Evaluation of Kady Biolysis System (BLS^{TM}) at the Plum Island Wastewater Treatment Plant

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ABSTRACT

This paper presents results of full-scale pilot testing of the Kady Biolysis System (BLS^{TM}) at the Commissioner's of Public Works' (of the City of Charleston, SC) Plum Island Wastewater Treatment Plant. This is a 36 million gallon per day (MGD) (136,000 cubic meters per day) conventional activated sludge wastewater treatment plant (WWTP). Various researchers (Claus and Springer (1); Borgatti et al. (2); Springer and Higgins (3); Springer et al.(4); Springer et al.(5)), demonstrated that through microbial membrane disintegration (lysis) it was possible to recycle waste activated sludge (WAS), and operate an activated sludge process (ASP), while maintaining acceptable 5 day biological oxygen demand (BOD_5) and total suspended solids (TSS) removal efficiencies while simultaneously achieving a reduction in secondary solids production, or sludge yield. The Kady Biolysis System (BLS^{TM}) consists of high speed "rotary mills" which are designed to shear a portion of the Return Activated Sludge (RAS). This shearing mechanically disrupts or lyses the bacterial cells, releasing the cytoplasm for further biological assimilation. In essence, the BLS^{TM} accelerated endogenous decay of the activated sludge. The purpose of this study was to evaluate the effectiveness of the BLS^{TM} in reducing secondary sludge production at the Plum Island Facility, and assess any impact on effluent quality. After operating the biolysis unit for a four-month period, it was concluded that the system had neither a positive nor negative impact on sludge yield. Likewise, there was no documented impact on effluent quality based upon BOD_5 and TSS data. The Biolysis system did have a definite impact on soluble BOD_5 and respiration rates, from which one could infer that the system does shear cell membranes, releasing more cytoplasm as food and energy to the ASP. Interestingly, the Biolysis system demonstrated enhanced phosphorus removal. The ASP without the BLS^{TM} had a 39.1 % phosphorus removal, while the ASP with the BLS^{TM} removed 65.2% of the phosphorous.

While this Pilot study was unable to duplicate the sludge yield reduction of other researchers, the reduction in phosphorus is an interesting benefit that may be of use to wastewater treatment plants that might not be able to incorporate more conventional methods of nutrient removal.

Introduction

Description of Facilities

The Plum Island Wastewater Treatment Plant was first placed into operation in 1970 to provide primary wastewater treatment at a capacity of 18 MGD (68,130 cubic meters per day). In 1984, Plum Island was upgraded to secondary treatment and in 1990, the plant was expanded to 27 MGD (102,000 cmd). In 1995, the Plant was up-rated through the use of a computer model and calibration using historical data to 36 MGD (136,000 cmd)average daily flow, and 81 MGD (307,000 cmd) peak daily flow. Wastewater is received at Plum Island at two circular wet wells from where it is pumped by influent lift pumps into a stilling basin for treatment by coarse screening and comminution.

From this point in the process, the total plant flow is divided, with two-thirds directed to the "A-Side" of the plant and one-third directed to the "B-Side." A circular grit collector and detritor is provided for each side of the plant and circular collectors move the settled grit to grit hoppers for ultimate disposal. Following the grit collectors, the wastewater enters six (6) primary rectangular sedimentation basins for removal of settleable solids and floating debris. The primary treatment is also important for removing a significant portion of BOD_5 and suspended solids, and historical data shows average concentrations leaving the primary sedimentation basins of 84 mg/L and 72 mg/L for BOD_5 and suspended solids, respectively.

Next, the aeration of the wastewater is provided by six (6) aerations basins for the A-Side and three (3) for the B-Side, through fine-bubble diffused air system using porous dome diffusers for a complete-mix, activated sludge reactor. Following aeration, final settling is provided by four (4) rectangular clarifiers for the A-Side, and two (2) for the B-Side. Eight (8) return activated sludge (RAS) pumps and five (5) waste activated sludge (WAS) pumps are provided for both trains. Effluent from the secondary clarifiers is chlorinated in dual chlorine contact chambers using sodium hypochlorite, and de-chlorination is achieved through detention time in a 4000 foot (1220 m) outfall line to Charleston Harbor.

Objectives of Research

The Plum Island Facility currently spends approximately $750,000 per year to waste, dewater , transport and dispose of approximately 3,500 dry tons of Biosolids. This represents approximately 25 percent of the annual O&M Budget. Laboratory studies done by Springer, et.al. (1) and Claus and Springer (2) indicated that up to an eighty-four percent (84%) reduction in sludge yield could be recognized through the use of the Kady system, when compared to an ASP without a BLS^{TM}. Borgatti, et.al. (3) reported a twelve percent (12%) reduction in the Observed Sludge Yield in an ASP over a 10 month period. A reduction of 12 % in sludge production at the Plum Island would result in a savings of approximately $90,000 per year. However, given the fact that the BLS^{TM} breaks open bacterial cells and increases the available food source, there is speculation it could actually increase sludge production.

The focus of this study was to determine if the BLS could effectively reduce the observed sludge yield in the activated sludge portion of the treatment process, without degrading effluent quality or creating any additional operational problems.

Materials and Methods

Equipment

The Kady Biolysis System (BLS™) which was tested at the Plum Island Treatment Facility consisted of two (2) Model OOCFII Mills powered by two (2) 30 hp, 460 volt three phase motors. The BLS™ was also equipped with two (2) progressive cavity feed pumps, a magnetic flow meter, an in-line basket type strainer and control panel with a programmable logic controller (PLC). The units were skid mounted and were shipped to the facility via common carrier.

The Plum Island facility has two process trains which differ only in flow capacity. The "A" side is rated for 24 MGD (91,000 cmd) and the "B" side is rated for 12 MGD (45,000 cmd). The BLS™ was placed in the "B" side of the facility. The units were plumbed into the RAS piping as shown in Figure 1. The flow through the BLS™ was controlled through the use of orifice plates. The system was controlled through the cabinet mounted PLC.

