The Use of Fixed Film Media to Reduce Nutrient Levels in a Sequencing 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:

The Use of Fixed Film Media to Reduce the Nutrient Levels in a Sequencing Batch Reactor

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

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ABSTRACT

An established Sequencing Batch Reactor (SBR) unit at the Hepburn Lycoming Elementary School, located in the Susquehanna Valley of Pennsylvania, was fit with four fixed film media units for observation by Lycoming College's Clean Water Institute in partnership with the Cromaglass® Corporation. Prior to the installation of the fixed film media, the maintenance staff at the Hepburn Lycoming Elementary School were required to add stock bacteria to the unit in order to reduce the lipid buildup which also presented a foaming problem. The unit purifies all of the school's wastewater, which includes approxamately three hundred-fifty students and staff. The hypothesis of the project was that the fixed film media would reduce nutrient levels in the effluent waste, while maintaining the required standards for carbonaceous biochemical oxygen demand (CBOD) and total suspended solids (TSS). Initial testing was conducted with the addition of the stock bacteria and then progressed to the removal of the bacteria, the addition of the fixed film media, and sampling after the fixed film media had colonized. Sampling was done twice a week for the length of the project. The Rank Sum Test results, used to compare two samples with low sample sizes, at the conclusion of the project showed a significant increase in the nitrate and total Kjeldahl nitrogen (TKN, the sum of inorganic nitrogen, ammonia, and ammonium in a sample) levels. The mean nitrate levels in the chlorine contact tank samples prior to the installation of the fixed film media was 1.32 ± 0.7 parts per million (ppm), the mean after the installation was 4.16 ± 3.19 ppm. The mean TKN levels for the chlorine contact tank samples prior to the installation of the fixed film media was 20.18 ±3.36 ppm, the mean for the chlorine contact tank samples following the installation of the fixed film media was 23.8 ±2.6 ppm. It is suspected that the lack of an anoxic period could be the

cause of the negative results. The permit regulations were able to be maintained for the unit throughout the project, even with the increased nutrient levels.

INTRODUCTION

The Cromar Company, a pre-finished hardwood flooring company, began to manufacture fiberglass products in 1965; this eventually lead to the production of fiberglass wastewater treatment systems. As time progressed, their wastewater treatment technologies expanded past the realm of the company, and in 1969 The Cromaglass® Corporation was born; the main headquarters of the Cromaglass® Corporation was and still is located in Williamsport, Pennsylvania. In 1972, the company's newest design for a batch treat system was patented and made available for purchase on the market. Their wastewater treatment systems were sold in place of the traditional septic system and in areas where central sewage facilities were not available; the systems are currently sold worldwide in over twenty-six different countries. As the product was further developed, it grew from a system that could treat capacities up to 1,500 gallons per day (gpd), acceptable for single family homes and small businesses, to a system that could treat up to 200,000 gpd, suitable for large facilities and schools (Young, 2008).

Today, the Cromaglass® Corporation manufactures Sequencing Batch Reactor (SBR) style wastewater treatment systems. The individual SBR tanks are sold in sizes ranging from a CA-5 (500 gpd) to a CA-150 (15,000 gpd), multiple tanks can be arranged to treat capacities up to 200,000 gpd (Young, 2006). A CA-5 tank and a multiple tank arrangement can be seen in Figures 1 and 2 respectively (see Appendix I). In addition to the SBR tanks, the Cromaglass®

Corporation also manufactures SBR tanks with denitrification capabilities, chlorine contact tanks, equalization tanks, and sludge processing tanks (Young, 2006).

The SBR uses a four step process or five step process in the case of the denitrification tank to purify wastewater and make it suitable for discharge. Step one is the fill process (see Figure 3): the raw wastewater, called influent, is pumped into the solids retention section. The solids retention section is separated from the rest of the tank by a screen; this screen blocks the solids and inorganic materials from entering the remaining chambers since they cannot be efficiently broken down. The organic material is broken up as it flows through the screen into the aeration chamber.

Step two is the aeration cycle (see Figure 4): the activated sludge that is now in the aeration chamber is aerated by submerged pumps which circulate air through the sludge. The aeration, through agitation created by the mixing motion, further breaks up the sludge, called mixed liquor during aeration, and allows for biological growth. The biological growth helps to further break down the sludge particles and reduce the nutrients. Aerobic, nitrifying bacteria are able to break down the ammonia in the influent into nitrites and nitrates. In the systems that have a denitrification cycle (see Figure 5), the aeration is suspended, though mixing continues, and an anoxic period occurs allowing for the growth of anaerobic bacteria (Young, 2006). The anaerobic bacteria include denitrifying bacteria which convert nitrate into nitrogen gas. The nitrogen gas is then able to escape into the atmosphere (Welch, 1980).

Step three is the settling period (see Figure 6): the treated mixed liquor is pumped into the clarification section and isolated from the rest of the system. The treated wastewater is allowed to settle under quiescent conditions. Flock particles settle and trap nutrients on their way to the bottom of the tank leaving the clarified supernatant, which is considered the wastewater effluent upon expulsion from the tank.

Step four is the discharge (see Figure 7): once settling has completed, the purified effluent is pumped out of the tank for discharge. The effluent can be discharged into a chlorine contact tank, a body of water, a sand mound, an irrigation system, or it can be recycled as toilet bowl medium. The remaining sludge can be pumped back into the aeration section for further treatment or it can be wasted to a sludge processing tank (Young, 2006).

To further increase the effluent quality and decrease the nutrient levels (primarily total nitrogen because of its ability to trigger algal blooms in water systems, which may lead to eutrophication) in their systems, the Cromaglass® Corporation has developed new fixed film media technologies (Young, 2008). The fixed film media is comprised of a hollow PVC pipe (see Figure 8), capped off at both ends, filled with eight plastic matrixes called "coffee cans" (see Figure 9). The coffee cans provide extra surface area for bacterial growth; this bacterial growth is called a biofilm (see Figure 9) (Young, 2008).

Integrated fixed film activated sludge (IFFAS) is the name given for the use of fixed film media in the activated sludge process. The Cromaglass® Corporation has performed numerous research projects, including several in conjunction with Lycoming College's Clean Water Institute, using IFFAS in order to perfect their fixed film media technology (Young, 2008). The project performed at the Hepburn Lycoming Elementary School from January 27, 2009 through April 9, 2009 was an IFFAS based research project (see Table 1 for timeline of events).

Hepburn Lycoming Elementary School, located in the Susquehanna Valley of Pennsylvania, is the Cromaglass® Corporation's most recent school installation project (Young, 2008). A CA-60 (6,000 gpd) continuous aeration SBR unit was installed at the school approximately three years prior to the start of the project and is considered an established system (see Figure 10 and Figure 11). The site also contains a chlorine contact tank (see Figure 12) and a sludge wasting tank. The discharged effluent from the unit passes through the chlorine contact(tank prior to its final discharge in Lycoming Creek (see Figure 13), a tributary of the West Branch Susquehanna River. The Hepburn Lycoming Elementary School currently holds a National Pollution Discharge Elimination System (NPDES) permit under the Clean Water Act administered by the PA DEP, the permit number is PA0032352 and it is valid until September 30, 2011. This permit requires monthly testing of pH, carbonaceous biochemical oxygen demand (CBOD, which is the amount of oxygen depleted over a five day period in order to remove the wastewater from the sample), total suspended solids (TSS, which is used to estimate the total solids suspended in the liquid sample), total chlorine residual, and fecal coliforms; the pH must be within the range of 6.0-9.0, the CBOD under 25 ppm, TSS under 30 ppm, total chlorine residual under 1.0, and total coliforms under 1,000 #/100 mL. The nutrients have no permit limitations at this time, but the school is required to report results of a grab sample every quarter (currently tested by Seewald Laboratories) (see Table 9 for the Seewald Data in comparison to the NPDES regulations).

The school faced a problem with excess lipid buildup in their system which caused excessive foaming. In order to correct this problem, a pound of mixed *Bacillus* and *Pseudomonas* bacteria, provided by Maryland Biochemical Company (Bioaugmentation, 2007), was added daily in a process called bioaugmentation to break down the lipids. They also sprayed a liquid chlorine solution on the foam in the tank daily to help further reduce it. The foam caused the system to be less efficient when left unattended.

The Hepburn Lycoming Elementary School was selected as the test site for this project because it provided an established system and successful results with the fixed film media would greatly reduce the upkeep cost of the system to the school. The school would no longer need to purchase the stock bacteria and the nutrient levels in the effluent would be reduced making it easier to meet any potential future nutrient level regulations. The stages of the project can be seen in Table 1 along with any system error that occurred over the project testing period.

The hypothesis of the project was that a reduction in nutrients and an increase in effluent quality would be observed after the introduction of the fixed film media. Since the effluent is discharged into Lycoming Creek, the quality of the effluent is very important not only to the aquatic life of Lycoming Creek but farther down the water system as well. Lycoming Creek, as mentioned above, is a tributary of the West Branch Susquehanna River. The Susquehanna River provides approximately fifty percent of all the Chesapeake Bay's water, which is the first estuary in the nation to be targeted for restoration (Chesapeake).

In 2005, the Environmental Protection Agency (EPA), along with the six states included in the Chesapeake Bay watershed, and the District of Colombia, agreed upon new, stricter limits for all wastewater nutrient levels that are discharged within the Chesapeake Bay watershed. The goal of the new limits is to reduce the amount of nitrogen and phosphorus that enter the Chesapeake Bay (Landers, 2005). These nutrients cause algal blooms in the Bay which block sunlight from penetrating into the water as well as reducing oxygen levels in the water. Both of these things are vital to the success of many of the plants and animals that make the Chesapeake Bay their home. These plants and animals, as well as the overall health of the system, provide humans with food, jobs, and recreation. For example, the Chesapeake Bay is responsible for producing 500 million pounds of seafood each year (Chesapeake).

The stricter limits on nutrient discharge levels affect all wastewater treatment systems in the Chesapeake Bay watershed. Williamsport Area Sanitary Authority, the large scale treatment plant in the local area, is estimating renovation costs of $110 million to comply with the new regulations (Walker, 2009). The Cromaglass® Corporation may not have to comply in the same manner as the larger treatment plants, because they can sell their systems in areas with less strict regulations, but in order for their products to be sold locally they will need to meet these requirements. The more testing their nutrient removal technologies undergo, the better they become. Eventually, the Cromaglass® Corporation will need to gain certification from the National Sanitation Foundation for their nutrient reducing technologies. That can only be accomplished if their technologies have been thoroughly tested and can be proven to work efficiently.

METHODS

Sampling was conducted every Tuesday and Thursday for the duration of the project, unless specified. Three samples were collected on site during each sampling day. The samples consisted of one from the aeration tank, called the mixed liquor sample; one from the clarifier tank; and one from the chlorine contact tank. The samples were collected as close to the start of a discharge cycle (always the morning discharge time between 8:00 am and 9:30 am) to ensure the clarifier had had enough time to settle before sampling commenced. Each sample was comprised of 1000 mL of sample liquid; the samples were collected by means of a grab sample. A grab sample is a single sample collected at a specific time. The grab samples were collected using a sampling device, called a grab stick, comprised of an acid washed 500 mL plastic bottle attached to the base of an eight foot pole. The pole had a wire that ran the internal length of the pole and attached to an apparatus inside the device that connected the bottle to the pole. This wire, when pulled, opened up holes in the attachment apparatus and allowed the sample liquid to fill the bottle (see Figure 14). The bottle was then able to be detached and used to fill up the brand new sample bottle. This had to be done twice to obtain 1000 mL of sample.

The first sample was collected on January 27, 2009. This was the last day the stock bacteria were added to the system. Samples were collected to obtain baseline data for the system. It was estimated that the stock bacteria would take two weeks to be flushed completely from the system once the daily bioaugmentation was discontinued; sampling occurred over those two weeks, with the exception of January 29. The following two weeks of sampling were to obtain data from the system as it would normally be running without the addition of the stock bacteria. On February 26, no sampling occurred while the fixed film media were added to the unit. Four fixed film media units were added to the CA-60 tank, two in the aeration chamber and two in the clarification chamber. The fixed film media were allowed to colonize for a week undisturbed; the sampling resumed on March 10. The last day of sampling was on April 9 and a sample of the biofilm from the fixed film media was extracted on April 14. For a complete timeline of all significant project dates, see Table 1.

