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APPENDICES

Appendix A Experimental Data of Characterization of Fish Steaming Waste, Diluted Fish Steaming Waste and Mineral medium, and Palm Oil

Table A1 Characterization of the non-diluted fish steaming waste feed

Parameters	Non-diluted FSW
COD (mg/l)	33,333
Total nitrogen (mg/l)	4,766.7
Total phosphorus (mg/l)	454.7
TOC (mg/l)	25,107.3
C:N ratio	5.3
C:P ratio	55.2
Oil concentration (mg/l)	0
Total suspended solids (mg/l)	878
Surface tension (mN/m)	40.80
Surfactant concentration (xCMC)	0

Table A2 Characterization of the diluted fish steaming waste feed

Parameters	Diluted FSW
COD (mg/l)	377
Total nitrogen (mg/l)	78.7
Total phosphorus (mg/l)	7.5
TOC (mg/l)	465.7
C:N ratio	5.9
C:P ratio	61.7
Oil concentration (mg/l)	0
Total suspended solids (mg/l)	65
Surface tension (mN/m)	65.93
Surfactant concentration (xCMC)	0

Table A3 Characterization of the mineral medium (MM) feed

Parameters	Mineral medium
COD (mg/l)	0
TOC (mg/l)	0
C:N ratio	16.0
C:P ratio	14.0
Oil concentration (mg/l)	0
Total suspended solids (mg/l)	0
Surfactant concentration (xCMC)	0

Table A4 Characterization of the palm oil feed

Parameters	Palm oil
COD (mg/l)	555,111
Total nitrogen (mg/l)	1,600.0
Total phosphorus (mg/l)	183.3
TOC (mg/l)	41,400.0
C:N ratio	25.9
C:P ratio	225.8
Total suspended solids (mg/l)	0
Surfactant concentration (xCMC)	0

Table A5 Surface tension in the influent

Influent	Cycle time (days)	Surface tension (mN/m)			
		No.1	No.2	No.3	Avg.
Non-diluted FSW	1	40.8	40.1	41.5	40.8
Diluted FSW		65.4	65.6	66.8	65.9
MM at an OLR of 1 kg/m ³ d		65.9	68.5	-	67.2
MM at an OLR of 2 kg/m ³ d		66.9	69.0	66.9	67.6
MM at an OLR of 6 kg/m ³ d		66.7	68.2	66.7	67.2
MM at an OLR of 10 kg/m ³ d		68.3	68.2	68.1	67.8
MM at an OLR of 0.67 kg/m ³ d	3	70.9	66.9	68.5	68.8

Table A6 TSS in the influent

Influent	No.	Volume of sample (ml)	Wt.floy+filter (g)	Wt.tot. (g)	TSS (g)	TSS (mg/l)	Avg. TSS (mg/l)
Non-diluted FSW	1	10	0.4670	0.4760	0.009	900.00	877.78
	2	12	0.4704	0.4813	0.0109	908.33	
	5	20	0.4494	0.4659	0.0165	825.00	
Diluted FSW	1	70	0.4481	0.4530	0.0049	70.00	65.24
	3	70	0.4893	0.4936	0.0043	61.43	
	4	70	0.4498	0.4543	0.0045	64.29	

Table A7 Total nitrogen (TN) of substances in the influent

Substances	No.	Vol. of test (ml)		Time of test (00:00)					TN (mg/l)		
		Sample	DO. Water	Heating stop	Cool to T _{room} stop	Reaction 1 stop	Reaction 2 stop	Reaction 3 stop	Diluted	Actual	Avg.
				30 min	45 min	3 min	2 min	5 min			
Palm oil	1	1	99	15.55			42.33	12.11	19.0	1900.0	1600.00
	2			15.56.46		16.44.28	50.52	17.36	13	1300.0	
Non-diluted FSW	1	1	99	16.03.46		16.55.48	59.48	20.40	44	4400	4766.67
	2			16.09.30		17.1.4	6.30	22.45	46	4600	
	3					17.6.4	9.00	25.10	53	5300	
0.2004g NaNO ₃ in 100 ml DO. water	1	1	4						45	225	227.5
	2								46	230	

Table A8 Total phosphorous (TP) of substances in the influent

Substances	No.	Vol. of test (ml)		Time of test (00:00)			TP (mg/l)		
		Sample	DO. Water	Heating stop	Cool to T _{room} stop	Reaction stop	Diluted	Actual	Avg.
				30 min	45 min	7 min			
Palm oil	2	1	99	16.38	17.38	18.11	1.8	180.00	183.3
	3					18.13	2.7	270.00	
	4					18.15	1	100.00	
Non-dilluted FSW	5	1	99	16.45	17.45	18.18	4.7	470.00	456.7
	6					18.20	4.6	460.00	
	8					18.25	4.4	440.00	
0.0506g KH ₂ PO ₄ in 100 ml DO. water	5	3	27				9.0	90.00	90.0
	6						9.0	90.00	
0.1001g K ₂ HPO ₄ in 100 ml DO. water	1	3	27			18.08	14.1	141.00	142.0
	2					18.11	14.5	145.00	
	4					18.15	14.0	140.00	

