Total Nitrogen Discharge of a Sequence Batch Reactor

Presented to the faculty of Lycoming College in partial fulfillment of the requirements for Departmental Honors in Biology

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Honors Project Thesis:

Total Nitrogen Discharge of a Sequence Batch Reactor (SBR)

**Lycoming College Clean Water Institute in partnership
with The Cromaglass® International Wastewater Corporation**

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INTRODUCTION

Clean water supplies are essential to human and aquatic life forms (Horan, 1990). Water utilized and discharged from domestic dwellings, institutions, and commercial companies alike is termed domestic wastewaters, whereas waters discharged from manufacturing facilities are industrial wastes. Both hold several potentially harmful compounds (Horan, 1990). In developed countries and most urban areas of the United States, most waterborne waste from homes, businesses and storm water runoff flow through a network of sewer pipes to a wastewater or sewage treatment plant. In rural and suburban areas, sewage from each house is usually discharged into a septic tank. In this system, household sewage and wastewater is pumped into a settling tank, where grease and oil rise to the top and solids fall to the bottom for decomposition by bacteria (Miller & Spoolman, 2008). The partially treated wastewater on top is discharged via drainage (absorption) field or sand mound with small holes in perforated pipes embedded in porous gravel and stone. About ¼ of all homes in United States are served by septic tanks (Miller & Spoolman, 2008).

In municipal areas, raw sewage often undergoes one or two levels of treatment including primary and secondary sewage treatment. Two typical wastewater treatment plants exist including one incorporating physical treatment (primary sewage treatment) and one of biological treatment (secondary sewage treatment) for the removal of dissolved organic matter (Gerardi, 2002). Biological treatment can be defined as the process in which bacteria convert ammonia nitrogen to nitrate and contribute to the removal of organics from wastewater (Gerardi, 2001). Biological treatment is considered technology, utilizing filters, fluidized beds or packed beds for treatment; these systems primarily involve settling and the removal of solids (Droste, 1997). Primary treatment is a physical process of bars, screens, and settling discharge that achieve 40-60% reduction of CBOD (Carbonaceous Biochemical Oxygen Demand) and TSS (Total Suspended Solids). Secondary treatment is biological and generally occurs by bubbling air into what is termed activated sludge chambers. The aeration stimulates bacterial (microbial) growth that further treats the wastewater to remove total nitrogen, CBOD and TSS. This nutrient removal process decreases the need for disinfection agents at the end of wastewater treatment due to aeration and bacteria which can remove 90% of the CBOD (Gerardi & Zimmerman, 2005). Modern wastewater facilities incorporate both physical-chemical and biological operations for removal rates of 95-97% of total suspended solids TSS and BOD , 70% of most metal compounds and non-persistent synthetic organic chemical compounds, 70% of phosphorus and about 50% of the nitrogen loading (Gerardi & Zimmerman, 2002).

Sludge produced by a physical-chemical treatment will be higher sewage quality than for a plant using biological treatment with additions of coagulation agents and the absence of biological oxidation of organics (Gerardi, 2002). Physical-chemical treatment operations are termed advanced treatment processes; these physical-chemical mechanisms of filtration and carbon adsorption can follow the biological treatment process for further treatment of purified wastewater effluent (Droste, 1997).

An emerging third stage of treatment is tertiary treatment. These systems require additional chemicals or additional biological treatment of toxins and a further reduction in nitrogen and phosphorus levels. Tertiary systems utilize additional chemical treatment or natural biological treatment found in wetlands to achieve 97-100% reduction of TSS, BOD and Total Nitrogen. Interests of natural treatment serve particularly well as nutrient sinks and buffering zones to enhance the preservation of wetlands and economic feasibility (Gerardi, 2001 & EPA).

Sewage effluent can be used for land application, though due to pathogenic and sanitary concerns has not been an accepted practice throughout North America (Droste, 1997). However, after primary and secondary treatment, land applications of wastewater or sludge are encouraged due to feasibility. Land applications are also utilized for irrigation and fertilization processes of limited nutrient loads (Droste, 1997). Landfills remain the most common means for disposal of sludge produced during the treatment operations (Droste, 1997).

In Lycoming County, Pennsylvania, the two largest secondary wastewater plants, Williamsport Central and West Plants, are facing serious implications due to adherence to recent sewage treatment regulations. Last year, the estimated annual nitrogen discharge for these two plants was 540,000 lbs of nitrogenous waste (Chesapeake Bay Foundation).

Increased sediment and nitrogen removal will also be required of more rural areas where alternatives to septic tanks are desirable. Therefore, Lycoming College Clean Water Institute in conjunction with the Cromaglass® International Wastewater Treatment Systems of Williamsport, Pa is researching proper nutrient reduction of wastewater. The Cromaglass® Corporation developed Sequencing Batch Reactor (SBR) technologies in 1965 for wastewater treatment of small communities, individual residences and commercial establishments such as international vacation resorts. These systems are considered biological treatment systems because of their use of fixed film media also known as the “coffee can” to increase surface area for microbial growth.

Cromaglass® markets SBR wastewater treatment systems worldwide that process from 500 gallons per day (GPD) up to 1,500 GPD of wastewater. The flow rate is comparable to the CA-5 which is fed 500 GPD and the CA-150 for 1,500 GPD. This technology differs from traditional treatment systems based on space because it functions in time on a batch basis. In this sense, the systems can be regulated for discharge and aeration cycling with submersible pumps in coordination with sampling. Also, all wastewater treatment processes function in one fiberglass tank separated in three chambers; these chambers are labeled as A, B and C accordingly (Figure 1).

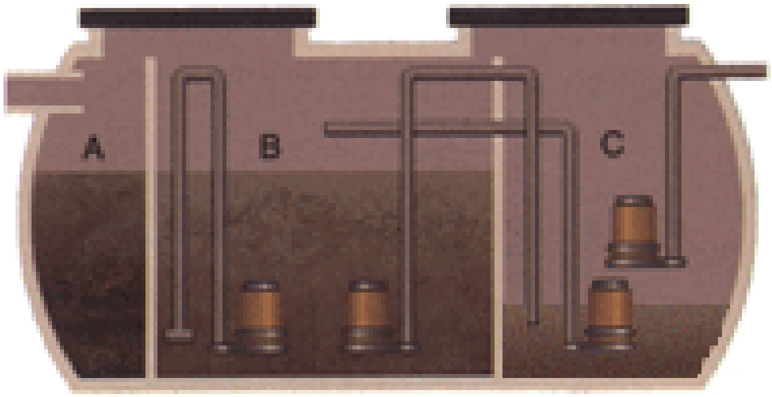
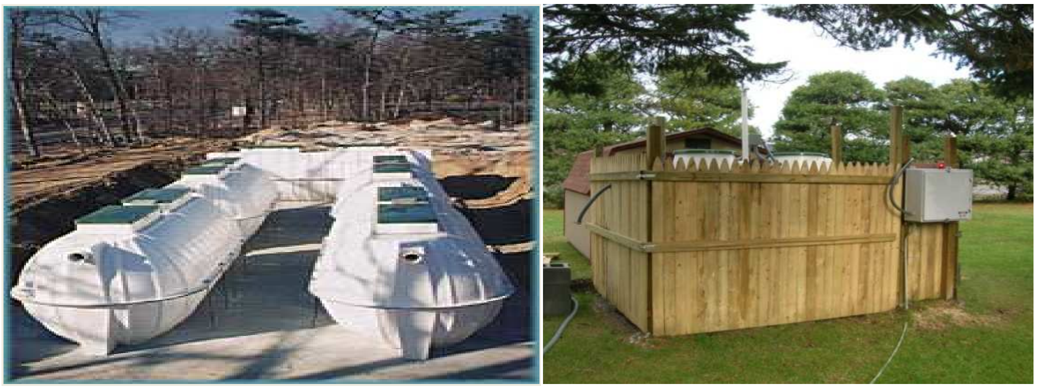


Figure 1: CA-5 Sequencing Batch Reactor (SBR) technology model
(Adapted from Cromaglass, 2006)

Chamber A, the first step in the treatment process involves input and settling of influent and screening of solids. Chamber B maintains on and off aeration cycling, allowing for denitrification within the system. The final step occurs in chamber C (the clarifier) in which particulates are settled and the supernatant liquid is discharged to a leach field, sand mound, or permitted surface water (a nearby body of water) requiring a National Pollutant Discharge Elimination System (NPDES) permit from the necessary state agency. These SBR units may be accommodated above or below ground depending on location (Figures 2a & 2b).



