

APPENDIX A:

DATA, FIGURES, AND TABLES
FROM MANUSCRIPT #1:

INFLUENCE OF ORGANIC AND AMMONIA LOADING ON
NITRIFIER ACTIVITY AND NITRIFICATION PERFORMANCE
FOR A TWO-STAGE BIOLOGICAL AERATED FILTER SYSTEM

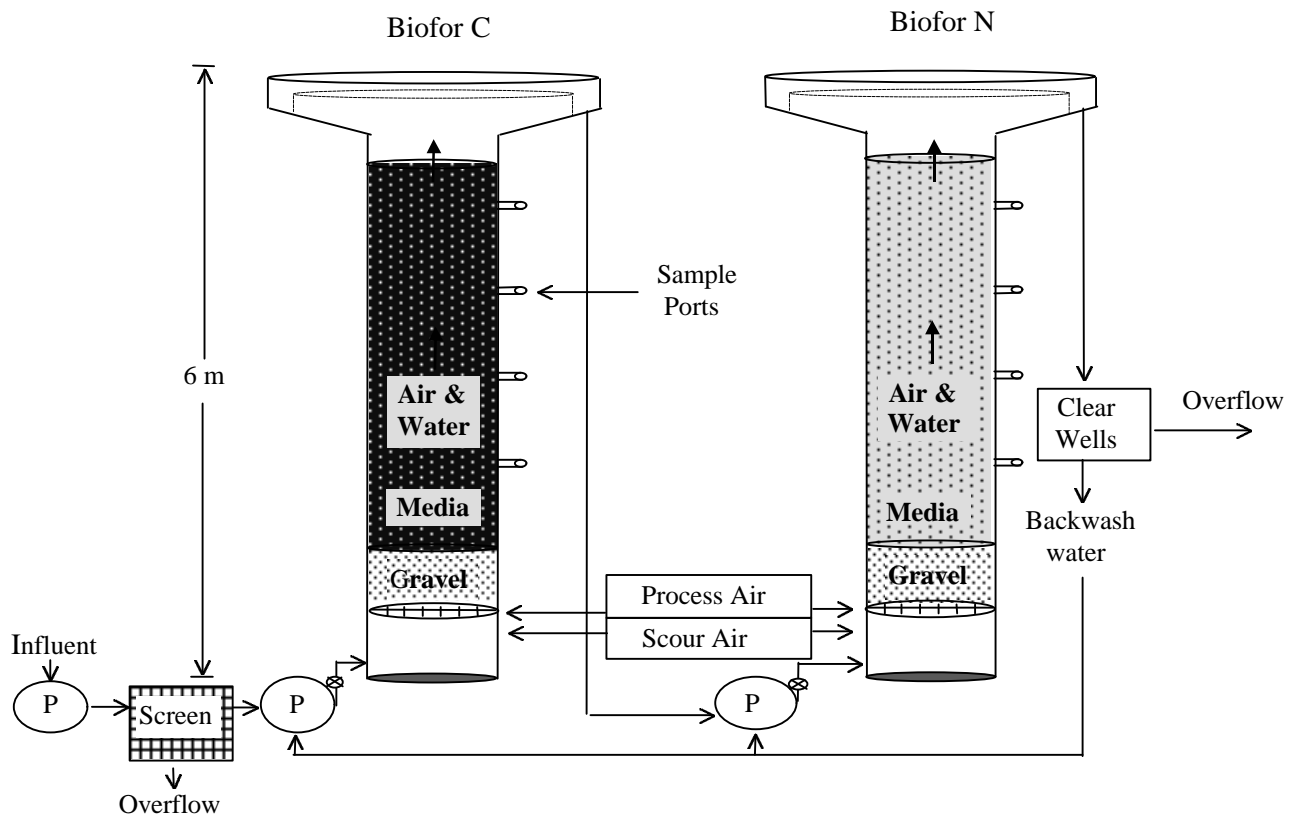


Figure A-1. Schematic of Pilot-Scale Biofor[®] BAF System. (P=pump).

Table A-1.