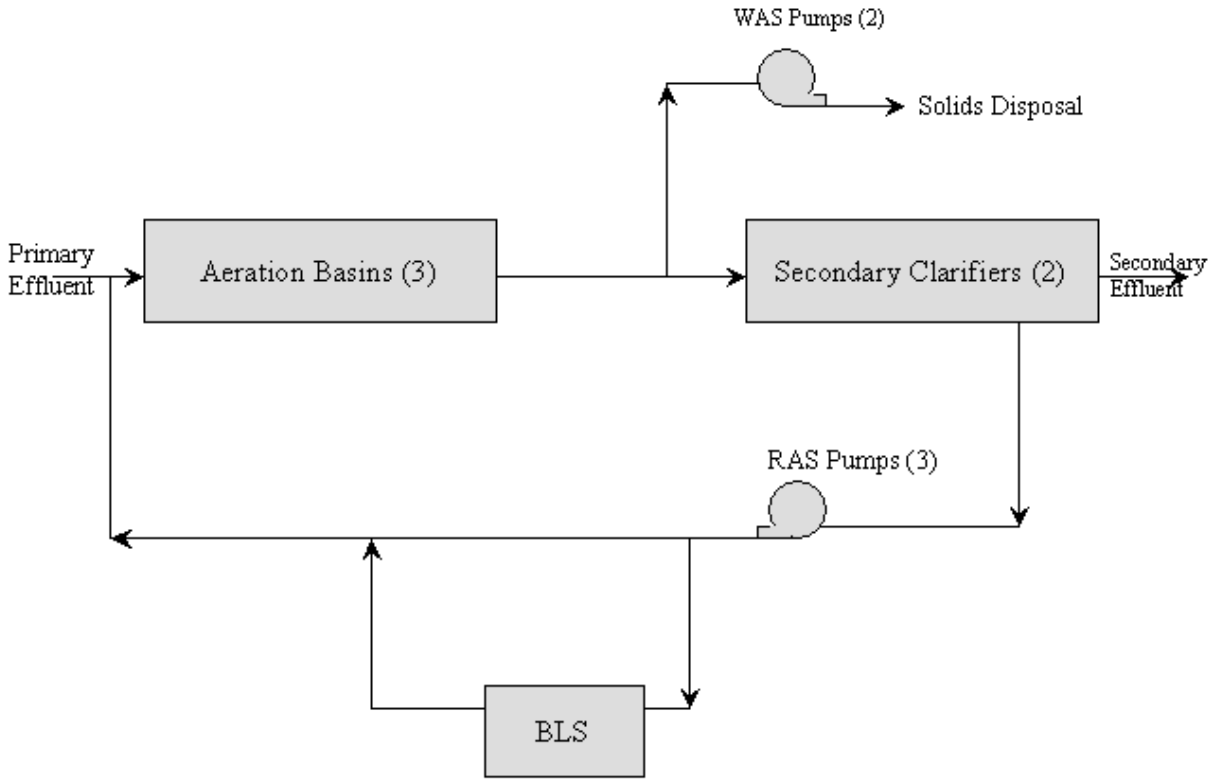

Figure 1.Schematic of B-side with BLS™ on RAS sidestream

Experimental Schedule

The formal data analysis period was established from March 6, 2003 to May 30, 2003, an eighty-six (86) day period. Data collection included routine plant process analyses plus additional sampling to document the efficacy of the BLS™. Sample collection points are shown in Figure 2. Table 1 gives the sample frequency and variables analyzed at each sample point.

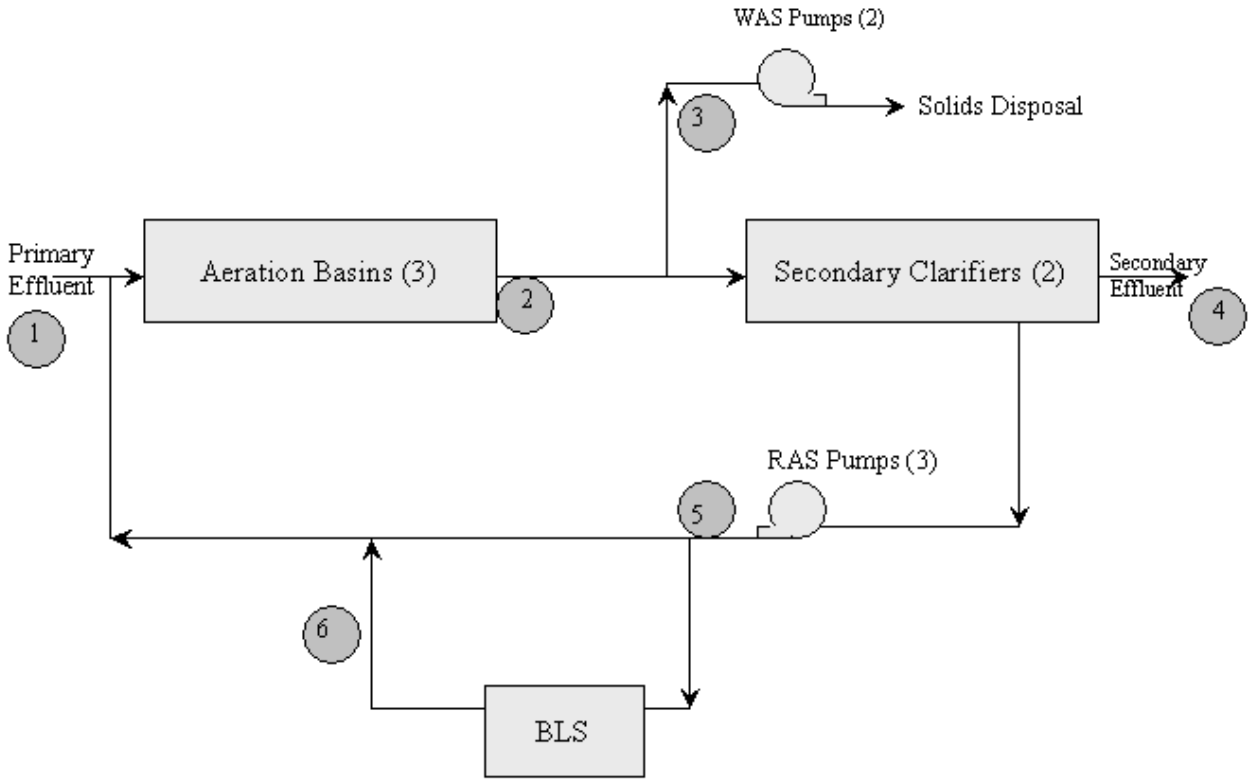

Figure 2. Sampling points during experimental period

	Sample Frequency					
Sample Location	7 X week	5 X Week	2 X Week	1 X Week	Continuous	Other
#1 Primary Effluent		TSS	BOD_5		Flow	Phosphorus
#2 Aeration Basin Effluent	MLSS, Settlometer			MLVSS		
#3 Waste Activated Sludge	MLSS			MLVSS	Flow	
#4 Secondary Effluent		TSS	BOD_5			Phosphorus
#5 Return Activated Sludge		MLSS	Soluble BOD_5	MLVSS		Respiration Rate
#6 BLS Effluent			Soluble BOD_5		Flow	Respiration Rate

Table 1. Sample locations, frequency and variables

Laboratory Analysis

5-Day Biochemical Oxygen Demand (BOD_5)

The BOD_5 analyses were performed by in-house laboratory staff following Std. Methods (18th ed.) procedure 5210 B. BOD_5 analyses were performed on the Primary effluent to the "B"side aeration basins and the "B" side secondary effluent, to monitor the removal efficiency of the treatment train and the effluent quality. The BOD_5 test was run on composite samples collected from the Primary Effluent, and Secondary Effluent five (5) days per week.

