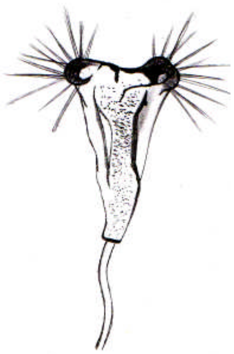
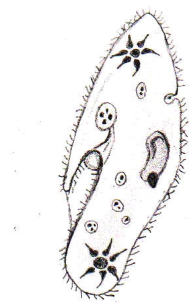


Nutrient Study

Pulp and Paper Mill
Southeastern United States



Conducted by:

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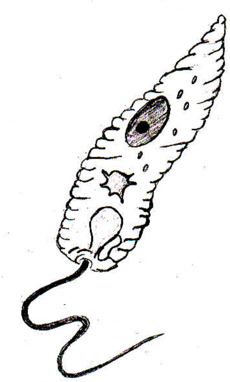
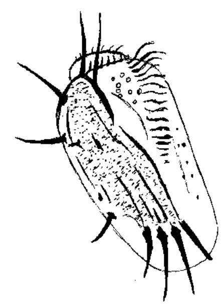


Study dates:

December 5 – 12, 2000



INTRODUCTION

This paper mill operates an aerated stabilization basin for wastewater treatment. Typical untreated effluent flow from the primary clarifier is 17–18 MGD, with an initial BOD_5 level of approximately 350 mg/l.

Previous computer modeling conducted indicated that an increase in nutrient addition would improve BOD_5 removal efficiency. EBS was selected to perform a respirometry study to evaluate the current nutrient feed conditions and commercial nutrient formulation. The purpose of this study was to evaluate the relative impact of varying nutrient formulations and dosages on the BOD_5 removal capability of the aerated stabilization basin (ASB) at the mill.

Two key questions were addressed by this study.

1. What is the potential for enhanced ASB performance via additional nutrient addition, particularly nitrogen?
2. Are there more appropriate and/or economical alternatives to the current commercial nutrient formulation?

STUDY DESCRIPTION

An 8-cell Challenge Respirometer was utilized for the study. The respirometer simulates biological treatment performance by continuously monitoring oxygen uptake rates of samples in a well mixed, fully aerated and temperature controlled environment. By comparing relative oxygen uptake rates and final treated water quality, one can determine the differences among various treatment scenarios and make informed decisions regarding commercial additives, such as nutrient blends. This test method simulates a complete mix batch reaction with no oxygen limitations. It cannot account for such real world phenomena such as benthic feedback, low dissolved oxygen levels or irregular flow patterns.

TEST PROTOCOL

Samples containing primary clarifier effluent were received on December 5, 2000. Nutrient residuals and pH were determined prior to test initiation @ (pH=8.9; TKN=4.5 mg/l; PO_4=0.33 mg/l). 100 ml of ASB effluent was added to 4900 ml of influent and mixed well. 500 ml aliquots were separated into respirometer bottles and treated as follows:

Sample	Description
1	Control (received no additives)
2	Current product
3	Current product (duplicate)
4	Triple current product
5	Current product @ 100:4.2 BOD:N
6	Urea @ 100:4.2 BOD:N
7	Phosphoric Acid @ 100:0.7 BOD:P
8	Urea/Phos Acid @ 100:4.2:0.9 BOD:N:P

The study was run at a constant temperature of 28°C (82°F) for 160 hours. Treated samples were submitted to an outside lab for further analysis.

RESULTS

The respirometer test ran well with excellent reproducibility of the duplicates. The cumulative oxygen uptake results agreed with both expectations and final BOD_5 levels based on nutrient feed rates, with the exception of cell #4. The sample containing the triple current product dosage demonstrated some technical problems midway through testing in regards to recording the amount of oxygen being consumed. Due to the problem experienced by this cell, analytical results for this sample were used as indicators of performance rather than cumulative oxygen uptake data.

Results of analytical testing and the test protocol are provided in Figure A. The results demonstrate greater BOD_5 removal as nutrient dosages increased. Cumulative oxygen uptake rates after 24 hours and at test conclusion test show the importance of both nitrogen and phosphorus in achieving maximum performance. This information is provided in Figures B and C. To greater demonstrate the relationship of cumulative oxygen uptake versus BOD_5 removal, a comparative graph is provided in Figure D. Cumulative oxygen consumed was inversely proportional to the remaining soluble BOD_5 with the exception of sample #4. Figures E and F show the effect of nutrient dosage on final soluble BOD_5 levels. Figure G shows the correlation between overall (total) BOD_5 removal efficiency and nutrient feed rates.