Table A9 Total organic carbon (TOC) of substances in the influent

Substances	Sample no.	Wt. of sft (g)	Volume (ml)			[sft] (%w/v)	[Palm oil] (%v/v)	TOC (mg/l)				
			DO. water	Sample	sft solution			Sample dilution	Palm oil	Palm oil 100%v/v	Actual	Avg.
Palm oil+sft solution	1	0.15	150	0.05	10	0.1	0.5	1042.0	217.7	43,533.3		41,400.0
	2	0.15	150	0.04	10	0.1	0.4	981.4	157.1	39,266.7		
sft solution	5	0.15	150			0.1		829.4				824.3
	6	0.15	150			0.1		819.3				
	8	0.15	150			0.1		824.3				
Non-diluted FSW	1		12	5				7,482.0			25,438.8	25,107.3
	2		12	5				7,400.0			25,160.0	
	3		16	2				2,733.0			24,597.0	
	4		12	5				7,467.0			25,387.8	
	5		10	8				11,060.0			24,885.0	
	7		12	3				5,035.0			25,175.0	
Diluted FSW	7		0	1				467.80			467.80	465.7
	8		0	1				464.70			464.70	
	9		0	1				464.40			464.40	
	10		0	1				464.4			464.4	
	11		0	1				466.8			466.8	
	12		0	1				466.0			466.0	

Table A10 Composition in the influent with different oil loading rates

OLR (kg/m ³ d)	[Oil] (%w/v)	[Oil] (%v/v)	[Media] (%v/v)	Vol. of Media (ml)	Vol. of Oil (ml)	COD of oil (mg/l)	COD of media (mg/l)	Total COD (mg/l)	TOC of oil (mg/l)	TP of oil (mg/l)	TP of media (mg/l)	Total TP (mg/l)
1	0.3	0.35	99.65	498.24	1.76	1,956.45	0	1,956.45	145.91	0.65	231.18	231.83
2	0.6	0.70	99.30	496.48	3.52	3,912.90	0	3,912.90	291.82	1.29	230.36	231.66
6	1.8	2.11	97.89	489.43	10.57	11,738.71	0	11,738.71	875.47	3.88	227.09	230.97
8	2.4	2.82	97.18	485.90	14.10	15,651.61	0	15,651.61	1,167.29	5.17	225.46	230.63
10	3.0	3.52	96.48	482.38	17.62	19,564.51	0	19,564.51	1,459.12	6.46	223.82	230.28
		100	-	0.00	500.0	555,110.5			41,400.0	183.33		
			100	500.00	0.00						232.00	

Density of palm oil = 0.8512 g/ml

OLR (kg/m ³ d)	[Oil] (%w/v)	TN of oil (mg/l)	TN of media (mg/l)	Total TN (mg/l)	Total wanted TN (mg/l)	Wanted TN in media (mg/l)	Fill NaNO ₃ in media (g/l)	C:N ratio	Total wanted TP (mg/l)	Wanted TP in media (mg/l)	Fill KH ₂ PO ₄ in media (g/l)	Fill K ₂ HPO ₄ in media (g/l)	C:P ratio
1	0.3	5.64	226.70	232.34	9.12	3.48	0.03066	16	10.42	9.78	0.021466	0.042000	14.00
2	0.6	11.28	225.90	237.17	18.24	6.96	0.06132	16	20.84	19.55	0.042135	0.085000	14.00
6	1.8	33.83	222.69	256.52	54.72	20.88	0.18395	16	62.53	58.66	0.250025	0.100000	14.00
8	2.4	45.11	221.09	266.20	72.96	27.84	0.24526	16	83.38	78.21			14.00
10	3	56.39	219.48	275.87	91.19	34.80	0.30658	16	104.22	97.76	0.250551	0.375000	14.00

Appendix B Experimental Data of Biosurfactant Production with Different Oil Loading Rates, Nutrient Sources, and Cycle Times

1 Non-Diluted FSW at an OLR of 2 kg/m³d and 1-d cycle

Table B1 Effluent COD and COD removal on days 1-13 of operation in the SBR at an oil loading rate of 2 kg/m³d, non-diluted FSW feed and 1-d cycle

Day	Cycle no.	Volume of test (ml)		Diluted effluent COD (mg/l)			Actual effluent COD (mg/l)	COD removal (%)
		Sample	DO. Water	No.1	No.2	avg.		
0	0	-	-	-	-	-	-	-
1	1	1	199	145	162	153.5	30,700.00	17.05
2	2	1	199	155	127	141	28,200.00	23.81
3	3	1	199	149	126	137.5	27,500.00	25.70
4	4	1	199	132	99	115.5	23,100.00	37.59
5	5	1	199	113	84	98.5	19,700.00	46.77
6	6	1	199	132	130	131	26,200.00	29.21
7	7	0.95	99	233	227	230	24,301.14	34.34
8	8	1	99	230	255	242.5	24,250.00	34.48
9	9	1	99	236	271	253.5	25,350.00	31.51
10	10	1	99	287	300	293.5	29,350.00	20.70
11	11	1	99	266	269	267.5	26,750.00	27.72
12	12	1	99	265	280	272.5	27,250.00	26.37
13	13	1	99	256	244	250	25,000.00	32.45

2 Diluted FSW at OLRs of 2 and 8 kg/m³d, and 1-d cycle**Table B2** Effluent COD and COD removal with operation time in the SBRs at oil loading rates of 2 (days 1-12) and 8 (days 1-16) kg/m³d with diluted FSW feed and 1-d cycle