Figures 2a & 2b: The above left photo is of a preliminary below ground system and the photo to the right is of an operating above ground SBR system.

The market for Cromaglass SBR technologies is in rural areas where conventional sewage treatment plants have not been built. Over the last decade, there has been increased pressure worldwide for reducing total Nitrogen, total Phosphorus, Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), and Total Suspended Solids (TSS) to both surface and groundwater receiving wastewater. This is true for Pennsylvania and especially the Susquehanna River watershed. The Susquehanna River contributes over 50% of the fresh water to the largest estuary in the United States, the Chesapeake Bay.

In 2000, the states of Pennsylvania, New York and Maryland signed the Chesapeake Bay Nutrient Removal agreement (C2K) with the purpose to reduce nutrients (specifically nitrogen and phosphorus) and sediment load to the Chesapeake Bay by the year 2010. The agreement carries a federal mandate by the Environmental Protection Agency (EPA) that if certain targeted levels are not reached then Total Maximum Daily Loads (TMDL) will be mandated in all sub-watersheds of the bay. TMDL’s are defined by the Pennsylvania DEP as the sum of the individual waste load allocations and load allocations; a margin of safety is included so that additional loading, regardless of the source will not violate current standards (PADEP). The aim of the bill is to reduce these discharged eutrophic chemicals from the Susquehanna River waters before draining into the Chesapeake Bay. The Susquehanna River receives nutrient loads from the states of New York and Maryland as well as Pennsylvania, though Pennsylvania is by in large, the heaviest contributor (Figure 3). To reach nutrient reduction, new NPDES permits for PA sewage treatment plants must abide by outflow standards between 6 -8ppm of nitrogen levels with regard to the current standards of 10ppm; these requirements will be implemented from 2010 to 2015. Non-municipal sewage treatment systems will all need to improve their efficiency due to there standards, hence the intent of the Cromaglass® corporation to improve the SBR technologies.

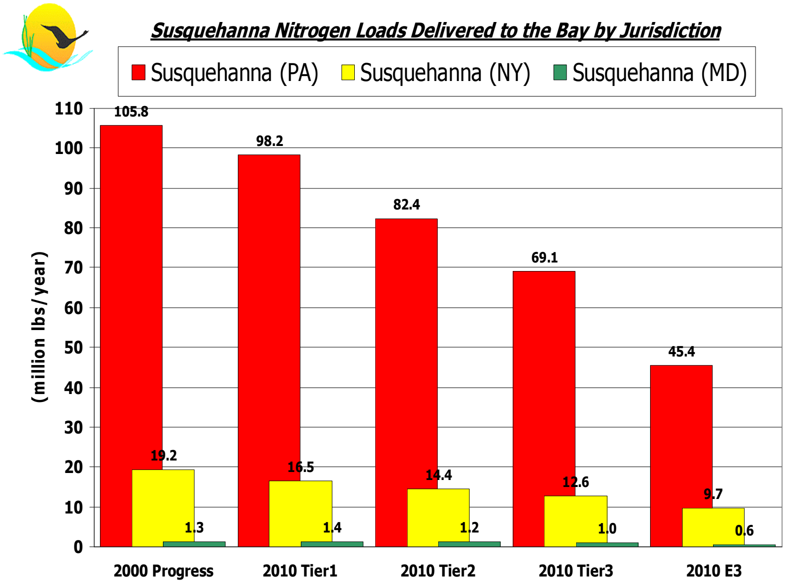


Figure 3: Susquehanna River Nitrogen loads (million lbs./year) to the Chesapeake Bay

There has been a history of cooperative projects between Lycoming College (Dr. Mel Zimmerman) and the Cromaglass® Corporation, with research projects in 1991 and

1996. Both research initiatives were partially funded by the Pennsylvania Ben Franklin Partnership Program. Between 1991 and 1992 an alternating aerobic and anoxic cycling SBR at the Meadow Brook Christian Academy in Milton, Pa was set up as a preliminary test for the ability of the unit to denitrify. In 1996, this preliminary study examined recycle and reuse of an SBR system in which a CA-5 unit was set up at the Jersey Shore, Pa sewage treatment plant. Conclusions regarding the percent reduction were drawn from the 1996 SBR study (Figure 4) and used to propagate the 2007-2008 nutrient and solids removal research. The figure below demonstrates the ability of SBR technologies to reduce and improve Carbonaceous Biochemical Oxygen Demand (CBOD), Total Suspended Solids (TSS) and Ammonia levels.

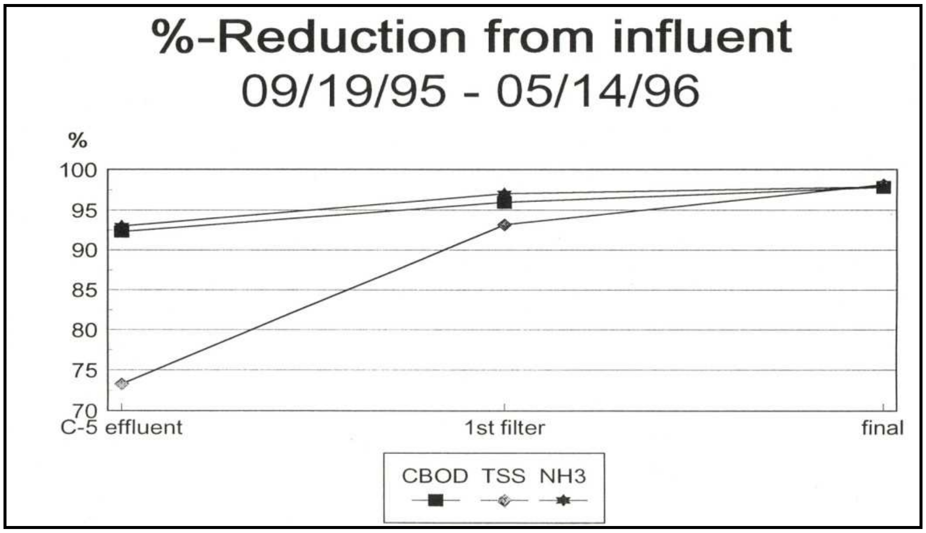


Figure 4: Percent Reduction of wastewater influent CBOD, TSS and NH_3 compounds from 1996 Recycle/Reuse SBR study.

Sequencing Batch Reactor technologies have the ability to alter the operation strategies of sewage treatment for achieving improved removal efficiency for BOD and total nitrogen levels for nitrification and denitrification (Reed *et al*., 2001; Zimmerman *et al*., 2008).

In preparation for this project, the spring and fall semesters of 2007 were used to research the protocols for sampling and analysis of wastewater treatment systems developed by the National Sanitation Foundation (NSF) and Williamsport Sanitary Authority. In December 2007, a Cromaglass CA-5 unit was set up above ground (insulated with wood chips) at the Williamsport Sanitary Authority: Central Plant in Williamsport, PA with a new bio-film media “coffee can” construction to further aid in nitrogen and solids removal (Figure 5).