CONCLUSIONS

The answer to both questions posed in the introduction is "yes." An increase in nutrient addition offers potential for improved BOD_5 removal. The current commercial nutrient blend is not appropriate to provide optimum cost effectiveness at the increased nutrient addition rates.

Both supplemental nitrogen (N) and phosphorus (P) are required to ensure optimum microbiological activity. Nitrogen appears to be the primary limiting nutrient in this study. From these results, we conclude that increasing nutrient concentrations–primarily nitrogen–would benefit by increasing BOD_5 removal, compensate for reduced retention times, and provide a safeguard during upset conditions.

The optimum BOD:N:P ratio for this mill is estimated at 100:3.1:0.6. At 100:4.2:1, both N and P residuals were well above those generally accepted as necessary. At a BOD:N ratio of 100:2.3, the BOD_5 removal was good but not optimal.

Based on the study results, it appears that a single, blended product continues to be a viable approach for this mill. However, the results indicate that the current 8:12 blend does not provide adequate nitrogen unless fed at extremely high rates, resulting in unnecessarily high orthophosphate residuals. Based on historical N and P load and test results, an 18:12 N:P blend should be a more cost-effective formulation. Note that the P concentration of commercial blends is reported as P_2O_5.

EBS is available to provide on-site customization of The EBS BioWizard™ Nutrient Control Model and additional training, if desired. An example of The BioWizard model is included on the last page of this document.

Figure A

Nutrient Study Protocol

Flow	17.4	MGD
Influent BOD5	368	mg/l
Influent TKN	4.5	mg/l
Influent NH3	2.5	mg/l
Influent P	0.33	mg/l
Fang %N	8.0%	
Fang %P	5.2%	

Test No.	Description	Solution #	N Solution Strength	P Solution Strength	ppm N added	ppm P added	ml solution added	Available N	Available P	~BOD:N	~BOD:P
1	Control	N/A	N/A	N/A	0	0	0.00	4.50	0.33	1.2	0.1
2	Normal Fang Dosage	1	0.80%	0.52%	1.28	0.83	0.08	5.78	1.16	1.6	0.3
3	Normal Fang Dosage -- Duplicate	1	0.80%	0.52%	1.28	0.83	0.08	5.78	1.16	1.6	0.3
4	Triple normal Fang	1	0.80%	0.52%	3.84	2.50	0.24	8.34	2.83	2.3	0.8
5	Fang @ 100:4.3 BOD:N	1	0.80%	0.52%	11.04	7.18	0.69	15.54	7.51	4.2	2.0
6	Urea alone at 100:4.3 BOD:N	2	0.80%	0.00%	11.04	0.00	0.69	15.54	0.33	4.2	0.1
7	Phos Acid alone at 100:1 BOD:P	3	0.00%	0.52%	0.00	2.08	0.20	4.50	2.41	1.2	0.7
8	Urea/Phos acid blend at 100:4.2:1	4	0.80%	0.22%	11.04	3.04	0.69	15.54	3.37	4.2	0.9
8	Extrapolated Optimum		0.80%	0.22%	7.00	1.94	0.44	11.50	2.27	3.13	0.62

Nutrient Study
Analytical Results

Test No.	Description	~BOD:N	~BOD:P	Total BOD_5	Soluble BOD_5	TSS	VSS	TKN	NH_3	$o\text{-}PO_4$	NO_3
1	Control	1.2	0.1	150	138	190	190	4.5	0	0.07	NA
2	Normal Fang Dosage	1.6	0.3	121	96	200	170	4.8	0	0.68	NA
3	Normal Fang Dosage -- Duplicate	1.6	0.3	117	88	200	140	5.1	0	1.11	NA
4	Triple normal Fang	2.3	0.8	64	18	180	170	8.5	0.4	3.44	NA
5	Fang @ 100:4.2 BOD_5:N	4.2	2.0	35	11	230	190	13.3	4.7	8.96	NA
6	Urea alone at 100:4.2 BOD_5:N	4.2	0.1	100	34	230	180	13.8	5.6	0.12	NA
7	Phos Acid alone at 100:0.9 BOD_5:P	1.2	0.7	118	114	200	140	4.5	0	2.08	NA
8	Urea/Phos acid blend at 100:4.2:1.1	4.2	0.9	39	10	210	190	13.8	6.6	1.52	NA

Nitrate results were discarded due to test interference. No evidence of biological nitrification was observed.