Soluble BOD_5

A soluble BOD_5 method was developed to provide an indirect measure of the effectiveness of the BLS™ in lysing microbial cells and making the cellular cytoplasm available as a food source. This was accomplished by filtering an aliquot of Returned Activated Sludge (RAS) which had been collected prior to and after the BLS™ . The RAS was filtered through a VWR Grade # 696, 11.0 cm, 1.2 *u*m nominal pore size glass fiber filter, following an in-house procedure, to remove any suspended solids. The BOD_5 analysis was then performed on the filtrate using Std. Methods (18th ed.) procedure 5210 B. Soluble BOD_5 was run on grab samples collected from the Return Activated Sludge and the Biolysis Effluent two (2) times per week.

Respirometer

Respirometer analysis was performed by in-house staff using an Arthur Technology Automatic Bench Respirometer Model No. 026-200. The procedure followed was method 2710 B from the 18th ed. of Std. Methods. Oxygen uptake rates (OUR) in mg/l/hr and specific oxygen uptake rates (SOUR) mg/l/hr/g were calculated as described by in-house Standard Operating Procedure: ***Respirometric Analysis of Activated Sludge No: ERL.2103.9*** Respirometry was conducted during the trial on the days indicated in Table 1. Samples were collected on the "B" side RAS prior to and after the BLS™ .

Total Phosphorus

Total Phosphorous analyses were conducted by a commercial laboratory following U.S.E.P.A. Method 365.3. Total Phosphorous was monitored for a one month period on the raw wastewater and both flow trains to document the effects of the BLS™ on phosphorous removal. Total Phosphorus was conducted during the final month of the study to determine if the BLS™ had any impact on the removal of phosphorus. The samples were 24 hour time composite samples collected on both the "A" side and "B" side flow trains

Process Control Procedures

Routine plant process control procedures were used to monitor the "B" side of the facility and document the effect of the BLS™ . The ASP is controlled at the Plum Island facility by the use of Mean Cell Residence Time (MCRT). A target MCRT of 10 days was used during the study period. Operational staff uses a computer program to calculate MCRT on a daily basis. The MCRT is trended on a daily basis and with a 10 day moving average (DMA) applied. The program predicts daily waste sludge rates needed to maintain the target MCRT. Sludge waste rates are adjusted as needed to maintain the target MCRT on a 10 DMA basis.

Observed sludge yield (OSY) was calculated to determine the effectiveness of the BLS™ in reducing the amount of sludge generated by the ASP as shown in Equation 1. For this study, the observed sludge yield was calculated as the pounds of biomass generated per pound of BOD_5 removed. The pounds of biomass generated equal the sum of the pounds of waste activated sludge and the pounds of secondary effluent total suspended solids minus the pounds of inert solids, as determined by the volatile solids test. For the experimental period, the volatile TSS averaged 78%. The pounds of BOD_5 removed equal the pounds of BOD_5 in the primary effluent minus the pounds of BOD_5 in the secondary effluent. The observed sludge yield was calculated on a daily basis and a 10 DMA was applied for trending.

Equation 1.

OSY = pounds of solids generated / pounds of BOD_5 removed
= [lbs. WAS + lbs. effluent TSS]* volatile fraction / [lbs, primary effluent BOD_5 + lbs. BOD_5 from cell lysis] – lbs. effluent BOD_5

Results

The following Tables and Graphs present both the analytical and treatment process data collected to evaluate the effectiveness of the BLS™.

Analytical Data

5-Day Biochemical Oxygen Demand (BOD_5)

BOD_5 was analyzed on the raw wastewater, the Primary clarifier effluent, and the secondary clarifier effluent. Table 2 presents a summary of the BOD_5 data and Figure 3 shows the BOD_5 percent removal with the Primary and Secondary effluent values.

	Influent BOD_5	Primary Effluent BOD_5	Secondary Effluent BOD_5	Percent Removal through Primary Clarifiers	Percent Removal through Secondary Clarifiers	Percent Removal Primary effluent through Secondary Clarifiers
Date	mg/l	mg/l	mg/l	%	%	%
Average	175	84	8	51	94	90
Maximum	400	180	21	78	98	99
St.Dev.	74	31	6	18	4	8