Figure 5: “Coffee can” construction for biofilm growth; the image to the left is prior to microbial growth and the image to the right is after growth.

It is proposed that the increased surface area provided by the “coffee can” will allow significant growth of both nitrifying and denitrifying bacteria, the nitrifying bacteria will function when oxygen concentrations are greater than 3 ppm in the unit to convert ammonia to NO_3 (nitrate) and the denitrifying bacteria growing in the heart of the “coffee can” will convert nitrate to N_2 (elemental nitrogen) as gas, thus reducing total nitrogen to the waste stream during both the aerobic and anaerobic SBR cycles. For one of these reasons, SBR’s are considered biological treatment systems for their use of fixed film media also known as the “coffee can”. A complementary study of microbial growth and diversity on the “coffee can” biofilm was investigated by another Lycoming College Honors Project student, Brittane Strahan in 2007-2008.

The purpose of my project was to evaluate total nitrogen discharge (mg/L), total suspended solids (TSS in mg/L) and biochemical oxygen demand (BOD in mg/L) of a Cromaglass CA-5. The unit was to have been set up at the Williamsport Municipal Sewage Treatment plant during August-September 2007 but due to unavoidable engineering delays it did not go online until January 2008. Beginning the project in the middle of winter caused difficulties with treatment efficiency.

METHODS

In Fall 2007, as an independent study course, preliminary testing was performed on the below ground CA-5 SBR at the Cromaglass Corporation manufacturing facility. This preliminary work was utilized to develop quality assurance (QA) and quality control (QC) protocols for confidence in analytical testing such as calibration, standardization of reagents and assessment of individual analyses (Standard Methods, 1998). All protocols were written with regard to standard procedures of the Williamsport Wastewater and Water Authority laboratory, the 20th Edition of Standard Methods for the Examination of Water and Wastewater and the HACH Corporation. Accessory protocols were written for preparation of standards and necessary solutions (phosphate buffer, BOD dilution water etc.) Data sheets and Excel charts were also created for data compilation and calculations.

Preliminary data concerning the Cromaglass Corporation's CA-5 SBR was compiled during September and December 2007 for the analysis of water chemistry. Effluent samples were collected twice a week (Tuesday and Thursday) from Clarifier C of the Cromaglass Corporation's underground CA-5 SBR (Figure 6). Effluent samples were collected using a plastic water sampling apparatus attached to a metal pole (Figure 6). An o-ring chain was pulled at the handle, which allowed filling the sampling bottle. The bottle was submerged a foot (about 30 cm) below the wastewater surface and two samples were collected each sampling day.

Figure 6: Clarifier C sampling chamber of the CA-5 SBR at the Cromaglass Wastewater manufacturing facility.

The effluent was analyzed for pH (field/laboratory), ammonia, nitrate, nitrite, total kjeldahl nitrogen (TKN), orthophosphate, total phosphate, total suspended solids (TSS) and Carbonaceous Biochemical Oxygen Demand (CBOD). Field pH was recorded with an YSI meter and confirmed with pH testing strips (2-12). All parameters were measured in milligrams per liter (mg/L), which is roughly equivalent to parts per million (ppm). A temperature data logger maintained a foot above the wastewater surface monitored temperature changes in the underground SBR as a control.

Laboratory water chemistry analyses were carried out using a HACH water quality company test n’ tube vial kit which determined the amount of ammonia nitrogen (0.4-50.0 mg/L), nitrate (0.2-30.0 mg/L), nitrite (0.003-0.500 mg/L), reactive phosphorus (orthophosphorate) (1.0-100.0 mg/L) and total phosphate (1.0-100.0 mg/L) and read using the HACH DR spectrophotometer 5000. The pH was recorded using a 510 Series Oakton pH meter.

Determinant of total suspended solids (TSS) was carried out by drying four Gooch crucibles in a 105ºC incubator. The drying cycles alternated heating in a 550 ºC muffle oven, cooling in desiccators and weighing of crucibles. Crucibles were dried, weighed for analysis and solids accumulation on filters was calculated. Whatman 24mm Glass Microfiber Filters were placed in the bottom of each crucible (rough side up) seated with de-ionized water and dried before filtering of influent and effluent samples occurred with vacuum filtration.

Carbonaceous biochemical oxygen demand (CBOD) analyzes dissolved oxygen levels over a five day time period. This parameter analyzes the influent and effluent with nitrification inhibitor (inhibits nitrogenous sources available for microbes), CBOD blanks (serve as controls filled with BOD dilution water), CBOD Seed blanks (serve as microbial planted blanks for oxygen concentration controls) and a series of six CBOD sample bottles per influent and/or effluent sample with varying volumes of seed, wastewater and with or without inhibitor addition.

In January 2008, the above ground, CA-5 (Figure 7A) was connected to influent and effluent discharges of the Williamsport Sanitary Authority in Williamsport, PA. The influent and effluent wastewater was discharged to two large sampling tees which are housed in an insulated and heated shed (Figure 7B).

Figure 7A & 7B: The above ground CA-5 at the Williamsport Sanitary Authority on the left. On photograph on the right displays the influent and effluent sampling tees housed inside the shed.

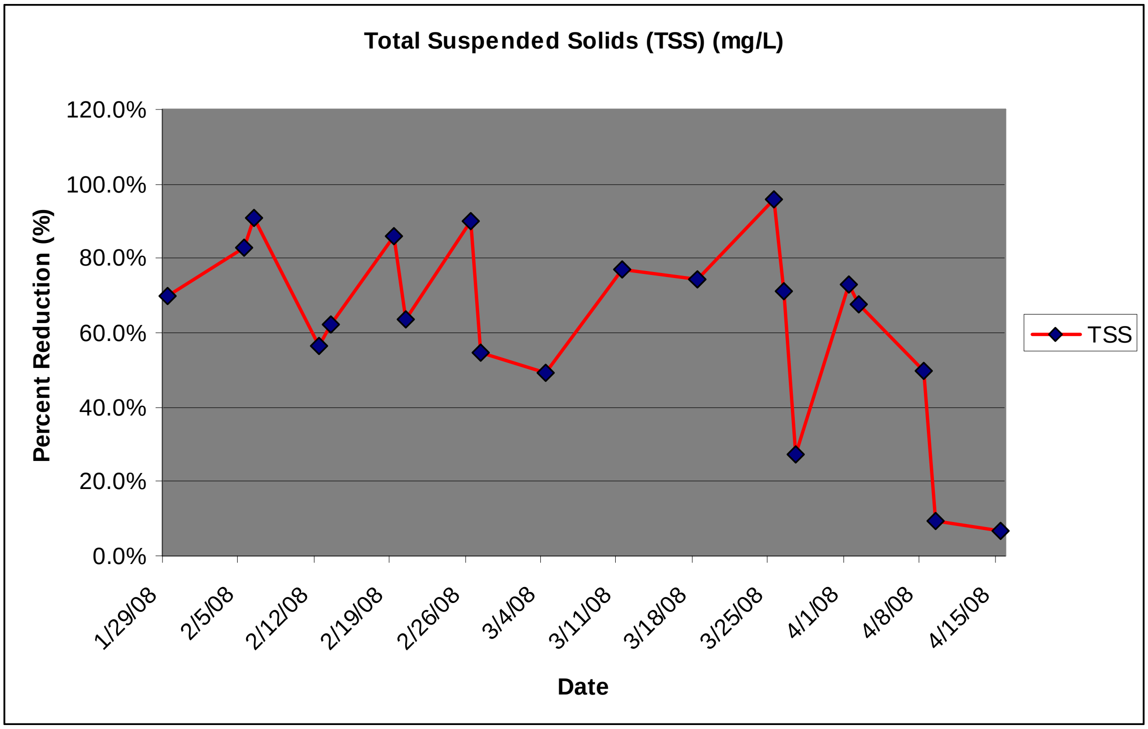
The same parameters as in the preliminary independent study were examined; however, the focus was on the total suspended solids (TSS) and carbonaceous biochemical oxygen demand (CBOD). Temperatures were monitored as in the previous study with temperature loggers, one was placed in the above ground CA-5 (in clarifier C above the wastewater) and a second was placed a foot below the surface of the mulch. These temperatures were compared against the control at the underground factory CA-5 to analyze temperature interference with the nitrification process.