Figure B

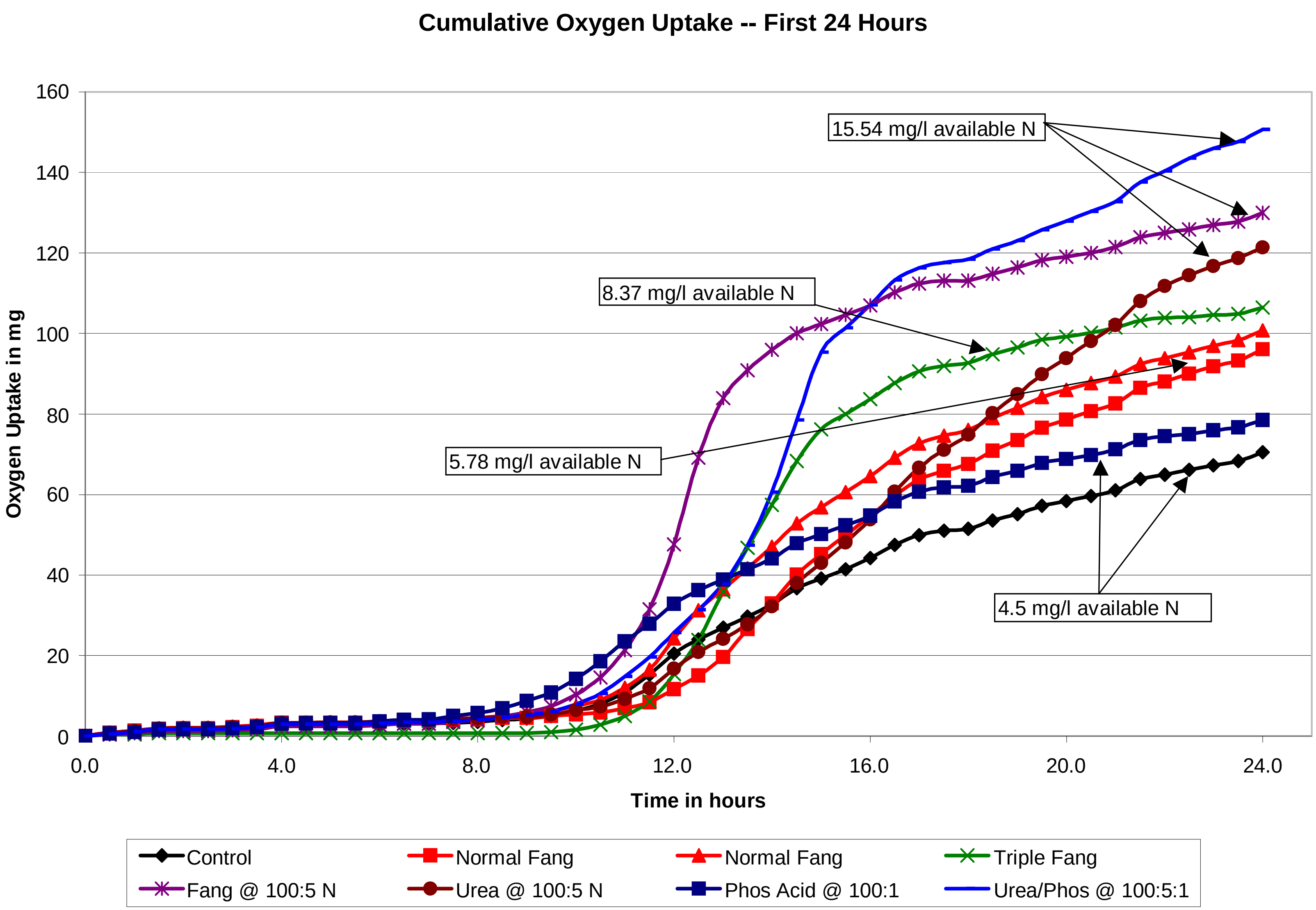

Cumulative Oxygen Uptake -- First 24 Hours
15.54 mg/l available N
8.37 mg/l available N
5.78 mg/l available N
4.5 mg/l available N
Oxygen Uptake in mg
160
140
120
100
80
60
40
20
0
0.0
4.0
8.0
12.0
16.0
20.0
24.0
Time in hours
Control
Normal Fang
Normal Fang
Triple Fang
Fang @ 100:5 N
Urea @ 100:5 N
Phos Acid @ 100:1
Urea/Phos @ 100:5:1