Ammonia Removal Data, Winter Operation

1/8/98-3/29/98

Date	C Column Eff. NH ₃ , mg/L	N Column Flow, m/hr	N Column Ammonia Data				
			Load Applied kg/m ³ -day	Mass removed kg/m ³ -day	Effluent Mass kg/m ³ -day	Effluent Conc., mg/L	% Removed
08 Jan 98	10.4	3.9	0.265	0.251	0.014	0.53	95
15 Jan 98	11.2	3.9	0.285	0.279	0.007	0.26	98
22 Jan 98	23.4	3.9	0.596	0.589	0.007	0.29	99
16 Mar 98	11.9	3.9	0.303	0.285	0.018	0.7	94
18 Mar 98	15.6	3.9	0.398	0.392	0.005	0.2	99
19 Mar 98	14.5	3.9	0.369	0.347	0.023	0.9	94
19 Jan 98	8.1	6.8	0.359	0.333	0.027	0.6	93
26 Jan 98	13.3	6.8	0.590	0.563	0.027	0.61	95
29 Jan 98	4.6	6.8	0.204	0.200	0.004	0.08	98
02 Feb 98	6.8	6.8	0.301	0.288	0.013	0.3	96
04 Feb 98	2.2	6.8	0.098	0.094	0.004	0.08	96
09 Feb 98	8.8	6.8	0.390	0.372	0.018	0.4	95
14 Feb 98	9.5	6.8	0.421	0.412	0.009	0.2	98
16 Feb 98	9.8	6.8	0.435	0.417	0.018	0.4	96
28 Feb 98	15.3	6.8	0.678	0.669	0.009	0.2	99
02 Mar 98	11.3	6.8	0.501	0.472	0.029	0.7	94
21 Mar 98	3.7	6.8	0.164	0.161	0.003	0.06	98
<i>19 Feb 98</i>	<i>10.6</i>	<i>10.2</i>	<i>0.702</i>	<i>0.530</i>	<i>0.172</i>	2.6	75
<i>05 Mar 98</i>	<i>23.4</i>	<i>10.2</i>	<i>1.550</i>	<i>0.543</i>	<i>1.007</i>	15.2	35
<i>07 Mar 98</i>	<i>19.8</i>	<i>10.2</i>	<i>1.312</i>	<i>0.576</i>	<i>0.735</i>	11.1	44
<i>09 Mar 98</i>	<i>11.5</i>	<i>10.2</i>	<i>0.762</i>	<i>0.477</i>	<i>0.285</i>	4.3	63
11 Mar 98	16.0	10.2	1.060	0.689	0.371	5.6	65
12 Mar 98	13.1	10.2	0.868	0.576	0.292	4.4	66
14 Mar 98	10.2	10.2	0.676	0.557	0.119	1.8	82
23 Mar 98	5.1	10.2	0.338	0.334	0.004	0.06	99
28 Mar 98	9.3	10.2	0.616	0.517	0.099	1.5	84