Dissolved oxygen (DO) and temperature were both measured during the onsite sampling period. The DO and temperature were measured with a YSI 55 Dissolved Oxygen Meter; the probe was placed inside the aerating aeration tank to generate both values. The DO meter was calibrated prior to each use and the membrane was checked regularly for problems. The membrane must be replaced if it becomes clogged with dirt, has a bubble in or, or if it is dried out. After each sample was retrieved, the grab stick and the sample bottles were all washed off thoroughly with deionized water. The DO meter was also rinsed off with deionized water after being used.

Once all of the samples were collected and the DO and temperature readings were finished, the samples were taken back to the lab and placed immediately in the refrigerator. The samples were analyzed as soon as possible so as to keep them fresh without having to add preservative chemicals for longer storage periods; the samples were always analyzed within twenty-four hours of collection.

Chemical tests were performed on all of the samples; the chemical tests included orthophosphate, total phosphorus, nitrate, nitrite, and TKN. The chemical test kits are produced by the HACH Company, all of which are EPA approved except for the nitrate tests which are pending EPA approval. To perform the tests, small portions of each sample type were placed in beakers and continuously stirred to keep all particles suspended in the samples. Two tests were run per sample per chemical parameter. The two samples were to ensure accuracy and were each averaged together to get a mean result for the parameter being tested. The instrument used to generate the results for each test was the Hach DR 5000 spectrophotometer.

Testing for orthophosphate in the samples was performed using the Hach Phosphorus Total and Reactive Testing Kit, TNT 845 model. The standard test procedures were followed when performing these tests, they can be found in the *Hach Water Analysis Handbook Procedures, 5th Edition* download that is available on the Hach Company website (Hach, 2008). At the completion of these tests, a blue color was indicative of a positive result and the DR 5000 measured the amount of coloration and produced the results in mg/L PO_4^{3-}. The testing performed for Total Phosphorus was also conducted using the Hach Phosphorus Total and

Reactive Testing Kit, TNT 845 model. The procedures were slightly different from those of the orthophosphate test and can also be found on the Hach website (Hach, 2008). The results for the total phosphorus test were reported in the same manner as the orthophosphate tests.

The nitrate tests were performed using the Hach Nitrate Testing Kit, TNT 835 model. The tests followed the Hach procedures (Hach, 2008). A pink color was indicative of nitrate in the samples; the DR 5000 measured the results in mg/L NO_3^--N. The nitrite tests were performed using the Hach Nitrite Testing Kit, TNT 839 model. The tests followed the Hach procedures (Hach, 2008). A positive tests result was indicated by the formation of a pink color and the results were measured in mg/L NO_2^--N by the Hach DR 5000. The TKN tests were performed using the Hach Ammonia Testing Kit, TNT 832 model. The tests followed the Hach procedures (Hach, 2008). The results were positive for TKN if a green coloration was produced; the Hach DR 5000 measures the results in mg/L NH_3-N. In addition to the nutrient levels, the pH was also taken during the chemical testing. The samples used for the chemical tests were used to measure the pH with the aid of an Oakton pH 510 meter in accordance with the *Standard Methods* (Clesceri et al., 1998) 4500 Electrometric Method.

The solids in the clarification chamber and the chlorine contact tank were measured using the total suspended solids (TSS) tests. In order to prepare the Gooch crucibles used for testing, they were kept in a 105°C drying oven to keep them from collecting moisture. When the crucibles were needed for testing they were removed from the oven and allowed to cool in a desiccator. They were then weighed using a calibrated analytical balance. The crucibles were placed in the 550°C muffle furnace, Barnstead Thermolyne 1300 Furnace Model B1315M, for ten minutes. Upon removal, the crucibles were again cooled in the desiccator and then weighed. Each crucible was weighed with a Whatman™ 943-AH glass microfiber filter, 24 mm, and following the dry weighing, the filter was seated in the crucible by washing it with 100 mL of deionized water using vacuum filtration. The crucibles with seated filters were then allowed to dry in the 105°C drying oven for at least one hour. At the end of the hour, the crucibles were ready for the TSS test. The TSS test followed the *Standard Methods* (Clesceri et al., 1998) 2540 D Total Suspended Solids Dried at 103-105°C method. The same procedures were followed for the mixed liquor suspended solids (MLSS), with the exception of crucible and filter size, which were considerably larger.

The MLSS samples also had mixed liquor volatile solids (MLVS) performed on them. MLVS required that the crucibles, with the filtered sample, be burned in the 550°C muffle oven. The MLVS tests followed the *Standard Methods* (Clesceri et al., 1998) 2540 E Fixed and Volatile Solids Ignited at 550°C method.

The tests for carbonaceous biochemical oxygen demand (CBOD) were started on March 19, 2009. Because of their five day incubation period, the CBOD tests were only run on the Thursday testing days, which allowed them to be analyzed on Tuesdays. The CBOD tests were done in acid washed, autoclaved CBOD bottles. The dissolved oxygen of each sample was taken at the start and end of the five day period using a YSI 52 dissolved oxygen meter attached to a YSI model 5905 BOD probe. The CBOD tests were performed following the *Standard Methods* (Clesceri et al., 1998) 5210 Biochemical Oxygen Demand method.

The data will be statistically evaluated using the Rank Sum Test. The Rank Sum Test compares two sets of data with small sample sizes to determine any statistical significance between the two. The method followed for the Rank Sum Test follows standard procedures (Zimmerman, 2002). Three different comparisons were made using the Rank Sum Test;

comparison of the pre and post installation data, comparison between Tuesday and Thursday data, and a comparison between the mixed liquor sample and the chlorine contact tank sample.

RESULTS

During the project, several unforeseen events affecting the Hepburn Lycoming Elementary School, such as power failures; some of these events even altered the cycling times of the CA-60 unit, changing the sampling times of the project. These changes affected the settling times in the clarification chamber thus affected the data. It was decided that the data involving the clarification chamber was not pertinent to the results of the project because they had no effect on what the final effluent results were. Therefore, they were excluded from this report. It should also be noted that when Seewald Laboratories tests the final effluent of the Hepburn Lycoming Elementary School they use the contents of the chlorine contact tank, as opposed to the clarification tank. This project is concerned with the final effluent discharge and not the intermediate steps, therefore the most pertinent pieces of data are that which are derived from the chlorine contact tank.

The results that were compared include pre and post installation of the fixed film media data to determine if there was a change in the wastewater quality with the addition of the fixed film media. Pre data is considered all sample days prior to the installation of the fixed film media on January 26, 2009 and the post installation data is all sample days following that date. Tuesday and Thursday data was compared in order to determine that there was no significant difference between the two sampling days due to the school being vacant over the weekend. It was speculated that the lack of use on the weekends could affect the Tuesday data since the Thursday data was following days of consecutive use. The mixed liquor sample was also compared to the chlorine contact tank sample to ensure that the system was properly treating the wastewater.

The graphs are all located in Appendix III; the dividing line in the middle of each graph represents the installation of the fixed film media and thus divides the pre and post installation data sets. Figure 15 is the temperature recorded from the aeration chamber throughout the project. Temperature is important because some bacteria must be kept in a specific temperature range to survive. The bacteria that perform nitrification are inhibited when temperatures drop below 15°C (Gerardi, 2001). Figure 16 depicts the fluctuation in dissolved oxygen over the length of the project. The dissolved oxygen was taken in the aeration chamber; the aeration chamber is continuously aerating and has no anoxic periods incorporated into its cycle.

Figures 17 and 18 are the graphs pertaining to the orthophosphate data. Figure 17 is the mixed liquor samples' (top) and chlorine contact tank samples' (bottom) results for orthophosphate (see also Tables 2 and 3 for statistical significance). One line represents Tuesday's data and the second represents Thursday's data. These graphs show the changes in the orthophosphate over time as well as the differences between the two test days' data. Figure 18 compares the Tuesday orthophosphate data (top) and the Thursday's orthophosphate data (bottom) from both the mixed liquor samples and the chlorine contact tank samples (see also Tables 4 and 5). Figures 19 and 20, 21 and 22, 23 and 24, and 25 and 26 follow the same pattern as Figures 17 and 18 (meaning each set of two figures show the same as Figures 17 and 18) but they represent total phosphorus, nitrate, nitrite, and TKN, respectively.

Figure 27 represents the total suspended solids from the chlorine contact tank over the entire project. Figure 28 represents the BOD results from the chlorine contact tank from the project. Figure 29 represents the mixed liquor suspended solids from the mixed liquor samples for the length of the project. Figure 30 represents the mixed liquor volatile solids for the mixed liquor samples throughout the project.

Appendix III also contains the results of the statistical data. Ranks Sum Tests, with α=0.05, were used to determine whether or not sets of data were statistically similar of different. Rank Sum Tests are used to determine statistical significance between two samples with small sample sizes. If they were similar, then the Rank Sum results found no significant difference or they accepted the null hypothesis; if the Rank Sum Test rejected the null, they were considered significantly different (Zimmerman, 2002). If the Rank Sum Test determined that two sets of data were significantly different, the mean and standard deviations for those sets of data were consulted to determine which the higher data set was and which the lower was. The comparisons made were between pre and post installation data for the mixed liquor samples and the chlorine contact tank samples (see Tables 2 and 3). Tuesday and Thursday data sets were also evaluated using this method (see Tables 4 and 5), as were the data sets between the mixed liquor samples and the chlorine contact tank samples (see Table 6).

Appendix IV contains the Hepburn Lycoming Elementary School's wastewater test results from Seewald Laboratories, Inc (see Table 7, 8 and 9). Seewald Laboratory, Inc. is an independent analytical laboratory that is certified in the State of Pennsylvania for compliance under the Safe Water Act (Seewald, 2006). The Hepburn Lycoming Elementary School holds an NPDES permit which specifically regulates CBOD and TSS (among other parameters less pertinent to this study) (see Table 9). The permit has no regulation on nutrient levels. It was very important that this project did not cause the system to fall out of compliance. The Seewald data was also used as a reference to ensure the results obtained during the project were accurate (see

Table 9). The nutrient levels are only required to be reported quarterly so there are fewer data sets for them.

Appendix IV also contains the daily data from each parameter, for both mixed liquor and chlorine contact tank samples. Each day's data, in the tables, are an average of the two samples run for each parameter. Some samples were not able to be evaluated by the Hach DR 5000 spectrophotometer either due to high particulate matter, a value above the measuring range, or a value under the measuring range; the reason for the missing data set is noted in the table. Table 10 represents the mixed liquor samples' data for the pre installation segment of the project. Table 11 represents the mixed liquor samples' data for the post installation segment of the project. Tables 12 and 13 were the same as Tables 10 and 11 respectively, except Tables 12 and 13 were for the chlorine contact tank's samples.

DISCUSSION

The primary goal of the project was to view a reduction in nutrients with the use of the fixed film media. It was also important to see no change, or a decrease, in solids; an increase in solids could cause the system to break the regulations set by the NPDES permit. The results were carefully monitored to ensure that the TSS remained under 30 ppm and the CBOD remained under 25 ppm. These values were the limitations set forth by the NPDES permit.

The results of the test showed some significant changes in nutrient levels. According to the Rank Sum Tests performed on the pre and post installation of the fixed film media data, a significant change was seen in the nitrate levels from the mixed liquor sample (see Table 2) and the nitrate, nitrite, and TKN levels from the chlorine contact tank (see Table 3). To determine if these significant changes were due to an increase or a decrease between the pre and post installation data, the mean values (see Table 2 and Table 3) were reviewed from both the pre and post data and compared to see which was the higher and which was the lower value. In the case of the nitrate levels in the mixed liquor sample, a statistically significant increase was seen between the pre and post installation data (see Table 2). The mean value for the pre data was 0.97 ±1.1 ppm and the post data had a mean of 9.74 ±2.61 ppm. For the chlorine contact tank (see Table 3), the mean values for nitrate went from 1.32 ±0.7 ppm in the pre data to 4.61 ±3.19 ppm in the post data, a significant increase; the nitrite went from a mean of 27.4 ±16.24 ppm in the pre data to a mean of 8.89 ±5.21 ppm in the post data, a significant decrease; and the TKN mean went from 20.18 ±3.36 ppm in the pre data to a mean of 23.8 ±2.6 ppm in the post data, a significant increase.

