40	123.27	15.53
7	99.85	30.73	96.73	32.90	87.39	25.08	93.84	36.15	107.00	27.20	124.43	14.73
8	103.00	28.55	100.61	30.20	91.14	21.86	95.16	35.26	111.60	24.07	131.23	10.07
9	106.85	25.88	108.70	24.59	89.04	23.66	105.40	28.29	104.67	28.79	132.87	8.95
10	105.95	26.50	104.90	27.23	88.61	24.03	97.14	33.91	103.09	29.86	120.83	17.20
11	102.85	28.65	102.35	29.00	85.75	26.48	100.42	31.68	103.52	29.57	132.10	9.48
12	103.60	28.13	109.10	24.31	86.92	25.48	98.24	33.16	105.31	28.35	123.10	15.64
13	111.70	22.51	98.30	31.81	83.46	28.45	103.86	29.34	105.46	28.25	-	-
14	91.17	36.75	99.53	30.95	79.47	31.87	-	-	-	-	-	-
15	93.37	35.23	101.20	29.80	75.33	35.42	-	-	-	-	-	-
16	95.27	33.91	96.30	33.19	-	-	-	-	-	-	-	-
17	91.05	36.84	92.20	36.04	-	-	-	-	-	-	-	-

3. MLSS Method

Table B-3 MLSS and F/M ratio of the dilute biodiesel wastewater

Day	COD loading rate 0.05 kg/m ³ d		COD loading rate 0.075 kg/m ³ d		COD loading rate 0.10 kg/m ³ d		COD loading rate 0.20 kg/m ³ d		COD loading rate 0.40 kg/m ³ d		COD loading rate 0.60 kg/m ³ d	
	MLSS (mg/L)	F/M ratio	MLSS (mg/L)	F/M ratio	MLSS (mg/L)	F/M ratio	MLSS (mg/L)	F/M ratio	MLSS (mg/L)	F/M ratio	MLSS (mg/L)	F/M ratio
1	-	-	-	-	-	-	-	-	-	-	-	-
2	-	-	-	-	-	-	-	-	-	-	-	-
3	-	-	-	-	-	-	-	-	-	-	-	-
4	1,520	0.03	1,480	0.05	1,270	0.06	1,720	0.09	1,295	0.21	840	0.49
5	-	-	-	-	-	-	-	-	-	-	-	-
6	-	-	-	-	-	-	-	-	-	-	-	-
7	-	-	-	-	-	-	-	-	-	-	-	-
8	2,220	0.02	1,420	0.05	1,655	0.05	1,610	0.11	1,315	0.25	950	0.43
9	-	-	-	-	-	-	-	-	-	-	-	-
10	-	-	-	-	-	-	-	-	-	-	-	-
11	-	-	-	-	-	-	-	-	-	-	-	-
12	1,927	0.02	1,867	0.04	1,575	0.04	-	-	-	-	1,830	0.23
13	-	-	-	-	-	-	1,630	0.10	1,250	0.28	-	-
14	-	-	-	-	-	-	-	-	-	-	-	-
15	-	-	-	-	1,785	0.04	-	-	-	-	-	-
16	-	-	-	-	-	-	-	-	-	-	-	-
17	1,815	0.03	1,750	0.04	-	-	-	-	-	-	-	-

4. Effluent SS Method

Table B-4 Effluent SS of the dilute biodiesel wastewater

Day	Effluent SS at COD loading rate 0.05 kg/m ³ d (mg/L)	Effluent SS at COD loading rate 0.075 kg/m ³ d (mg/L)	Effluent SS at COD loading rate 0.10 kg/m ³ d (mg/L)	Effluent SS at COD loading rate 0.20 kg/m ³ d (mg/L)	Effluent SS at COD loading rate 0.40 kg/m ³ d (mg/L)	Effluent SS at COD loading rate 0.60 kg/m ³ d (mg/L)
1	-	-	-	-	-	-
2	-	-	-	-	-	-
3	-	-	-	-	-	-
4	55	52	32	51	65	112
5	-	-	-	-	-	-
6	-	-	-	-	-	-
7	-	-	-	-	-	-
8	52	58	60	51	52	132
9	-	-	-	-	-	-
10	-	-	-	-	-	-
11	-	-	-	-	-	-
12	40	67	44	-	-	113
13	-	-	-	45	47	-
14	-	-	-	-	-	-
15	-	-	60	-	-	-
16	-	-	-	-	-	-
17	31	33	-	-	-	-

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