Bold type represents grab samples

Italics represent days in which N column was oxygen limited

Detection Limit is 0.06 mg/L

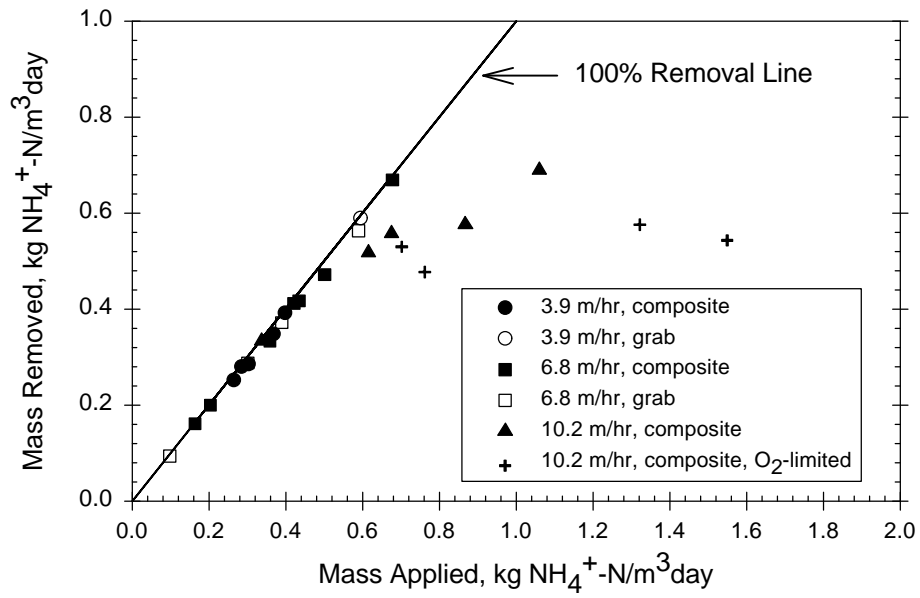


Figure A-2. Ammonia Removal Performance for the Second Stage N Column During Wintertime

Table A-2. Profile 1 C Column Probing Analysis With Nso190

2/5/98

Flows: C column: 10.0 gpm 7.8 m/hr N column: 8.7 gpm 6.8 m/hr

Densitometric Analysis of Film from Biofor C at 10 gpm (7.8 m/hr) loading with Nso190.

Sample	Total Nucleic Acids (ug/ml)	denatured conc. (ug/ml)	Mass NA blotted, ng	Peak Area	Peak Area/ mass NA, ng	Average	Std. Dev.	N	std error of mean
C1	795	198.8	994	36549.2	36.78	35.9	4.0	3	2.34
			994	39183.8	39.42				
			994	31287.3	31.48				
C2	394	98.5	493	18045.9	36.64	37.8	5.6	3	3.25
			493	21683.7	43.98				
			493	16225.8	32.91				
C3	358	89.5	448	41192.4	92.05	87.6	6.2	2	4.40
			448	37293.7	83.24				
C4	276	69.0	345	13628.3	39.50	35.6	10.0	3	5.77
			345	14852.0	43.05				
			345	8362.0	24.24				
Sludge	203	50.8	254	22124.2	87.19	92.7	7.7	2	5.46
			254	24921.8	98.12				
Pure Culture	49.7	12.4	62	151103.6	2432.25	2426.1	157.9	4	78.94
			62	142309.9	2295.32				
			62	144493.0	2330.53				
			62	164072.4	2646.33				

Table A-3. Profile 1 N Column Probing Analysis With Nso190

2/5/98

Flows: C column: 10.0 gpm 7.8 m/hr N column: 8.7 gpm 6.8 m/hr

Densitometric Analysis of Film from Biofor N at 8.7 gpm (6.8 m/hr) loading with Nso190.

Sample	Total Nucleic Acids (ug/ml)	denatured conc. (ug/ml)	Mass NA blotted, ng	Peak Area	Peak Area/ mass NA, ng	Average	Std. Dev.	N	std error of mean
N1	114	28.5	143	42040.9	295.0	206.4	53.0	5	23.68
			143	26765.1	187.2				
			143	26647.9	186.3				
			143	22239.9	155.5				
			143	29763.1	208.1				
N2	18.7	4.7	23	6795.1	290.7	279.1	16.5	2	11.64
			23	6150.6	267.4				
N3	18.8	4.7	24	1296.5	55.2	51.0	18.9	5	8.43
			24	842.4	35.1				
			24	1324.3	55.2				
			24	1876.7	78.2				
			24	746.6	31.1				
N4	14.8	3.7	19	733.7	39.7	34.6	5.4	3	3.10
			19	666.2	35.1				
			19	550.4	29.0				
Act. Sludge	203	50.8	254	43213	170.3	140.4	23.3	5	10.42
			254	38004.5	149.6				
			254	28147.2	110.8				
			254	31471.8	123.9				
			254	37408.4	147.3				
Pure Culture	49.7	12.4	62	249043.5	4008.7	3780.5	238.2	5	106.52
			62	249447.5	4023.3				
			62	217201.6	3503.3				
			62	222149.2	3583.1				
			62	234615.2	3784.1				