Table 2. Summary of BOD_5 results for experimental period

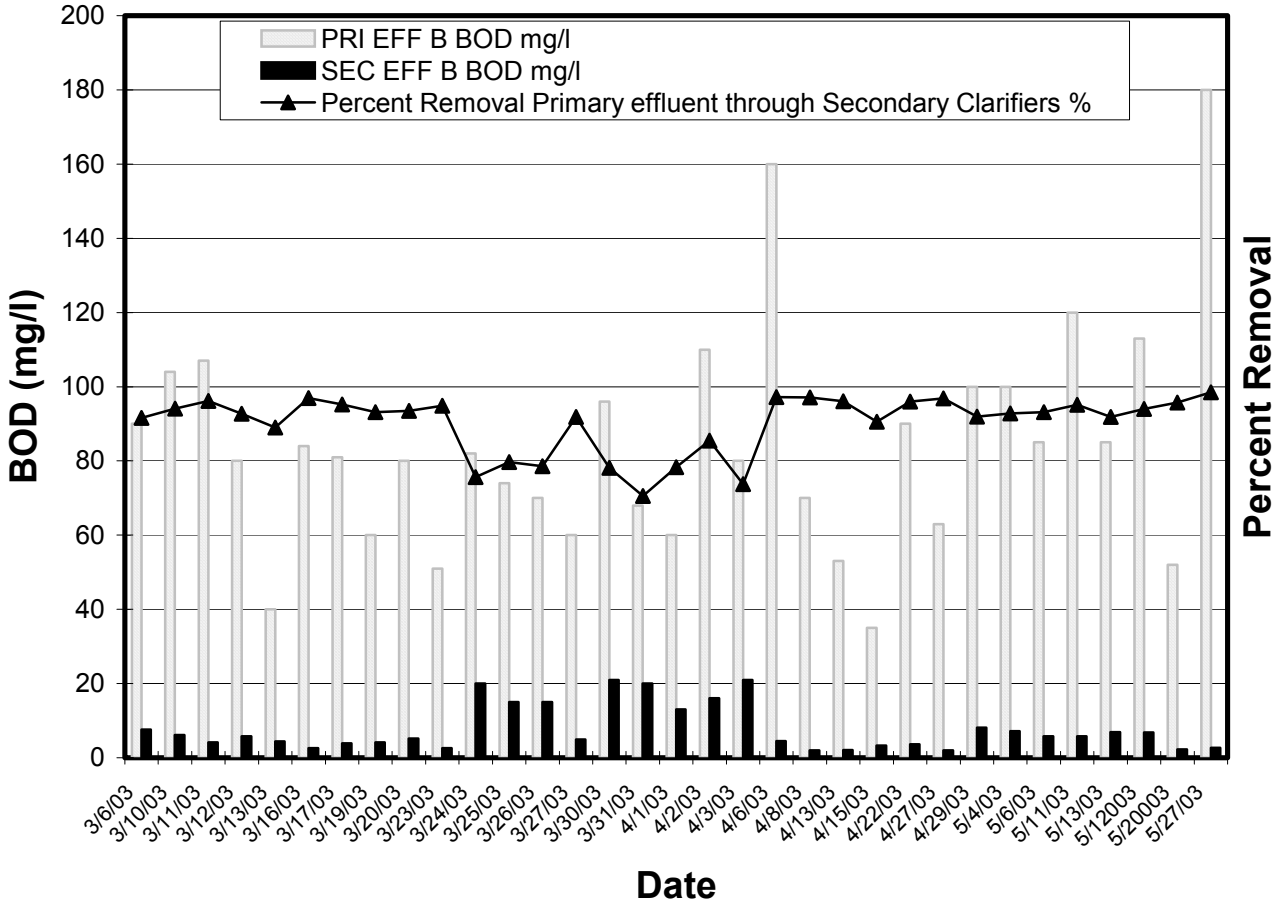

Figure 3. Percent removal of primary and secondary BOD_5

Soluble BOD_5

Soluble BOD_5 was collected and analyzed for the return activated sludge before and after the BLS™. Samples were analyzed and a summary of the results is shown in Table 3 and Figure 4.

Soluble BOD_5 (mg/l)

Date	RAS "B"	RAS "B" Biolysis	Date	RAS "B"	RAS "B" Biolysis	Date	RAS "B"	RAS "B" Biolysis
3/5/2003	5.2	30	4/4/2003	<2.0	80	5/7/2003	6.3	40
3/7/2003	4.8	45	4/9/2003	4.7	24	5/9/2003	11.0	31
3/12/2003	13.0	71	4/11/2003	20.0	4.3	5/14/2003	10.0	50
3/14/2003	19.0	100	4/16/2003	2.0	20	5/16/2003	2.8	60
3/19/2003	14.0	45	4/23/2003	7.0	47	5/21/2003	<2.0	38
3/21/2003	4.0	50	4/25/2003	7.6	50	5/23/2003	5.8	63
3/26/2003	11.0	89	4/30/2003	6.4	15	5/28/2003	2.6	60
3/28/2003	15.0	100	5/2/2003	4.8	50	5/30/2003	10.0	40
4/2/2003	5.8	60						

Mean	8.4	50.5
Minimum	2.0	4.3
Maximum	20.0	100.0
Std.Dev.	5.1	24.5

Table 3. Summary of soluble BOD_5 as measured before and after the BLS™

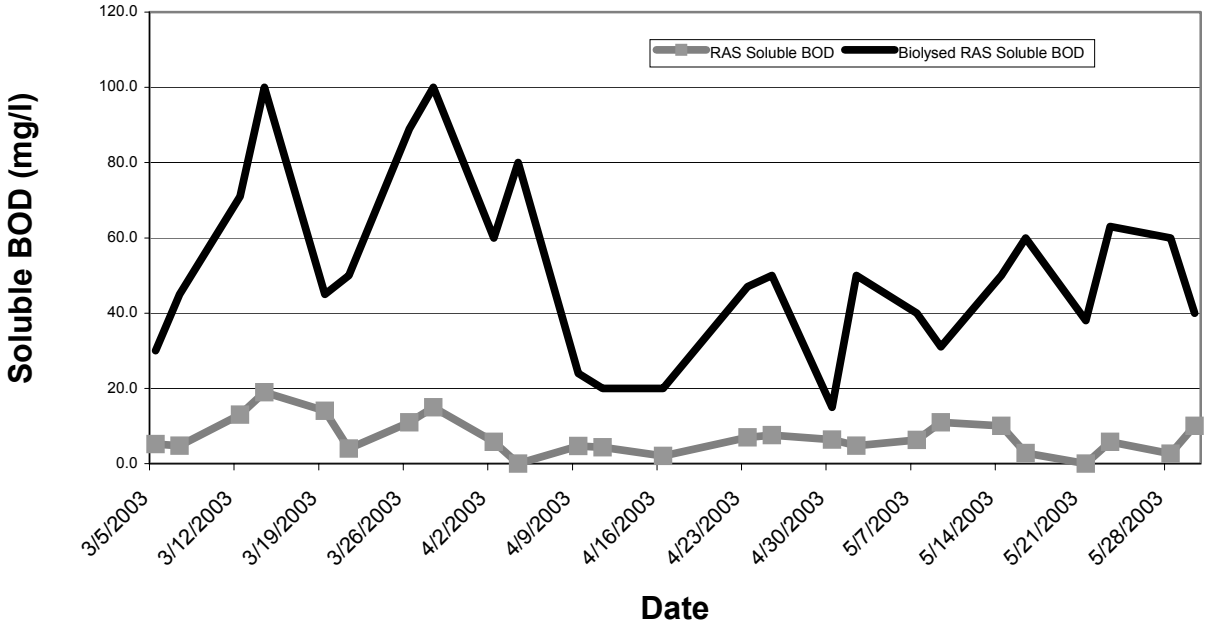

Figure 4. Soluble BOD_5 for both RAS and Biolysed RAS

Respirometer

Oxygen uptake rate was performed on samples from the return activated sludge line prior to and after the BLS™. Table 4 and Figures 5 and 6 present this data.