RESULTS

Data recorded during the fall 2007 study on the unit at the Cromaglass Wastewater Corporation facility was compiled in a report; however, the water chemistry values collected varied broadly over the collection period due to suspected chemical discharges and varying wastewater flow from the manufacturing facility. Due to a prior agreement, the data cannot be published since the data was used to change the manufacturing facility discharge to allow for pretreatment of the industrial effluent. However, it can be summarized that the unit was setup to receive 500 gallons per day raw sewage from the Williamsport Central Plant (January-April 2008).

Appendices I-IV summarizes raw data from the months of January-April at the CA-5 SBR at the Williamsport Municipal Authority. Appendix I displays Water Chemistry data on pages 1-4. Appendix II displays Carbonaceous biochemical oxygen demand (CBOD) on pages 1-4. Appendix III displays total suspended solids (TSS) on pages 1-4. Appendix IV displays total nitrogen on pages 1-5.

Since the goal of a SBR unit is to decrease nutrient load in the effluent, the percent reduction of TSS, CBOD and total nitrogen was calculated over the course of the study from January to April 2008. The total suspended solids (mg/L) reduction ranged from 6.61 to 95.7% over the course of the study (Figure 8). The total suspended solid protocol was modified throughout the study for improved consistency. Initially, influent and effluent wastewater was added to the fiber filters by pipette, this allowed for only particles small enough to pass through the pipette tip and prevented larger solid passage for filtering. Also, stir plates and stir bars were eliminated due to solid particulates being pushed to the outside of the beakers and altering the homogeneity of the solutions. Instead, influent and effluent sample bottles were inverted ten times for homogeneity.



<u>Figure 8:</u> TSS percent change in the CA-5 SBR from January 29th to April 15th.

Carbonaceous biochemical oxygen demand (mg/L) was evaluated for the course of the study, revealing percent reductions in the effluent of 38.7-86.2%. The microbial growth on the fixed film media construction grew, utilizing oxygen concentrations in the wastewater. The fixed film media “coffee cans” were positioned in a vertical cylinder to be placed in chamber B of the CA-5 SBR. Though, appropriate flow in unit was not able to continuously keep the cylinder submerged, resulting in microbial death and sloughing off. It is hypothesized that the cylinder needs to be modified, cutting it in half for the fixed film to be submerged at all times and allowing for consistent microbial growth.

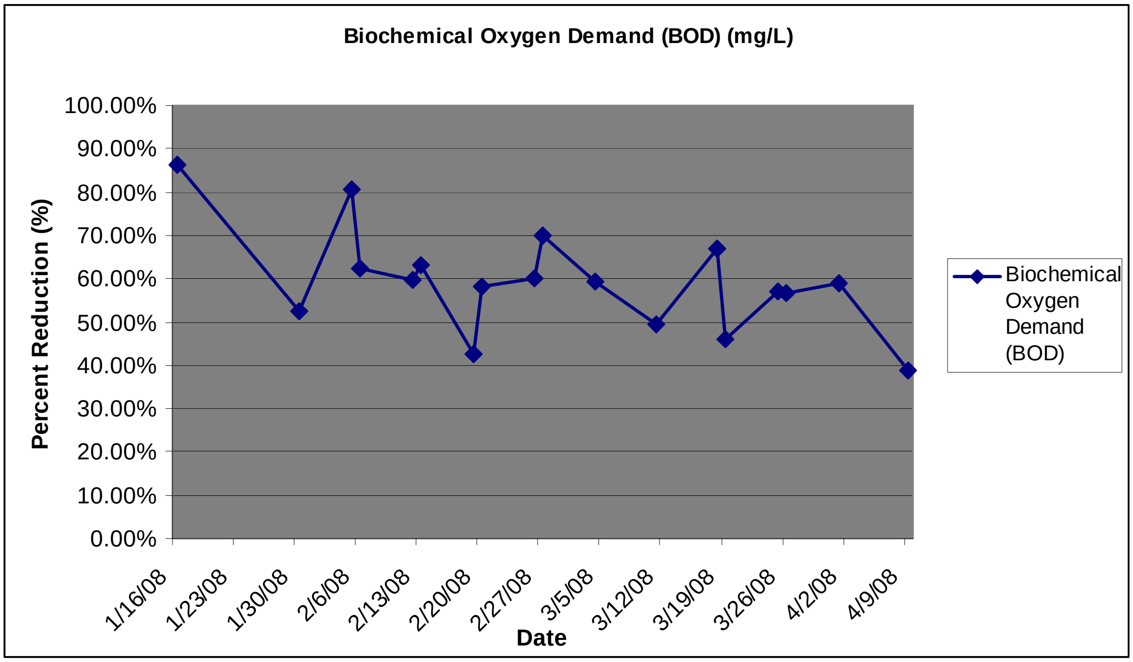


Figure 9: CBOD percent change in the CA-5 SBR from January 16th to April 9th.

Total nitrogen levels were expressed by the sum of analytical testing of nitrate, nitrite and total kjeldahl nitrogen (TKN). Due to temperature fluctuations throughout the study period, consistently warmer temperatures would have allowed for proper nitrification of the sequence batch reactor system. Therefore, all reductions of nitrogen, though minimal, were not seen until March 11th and have steadily increased the percent reduction of total nitrogen discharge in effluent. The percent reduction seen in total nitrogen ranged from 14.2 to 17.2%; it is hypothesized warmer temperatures will no longer inhibit the process of nitrification. Therefore, microbial growth will also assist in the breakdown of total suspended solid concentrations and alter biochemical oxygen demand levels.

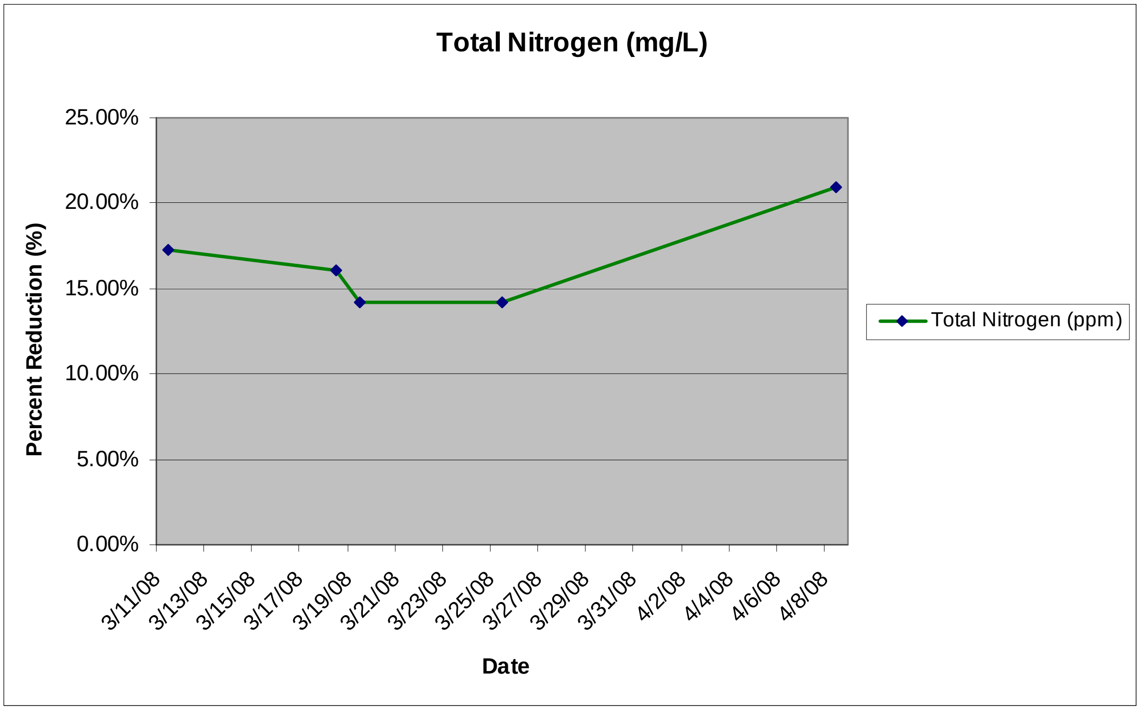


Figure 10: Total nitrogen percent change in the CA-5 SBR from March 11th to April 8th.