Rank Sum Tests were performed to evaluate the difference in test results between Tuesdays and Thursdays. It was speculated that due to the absence of students and faculty over the weekends at the school, the wastewater that entered the system could be significantly different from that of Thursday when there are people in the building. After evaluating the Rank Sum Test results and the mean values for the data sets between those days (see Table 4 and Table 5), it was determined that there was no significant difference between the two test days.

In a properly functioning SBR unit, the nutrients and solids should decrease between the aeration chamber (mixed liquor samples) and the final effluent (chlorine contact tank samples). Rank Sum Tests were used to evaluate statistically significant changes between the mixed liquor samples' data and the chlorine contact tank samples' data (Table 6). The mean values were then used to determine in which direction the change occurred (Table 6). It was determined that there was a significant decrease between the mixed liquor samples and the chlorine contact tank samples in the areas of orthophosphate, total phosphorus, nitrate, and the solids. There was a significant increase in TKN from the mixed liquor samples to the chlorine contact tank samples.

The results of the test did not meet with the expectations set for the results of the fixed film media. There was a significant increase in many of the nutrient levels between the pre installation testing and the post installation testing. There was also an increase in TKN levels through the treatment process (aeration chamber to final effluent). The results of this experiment are contrary to many other experiments performed with fixed film media and biofilms in SBR units. Previous experiments concluded that fixed film media and the biofilm they produce, significantly lower nitrogen and phosphorus levels in SBR systems (Sriwiriyarat, 2005), (Terada, 2006), (Kim, 2001), and (Hu, 2005).

Through researching successful experiments with fixed film media and biofilms, possible causes of the results from this experiment have presented themselves. The most major possibility is the aeration cycles of the Hepburn Lycoming Elementary School's CA-60 unit. As previously mentioned, this unit employs a continuous aeration cycle with no anoxic, denitrification cycles. One source found that when the fixed film media was installed in aerated areas there was little denitrification and the phosphorus removal remained the same (Sriwiriyarat, 2005). Another source found that for proper nutrient removal, the fixed film media had to be properly aerated. They used a membrane-aerated biofilm, so as to form different environments for different types of bacteria to grow (Terada, 2006). A third source showed that the most important factor in the amount of nitrogen left in a system is based on the ratio of mixing-to-aeration (Hu, 2005). A fourth source also found that aeration levels played a role in the reduction of nitrogen and phosphorus levels (Kim, 2001).

The data results showing an increase in nitrate and TKN with a decrease in nitrite are somewhat difficult to interpret. It is speculated that the introduction of the biofilm caused the nitrite to be nitrified into nitrate, causing a drop in nitrite and an increase in nitrate. The nitrate did not become reduced as it should have because the bacteria needed for denitrification were unable to colonize the continuously aerated biofilm, inhibiting the denitrification of nitrate into nitrogen gas. The increased amounts of TKN could then be due to the new biota colonizing the biofilm. This project has an accompanying study performed on the changing biota of the system; in that study, rotifers were found to be the only significantly increased organism (Rock, 2009). Rotifers are multicellular organisms, this means they excrete ammonia as waste. Ammonia is one of the main components of the TKN test; it is possible that the increase in the ammonia is in fact caused by the rotifers.

Another major factor in this project was the mechanical difficulties the unit faced. Over the sampling period, there were several power failures resulting in the system needing to be restarted. There were also two pump failures, leading to their replacement. In addition, there was a high water flow-through where the system received too much influent, in this case from a clogged toilet in the school, and the treatment of the wastewater stops; all the sewage is then allowed to run through the system and be discharged into the river untreated. This is used as a preventative measure to stop potential flooding of the units. All of these events play major factors in the nutrient results immediately after each event occurred. If these mechanical issues had not happened the results could have possibly been different. Unfortunately, within the parameters of this experiment, it is impossible to know what the results may truly have been.

All of the issues above factor into the results of the test, causing it to produce results contrary to those originally hypothesized. Although no positive results were observed through the installation of the fixed film media, it has not been a wasted effort. The research clearly showed that the fixed film media should not be placed in SBR units with a continuous aeration cycle. A future project should be one in which the same test is performed using a denitrification SBR unit. If this project were to be performed, it should be in an underground unit, unlike a pervious honors project performed similarly which was in an above ground unit. It was found that the low temperatures inside the tank inhibited the nitrification process (Yuda, 2008); this would be another deterrent to the project. The positive aspect of the project was that the installation of the fixed film media did not cause the unit to break compliance with its NPDES permit.

CONCLUSION

Over all it should be concluded that the introduction of a fixed film media into a continuously aerating SBR unit did not change the overall quality of the NPDES permitted TSS and CBOD, but it also did not improve the nutrient (nitrogen and phosphorus) reduction. The recommendation for the Hepburn Lycoming Elementary School is that the fixed film media did no harm and they can decide if the cost savings of not paying for the bioaugmentation is worth the increased nutrient levels cause by the fixed film media. In future permits requiring nutrient regulations, it would be recommended that they switch to a tank with denitrification capabilities or reset the aeration cycling on their current unit to include an anoxic cycle.

If a fixed film media is installed into a continuously aerating SBR it can be concluded that:

1. The continuous aeration may negatively affect the impact of the fixed film media and the biofilm grown on it.
2. The nitrogen levels will not be reduced and in some cases they will increase instead.
3. The phosphorus levels will not be affected.
4. The level of solids will not be affected.

The hypothesis of this experiment, that the fixed film media would reduce nutrient levels in an SBR, is rejected based on the findings of the project but could occur with the addition of a denitrification tank.

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APPENDIX I

Figures

Figure 1: A CA-5 SBR unit located at the Williamsport Area Sanitary Authority

Figure 2: Five units being installed in a single site to increase the amount of wastewater that can be treated per day (Young, 2006)

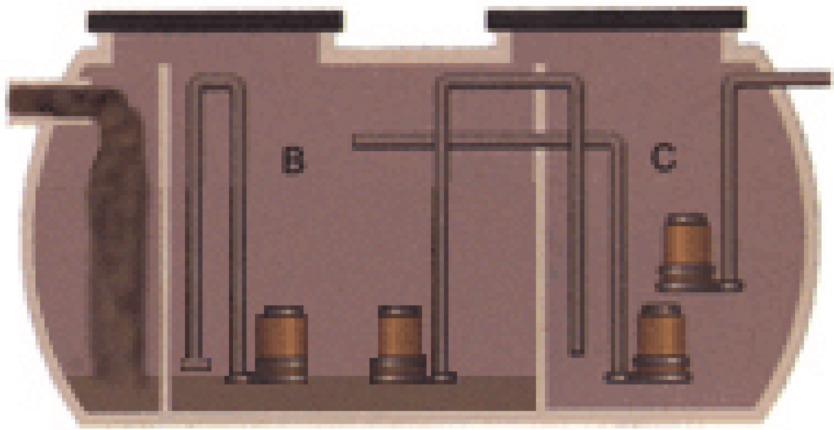


Figure 3: The filling cycle (Young, 2006)

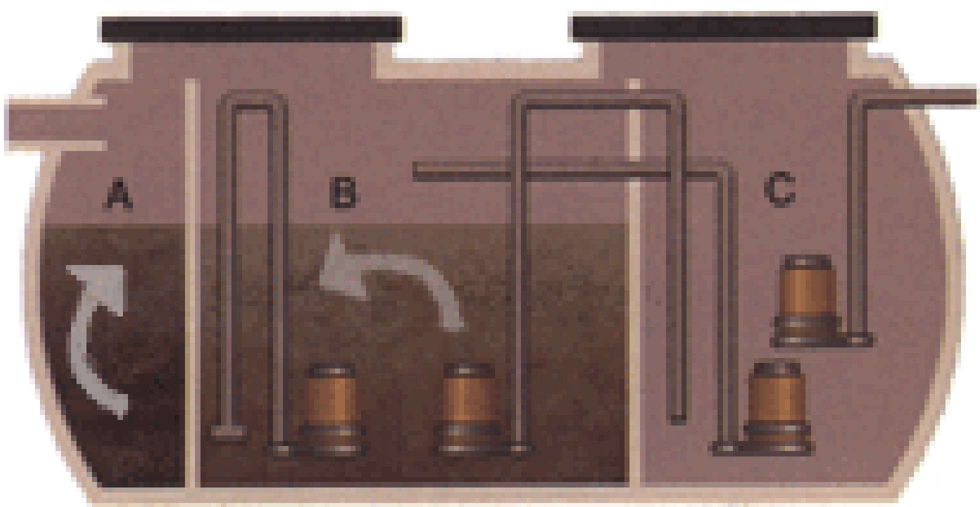


Figure 4: Aeration cycle (Young, 2006)

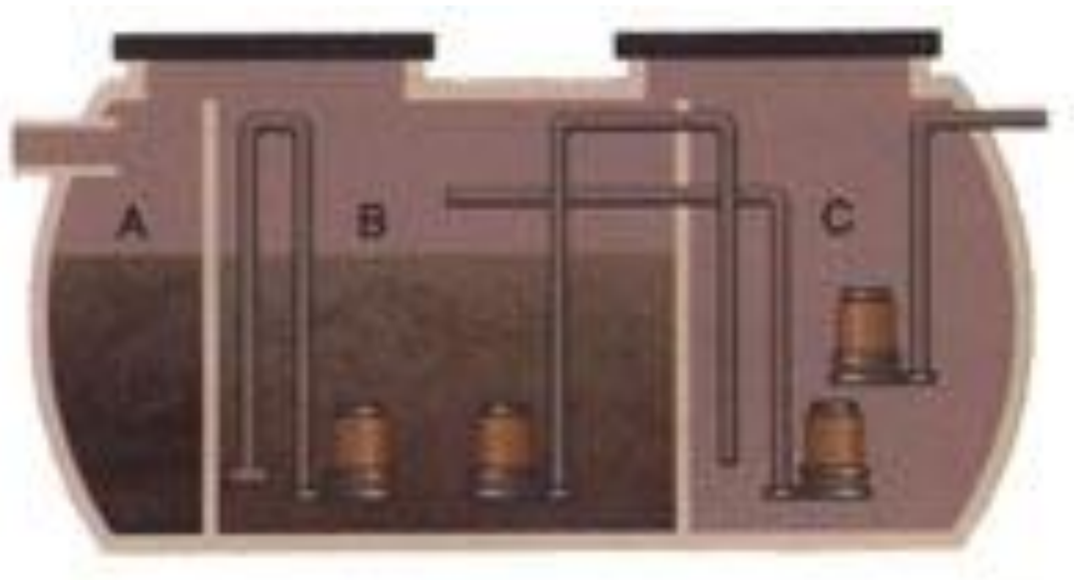


Figure 5: Denitrification cycle (Young, 2006)

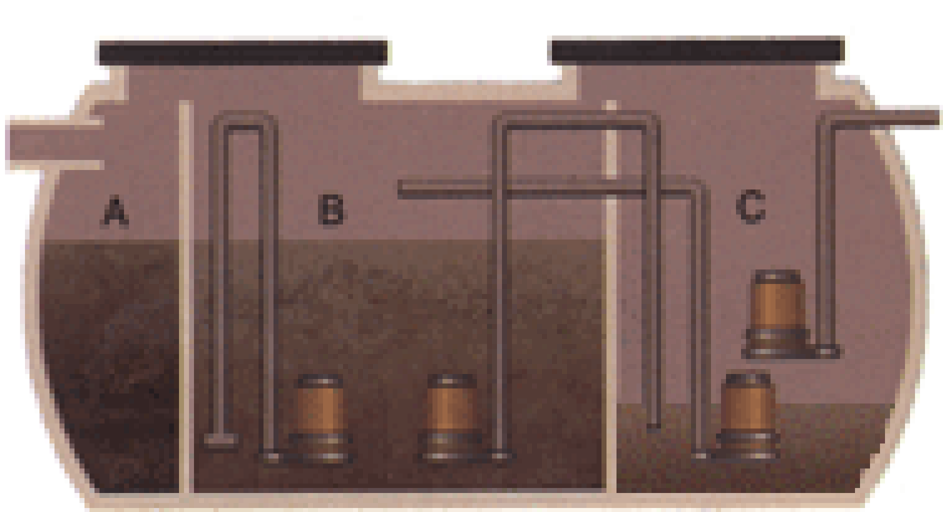


Figure 6: Transfer and settling cycle (Young, 2006)