Respirometric Analysis				
Date	RAS B Pumps		Biolysis	
	OUR (mg/l/hr)	SOUR (mg/l/hr/g)	OUR (mg/l/hr)	SOUR (mg/l/hr/g)
4/24/2003	61.2	8	185.9	24.4
5/8/2003	92.5	12		
5/9/2003			148.6	18.6
5/12/2003	32.2	4.5	123.7	17.3
5/14/2003	37.6	5.7		
5/15/2003			82	13.6
Mean	55.9	7.6	135.1	18.5
Minimum	32.2	4.5	82.0	13.6
Maximum	92.5	12.0	185.9	24.4
Std. Dev.	27.5	3.3	43.6	4.5

Table 4. Respiration as measured by OUR and SOUR, before and after BLS™

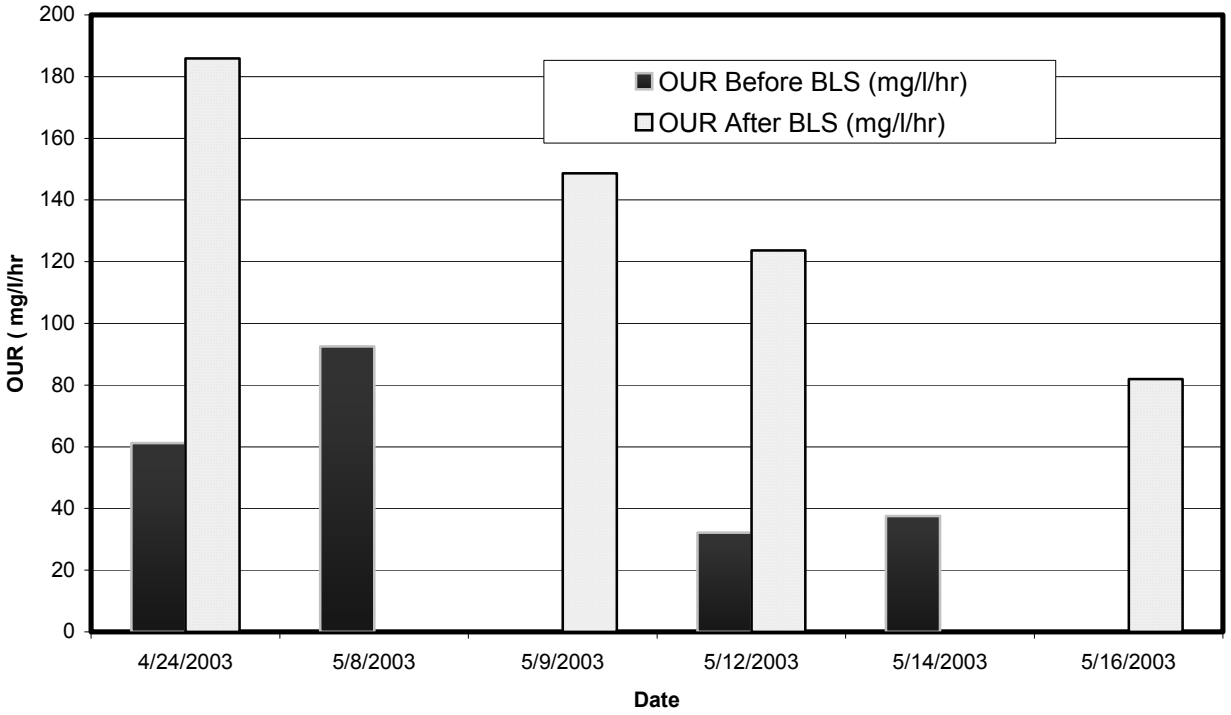

Figure 5. OUR for RAS and Biolysed RAS

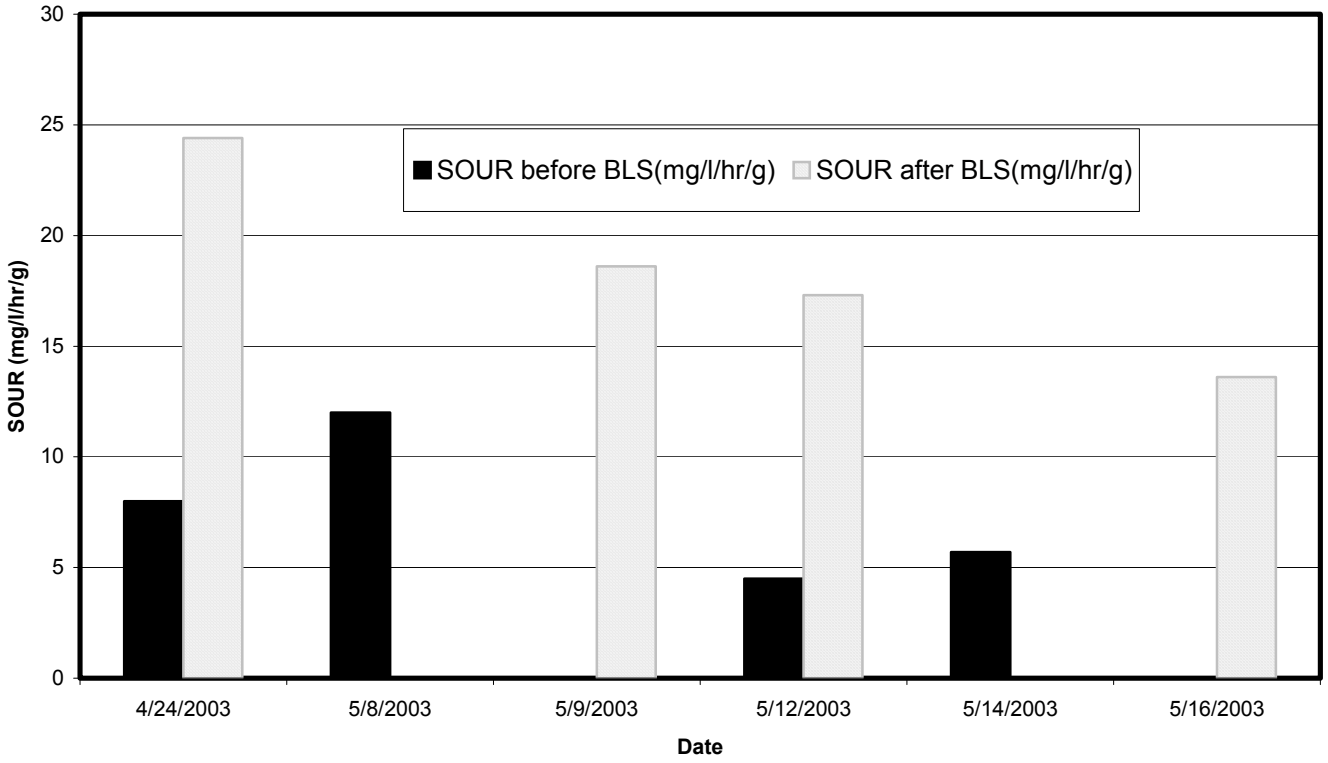

Figure 6. SOUR for RAS and Biolysed RAS

Total Phosphorus

During the final month of the study, Total Phosphorus was collected six times through the plant process to document the effect the BLS™ had on Phosphorus removal. Table 5 and Figure 7 present this information.