Internal and external temperature changes over time can be viewed in Figures 12 and 13 of the above ground CA-5 unit. The first temperature plot displays the slightly warmer temperatures found in the CA-5 chamber; this temperature difference is due to the microbial activity present in the chamber as opposed to the second temperature plot. Figure 13 displays the temperature changes with the data logger placed one foot beneath the mulch outside of the CA-5 unit.

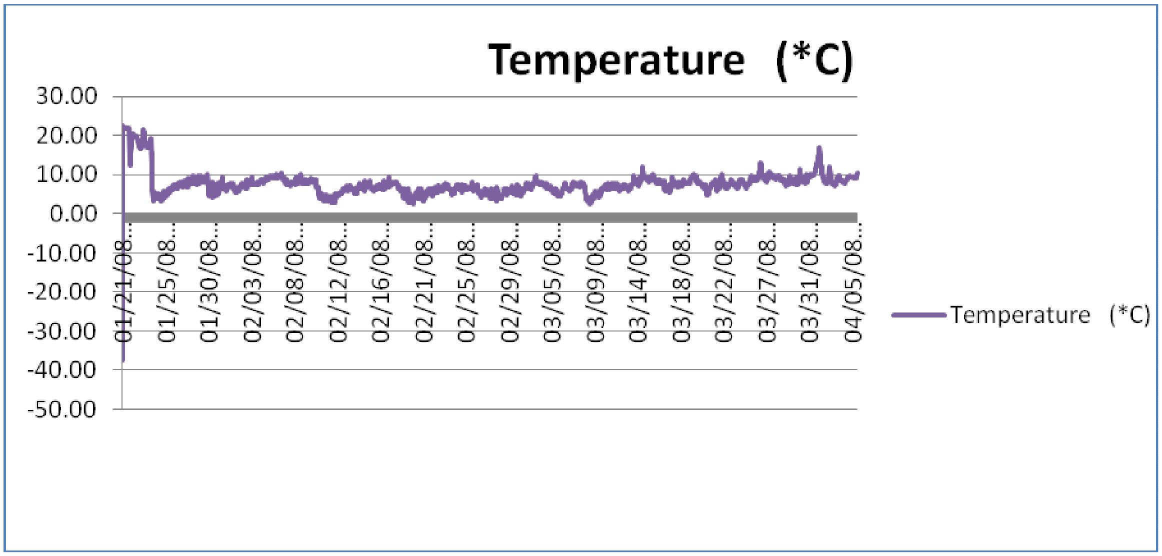


Figure 12: Data logger placed in CA-5 SBR clarifier C chamber; temperature probe was placed in the chamber on January 25th.

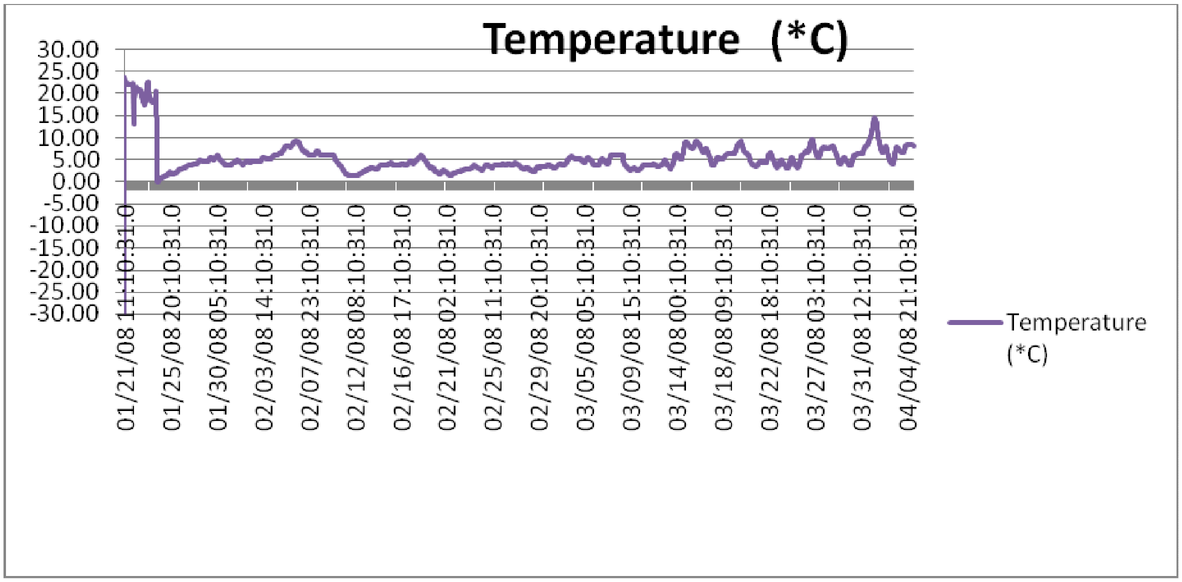


Figure 13: Data logger placed in the mulch surrounding the CA-5 SBR; temperature probe was placed in the mulch on January 25th at 20:10:31.

DISCUSSION

The CA-5 unit with biofilm did not achieve the efficiency of CBOD, TSS and nitrogen removal that has been previously observed and documented. There are two proposed reasons for this outcome. The main difficulty was the temperature; it was unfortunate that the study had to start in January. As noted by the data loggers, the internal temperature of the tank stayed below 15ºC throughout the study. This explains why the ammonia and TKN values remained high. Nitrification (the conversion of ammonia to nitrate and nitrite) by nitrifying bacteria is inhibited at temperatures below 15ºC (Gerardi, 2001). In addition it was discovered that the “coffee can” cylinder growing biofilm media was too tall. During transfer cycles (six times a day) from chamber B to C the microbes in the upper one third of the biofilm cylinder were exposed to air and resulted likely in microbial cell death and sloughing off. These dead or dying microbes would not have been nitrifying and most likely led to increased levels of TSS in the effluent from the SBR unit. These solid levels would also have contributed to higher BOD levels. Based on this study, starting on April 22, 2008 the unit will be drained, cleaned out and refilled for another study. This time the “coffee can” biofilm media container will be shorter so as to be submerged continuously and the above ground temperature will be above 15ºC, thus allowing for nitrification and denitrification to lead to a lower total nitrogen, suspended solids and BOD discharge. Another aspect of the study, after the nitrification/denitrification is stabilized will be to perform a “stress test” on the system following the NSF protocols (National Sanitation Foundation). These tests consist of everyday stressors such as power equipment failure, wash day stress, working parent stress and vacation stress in which there are increased and decreased sewage flows analyzed with five consistent sampling days. These studies will be maintained by Lycoming College Clean Water Institute interns during the summer to the fall of 2008.