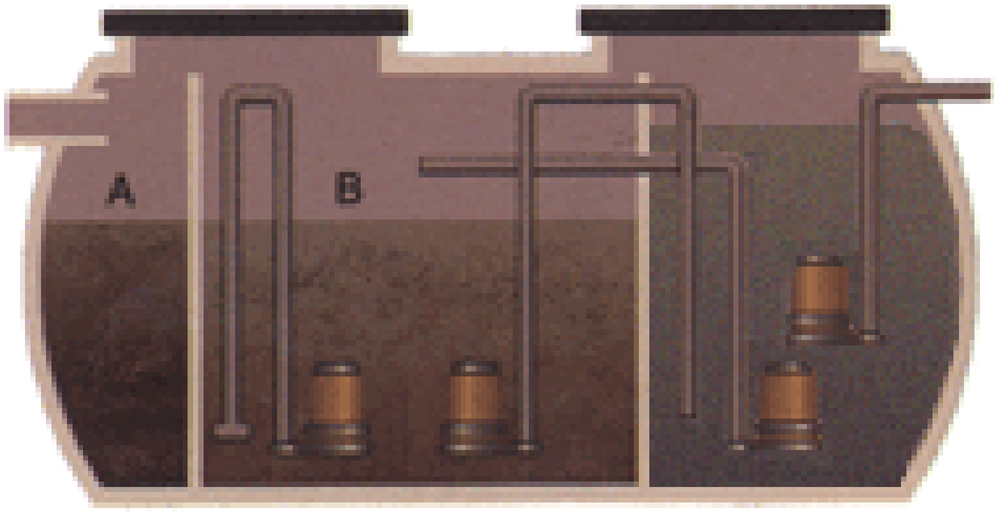


Figure 7: Discharge cycle (Young, 2006)

Figure 8: The fixed film media (after use in a SBR)

Figure 9: The coffee cans; the one on the right is brand new and clean, the one on the left has the biofilm on it

Figure 10: The Hepburn Lycoming Elementary School site, as viewed from the chlorine tank (bottom of the picture). The CA-60 SBR is in the center of the picture and the sludge wasting tank is in the left corner below the brick building

Figure 11: The maintenance hatch that covers the clarification chamber and the end portion of the aeration chamber

Figure 12: The chlorine contact tank

Figure 13: The view from the chlorine tank looking across the road at Lycoming Creek, the site of discharge

Figure 14: The 500 mL bottle attached to the grab stick

APPENDIX II

Timeline

Table 1: Timeline for Sampling Events and System Errors	
Date	Event
1/27/09	Project started, last day of bioaugmentation.
1/29/09	No sample collected
2/24/09	Power outage over the weekend, the system cycling was manually reset by Cromaglass®.
2/26/09	Installation of the fixed film media.
2/23/09-3/08/09	No sampling
3/09/09	Pump 2 failed and was replaced.
3/10/09	First sampling day after the installation.
3/11/09	Flow through, the system was not reset.
4/07/09	Pump 1 failed and was replaced on April 9.
4/09/09	Last sample day for the project.
4/14/09	Two fixed film media units were extracted for biofilm samples.

APPENDIX III

Results- Figures and Tables

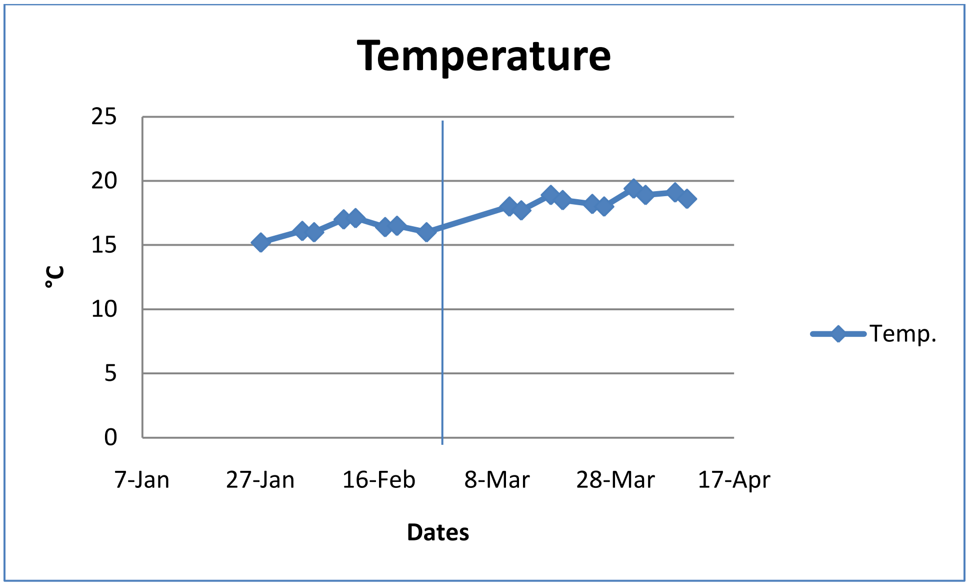


Figure 15: Temperature for the project; January 27-February 25 Pre Installation, February 26 Installation, February 27-April 9 Post Installation

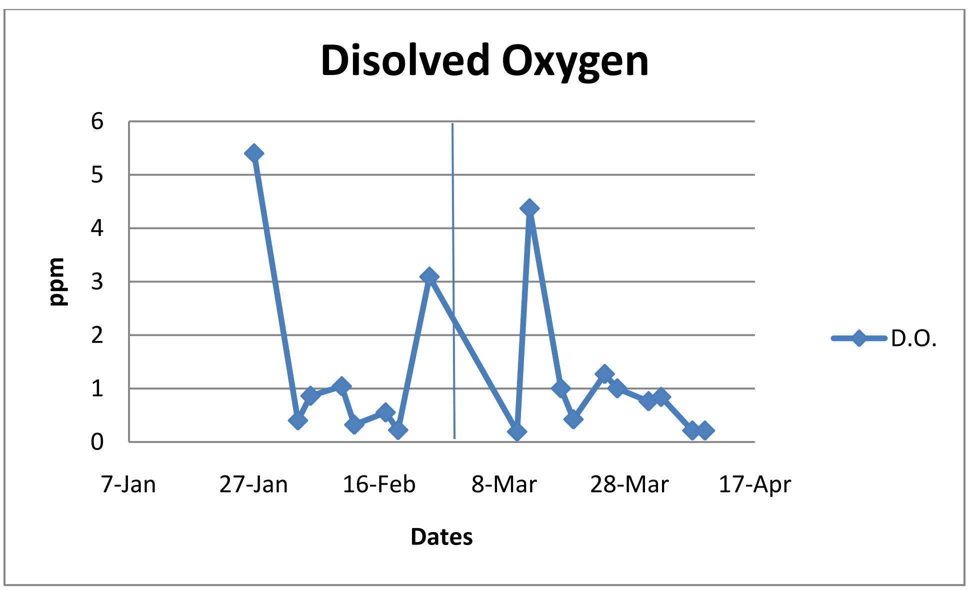
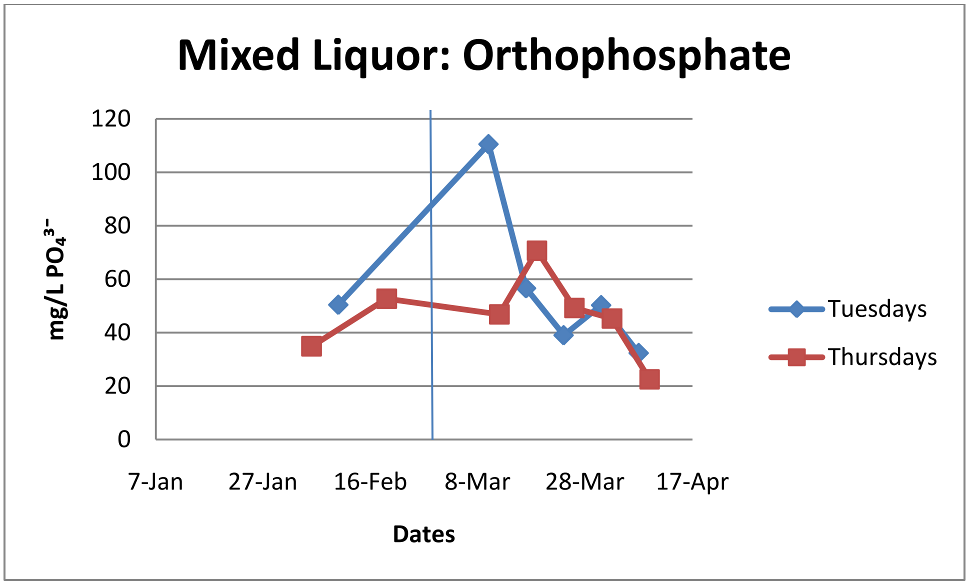


Figure 16: DO for the project; January 27-February 25 Pre Installation, February 26 Installation, February 27-April 9 Post Installation



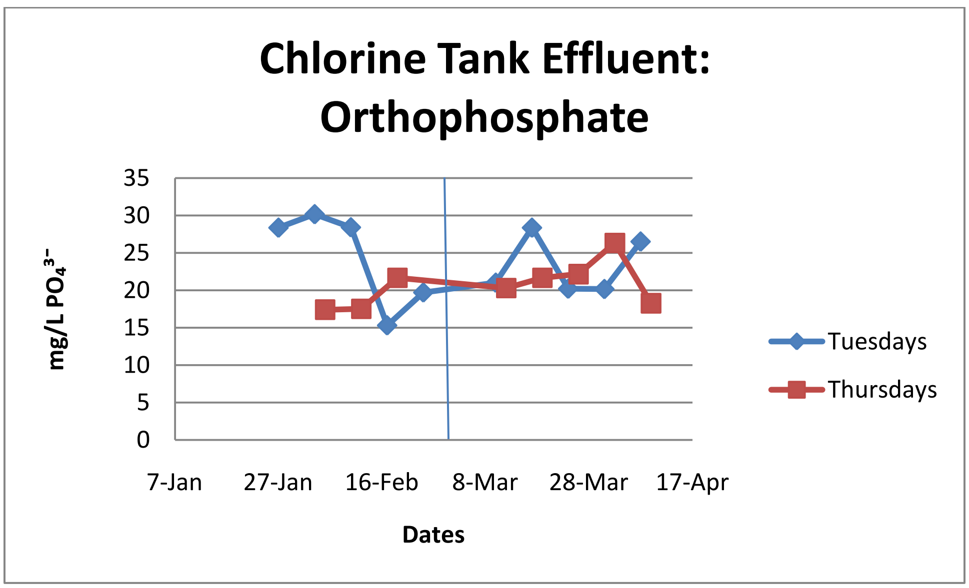
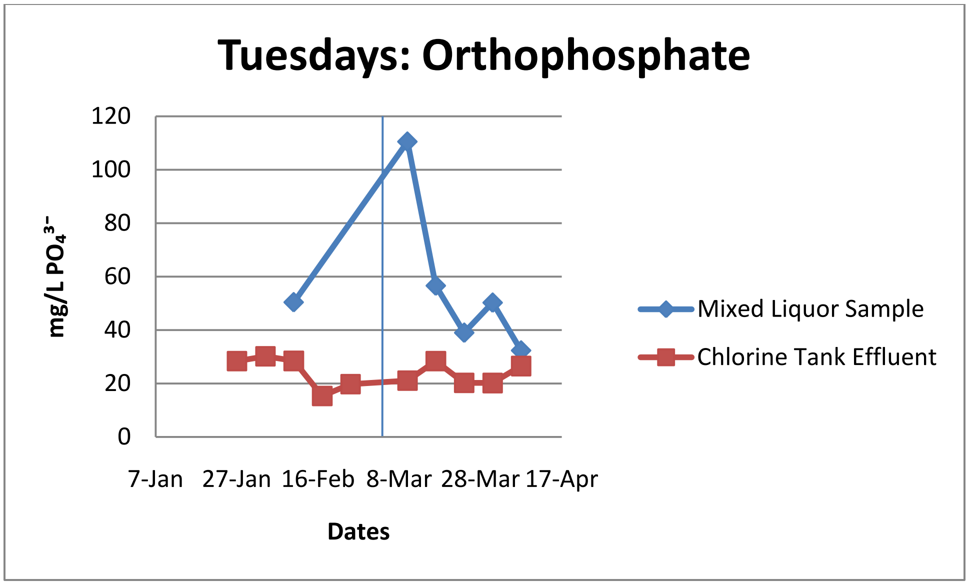