Figure C

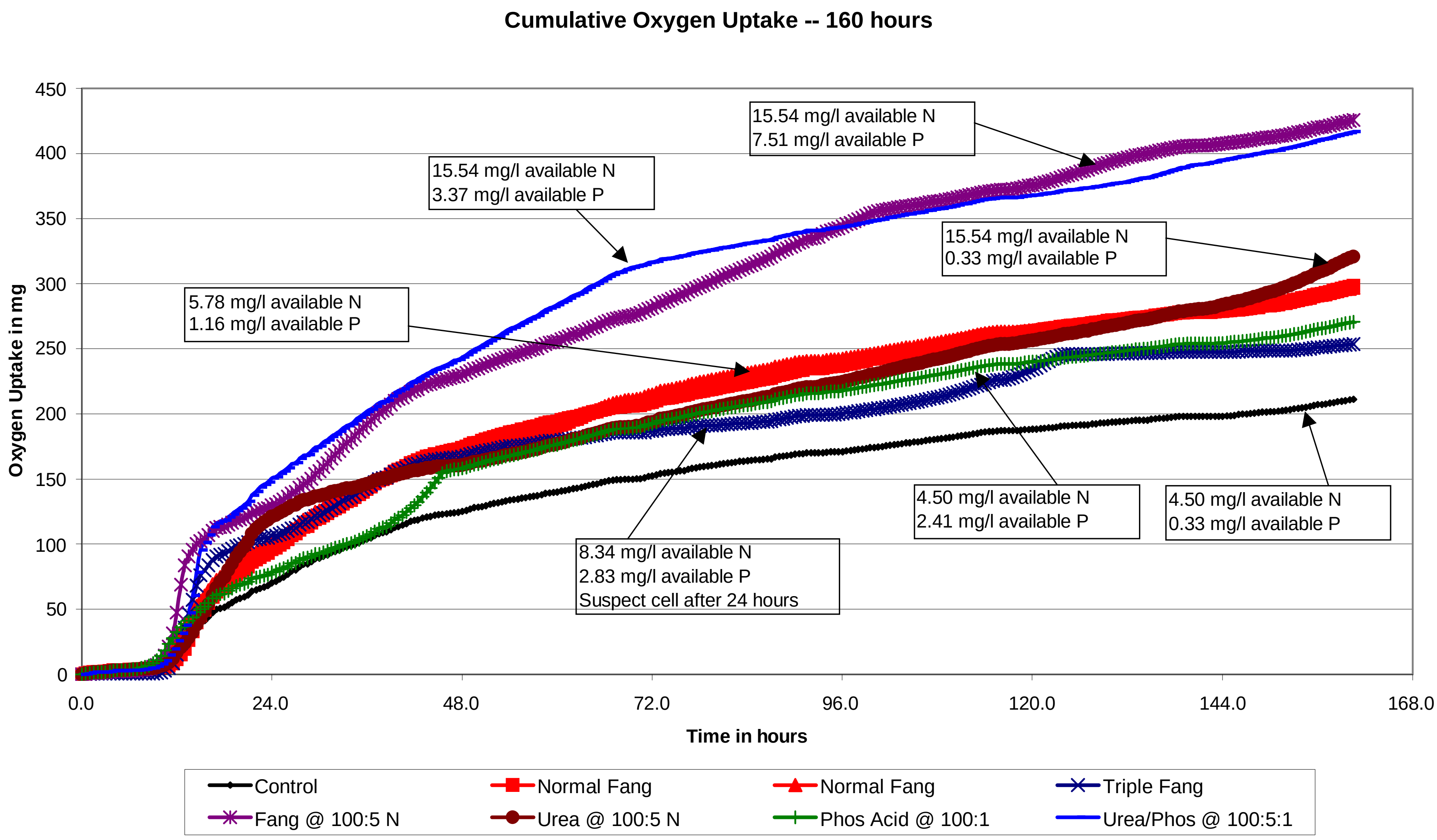