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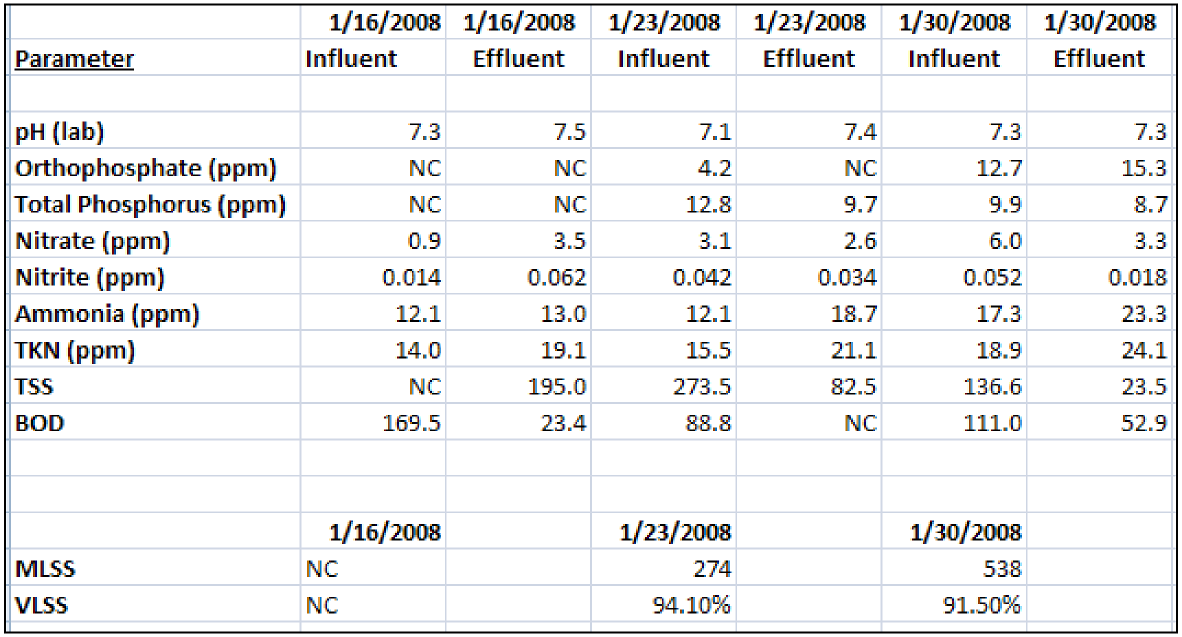
APPENDIX I

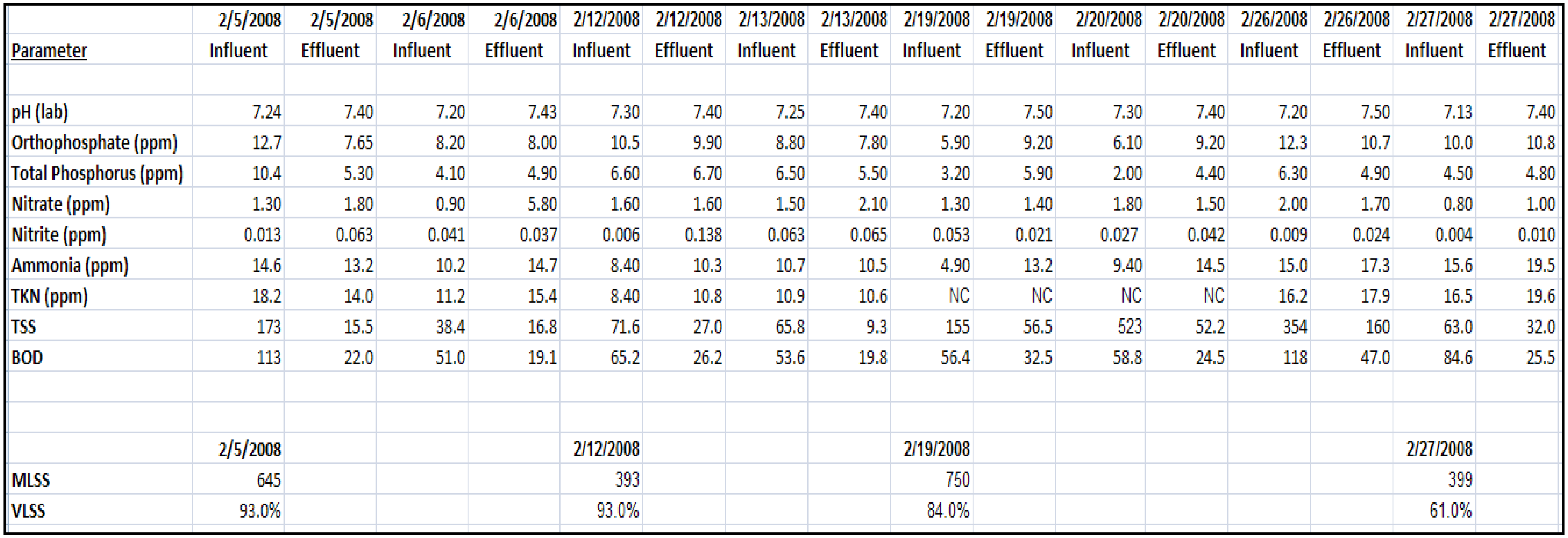
Table 1: January 2008 Water Chemistry data summary at Williamsport Municipal Authority Williamsport, Pa



	1/16/2008	1/16/2008	1/23/2008	1/23/2008	1/30/2008	1/30/2008
Parameter	Influent	Effluent	Influent	Effluent	Influent	Effluent
pH (lab)	7.3	7.5	7.1	7.4	7.3	7.3
Orthophosphate (ppm)	NC	NC	4.2	NC	12.7	15.3
Total Phosphorus (ppm)	NC	NC	12.8	9.7	9.9	8.7
Nitrate (ppm)	0.9	3.5	3.1	2.6	6.0	3.3
Nitrite (ppm)	0.014	0.062	0.042	0.034	0.052	0.018
Ammonia (ppm)	12.1	13.0	12.1	18.7	17.3	23.3
TKN (ppm)	14.0	19.1	15.5	21.1	18.9	24.1
TSS	NC	195.0	273.5	82.5	136.6	23.5
BOD	169.5	23.4	88.8	NC	111.0	52.9

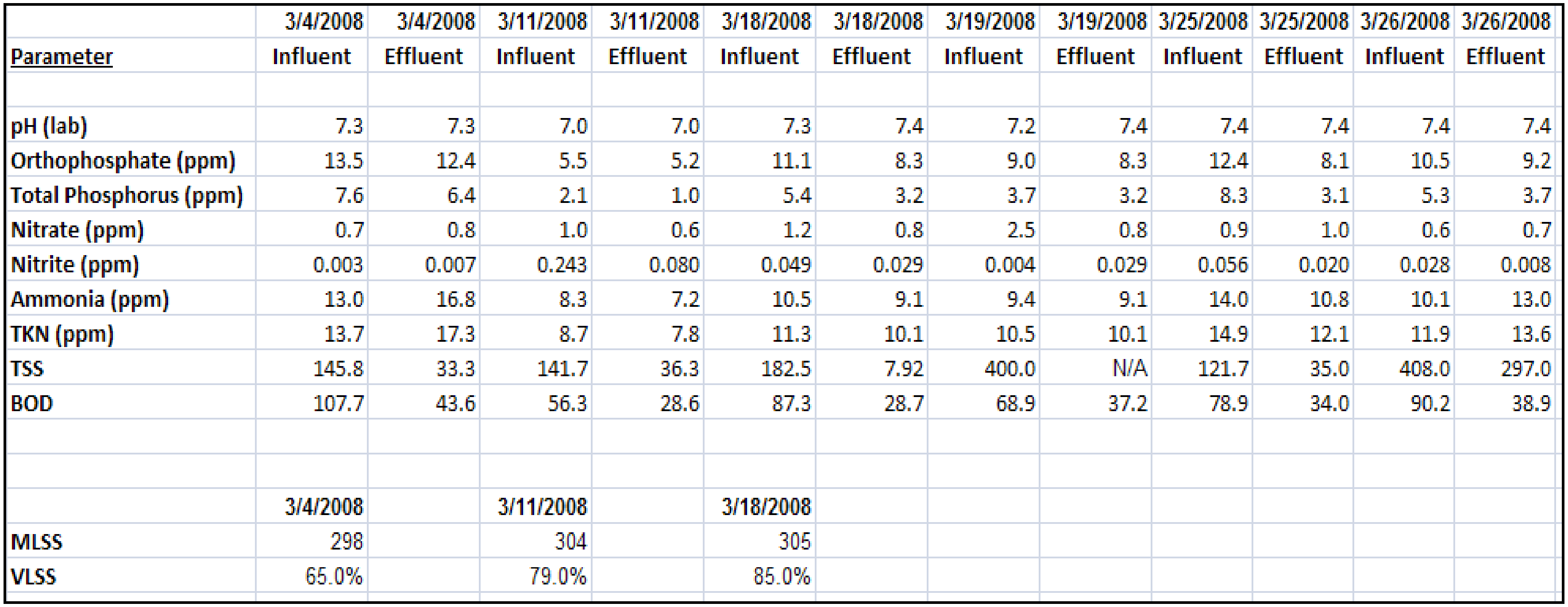
	1/16/2008		1/23/2008		1/30/2008	
MLSS	NC		274		538	
VLSS	NC		94.10%		91.50%	