Table A-4. Profile 1. Nitrogen Species and Ammonia Oxidizer Activity

2/5/98

Flows: C column: 10.0 gpm N column: 8.7 gpm
7.8 m/hr 6.8 m/hr

Sample	Media Distance, m	Chemical Nitrogen Species					Ammonia Ox. Activity	
		NH ₃ mg/L-N	TKN mg/L-N	N-org mg/L-N	Nitrate conc. mg/L - N	Nitrite conc. mg/L -N	Nitrifier Fraction	Std Error of Mean
I (comp)	0				0.87	0.33		
C1	0.58	4.6	6.8	2.2	1.81	0.29	35.9	2.34
C2	1.42	4.6	7.1	2.5	1.73	0.49	37.8	3.25
C3	2.26	4	5.6	1.6	1.65	0.72	87.6	4.40
C4	3.07	3.6	3.9	0.3	1.81	0.92	35.6	5.77
C5	3.91	2.2	3	0.8	2.55	1.51		
N1	4.39	1.8	2.1	0.3	4.77	0.65	206.4	23.68
N2	5.28	0.16	1.8	1.64	7.19	0.39	279.1	11.64
N3	6.10	0	0.83	0.83	7.70	0.29	51.0	8.43
N4	6.91	0	1.1	1.1	7.43	0.26	34.6	3.10
N5	7.75	0	0.5	0.5	7.58	0.26		

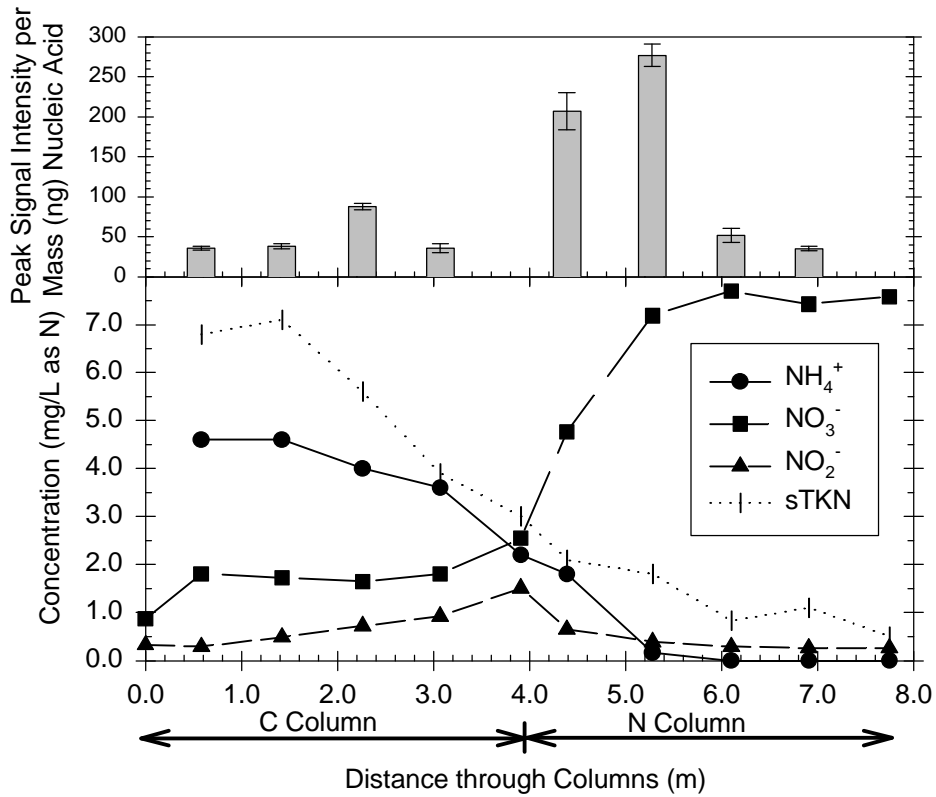


Figure A-3. Profile of nitrogen species and Nso190 signal intensity normalized to mass of nucleic acids with distance through the two-stage BAF system. Data were collected during Phase II when the hydraulic loading was 6.8 m/hr. The ammonia load to the N column was 0.1 kg NH_4^+ /m³-day (grab sample).