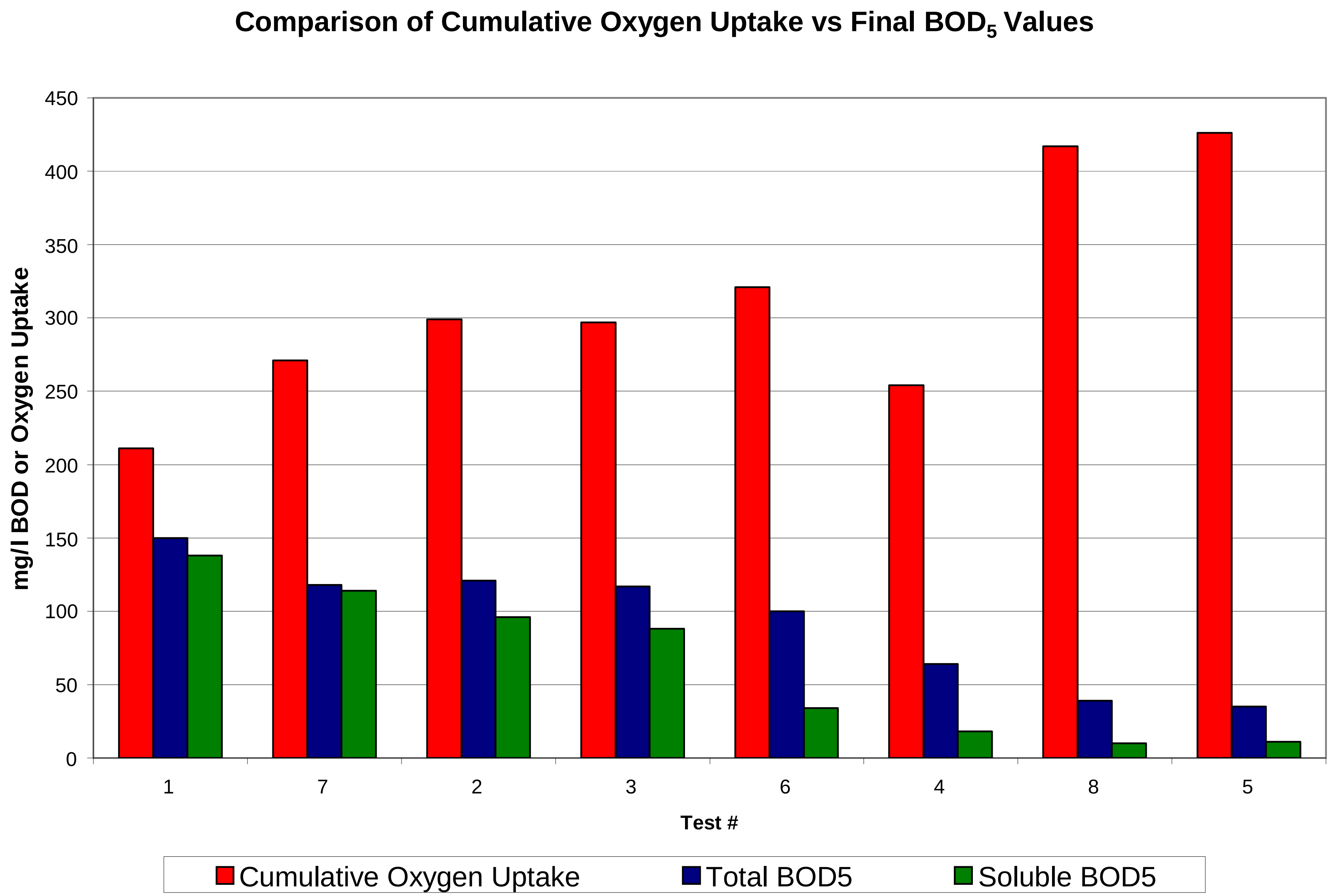
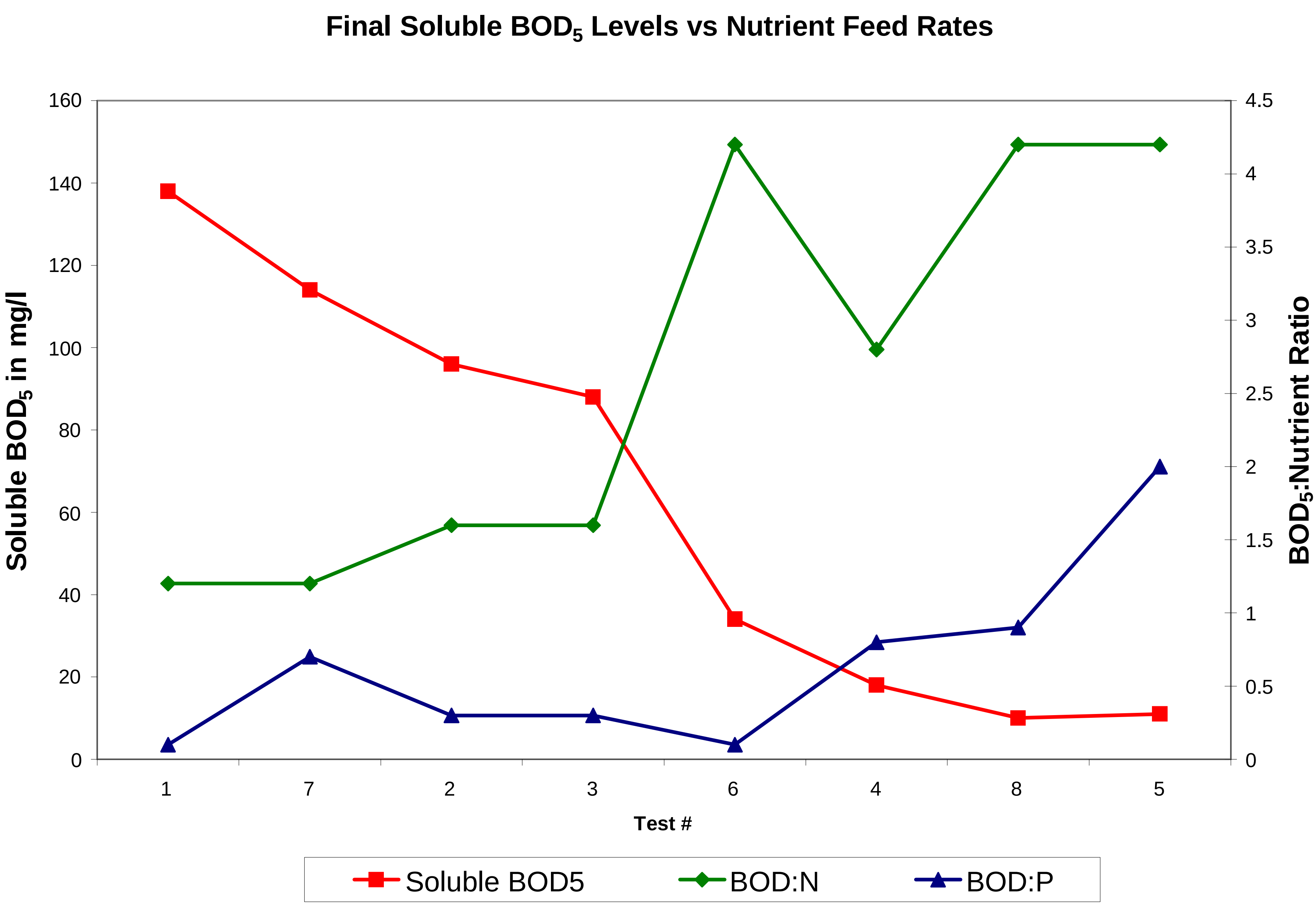