Table 2: February 2008 Water Chemistry data summary at Williamsport Municipal Authority Williamsport, Pa



	2/5/2008	2/5/2008	2/6/2008	2/6/2008	2/12/2008	2/12/2008	2/13/2008	2/13/2008	2/19/2008	2/19/2008	2/20/2008	2/20/2008	2/26/2008	2/26/2008	2/27/2008	2/27/2008
Parameter	Influent	Effluent	Influent	Effluent	Influent	Effluent	Influent	Effluent	Influent	Effluent	Influent	Effluent	Influent	Effluent	Influent	Effluent
pH (lab)	7.24	7.40	7.20	7.43	7.30	7.40	7.25	7.40	7.20	7.50	7.30	7.40	7.20	7.50	7.13	7.40
Orthophosphate (ppm)	12.7	7.65	8.20	8.00	10.5	9.90	8.80	7.80	5.90	9.20	6.10	9.20	12.3	10.7	10.0	10.8
Total Phosphorus (ppm)	10.4	5.30	4.10	4.90	6.60	6.70	6.50	5.50	3.20	5.90	2.00	4.40	6.30	4.90	4.50	4.80
Nitrate (ppm)	1.30	1.80	0.90	5.80	1.60	1.60	1.50	2.10	1.30	1.40	1.80	1.50	2.00	1.70	0.80	1.00
Nitrite (ppm)	0.013	0.063	0.041	0.037	0.006	0.138	0.063	0.065	0.053	0.021	0.027	0.042	0.009	0.024	0.004	0.010
Ammonia (ppm)	14.6	13.2	10.2	14.7	8.40	10.3	10.7	10.5	4.90	13.2	9.40	14.5	15.0	17.3	15.6	19.5
TKN (ppm)	18.2	14.0	11.2	15.4	8.40	10.8	10.9	10.6	NC	NC	NC	NC	16.2	17.9	16.5	19.6
TSS	173	15.5	38.4	16.8	71.6	27.0	65.8	9.3	155	56.5	523	52.2	354	160	63.0	32.0
BOD	113	22.0	51.0	19.1	65.2	26.2	53.6	19.8	56.4	32.5	58.8	24.5	118	47.0	84.6	25.5
	2/5/2008				2/12/2008				2/19/2008						2/27/2008	
MLSS	645				393				750						399	
VLSS	93.0%				93.0%				84.0%						61.0%	

Table 3: March 2008 Water Chemistry data summary at Williamsport Municipal Authority Williamsport, Pa



	3/4/2008	3/4/2008	3/11/2008	3/11/2008	3/18/2008	3/18/2008	3/19/2008	3/19/2008	3/25/2008	3/25/2008	3/26/2008	3/26/2008
Parameter	Influent	Effluent	Influent	Effluent	Influent	Effluent	Influent	Effluent	Influent	Effluent	Influent	Effluent
pH (lab)	7.3	7.3	7.0	7.0	7.3	7.4	7.2	7.4	7.4	7.4	7.4	7.4
Orthophosphate (ppm)	13.5	12.4	5.5	5.2	11.1	8.3	9.0	8.3	12.4	8.1	10.5	9.2
Total Phosphorus (ppm)	7.6	6.4	2.1	1.0	5.4	3.2	3.7	3.2	8.3	3.1	5.3	3.7
Nitrate (ppm)	0.7	0.8	1.0	0.6	1.2	0.8	2.5	0.8	0.9	1.0	0.6	0.7
Nitrite (ppm)	0.003	0.007	0.243	0.080	0.049	0.029	0.004	0.029	0.056	0.020	0.028	0.008
Ammonia (ppm)	13.0	16.8	8.3	7.2	10.5	9.1	9.4	9.1	14.0	10.8	10.1	13.0
TKN (ppm)	13.7	17.3	8.7	7.8	11.3	10.1	10.5	10.1	14.9	12.1	11.9	13.6
TSS	145.8	33.3	141.7	36.3	182.5	7.92	400.0	N/A	121.7	35.0	408.0	297.0
BOD	107.7	43.6	56.3	28.6	87.3	28.7	68.9	37.2	78.9	34.0	90.2	38.9
	3/4/2008		3/11/2008		3/18/2008							
MLSS	298		304		305							
VLSS	65.0%		79.0%		85.0%							

Table 4: April 2008 Water Chemistry data summary at Williamsport Municipal Authority Williamsport, Pa

	4/1/2008	**4/1/2008**	**4/2/2008**	**4/2/2008**	**4/8/2008**	**4/8/2008**	**4/9/2008**	**4/9/2008**	**4/15/2008**	**4/15/2008**
Parameter	**Influent**	**Effluent**	**Influent**	**Effluent**	**Influent**	**Effluent**	**Influent**	**Effluent**	**Influent**	**Effluent**
pH (lab)	7.1	7.5	6.9	7.6	7.3	7.4	7.4	7.6	7.4	7.3
Orthophosphate (ppm)	21.5	18.3	42.7	16.7	13.3	19.2	12.4	16.5	12.0	16.9
Total Phosphorus (ppm)	9.9	6.5	20.3	7.7	6.6	10.7	0.4	0.2	5.8	9.9
Nitrate (ppm)	2.0	2.7	4.3	4.7	0.8	0.8	1.9	1.7	0.7	0.4
Nitrite (ppm)	0.029	0.013	0.014	0.017	0.017	0.016	0.007	0.003	0.098	0.015
Ammonia (ppm)	11.4	16.3	6.65	12.4	20.0	17.4	16.0	22.3	15.9	19.4
TKN (ppm)	12.6	18.8	11.4	26.2	22.1	17.3	17.2	24.0	16.9	21.1
TSS	113.3	30.8	360.0	115.8	111.6	56.0	290.0	263.3	124.0	115.8
BOD	102.9	42.2	N/A	36.9	69.9	90.9	85.5	52.4	94.9	99.0
	4/1/2008				**4/8/2008**				**4/15/2008**	
MLSS	400				273.3				599	
MLVSS	88.0%				88.0%				62.50%	

APPENDIX II

Table 1: January 2008 Carbonaceous Biochemical Oxygen Demand (CBOD) data summary at Williamsport Municipal Authority Williamsport, Pa