Oil loading rate (kg/m ³ d)	Day	Volume of test (ml)		Diluted effluent COD (mg/l)			Actual effluent COD (mg/l)	COD removal (%)
		Sample	DO. Water	No.1	No.2	Avg.		
2	1	1	10	460	468	464.0	5,104.00	-19.06
	2	1	15	294	273	283.5	4,536.00	-5.81
	3	1	16	219	219	219.0	3,723.00	13.15
	4	1	9	287	287	287.0	2,870.00	33.05
	5	1	9	152	146	149.0	1,490.00	65.24
	6	1	9	83	87	85.0	850.00	80.17
	7	1	9	84	77	80.5	805.00	81.22
	8	1	9	93	112	102.5	1,025.00	76.09
	11	1	9	103	99	101.0	1,010.00	76.44
	12	1	9	105	95	100.0	1,000.00	76.67
8	1	1	99	64	65	64.5	6,450.00	59.73
	2	1	99	33	43	38.0	3,800.00	76.28
	3	1	99	30	27	28.5	2,850.00	82.21
	4	1	24	354	352	353.0	8,825.00	44.90
	5	1	20	450	444	447.0	9,387.00	41.40
	6	1	15	449	466	457.5	7,320.00	54.30
	7	1	16	449	452	450.5	7,658.50	52.19
	8	1	9	536	535	535.5	5,355.00	66.57
	9	1	9	497	495	496.0	4,960.00	69.03
	10	1	9	536	537	536.5	5,365.00	66.51
	11	1	9	489	487	488.0	4,880.00	69.53
	12	1	9	506	502	504.0	5,040.00	68.53
	15	1	9	502	509	505.5	5,055.00	68.44
	16	1	9	495	491	493.0	4,930.00	69.22

Table B3 Surface tension and surface tension reduction during steady state operation in the SBRs at oil loading rates of 2 (days 15-16) and 8 kg/m³d (days 14-16) with diluted FSW feed and 1-d cycle

Oil loading rate (kg/m ³ d)	Day	Surface tension (mN/m)			Surface tension reduction (%)
		No.1	No.2	Avg.	
2	15	28.9	-	28.5	56.77
	16	28.5	28.1		
8	14	29.4	-	29.27	55.61
	15	29.1	-		
	16	29.3	-		

Table B4 Effluent COD and COD removal during steady state operation in the SBRs at oil loading rates of 2 (days 8-12) and 8 kg/m³d (days 12-16) with diluted FSW feed and 1-d cycle

OLR (kg/m ³ d)	Day	Volume of test (ml)		Diluted COD (mg/l)			Actual COD (mg/l)	Avg. actual COD (mg/l)	COD removal (%)	Avg. COD removal (%)
		Sample	DO. Water	No.1	No.2	Avg.				
2	8	1	9	93	112	102.5	1,025.00	1,011.67	76.09	76.40
	11	1	9	103	99	101.0	1,010.00		76.44	
	12	1	9	105	95	100.0	1,000.00		76.67	
8	12	1	9	506	502	504.0	5,040.00	5,008.33	68.53	68.73
	15	1	9	502	509	505.5	5,055.00		68.44	
	16	1	9	495	491	493.0	4,930.00		69.22	

Table B5 Effluent oil concentration and oil removal during steady state operation in the SBRs at oil loading rates of 2 (days 12-16) and 8 kg/m³d (days 12-16) with diluted FSW feed and 1-d cycle

OLR (kg/m ³ d)	Day	Volume (ml)				Wt.flask. (g)	Wt.flask + oil (g)	Wt.oil. (g)	Effluent [Oil] (g/500ml)	Effluent [Oil] (g/l)	Avg. effluent [Oil] (mg/l)	Oil removal (%)
		1:1 HCl	Total	Sample + 1:1HCl	Sample							
2	12	28	305	88	79.9213	113.2828	113.3167	0.0339	0.21	0.42	499.70	91.67
	14	30	315	76	68.7619	113.2812	113.3208	0.0396	0.29	0.58		
	16	28	310	76	69.1355	113.2825	113.3170	0.0345	0.25	0.50		
8	12	28	310	89	80.9613	194.4228	195.4867	1.0639	6.57	13.14	11650.44	51.46
	14	30	325	75	68.0769	109.8089	110.5296	0.7207	5.29	10.59		
	16	30	315	88.4	79.981	109.8092	110.7069	0.8977	5.61	11.22		

Table B6 Effluent TSS and MLSS during steady state operation (days 13-15) in the SBRs at oil loading rates of 2 and 8 kg/m³d with diluted FSW feed and 1-d cycle

OLR (kg/m ³ d)	Day	No.	Volume (ml)				Wt.floy+filter (g)	Wt. total (g)	Effluent TSS (g)	Effluent TSS (mg/l)	Avg. effluent TSS (mg/l)
			Sample	Sample+1:1HCl	1:1HCl	Total					
2	13	1	3	-	-	-	0.4817	0.4828	0.0011	366.67	349.42
	14	1	1.81	2	30	315	0.5064	0.5070	0.0006	331.58	
	15	1	2	-	-	-	0.5330	0.5337	0.0007	350.00	
8	13	1	2	-	-	-	0.5336	0.5454	0.0118	5,900.00	5,497.74
	14	1	1.82	2	30	325	0.5073	0.5170	0.0097	5,343.22	
	15	1	2	-	-	-	0.5358	0.5463	0.0105	5,250.00	

Wt. total = wt. floy + wt. filter paper + wt. TSS

OLR (kg/m ³ d)	Day	No.	Volume (ml)				Wt.floy+filter (g)	Wt. total (g)	MLSS (g)	MLSS (mg/l)	Avg. MLSS (mg/l)
			Sample	Sample+1:1HCl	1:1HCl	Total					
2	13	1	5	-	-	-	0.4933	0.4970	0.0037	740.00	746.67
	14	1	3	-	-	-	0.4847	0.4869	0.0022	733.33	
	15	1	3	-	-	-	0.4882	0.4905	0.0023	766.67	
8	13	1	2	-	-	-	0.5081	0.5193	0.0112	5,600.00	5,666.67
	14	1	2	-	-	-	0.5079	0.5192	0.0113	5,650.00	
	15	1	2	-	-	-	0.5070	0.5185	0.0115	5,750.00	