Total Phosphorous (mg/l)					
Date	Influent	Secondary A	Secondary B	Secondary A % Removal	Secondary B % removal
5/6/2003	5.1	2.4	1.3	52.9	74.5
5/8/2003	4.2	3.5	1.1	16.7	73.8
5/13/2003	5.2	2.4	1.7	53.8	67.3
5/15/2003	5.2	3.9	2	25.0	61.5
5/20/2003	4	1.7	no data	57.5	
5/22/2003	4.1	2.8	2.1	31.7	48.8
Mean	4.6	2.8	1.6	39.6	65.2
Minimum	4.0	1.7	1.1	16.7	48.8
Maximum	5.2	3.9	2.1	57.5	74.5
Std. Dev.	0.6	0.8	0.4	17.3	10.6

Table 5. Total Phosphorus concentrations

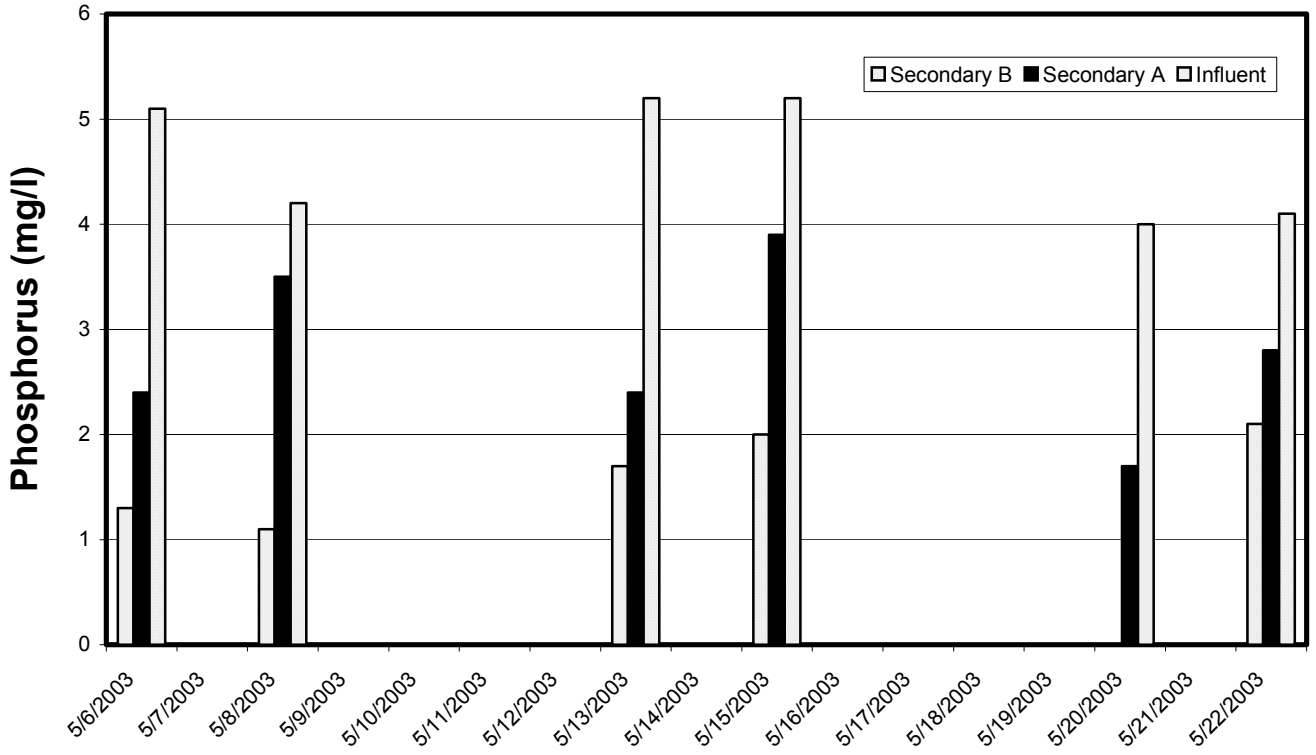

Figure 7. Phosphorus concentrations in Influent, A-side, and B-side (with BLS^{TM})

Process Data

Table 6 presents a summary of plant process data collected from March 6, 2003 through May 30, 2003 along with calculated parameters. Figure 8 represents the raw observed yield data and the same data with a 10 day moving average (DMA) applied.

	B Influent Flow	B Influent Flow with 10 day moving average (10 DMA)	B Solids Inventory	B Solids Inventory w/ 10 DMA	B Primary Effluent TSS	B Primary Effluent TSS	B Primary Effluent TSS (Non-Volatile Component)	Waste Activated Sludge B	Waste Activated Sludge B 10 DMA
	MGD	MGD	Lbs.	Lbs.	mg/l	lbs/day	lbs/day	lbs/day	lbs/day
Total	976.60	897.01	5965435	5444232	6990	659207	139422	563043	512617
Mean	11.36	11.65	69366	70704	81	7665	1621	6547	6657
Minimum	6.27	8.55	33046	54599	42	3570	755	3143	4763
Maximum	22.19	13.69	113561	87883	160	20058	4242	21200	9330
Std. Dev.	2.92	1.37	13944	8774	17	2548	539	2211	1030

	B Secondary Effluent TSS	B Secondary Effluent TSS w/ 10 DMA	Total Solids Wasted	Total Solids Wasted 10 DMA	B Primary Effluent BOD_5	B Primary Effluent BOD_5 w/ 10 DMA	BLS Soluble BOD_5	B Secondary Effluent BOD_5	B Secondary Effluent BOD_5 w/ 10 DMA
	Lbs/day	Lbs/day	lbs/day	lbs/day	Lbs/day	lbs/day	lbs/day	Lbs/day	Lbs/day
Total	63293	59526	486914	443565	661223	593327	2669	64726	59138
Mean	736	773	5662	5761	7689	7706	31	753	768
Minimum	95	316	2009	4133	2472	6337	2	170	446
Maximum	3784	1293	19919	8408	13931	8749	72	2578	1460
Std. Dev.	571	235	2245	988	1867	544	8	431	241