Cumulative Oxygen Uptake -- 160 hours
Oxygen Uptake in mg
Time in hours
0
50
100
150
200
250
300
350
400
450
0.0
24.0
48.0
72.0
96.0
120.0
144.0
168.0
15.54 mg/l available N
7.51 mg/l available P
15.54 mg/l available N
3.37 mg/l available P
15.54 mg/l available N
0.33 mg/l available P
5.78 mg/l available N
1.16 mg/l available P
4.50 mg/l available N
2.41 mg/l available P
4.50 mg/l available N
0.33 mg/l available P
8.34 mg/l available N
2.83 mg/l available P
Suspect cell after 24 hours
Control
Normal Fang
Normal Fang
Triple Fang
Fang @ 100:5 N
Urea @ 100:5 N
Phos Acid @ 100:1
Urea/Phos @ 100:5:1

Figure D



Note: Cumulative oxygen uptake is inversely proportional to final BOD_5, with the exception of #4 (Triple Fang) which demonstrated some technical problems concerning oxygen consumption.

Figure E



Final Soluble BOD5 Levels vs Nutrient Feed Rates
Soluble BOD5 in mg/l
BOD5:Nutrient Ratio
0
20
40
60
80
100
120
140
160
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
1
7
2
3
6
4
8
5
Test #
Soluble BOD5
BOD:N
BOD:P