Wt. total = wt. floy + wt. filter paper + wt. MLSS

Table B7 Effluent surface tension with aeration time during a steady state cycle (day 16) of the SBRs at oil loading rates of 2 and 8 kg/m³d with diluted FSW and 1-d cycle

OLR (kg/m ³ d)	Day	Time (00:00)	Time (h.)	Sample no.	Surface tension (mN/m)	
					No.1	Avg.
2	16	8:30	0	1	28.5	28.5
		9:30	1	1	29.0	29.4
				2	29.8	
		10:30	2	1	30.6	30.6
		11:30	3	1	30.9	30.9
		12:30	4	1	31.4	31.4
		13:30	5	1	32.0	32.0
		14:30	6	1	31.9	31.9
		15:30	7	1	32.4	32.4
				2	32.3	
		16:30	8	1	32.6	32.6
		17:30	9	1	33.3	32.9
				2	32.5	
		18:30	10	1	32.9	33.0
				2	33.1	
		19:30	11	1	33.4	33.4
		21:30	13	1	33.8	33.8
		22:30	14	1	34.0	34.0
23:30	15	1	34.4	34.4		
		2	34.3			
1:30	17	1	35.1	35.1		
3:30	19	1	35.9	35.9		
5:30	21	1	37.4	37.4		
7:30	23	1	37.5	37.5		

OLR (kg/m ³ d)	Day	Time (00:00)	Time (hr.)	Sample no.	Surface tension (mN/m)	
					No.1	Avg.
8	16	8:30	0			29.3
		9:30	1	1	28.8	29.5
				2	30.2	
		10:30	2	1	27.9	28.1
				2	28.3	
		11:30	3	1	29.0	29.0
		12:30	4	1	29.5	29.5
		13:30	5	1	29.8	29.8
		14:30	6	1	28.8	28.8
		15:30	7	1	29.2	29.2
				2	29.1	
		16:30	8	1	29.7	29.7
		17:30	9	1	29.1	29.2
				2	29.2	
		18:30	10	1	29.5	29.5
				2	29.4	
		19:30	11	1	29.2	29.2
		21:30	13	1	29.3	29.3
		23:30	15	1	29.3	29.3
		1:30	17	1	29.7	29.7
		3:30	19	1	29.5	29.5
		5:30	21	1	29.7	29.7
		7:30	23	1	29.7	29.7

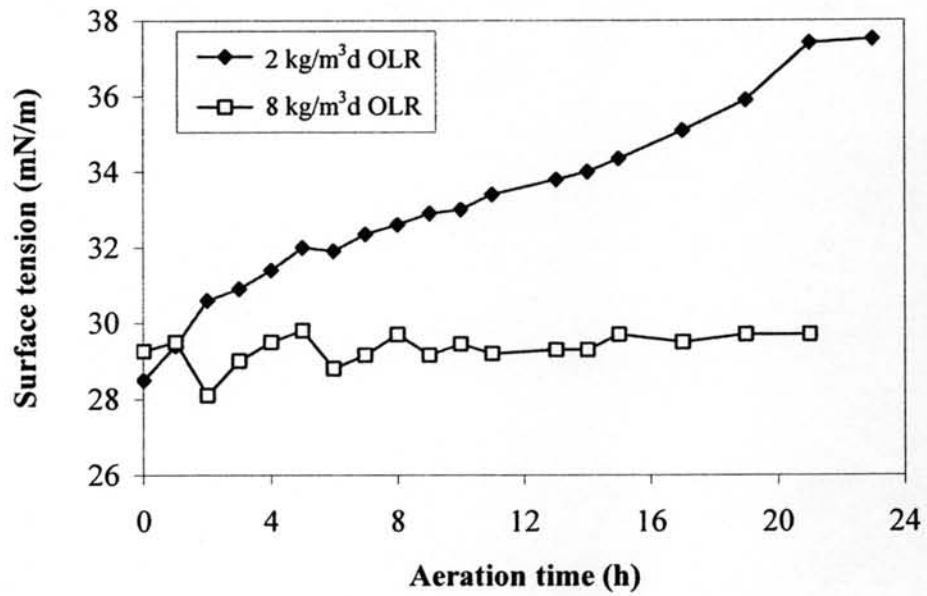


Figure B1 Effluent surface tension with aeration time during a steady state cycle (day 16) of the SBRs at oil loading rates of 2 and 8 kg/m³d with diluted FSW and 1-d cycle.