Figure 17: A comparison of Tuesday and Thursday data for the mixed liquor samples and the chlorine contact tank samples in regards to orthophosphate



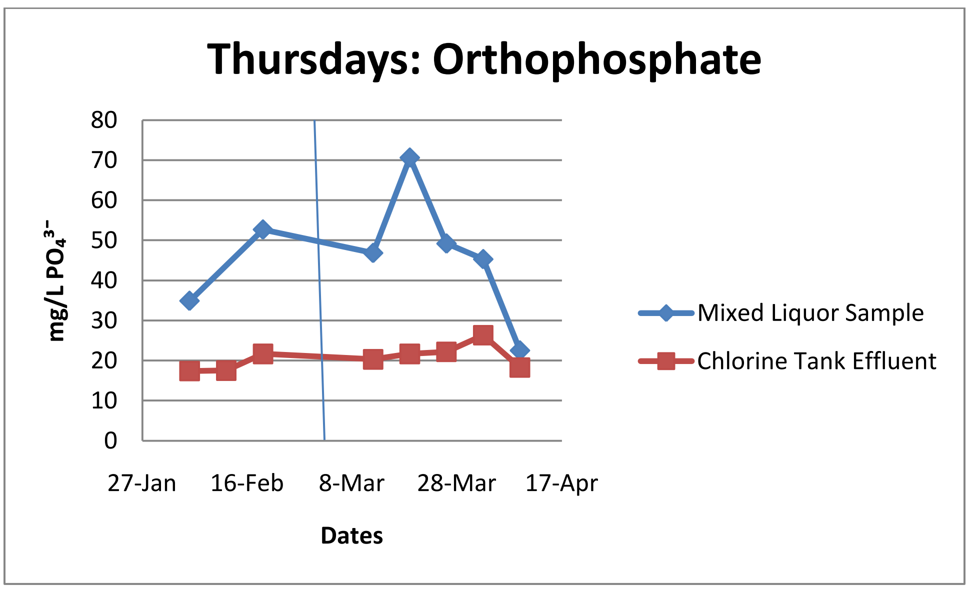
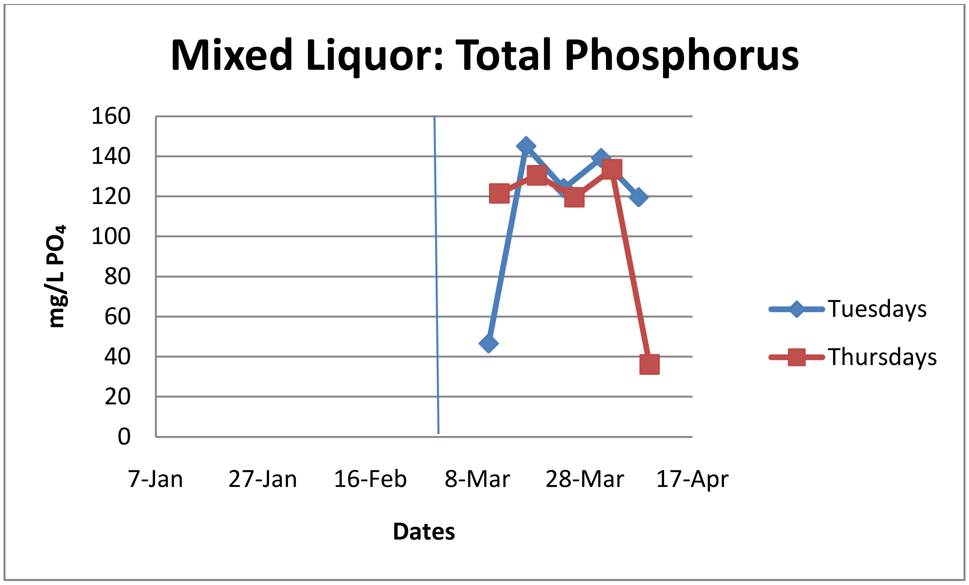


Figure 18: A comparison of the mixed liquor samples and the chlorine contact tank samples on Tuesdays and Thursdays in regards to orthophosphate



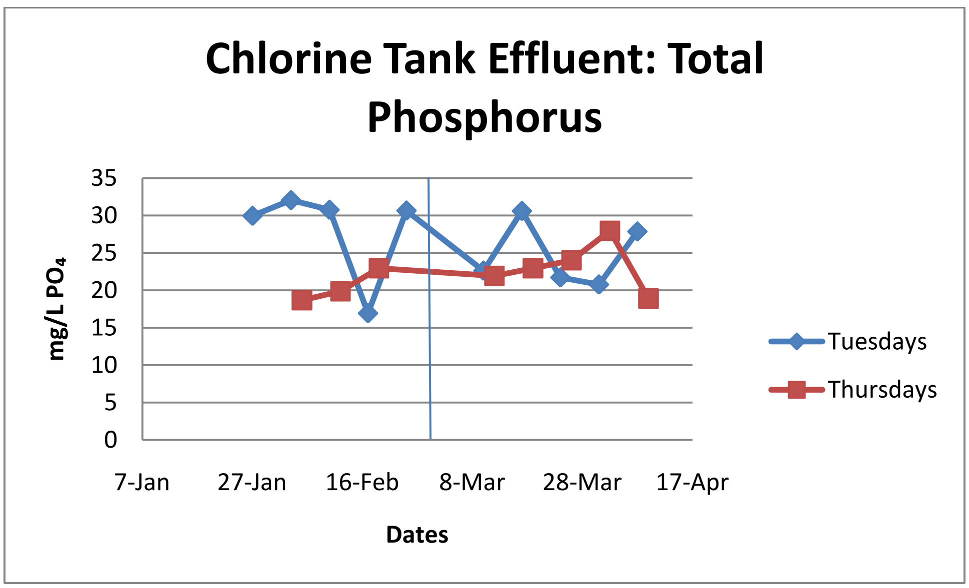
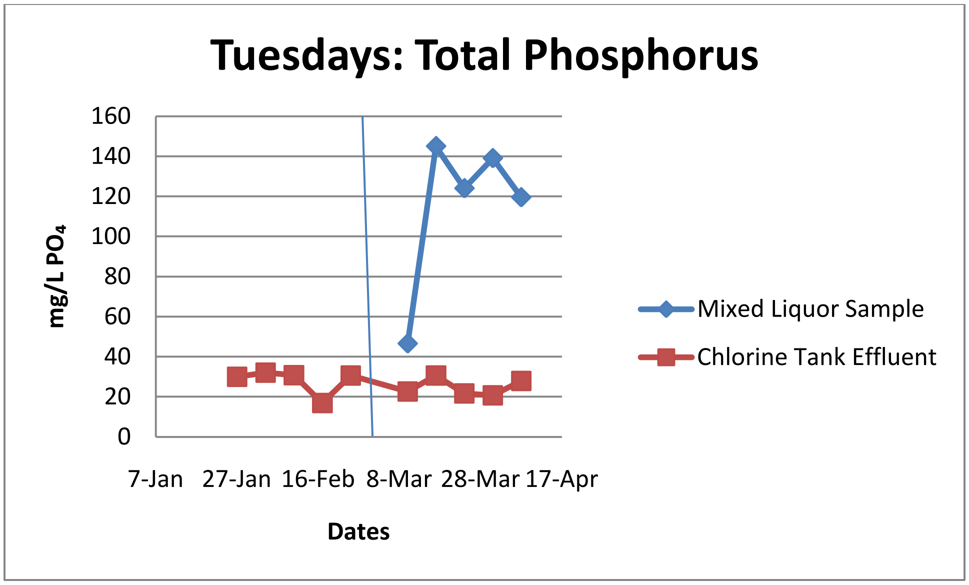


Figure 19: A comparison of Tuesday and Thursday data for the mixed liquor samples and the chlorine contact tank samples in regards to total phosphorus



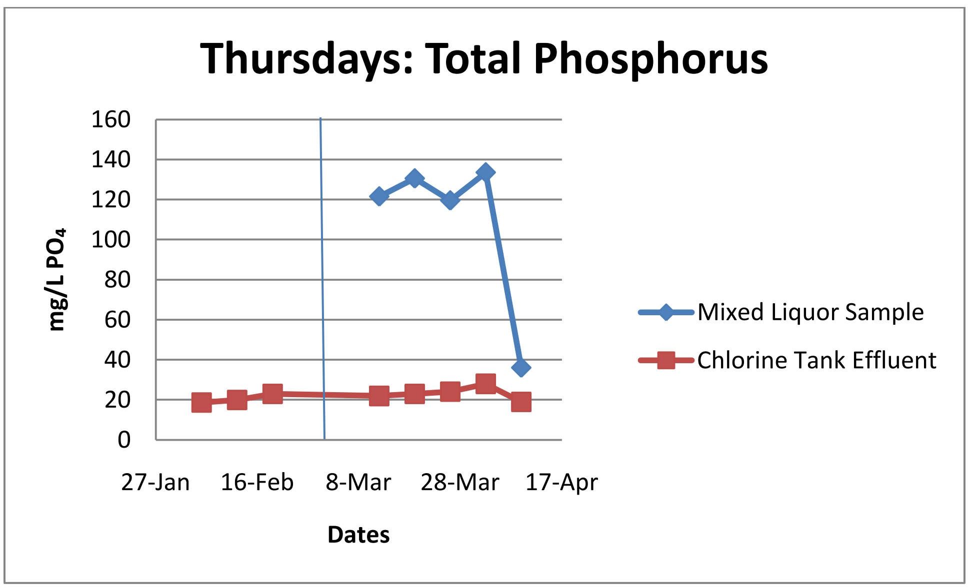
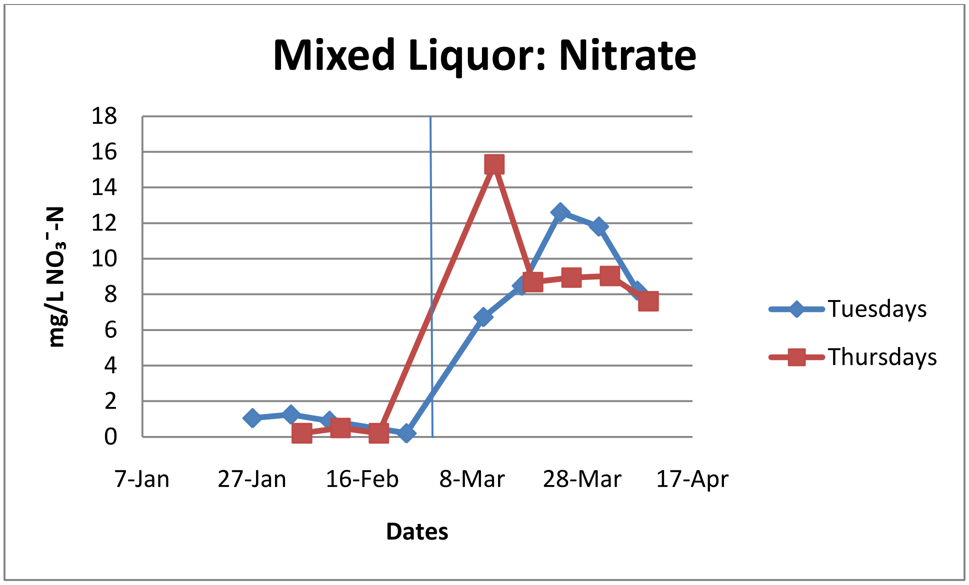