Figure F

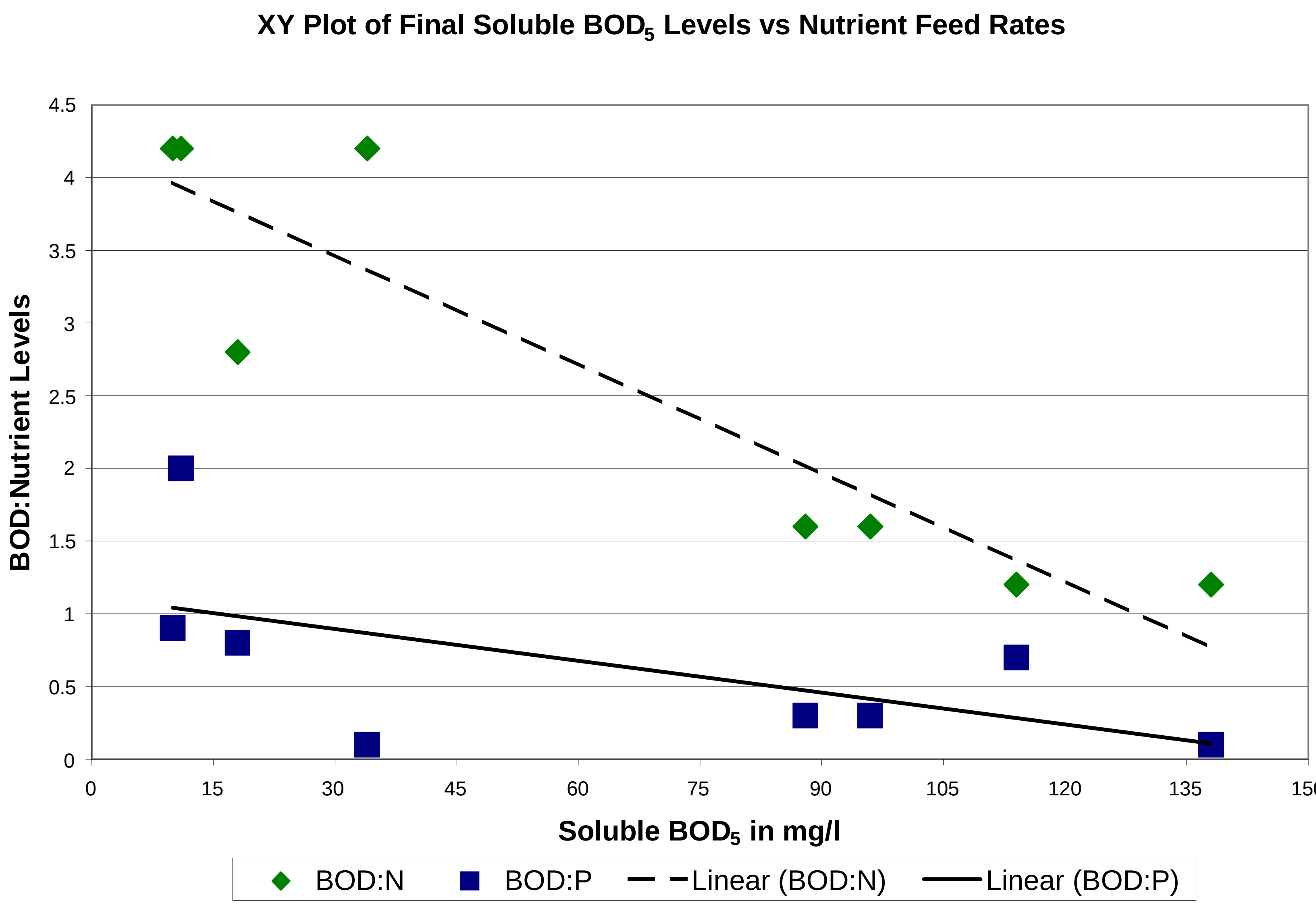
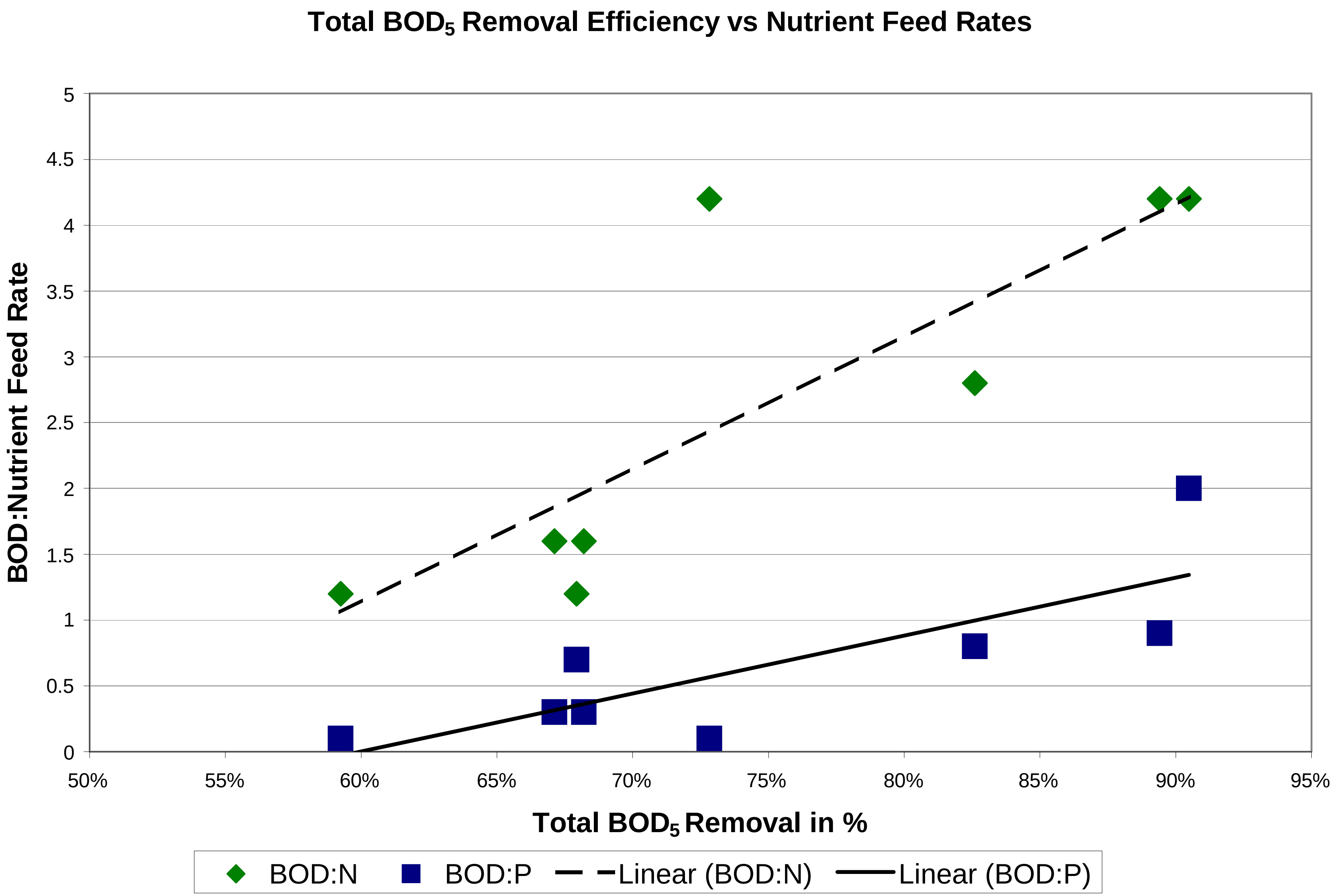