3 Mineral Medium at OLRs of 1, 2, 6, 10 kg/m³d and 1-d cycle**Table B8** Effluent COD and COD removal on days 1-13 of operation in the SBRs with mineral medium (MM) feed, and 1-d cycle at oil loading rates of 1 and 2 kg/m³d

Oil loading rate (kg/m ³ d)	Day	Volume of test (ml)		Diluted effluent COD (mg/l)			Actual effluent COD (mg/l)	COD removal (%)
		Sample	DO. Water	No.1	No.2	Avg.		
1	1	1	0	510	517	513.5	513.50	73.75
	2	1	0	574	568	571.0	571.00	70.81
	3	1	0	551	549	550.0	550.00	71.89
	4	1	0	614	611	612.5	612.50	68.69
	5	1	0	530	524	527.0	527.00	73.06
	6	1	0	614	613	613.5	613.50	68.64
	7	1	0	505	509	507.0	507.00	74.09
	8	1	0	597	601	599.0	599.00	69.38
	9	1	0	506	505	505.5	505.50	74.16
	10	1	0	494	495	494.5	494.50	74.72
	11	1	0	495	483	489.0	489.00	75.01
	12	1	0	415	382	398.5	398.50	79.63
	13	1	0	366	340	353.0	353.00	81.96
2	1	1	0	519	515	517.0	517.00	86.79
	2	1	0	505	498	501.5	501.50	87.18
	3	1	0	509	513	511.0	511.00	86.94
	4	1	0	521	529	525.0	525.00	86.58
	5	1	0	559	567	563.0	563.00	85.61
	6	1	0	542	549	545.5	545.50	86.06
	7	1	0	420	416	418.0	418.00	89.32
	8	1	0	513	513	513.0	513.00	86.89
	9	1	0	555	559	557.0	557.00	85.77
	10	1	0	516	537	526.5	526.50	86.54
	11	1	0	482	472	477.0	477.00	87.81
	12	1	0	477	488	482.5	482.50	87.67
	13	1	0	489	453	471.0	471.00	87.96

Table B9 Effluent COD and COD removal on days 1-13 of operation in the SBRs with mineral medium (MM) feed, and 1-d cycle at oil loading rates of 6 and 10 kg/m³d

Oil loading rate (kg/m ³ d)	Day	Volume of test (ml)		Diluted effluent COD (mg/l)			Actual effluent COD (mg/l)	COD removal (%)
		Sample	DO. Water	No.1	No.2	Avg.		
6	1	1	9	500	503	501.5	5,015.00	57.28
	2	1	9	538	544	541.0	5,410.00	53.91
	3	1	9	559	555	557.0	5,570.00	52.55
	4	1	9	521	528	524.5	5,245.00	55.32
	5	1	9	693	663	678.0	6,780.00	42.24
	6	1	9	659	652	655.5	6,555.00	44.16
	7	1	9	434	445	439.5	4,395.00	62.56
	8	1	9	536	533	534.5	5,345.00	54.47
	9	1	9	660	659	659.5	6,595.00	43.82
	10	1	9	545	545	545.0	5,450.00	53.57
	11	1	9	499	505	502.0	5,020.00	57.24
	12	1	9	472	480	476.0	4,760.00	59.45
	13	1	9	459	450	454.5	4,545.00	61.28
10	1	1	46	256	235	245.5	11,538.50	41.02
	2	1	46	202	216	209.0	9,823.00	49.79
	3	1	46	217	212	214.5	10,081.50	48.47
	4	1	46	223	227	225.0	10,575.00	45.95
	5	1	45	259	234	246.5	11,339.00	42.04
	6	1	41	229	239	234.0	9,828.00	49.77
	7	1	36	295	283	289.0	10,693.00	45.34
	8	1	36	289	289	289.0	10,693.00	45.34
	9	1	36	284	283	283.5	10,489.50	46.39
	10	1	36	260	259	259.5	9,601.50	50.92
	11	1	36	256	246	251.0	9,287.00	52.53
	12	1	36	260	267	263.5	9,749.50	50.17
	13	1	36	265	277	271.0	10,027.00	48.75

Table B10 Surface tension and surface tension reduction during steady state operation (days 11-13) in the SBRs with four oil loading rates (1, 2, 6, 10 kg/m³d) for mineral medium feed and 1-d cycle

Oil loading rate (kg/m ³ d)	Day	Surface tension (mN/m)		Surface tension reduction (%)
		No.1	Avg.	
1	11	30.7	31.6	52.98
	12	32.6		
	13	31.5		
2	11	28.0	28.1	58.38
	12	28.0		
	13	28.4		
6	11	28.9	28.9	56.99
	12	28.9		
	13	28.9		
10	11	30.7	30.3	55.52
	12	29.8		
	13	30.5		

Table B11 Effluent COD and COD removal with four oil loading rates (1, 2, 6, 10 kg/m³d) during steady state operation (days 11-13) in the SBRs for mineral medium (MM) feed and 1-d cycle

OLR (kg/m ³ d)	Day	Volume of test (ml)		Diluted COD (mg/l)			Actual COD (mg/l)	Avg. actual COD (mg/l)	COD removal (%)	Avg. COD removal (%)
		Sample	DO. Water	No.1	No.2	Avg.				
1	11	1	0	495	483	489.0	489.00	413.50	75.01	78.86
	12	1	0	415	382	398.5	398.50		79.63	
	13	1	0	366	340	353.0	353.00		81.96	
2	11	1	0	482	472	477.0	477.00	476.83	87.81	87.81
	12	1	0	477	488	482.5	482.50		87.67	
	13	1	0	489	453	471.0	471.00		87.96	
6	11	1	9	499	505	502.0	5,020.00	4,775.00	57.24	59.32
	12	1	9	472	480	476.0	4,760.00		59.45	
	13	1	9	459	450	454.5	4,545.00		61.28	
10	11	1	36	256	246	251.0	9,287.00	9,687.83	52.53	50.48
	12	1	36	260	267	263.5	9,749.50		50.17	
	13	1	36	265	277	271.0	10,027.00		48.75	

Table B12 Effluent oil concentration and oil removal with four oil loading rates (1, 2, 6, 10 kg/m³d) during steady state operation (days 11-13) in the SBRs for mineral medium (MM) feed and 1-d cycle