DATE	1/16/2008	1/30/2008
Influent	169.5	111
Effluent	23.4	52.9
Difference	146.1	58.1
Percent Reduction	86.20%	52.30%

Table 2: February 2008 Carbonaceous Biochemical Oxygen Demand (CBOD) data summary at Williamsport Municipal Authority Williamsport, Pa

DATE	2/5/2008	2/6/2008	2/12/2008	2/13/2008	2/19/2008	2/20/2008	2/26/2008	2/27/2008
Influent	113.4	51	65.2	53.6	56.4	58.8	117.6	84.6
Effluent	22	19.1	26.2	19.8	32.5	24.5	47	25.5
Difference	91.4	31.9	39	33.8	23.9	34.3	70.6	59.1
Percent Reduction	80.50%	62.50%	59.80%	63.10%	42.40%	58.30%	60.00%	69.90%

<u>Table 3:</u> March 2008 Carbonaceous Biochemical Oxygen Demand (CBOD) data summary at Williamsport Municipal Authority Williamsport, Pa

DATE	3/4/2008	3/11/2008	3/18/2008	3/19/2008	3/25/2008	3/26/2008
Influent	107.7	56.3	87.3	68.9	78.9	90.15
Effluent	43.6	28.55	28.7	37.2	34	38.9
Difference	64.1	27.75	58.6	31.7	44.9	51.25
Percent Reduction	59.50%	49.30%	67.10%	46.00%	56.90%	56.80%

Table 4: April 2008 Carbonaceous Biochemical Oxygen Demand (CBOD) data summary at Williamsport Municipal Authority Williamsport, Pa

DATE	4/1/2008	4/9/2008
Influent	102.9	85.5
Effluent	42.2	52.4
Difference	60.7	33.1
Percent Reduction	59.00%	38.70%

APPENDIX III

Table 1: January 2008 Total Suspended Solids (TSS) data summary at Williamsport Municipal Authority Williamsport, Pa

DATE	1/29/2008
Influent	273.5
Effluent	82.5
Difference	191
Reduction	69.80%

Table 2: February 2008 Total Suspended Solids (TSS) data summary at Williamsport Municipal Authority Williamsport, Pa

DATE	2/5/2008	2/6/2008	2/12/2008	2/13/2008	2/19/2008	2/20/2008	2/26/2008	2/27/2008
Influent	136.6	173	38.4	71.6	65.8	154.9	523.3	354.2
Effluent	23.5	15.5	16.75	27	9.25	56.5	52.24	160.4
Difference	113.1	157.5	21.65	44.6	56.55	98.4	471.06	193.8
Reduction	82.80%	91.00%	56.40%	62.30%	85.90%	63.50%	90.00%	54.70%

Table 3: March 2008 Total Suspended Solids (TSS) data summary at Williamsport Municipal Authority Williamsport, Pa

DATE	3/4/2008	3/11/2008	3/18/2008	3/25/2008	3/26/2008	3/27/2008
Influent	63	145.82	141.67	182.5	121.7	408
Effluent	32	33.26	36.25	7.92	35	297
Difference	31	112.56	105.42	174.58	86.7	111
Reduction	49.20%	77.20%	74.40%	95.70%	71.20%	27.20%

Table 4: April 2008 Total Suspended Solids (TSS) data summary at Williamsport Municipal Authority Williamsport, Pa

DATE	4/1/2008	4/2/2008	4/8/2008	4/9/2008	4/15/2008
Influent	113.3	360.0	111.6	290.0	124.0
Effluent	30.8	115.8	56	263	115.8
Difference	82.5	224.2	55.6	27	8.2
Reduction	73.00%	67.80%	49.80%	9.31%	6.61%

APPENDIX IV

Table 1: January 2008 Total Nitrogen data summary at Williamsport Municipal Authority Williamsport, Pa

	1/16/2008 Influent	1/16/2008 Effluent	1/23/2008 Influent	1/23/2008 Effluent	1/30/2008 Influent	1/30/2008 Effluent
Nitrate (ppm)	0.90	3.50	3.10	2.60	6.00	3.30
Nitrite (ppm)	0.014	0.062	0.042	0.034	0.052	0.018
TKN (ppm)	14.0	19.1	15.5	21.1	18.9	24.1
Total	14.914	22.662	18.642	23.734	24.952	27.418

Table 2: February 2008 Total Nitrogen data summary at Williamsport Municipal Authority Williamsport, Pa

	2/5/2008 Influent	2/5/2008 Effluent	2/6/2008 Influent	2/6/2008 Effluent	2/12/2008 Influent	2/12/2008 Effluent	2/13/2008 Influent	2/13/2008 Effluent	2/19/2008 Influent	2/19/2008 Effluent	2/20/2008 Influent	2/20/2008 Effluent	2/26/2008 Influent	2/26/2008 Effluent	2/27/2008 Influent	2/27/2008 Effluent
Nitrate (ppm)	1.30	1.80	0.90	5.80	1.60	1.60	1.50	2.10	1.30	1.40	1.80	1.50	2.00	1.70	0.80	1.00
Nitrite (ppm)	0.013	0.063	0.041	0.037	0.006	0.138	0.063	0.065	0.053	0.021	0.027	0.042	0.009	0.024	0.004	0.010
TKN (ppm)	18.2	14.0	11.2	15.4	8.40	10.8	10.9	10.6	NC	NC	NC	NC	16.2	17.9	16.5	19.6
Total	19.513	15.863	12.141	21.237	10.006	12.538	12.463	12.765	NC	NC	NC	NC	18.209	19.624	17.304	20.61

Table 3: March 2008 Total Nitrogen data summary at Williamsport Municipal Authority Williamsport, Pa

	3/4/2008 Influent	3/4/2008 Effluent	3/11/2008 Influent	3/11/2008 Effluent	3/18/2008 Influent	3/18/2008 Effluent	3/19/2008 Influent	3/19/2008 Effluent	3/25/2008 Influent	3/25/2008 Effluent	3/26/2008 Influent	3/26/2008 Effluent
Nitrate (ppm)	0.7	0.8	1.0	0.6	1.2	0.8	2.5	0.8	0.9	1.0	0.6	0.7
Nitrite (ppm)	0.003	0.007	0.243	0.080	0.049	0.029	0.004	0.029	0.056	0.020	0.028	0.008
TKN (ppm)	13.7	17.3	8.7	7.8	11.3	10.1	10.5	10.1	14.9	12.1	11.9	13.6
Total	14.403	18.107	9.943	8.48	12.549	10.929	13.004	10.929	15.856	13.12	12.528	14.308

Table 4: April 2008 Total Nitrogen data summary at Williamsport Municipal Authority Williamsport, Pa

	4/1/2008 Influent	4/1/2008 Effluent	4/2/2008 Influent	4/2/2008 Effluent	4/8/2008 Influent	4/8/2008 Effluent	4/9/2008 Influent	4/9/2008 Effluent	4/15/2008 Influent	4/15/2008 Effluent
Nitrate (ppm)	2.0	2.7	4.3	4.7	0.8	0.8	1.9	1.7	0.7	0.4
Nitrite (ppm)	0.029	0.013	0.014	0.017	0.017	0.016	0.007	0.003	0.098	0.015
TKN (ppm)	12.6	18.8	11.4	26.2	22.1	17.3	17.2	24.0	16.9	21.1
Total	14.629	21.513	15.714	30.917	22.917	18.116	19.107	25.703	17.698	21.515

Table 5: Summary of Total Nitrogen data summary at Williamsport Municipal Authority Williamsport, Pa

****NO REDUCTION SEEN BEFORE THESE DATES**					
	3/11/2008	3/18/2008	3/19/2008	3/25/2008	4/8/2008
Difference	2.0	2.4	2.2	2.5	4.8
Percent Reduction	17.24%	16.11%	14.19%	14.20%	20.95%