Figure 20: A comparison of the mixed liquor samples and the chlorine contact tank samples on Tuesdays and Thursdays in regards to total phosphate



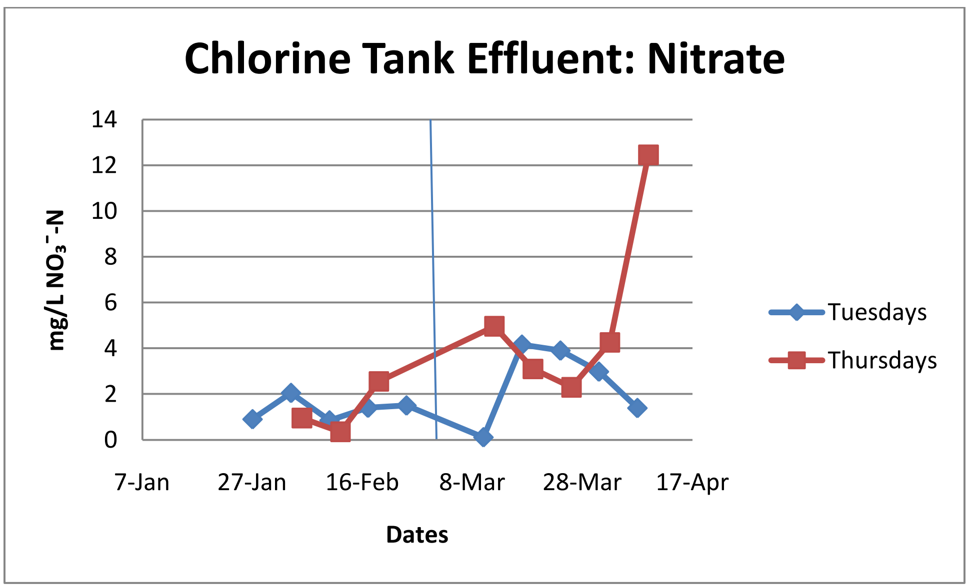
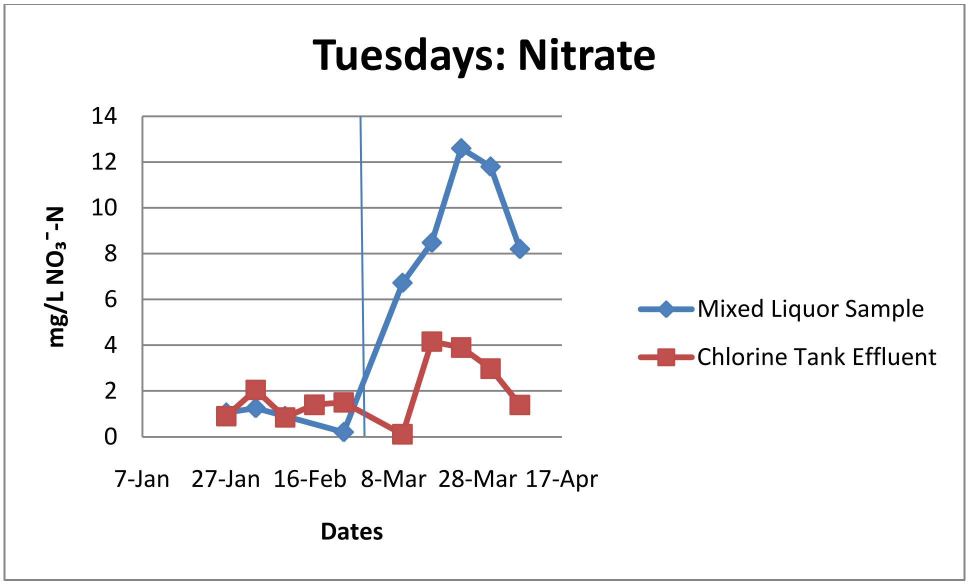


Figure 21: A comparison of Tuesday and Thursday data for the mixed liquor samples and the chlorine contact tank samples in regards to nitrate



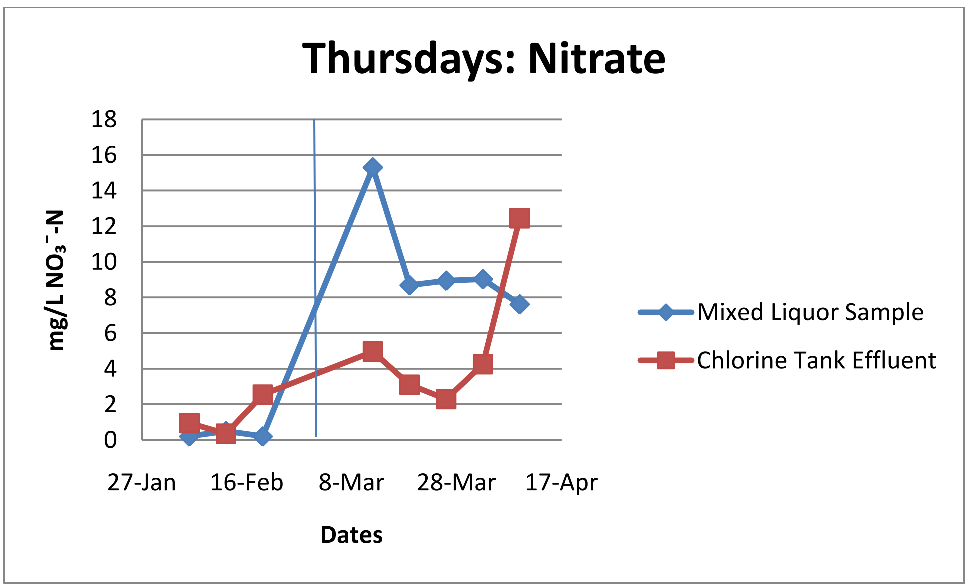
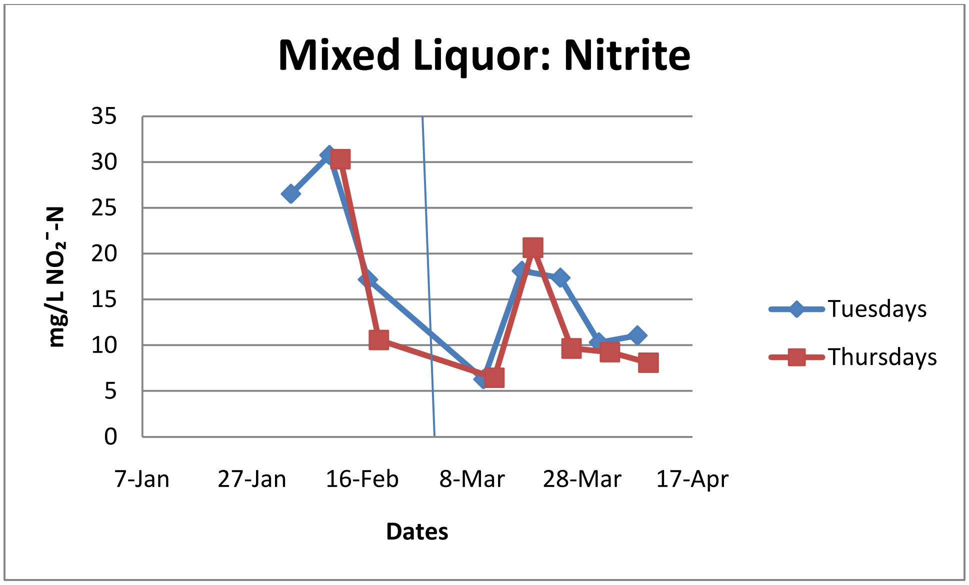


Figure 22: A comparison of the mixed liquor samples and the chlorine contact tank samples on Tuesdays and Thursdays in regards to nitrate



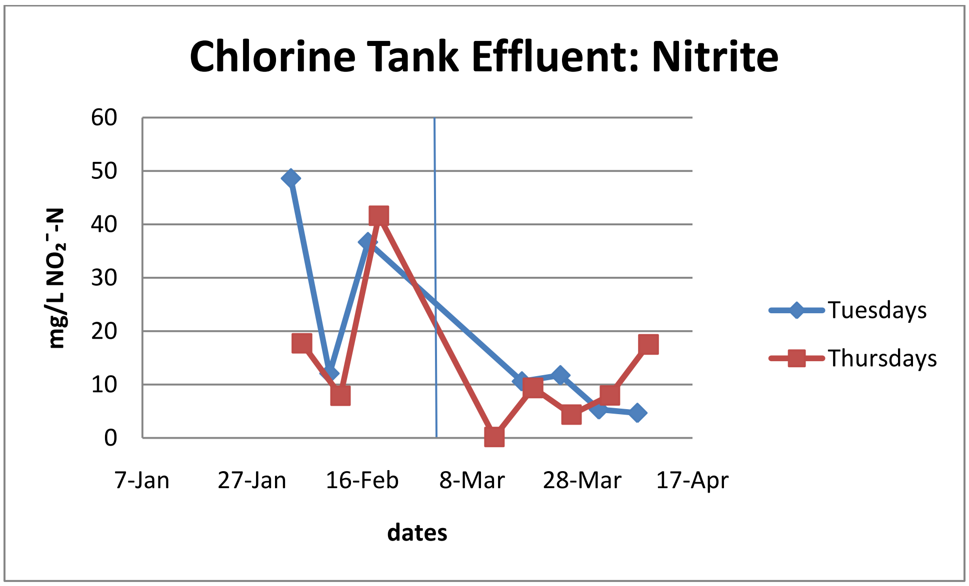
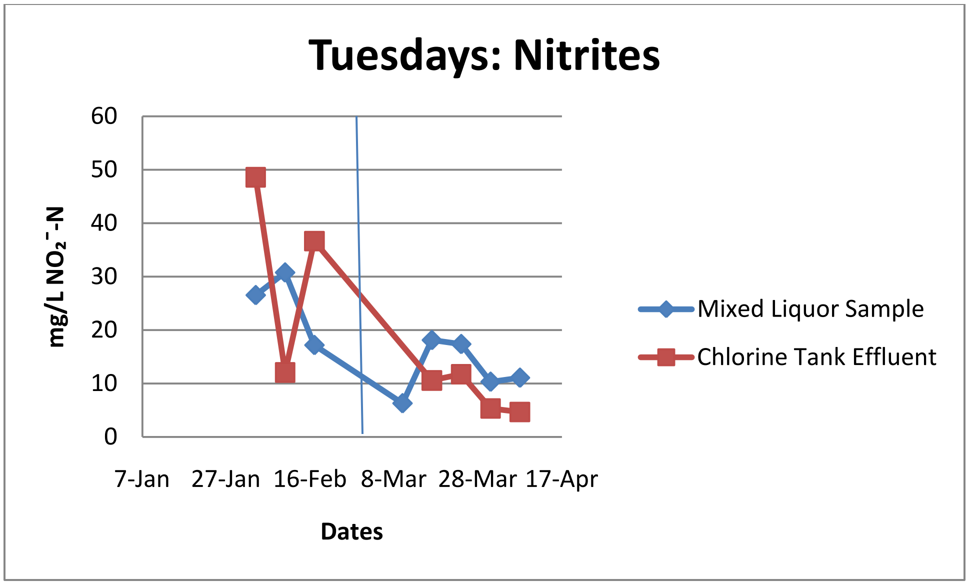


Figure 23: A comparison of Tuesday and Thursday data for the mixed liquor samples and the chlorine contact tank samples in regards to nitrite