OLR (kg/m ³ d)	Day	Volume of sample (ml)	Wt.flask. (g)	Wt.flask+oil (g)	Wt.oil. (g)	Effluent [Oil] (g/500ml)	Effluent [Oil] (g/l)	Avg. effluent [oil] (g/l)	Avg. effluent [oil] (mg/l)	Oil removal (%)
1	11	103.71	113.2779	113.3436	0.0657	0.3167	0.63	0.44	437.08	85.43
	12	95.81	113.2776	113.3033	0.0257	0.1341	0.27			
	13	94.50	113.2772	113.3159	0.0387	0.2048	0.41			
2	11	36.00	113.2803	113.2905	0.0102	0.1417	0.28	0.36	362.75	93.95
	12	78.99	194.4227	194.4612	0.0385	0.2437	0.49			
	13	80.00	113.2824	113.3078	0.0254	0.1588	0.32			
6	11	48.80	109.8072	109.9091	0.1019	1.0441	2.09	3.04	3037.04	83.13
	12	83.63	163.9183	164.2523	0.3340	1.9968	3.99			
	13	85.00	113.2779	113.5354	0.2575	1.5147	3.03			
10	11	105.06	194.4201	195.2697	0.8496	4.0435	8.09	8.53	8525.57	71.58
	12	90.90	109.8058	110.6361	0.8303	4.5674	9.13			
	13	80.00	113.2779	113.9463	0.6684	4.1775	8.35			

Table B13 Effluent TSS and MLSS with four oil loading rates (1, 2, 6, 10 kg/m³d) during steady state operation (days 11-13) in the SBRs for mineral medium (MM) feed and 1-d cycle

OLR (kg/m ³ d)	Day	No.	Volume of sample (ml)	Wt.floy + filter (g)	Wt. total (g)	Effluent TSS (g)	Effluent TSS (mg/l)	Avg. effluent TSS (mg/l)
1	11	1	18	0.4548	0.4587	0.0039	216.67	270.94
	12	1	26	0.4776	0.4830	0.0054	207.69	
	13	1	26	0.4716	0.4817	0.0101	388.46	
2	11	1	4	0.4731	0.4759	0.0028	700.00	525.00
	12	1	3	0.4523	0.4538	0.0015	500.00	
	13	1	4	0.4569	0.4584	0.0015	375.00	
6	11	1	2	0.4733	0.4893	0.016	8,000.00	7,533.33
	12	1	2	0.4533	0.4688	0.0155	7,750.00	
	13	1	2	0.4548	0.4685	0.0137	6,850.00	
10	11	1	2	0.4526	0.4693	0.0167	8,350.00	8,133.33
	12	1	3	0.4770	0.5019	0.0249	8,300.00	
	13	1	2	0.4533	0.4688	0.0155	7,750.00	

Wt. total = wt. floy + wt. filter paper + wt. TSS

OLR (kg/m ³ d)	Day	No.	Volume of sample (ml)	Wt.floy + filter (g)	Wt. total (g)	MLSS (g)	MLSS (mg/l)	Avg. MLSS (mg/l)
1	12	1	15	0.4543	0.4599	0.0056	373.33	364.23
		2	16	0.5074	0.5135	0.0061	381.25	
	13	1	21	0.4559	0.4630	0.0071	338.10	
2	12	1	2	0.4709	0.4732	0.0023	1,150.00	927.78
		2	3	0.4569	0.4606	0.0037	1,233.33	
	13	1	3	0.4565	0.4577	0.0012	400.00	
6	12	1	2	0.4552	0.4697	0.0145	7,250.00	7,783.33
		2	2	0.4537	0.4668	0.0131	6,550.00	
	13	1	2	0.4552	0.4743	0.0191	9,550.00	
10	12	1	2	0.5312	0.5457	0.0145	7,250.00	8,216.67
		2	2	0.4534	0.4701	0.0167	8,350.00	
	13	1	2	0.4598	0.4779	0.0181	9,050.00	

Wt. total = wt. floy + wt. filter paper + wt. MLSS

Table B14 Surface tension with aeration time during a steady state cycle (day 13) of the SBRs with four oil loading rates (1, 2, 6, 8 kg/m³d), mineral medium (MM) feed, and 1-d cycle

OLR (kg/m ³ d)	Day	Time (00:00)	Time (h.)	Sample no.	Surface tension (mN/m)	
					No.1	Avg.
1	13	8:30	0			30.1
		11:30	3	1	31.6	31.6
		14:30	6	1	30.6	30.6
		17:30	9	1	30.7	30.7
		19:30	11	1	30.9	30.9
		22:00	13.5	1	31.5	31.5
		1:30	17	1	33.2	33.2
		5:00	20.5	1	33.7	33.7
		7:30	23	1	32.0	32.0
2	13	8:30	0	1		28.1
		11:30	3	1	28.5	28.5
		14:30	6	1	28.3	28.3
		17:30	9	1	28.0	28.0
		20:30	12	1	28.4	28.4
		22:30	14	1	28.9	28.9
		1:00	16.5	1	29.9	29.9
		5:30	21	1	30.5	30.5
		7:30	23	1	29.0	29.0