XY Plot of Final Soluble BOD5 Levels vs Nutrient Feed Rates
BOD:Nutrient Levels
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
0
15
30
45
60
75
90
105
120
135
150
Soluble BOD5 in mg/l
BOD:N
BOD:P
Linear (BOD:N)
Linear (BOD:P)

Figure G


Total BOD5 Removal Efficiency vs Nutrient Feed Rates
BOD:Nutrient Feed Rate
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
50%
55%
60%
65%
70%
75%
80%
85%
90%
95%
Total BOD5 Removal in %
BOD:N
BOD:P
Linear (BOD:N)
Linear (BOD:P)

Nutrient Control Model
ASB
Blended Product

Product Information

Nutrient Blend %N	0.18
Nutrient Blend %P, as P2O5	0.12
Nutrient Blend lb/gal	11.5
Nutrient Blend Cost per ton	$0

Targets

	Target	Actual
BOD:N Ratio	3.1	3.4
BOD:P Ratio	0.6	0.7

Plant Information

Flow in MGD	17.4
Estimated BOD in mg/l	368
Estimated BOD Loading in lb/day	53,403
Influent N in mg/l	4.5
Influent P in mg/l	0.33
Minimum Residual Total N in mg/l	1
Minimum Residual P in mg/l	0.5

Nutrient Feed Rates

Target Pounds of N	1098 lbs/day
Target Pounds of P	335 lbs/day
Nutrient Feed Rate	1396 ml/min
Nutrient Feed Rate	530 gal/day
Nutrient Cost per day	$ -
Nutrient Cost per pound BOD	$ -
Annualized Cost	$ -

Nitrogen Based Dosage	1396 ml/min
Phosphate Based Dosage	1391 ml/min