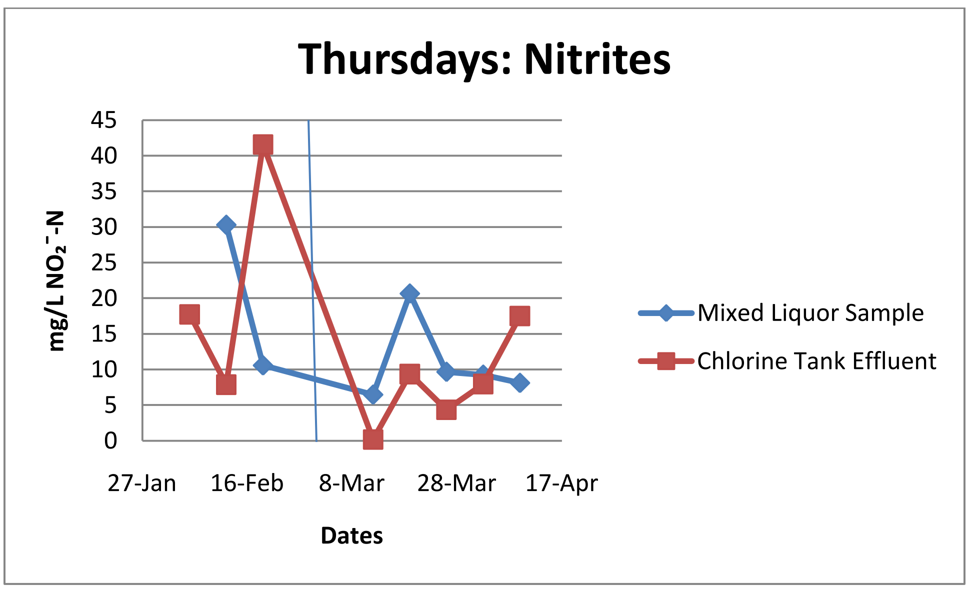
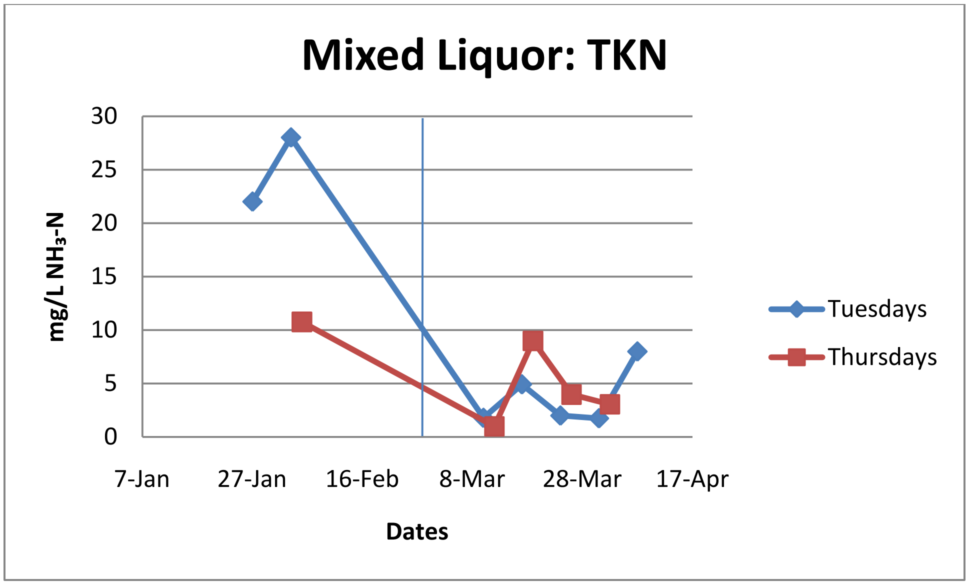


Figure 24: A comparison of the mixed liquor samples and the chlorine contact tank samples on Tuesdays and Thursdays in regards to nitrites



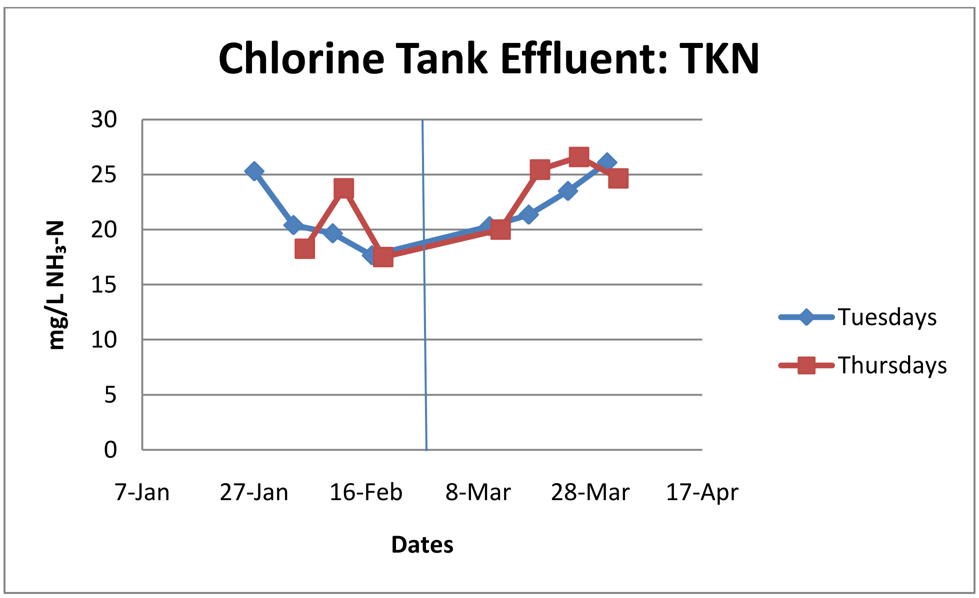
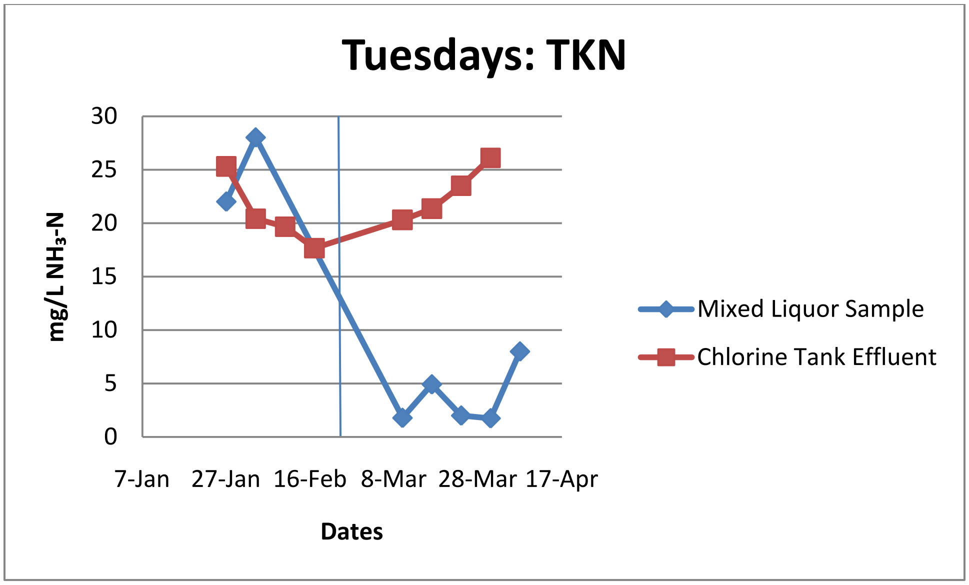


Figure 25: A comparison of Tuesday and Thursday data for the mixed liquor samples and the chlorine contact tank samples in regards to total Kjeldahl nitrogen



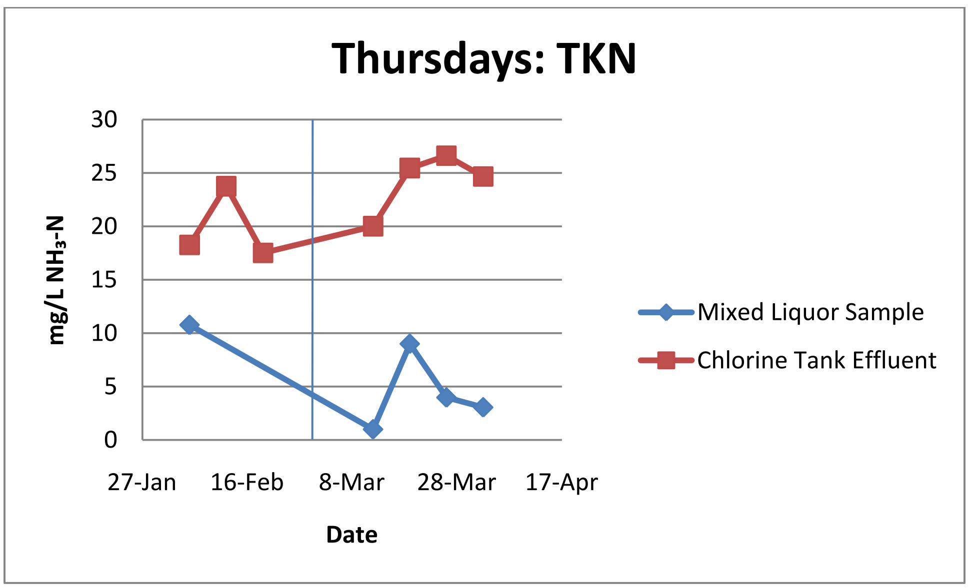


Figure 26: A comparison of the mixed liquor samples and the chlorine contact tank samples on Tuesdays and Thursdays in regards to total Kjeldahl nitrogen

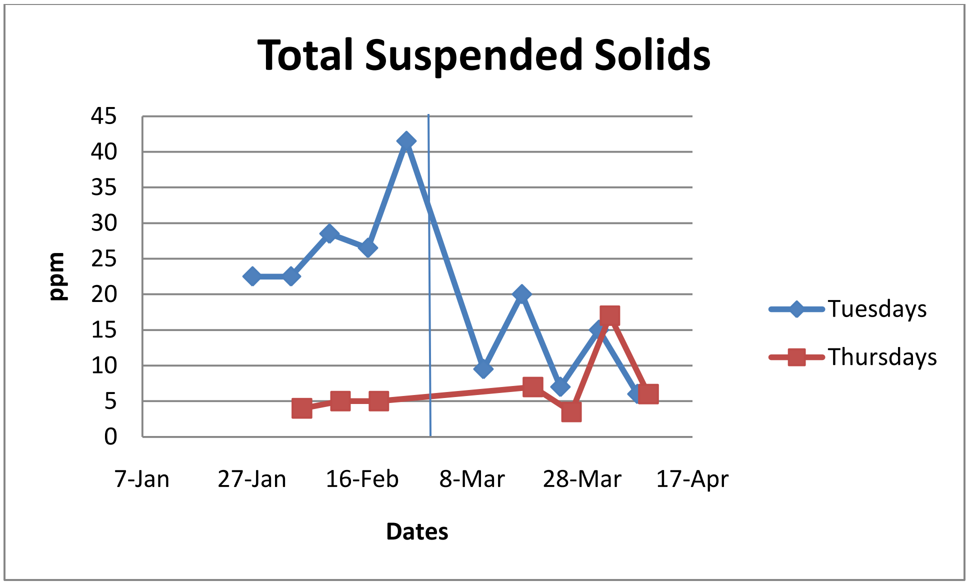


Figure 27: A comparison of the total suspended solids in the chlorine contact tank samples between Tuesdays and Thursdays