OLR (kg/m ³ d)	Day	Time (00:00)	Time (h.)	Sample no.	Surface tension (mN/m)	
					No.1	Avg.
6	13	8:30	0			28.9
		11:30	3	1	29.3	29.3
		14:30	6	1	29.6	29.6
		17:30	9	1	29.2	29.2
		20:30	12	1	29.0	29.0
		22:30	14	1	29.4	29.4
		1:00	16.5	1	29.6	29.6
		5:30	21	1	31.3	31.3
		7:30	23	1	31.0	30.1
10	13	8:30	0			30.3
		11:30	3	1	30.1	30.1
		14:30	6	1	29.1	29.1
		17:30	9	1	29.4	29.4
		19:30	11	1	29.5	29.5
		22:00	13.5	1	29.5	29.5
		1:30	17	1	30.4	30.4
		5:00	20.5	1	30.2	30.2
		7:30	23	1	30.3	30.3

4 1-d cycle and 3-d cycle with Mineral Medium and at an OLR of 2 kg/m³d-cycle**Table B15** Effluent COD and COD removal with operation time in the SBRs for 1-d cycle (days 1-13) and 3-d cycle (days 3-36) at an oil loading rate of 2 kg/m³cycle with mineral medium (MM) feed

Cycle time (days)	Oil loading rate (kg/m ³ d)	Oil loading rate (kg/m ³ d-cycle)	Day	Cycle no.	Volume of test (ml)		Diluted effluent COD (mg/l)			Actual effluent COD (mg/l)	COD removal (%)
					Sample	DO. Water	No.1	No.2	Avg.		
1	1	2	1	1	1	0	519	515	517.0	517.00	86.79
			2	2	1	0	505	498	501.5	501.50	87.18
			3	3	1	0	509	513	511.0	511.00	86.94
			4	4	1	0	521	529	525.0	525.00	86.58
			5	5	1	0	559	567	563.0	563.00	85.61
			6	6	1	0	542	549	545.5	545.50	86.06
			7	7	1	0	420	416	418.0	418.00	89.32
			8	8	1	0	513	513	513.0	513.00	86.89
			9	9	1	0	555	559	557.0	557.00	85.77
			10	10	1	0	516	537	526.5	526.50	86.54
			11	11	1	0	482	472	477.0	477.00	87.81
			12	12	1	0	477	488	482.5	482.50	87.67
			13	13	1	0	489	453	471.0	471.00	87.96

Cycle time (days)	Oil loading rate (kg/m ³ d)	Oil loading rate (kg/m ³ d-cycle)	Day	Cycle no.	Volume of test (ml)		Diluted effluent COD (mg/l)			Actual effluent COD(mg/l)	COD removal (%)
					Sample	DO. Water	No.1	No.2	Avg.		
3	0.67	2	3	1	1	0	481	473	477.0	477.00	87.81
			6	2	1	0	434	436	435.0	435.00	88.88
			9	3	1	0	555	544	549.5	549.50	85.96
			12	4	1	0	522	537	529.5	529.50	86.47
			15	5	1	0	421	423	422.0	422.00	89.22
			18	6	1	0	471	400	435.5	435.50	88.87
			21	7	1	0	465	455	460.0	460.00	88.24
			24	8	1	0	429	451	440.0	440.00	88.76
			27	9	1	0	480	493	486.5	486.50	87.57
			30	10	1	0	485	488	486.5	486.50	87.57
			33	11	1	0	486	489	487.5	487.50	87.54
			36	12	1	0	440	445	442.5	442.50	88.69

Table B16 Surface tension and surface tension reduction during steady state operation in the SBRs for 1-d cycle (days 11-13) and 3-d cycle (days 30-39) at an oil loading rate of $2 \text{ kg/m}^3\text{cycle}$ with mineral medium (MM) feed

Cycle time (days)	OLR ($\text{kg/m}^3\text{d}$)	OLR ($\text{kg/m}^3\text{d-cycle}$)	Day	Surface tension (mN/m)		Surface tension reduction (%)
				No.1	Avg.	
1	2	2	11	28.0	28.1	58.38
			12	28.0		
			13	28.4		
3	0.67	2	30	32.2	32.1	53.28
			33	32.0		
			36	32.0		
			39	32.3		

Table B17 Effluent COD and COD removal during steady state operation in the SBRs for 1-d cycle (days 11-13) and 3-d cycle (days 30-36) at an oil loading rate of 2 kg/m³d-cycle with mineral medium (MM) feed

Cycle time (days)	Day	Volume of test (ml)		Diluted COD (mg/l)			Actual COD (mg/l)	Avg. actual COD (mg/l)	COD removal (%)	Avg. COD removal (%)
		Sample	DO. Water	No.1	No.2	Avg.				
1	11	1	0	482	472	477.0	477.00	476.83	87.81	87.81
	12	1	0	477	488	482.5	482.50		87.67	
	13	1	0	489	453	471.0	471.00		87.96	
3	30	1	0	485	488	486.5	486.50	472.17	87.57	87.93
	33	1	0	486	489	487.5	487.50		87.54	
	36	1	0	440	445	442.5	442.50		88.69	

Table B18 Effluent oil concentration during steady state operation in the SBRs for 1-d cycle (days 11-13) and 3-d cycle (days 30-39) at an oil loading rate of $2 \text{ kg/m}^3\text{d}$ -cycle with mineral medium (MM) feed