	Total BOD_5 Removed	Total BOD_5 Removed 10 DMA	Actual yield	Actual yield 10 DMA
	lbs/day	lbs/day	#TSS/# BOD_5	#TSS/# BOD_5
Total	599166	536579	74.7167	67.8022
Mean	6967	6969	0.8688	0.8805
Minimum	2231	5830	0.1603	0.5669
Maximum	13753	7719	2.8660	1.2116
Std. Dev.	1745	472	0.4167	0.1439

Table 6. Summary of plant process data for experimental period

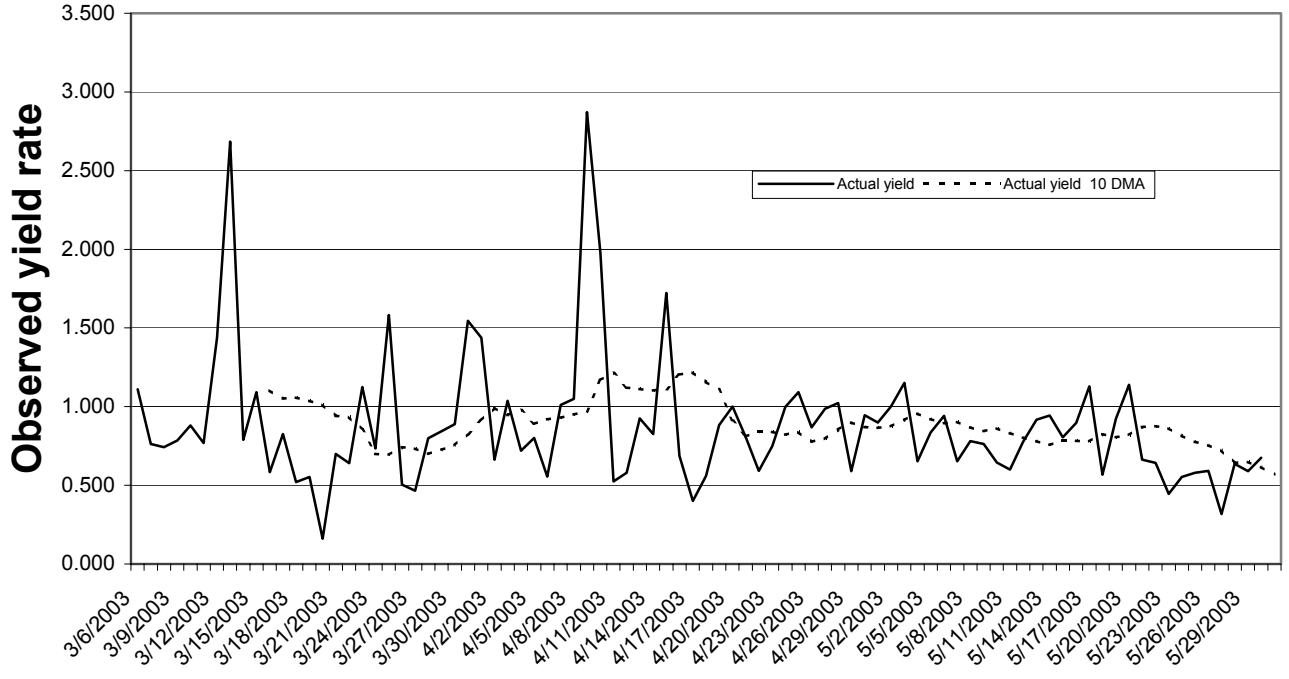

Figure 8. Raw observed yield rate and yield rate applying 10 day moving average

Table 7 presents the Observed Sludge Yield for the same calendar period (3/6-5/30) in 2001, 2002 and 2003 for B-side. Figure 9 presents the observed sludge yield data for 2001, 2002 (when the BLS™ was not installed) and 2003.

Observed Sludge Yield			
	2001	2002	2003
Mean	0.8169	0.9179	0.8688
Minimum	0.1607	0.3345	0.1603
Maximum	2.8718	2.8305	2.8660
Std. Dev.	0.4291	0.3652	0.4167

Table 7. Observed sludge yield rate for 2001, 2002, and 2003 for B-side of plant process