Table A-5. Profile 2 C Column Probing Analysis With Nso190

3/31/98

Flows: C column: 14.5 gpm 11.3 m/hr N column 13.0 gpm 10.2 m/hr

Densitometric Analysis of Film from Biofor C at 14.5 gpm (11.3 m/hr) loading with Nso190 10 ul blots

Sample	Total Nucleic Acids (ug/ml)	denatured conc. (ug/ml)	dilution blotted	Mass NA blotted, ng	Peak Area	Peak Area/ mass NA, ng	avg.	standard deviation	N	std error of mean
C1	311.2	77.8	1:1	778	21058.9	27.1	27.5	5.3	5	2.35
			3:4	584	13653.2	23.4				
			1:2	389	10860.6	27.9				
			1:4	195	7001.4	36.0				
			1:10	78	1781.45	22.9				
C2	206.7	51.7	1:1	517	10390.8	20.1	11.7	7.3	3	4.23
			3:4	388						
			1:2	258	1837.8	7.1				
			1:4	129	1003.3	7.8				
			1:10	52						
C3	265.6	66.4	1:1	664	7908.1	11.9	10.4	1.4	3	0.80
			3:4	498	4563.6	9.2				
			1:2	332						
			1:4	166						
			1:10	66	673.5	10.1				
C4	174.4	43.6	1:1	436	0					
			3:4	327	0					
			1:2	218	0					
			1:4	109	0.0					
			1:10	44	0.0					
Sludge	244.8	61.2	1:1	612	36742.4	60.0	52.3	18.0	5	8.03
			3:4	459	26742.4	58.3				
			1:2	306	22398.3	73.2				
			1:4	153	6754.8	44.1				
			1:10	61	1591.9	26.0				
Pure Culture	930.4	232.6	1:1	2326			1467.5	468.7	2	331.42
			3:4	1745						
			1:2	1163						
			1:4	582	660627.9	1136.1				
			1:10	233	418428.7	1798.9				

Table A-6. Profile 2 N Column Probing Analysis With Nso190

3/31/98

Flows: C column: 14.5 gpm 11.3 m/hr N column: 13.0 gpm 10.2 m/hr

Densitometric Analysis of Film from Biofor N at 13 gpm (10.1 m/hr) loading with Nso190.

Sample	Total Nucleic Acids (ug/ml)	denatured conc. (ug/ml)	dilution blotted	Mass NA blotted, ng	Peak Area	Peak Area/ mass NA, ng	Average	Standard deviation	# Samples N	Std. error of mean
N1	240	60.0	1:1	600	26493.1	44.2	39.7	3.7	5	1.68
			3:4	450	17599.6	39.1				
			1:2	300	10619.9	35.4				
			1:4	150	6442.2	42.9				
			1:10	60	2224.6	37.1				
N2	176	44.0	1:1	440	13596.3	30.9	27.9	4.3	2	3.03
			3:4	330	8198.5	24.8				
			1:2	220						
			1:4	110						
			1:10	44						
N3	107.2	26.8	1:1	268	12994.1	48.5	45.8	14.3	3	8.24
			3:4	201						
			1:2	134						
			1:4	67	3921.1	58.5				
			1:10	27	814.1	30.4				
N4	51.2	12.8	1:1	128	10942.6	85.5	112.5	51.2	3	29.57
			3:4	96						
			1:2	64						
			1:4	32	5490.8	171.6				
			1:10	13	1029.8	80.5				
Sludge	244.8	61.2	1:1	612	34759.6	56.8	61.2	26.4	4	13.19
			3:4	459						
			1:2	306	12809.6	41.9				
			1:4	153	7102.6	46.4				
			1:10	61	6096.1	99.6				
Pure Culture	930.4	232.6	1:1	2326			1854.0	867.0	2	613.06
			3:4	1745						
			1:2	1163						
			1:4	582	721612.4	1240.9				
			1:10	233	573842.7	2467.1				