Cycle time (days)	Day	Volume of sample (ml)	Wt.flask (g)	Wt.flask+oil (g)	Wt.oil. (g)	Effluent [Oil] (g/500ml)	Effluent [Oil] (g/l)	Avg. effluent [oil] (g/l)	Avg. effluent [oil] (mg/l)	Oil removal (%)
1	11	36.00	113.2803	113.2905	0.0102	0.1417	0.28	0.36	362.75	93.95
	12	78.99	194.4227	194.4612	0.0385	0.2437	0.49			
	13	80.00	113.2824	113.3078	0.0254	0.1588	0.32			
3	30	88.75	194.4203	194.4448	0.0245	0.1380	0.28	0.26	257.33	95.71
	33	106.23	194.4204	194.4475	0.0271	0.1276	0.26			
	39	107.14	113.2787	113.3045	0.0258	0.1204	0.24			

Table B19 Effluent TSS and MLSS during steady state operation in the SBRs for 1-d cycle (days 11-13) and 3-d cycle (days 33-36) at an oil loading rate of $2 \text{ kg/m}^3\text{cycle}$ with mineral medium (MM) feed

Cycle time (days)	Day	No.	Volume of sample (ml)	Wt. floy + filter (g)	Wt. total (g)	Effluent TSS (g)	Effluent TSS (mg/l)	Avg. effluent TSS (mg/l)
1	11	1	4	0.4731	0.4759	0.0028	700.00	525.00
	12	1	3	0.4523	0.4538	0.0015	500.00	
	13	1	4	0.4569	0.4584	0.0015	375.00	
3	33	1	25	0.4520	0.4598	0.0078	312.00	258.04
	36	1	22	0.4477	0.4531	0.0054	245.45	
		2	24	0.4493	0.4545	0.0052	216.67	

Wt. total = wt. floy + wt. filter paper + wt. TSS

Cycle time (days)	Day	No.	Volume of sample (ml)	Wt. floy + filter (g)	Wt. total (g)	MLSS (g)	MLSS (mg/l)	Avg. MLSS (mg/l)
1	12	1	2	0.4709	0.4732	0.0023	1,150.00	927.78
		2	3	0.4569	0.4606	0.0037	1,233.33	
	13	1	3	0.4565	0.4577	0.0012	400.00	
3	33	1	12	0.4761	0.4834	0.0073	608.33	538.81
		2	15	0.4557	0.4630	0.0073	486.67	
	36	1	14	0.4557	0.4630	0.0073	521.43	

Wt. total = wt. floy + wt. filter paper + wt. MLSS

Table B20 Surface tension with aeration time during a steady state cycle of the SBRs for 1-d cycle (day 13) and 3-d cycle (days 36-42) at an oil loading rate of $2 \text{ kg/m}^3 \text{ d}$ -cycle with mineral medium feed

Cycle time (days)	Day	Time (00:00)	Time (h)	Sample no.	Surface tension (mN/m)	
					No.1	Avg.
1	13	8:30	0	1		28.1
		11:30	3	1	28.5	28.5
		14:30	6	1	28.3	28.3
		17:30	9	1	28.0	28.0
		20:30	12	1	28.4	28.4
		22:30	14	1	28.9	28.9
		1:00	16.5	1	29.9	29.9
		5:30	21	1	30.5	30.5
		7:30	23	1	29.0	29.0
3			0.0			32.1
	36	14:30	6.0	1	30.3	30.3
	39	20:40	12.17	1	34.7	34.7
	40	2:30	18.0	1	31.3	31.3
		9:00	24.5	1	31.2	31.2
		14:30	30.0	1	32.9	32.9
		20:30	36.0	1	31.1	31.1
	41	7:00	46.5	1	33.4	33.4
		13:00	52.5	1	32.6	32.6
		20:10	59.67	1	32.2	32.2
	42	1:00	64.5	1	30.6	30.6
		7:30	71.0	1	31.4	31.4

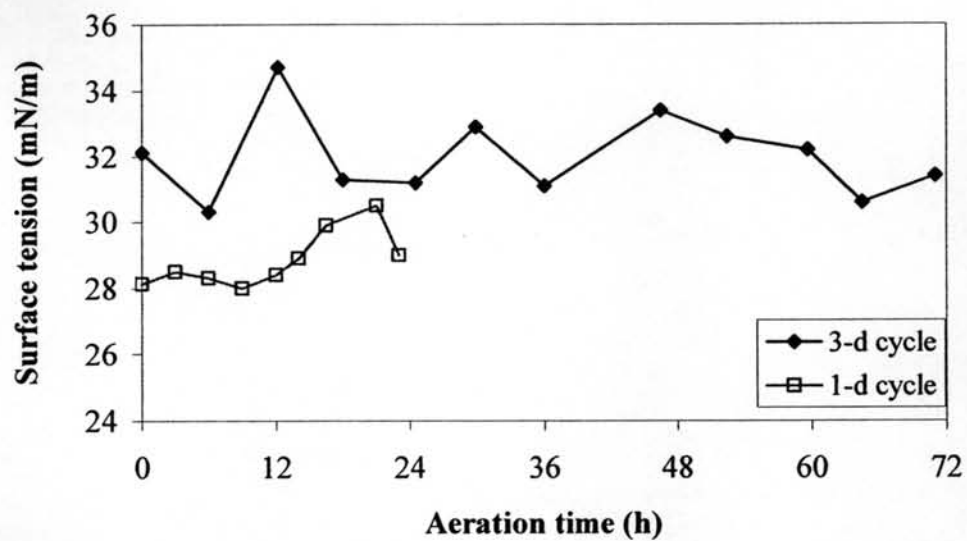


Figure B2 Surface tension with aeration time during a steady state cycle of the SBRs for 1-d cycle (day 13) and 3-d cycle (days 36-42) at an oil loading rate of $2 \text{ kg/m}^3\text{d}$ -cycle with mineral medium feed.

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