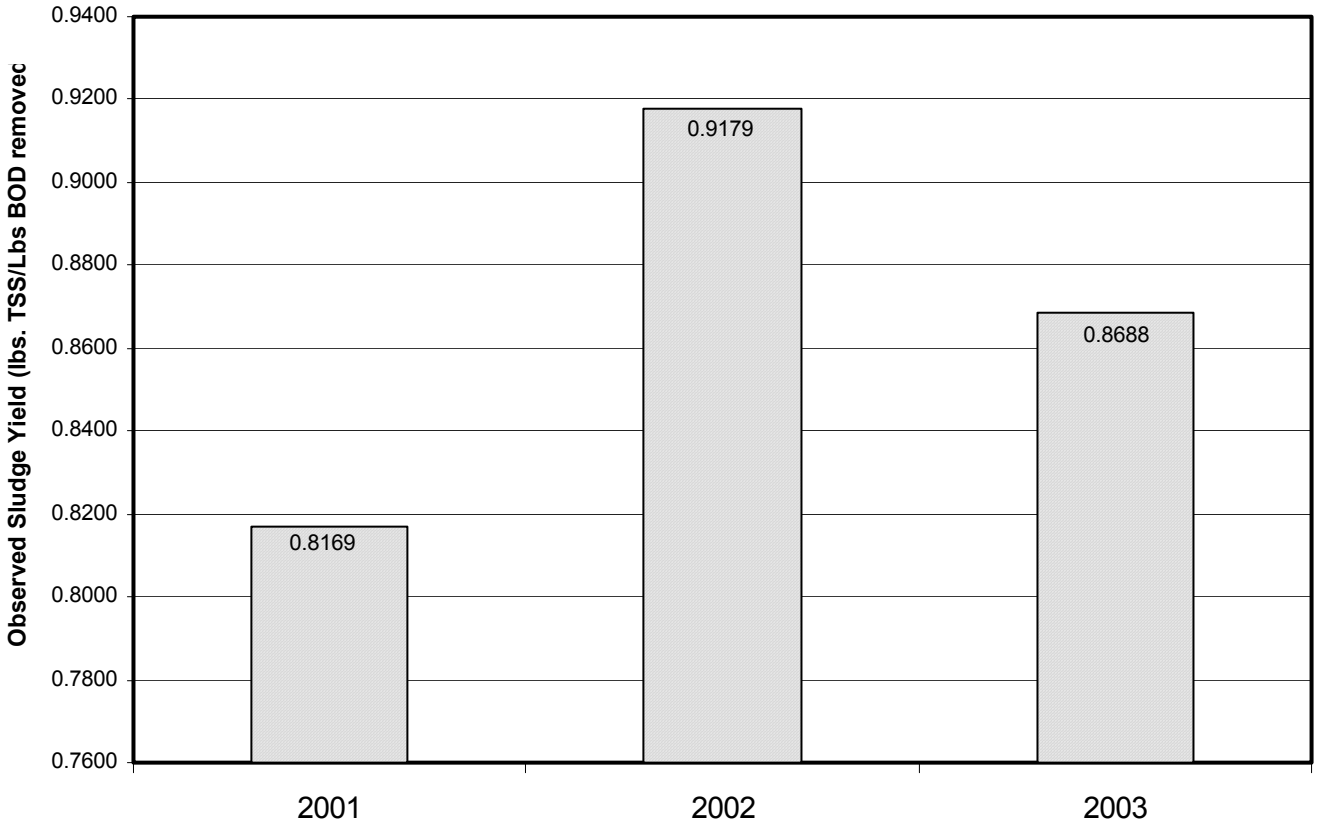

Figure 9 Observed sludge yield for 2001, 2002, and 2003 (when BLS™ was installed)

Discussion

Reviewing the BOD_5 data for the study period showed that the BLS™ did not have a noticeable impact on the quality of the effluent BOD_5. The secondary effluent quality stayed well within the permit limits. The B-side treatment train showed a 90 percent BOD_5 removal across the secondary treatment process and a 94% across the entire treatment process.

Soluble BOD_5 was measured on the RAS before and after the BLS™ to document the effectiveness of the BLS™ in disrupting the cell walls of the bacteria. There was a dramatic increase in soluble BOD_5 as shown in Figure 4. The average BOD_5 for the RAS was 8.4 mg/l while the "Biolysed" RAS averaged 50.5 mg/l soluble BOD_5. This represents a six (6) fold increase in biodegradable material.

This observation of having additional biodegradable material released by the BLS™ is supported by the results from the respirometer testing. Table 4 shows the average Oxygen Uptake Rate (OUR) for the RAS was 55.9 mg/l/hr and the "Biolysed" RAS was 135.1 mg/l/hr, a 2.4 times increase. The Specific Oxygen Uptake Rate (SOUR), which is the OUR normalized for the concentration of solids, showed the same increase in activity, with SOUR's of 7.6 mg/l/hr/g for the RAS and 18.6 mg/l/hr/g for the "Biolysed" RAS.

Table 5 presents the results of some limited Total Phosphorus testing that was conducted the last month of the study. The A-side treatment train of the facility was utilized as a "Control" against which to compare the performance of the BLS™. The A-side of the treatment plant averaged 39.1 percent removal of Total Phosphorus while the side with the Biolysis equipment averaged 65.2 percent removal.

The observed sludge yield during the study period was 0.8688 pounds of solids generated for every pound of BOD_5 removed. The daily values ranged from a minimum of 0.1603 lbs. TSS / lbs. BOD_5 removed to a maximum of 2.8660 lbs. TSS / lbs. BOD_5 removed. The standard deviation of the data for the study period was 0.4167 lbs. TSS / lbs. BOD_5 removed.

The yield value for the same period of time in 2002 was 0.9179 lbs. TSS / lbs. BOD_5 removed. This represents approximately a 5.35 % reduction in solids generated with the BLS™ in service. However, for the same time period in 2001 the sludge yield was 0.8169 TSS / lbs. BOD_5 removed, which is 5.97% less than the study period.

Conclusions

The Kady Biolysis system did not have either a positive or a negative impact on the sludge production at the Plum Island Facility during the study period, when compared to the two pervious years. There was no documented impact on effluent quality, when comparing BOD_5 and TSS values. The facility stayed in compliance with the NPDES Permit throughout the entire study period. There was an apparent reduction in Total Phosphorus in the effluent from the B-side. However, since this was the first sampling and analysis for Total Phosphorus at the facility, follow-up sampling without the BLS™ in operation will need to be conducted to determine the total effect. The BLS™ did have a very definite impact on Soluble BOD_5 and respiration data. This is indirect proof that the BLS™ does indeed shear the floc and bacterial cells of the mixed liquor, releasing more food and energy to the ASP.

However, this study was not able to support the findings of lab scale studies, which indicated significant reductions in sludge yield. While there seemed to be some reduction in sludge yield when compared to

non-study periods, there were indications of an increase in sludge production when compared to other time periods. This makes a cost comparison difficult at best.

The BLS™ performed through the entire study with no equipment problems. Preventive maintenance requirements were low and the units required a minimum of operator attention. Installation of the skid mounted units was simply a matter of positioning the units and completing the plumbing and electrical connections. Operation of the unit using the supplied Programmable Language Computer (PLC) was straightforward and intuitive.

Acknowledgements

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References

1. Claus, H.B.; Springer, A. Aeration Requirements of Biosolids Lysis and Modified Recycle in the Activated Sludge System. Proceedings of TAPPI Environmental Conference, 2002.

2. Borgatti, D; Brooks, J.; Kruppa, D; Higgins, J; Pincince, A. Evaluation of the KADY Biolysis System at the Springfield Regional Wastewater Treatment Facility. Unpublished Work.

3. Springer, A.; Higgins, J.; Mechanical Cell Lysis and Recycle to Reduce Waste Activated Sludge. Unpublished work.

4. Springer, A; Dietrich-Velazquez, G.; Higby, C. Feasibility Study of Sludge Lysis and Recycle in the Activated Sludge Process. Unpublished Work.

5. Springer, A; Dietrich-Velazquez, G.; Higby, C.; Digiacomo, D. Feasibility Study of Sludge Lysis and Recycle in the Activated-Sludge Process. *TAPPI Journal*, May 1996, Vol.79(5).

6. *Standard Methods for the Examination of Water and Wastewater, 18th Edition.* American Public Health Association: Washington, DC.