Table A-7. Profile 2. Nitrogen Species and Ammonia Oxidizer Activity

3/31/98

Flows: C column: 14.5 gpm N column: 13.0 gpm
11.3 m/hr 10.2 m/hr

Sample	Chemical Nitrogen Species							Ammonia Ox. Activity	
	Media Distance, m	NH3 mg/L-N	total TKN mg/L-N	sol. TKN mg/L-N	N-org mg/L-N	Nitrate mg/L - N	Nitrite mg/L -N	Nitrifier Fraction	Std Error of Mean
I (grab)	0	14.7	20.6	19.1	4.4	0.11	0.72		
C1	0.58	12.1		18.6	6.5	0.15	0.58	27.5	2.35
C2	1.42	13.0		18.8	5.8	0.10	0.58	11.7	4.23
C3	2.26	14.6		18.3	3.7	0.10	0.54	10.4	0.80
C4	3.07	15.1		18.0	2.9	0.10	0.54	0.0	
C5	3.91	14.6	16.2	17.1	2.5	0.28	0.51		
N1	4.39	13.1		14.7	1.6	1.13	0.61	39.7	1.68
N2	5.28	10.4		12.6	2.2	3.28	0.65	27.9	3.03
N3	6.10	7.4		10.2	2.8	5.73	0.61	45.8	8.24
N4	6.91	5.5		7.3	1.8	7.09	0.65	112.5	29.57
N5	7.75	1.4	2.5	1.3	-0.1	12.40	0.54		

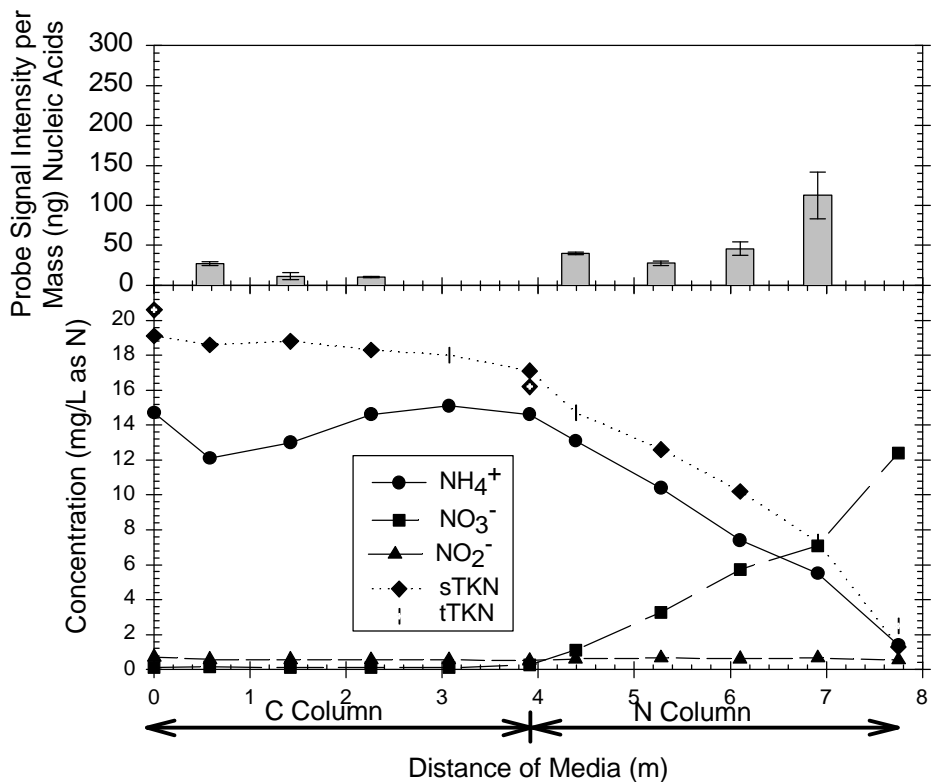


Figure A-4. Profile of nitrogen species and Nso190 signal intensity normalized to mass of nucleic acids with distance through the two-stage BAF system. Data were collected during Phase III when the hydraulic loading was 10.2 m/hr. The ammonia load to the N column was 0.66 kg NH_4^+ /m³-day.