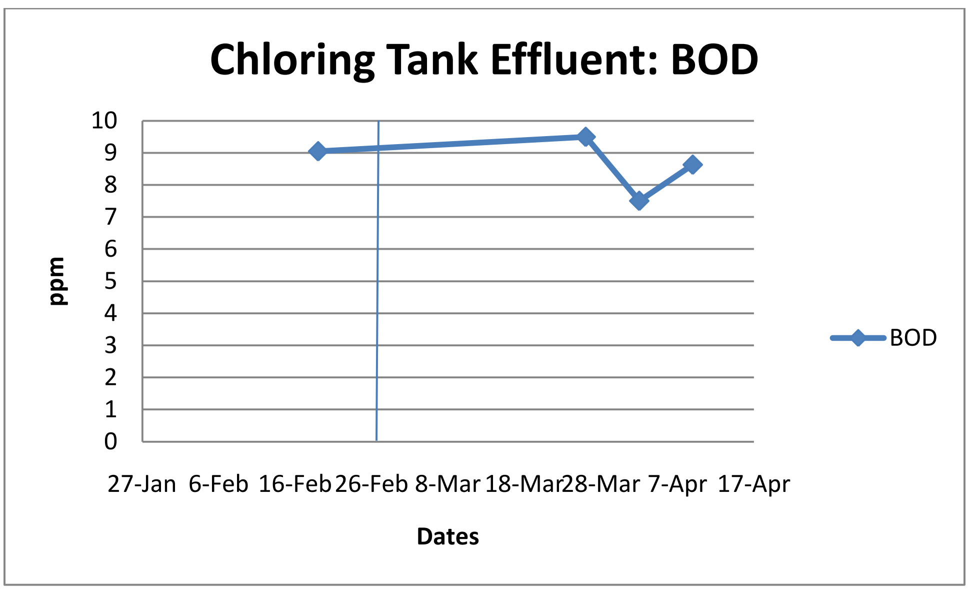


Figure 28: The biochemical oxygen demand from February 19 through April 9

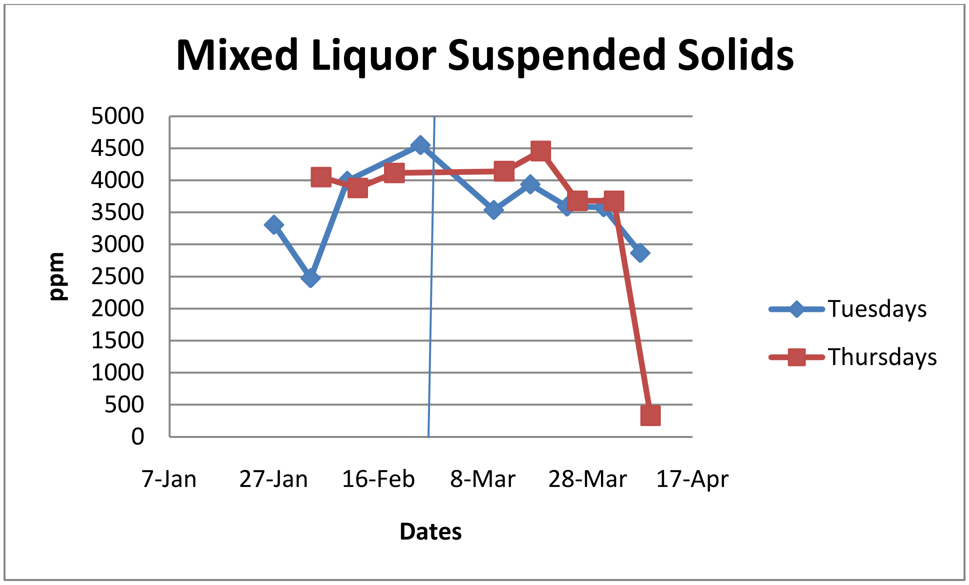


Figure 29: A comparison of the mixed liquor suspended solids from the mixed liquor sample between Tuesdays and Thursdays

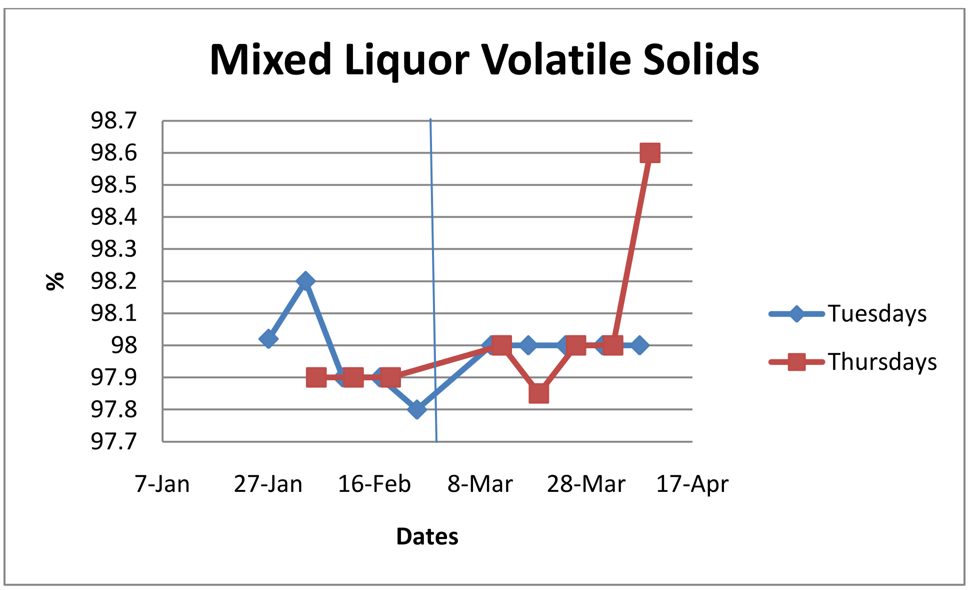


Figure 30: A comparison of the mixed liquor volatile solids from the mixed liquor sample between Tuesdays and Thursdays

Table 2: Rank Sum Statistical Test at α=0.05 Comparing Pre and Post Installation of the Fixed Film Media for the Mixed Liquor Samples

Parameters	Rank Sum Results	Sample Size	Mean: Pre Installation	Standard Deviation: Pre Installation	Sample Size	Mean: Post Installation	Standard Deviation: Post Installation
Orthophosphate ppm	No Significant Difference	3	46	9.68	20	45.93	12.9
Total Phosphorus ppm	NA	16	Over Range	Over Range	20	Over Range	Over Range
Nitrate ppm	Significant Difference	13	0.97	1.1	20	9.74	2.61
Nitrite ppm	No Significant Difference	12	22.7	8.68	20	11.72	5.02
TKN ppm	No Significant Difference	5	18.7	7.66	18	3.93	2.78
MLSS ppm	No Significant Difference	16	3749.25	637.83	20	3379.85	1120.07

Table 3: Rank Sum Statistical Test at α=0.05 Comparing Pre and Post Installation of the Fixed Film Media for the Chlorine Contact Tank Samples

Parameters	Rank Sum Results	Sample Size	Mean: Pre Installation	Standard Deviation: Pre Installation	Sample Size	Mean: Post Installation	Standard Deviation: Post Installation
Orthophosphate ppm	No Significant Difference	18	21.77	5.53	20	22.85	18.88
Total Phosphorus ppm	No Significant Difference	16	25.22	6.94	20	24.18	4.50
Nitrate ppm	Significant Difference	16	1.32	0.70	20	4.61	3.19
Nitrite ppm	Significant Difference	10	27.4	16.24	20	8.89	5.21
TKN ppm	Significant Difference	12	20.18	3.36	14	23.8	2.6
TSS ppm	No Significant Difference	16	19.44	16.07	20	11.3	7.81

Table 4: Rank Sum Statistical Test at α=0.05 Comparing Tuesday and Thursday Results for Post Installation of the Fixed Film Media for the Mixed Liquor Samples

Parameters	Rank Sum Results	Sample Size	Mean: Tuesdays	Standard Deviation: Tuesdays	Sample Size	Mean: Thursdays	Standard Deviation: Thursdays
Orthophosphate ppm	No Significant Difference	10	57.74	29.49	10	46.9	16.28
Total Phosphorus ppm	No Significant Difference	10	114.82	37.4	10	108.22	38.55
Nitrate ppm	No Significant Difference	10	9.53	2.45	10	9.91	2.93
Nitrite ppm	No Significant Difference	10	12.5	4.93	10	10.82	5.35
TKN ppm	No Significant Difference	10	3.68	2.6	8	4.24	3.15
MLSS ppm	No Significant Difference	10	3502	350.96	10	3257.7	1574.32

Table 5: Rank Sum Statistical Test at α=0.05 Comparing Tuesday and Thursday Results for Post Installation of the Fixed Film Media for the Chlorine Contact Tank Samples

Parameters	Rank Sum Results	Sample Size	Mean: Tuesdays	Standard Deviation: Tuesdays	Sample Size	Mean: Thursdays	Standard Deviation: Thursdays
Orthophosphate ppm	No Significant Difference	10	21.57	2.56	10	24	5.51
Total Phosphorus ppm	No Significant Difference	10	22.93	2.68	10	24.43	4.56
Nitrate ppm	No Significant Difference	10	3.82	2.32	10	5.41	3.84
Nitrite ppm	No Significant Difference	10	6.67	4.47	10	10.88	5.09
TKN ppm	No Significant Difference	6	23.3	2.61	8	24	2.89
TSS ppm	No Significant Difference	10	11.5	7.92	10	11.1	8.12

Table 6: Rank Sum Statistical Test at α=0.05 Comparing Mixed Liquor Sample and Chlorine Tank Sample Results for Post Installation of the Fixed Film Media

Parameters	Rank Sum Results	Sample Size	Mean: Mixed Liquor Samples	Standard Deviation: Mixed Liquor Samples	Sample Size	Mean: Chlorine Contact Tank Samples	Standard Deviation: Chlorine Contact Tank Samples
Orthophosphate ppm	Significant Difference	20	45.93	12.9	20	22.85	18.88
Total Phosphorus ppm	Significant Difference	20	111.52	37.12	20	24.18	4.50
Nitrate ppm	Significant Difference	20	9.75	2.61	20	4.61	3.19
Nitrite ppm	No Significant Difference	20	11.72	5.02	20	8.86	5.21
TKN ppm	Significant Difference	19	3.93	2.78	15	23.8	2.6
MLSS/TSS ppm	Significant Difference	20	3379.85	1120.07	20	11.3	7.81

APPENDIX IV

Seewald Laboratories Data and Raw Data from the Study

Table 7: Seewald Laboratories, Inc. Results for NPDES Permit PA0032352 for Hepburn Lycoming Elementary School Pre Installation of the Fixed Film Media		
Date Tested	Parameters	Result
12/23/08	Fecal Coliform	< 2 MPN/100 mL
12/24/08	CBOD	4 ppm
12/24/08	TSS	15 ppm
12/29/09	Fecal Coliform	< 2 MPN/100 mL
12/30/08	TSS	16 ppm
12/31/08	CBOD	7 ppm
1/08/09	Fecal Coliform	< 2 MPN/100 mL
1/09/09	Ammonia Nitrogen	2.24 ppm
1/09/09	CBOD	6 ppm
1/12/09	TKN	36.1 ppm
1/12/09	Total Nitrogen	40.2 ppm
1/12/09	Nitrate-Nitrite as N	4.09 ppm
1/13/09	TSS	25 ppm
1/14/09	Total Phosphorus as P	7.18 ppm
1/16/09	CBOD	6 ppm
1/16/09	Fecal Coliform	< 2 MPN/100 mL
1/21/09	TSS	13 ppm
2/03/09	Fecal Coliform	< 2 MPN/100 mL
2/05/09	CBOD	5 ppm
2/09/09	TSS	< 5 ppl
2/18/09	CBOD	34 ppm
2/18/09	Fecal Coliform	< 2 MPN/100 mL
2/23/09	TSS	10 ppm

Table 8: Seewald Laboratories, Inc. Results for NPDES Permit PA0032352 for Hepburn Lycoming Elementary School Post Installation of the Fixed Film Media		
3/04/09	Fecal Coliform	< 2 MPN/100 mL
3/05/09	CBOD	11 ppm
3/09/09	TSS	7 ppm
3/17/09	Fecal Coliform	< 2 MPN/100 mL
3/19/09	CBOD	9 ppm
3/21/09	TSS	11 ppm
4/08/09	Fecal Coliform	< 2 MPN/100 mL
4/09/09	CBOD	<3 ppm
4/14/09	TKN	25 ppm
4/14/09	Nitrate-Nitrite as N	14 ppm
4/14/09	TSS	5 ppm
4/17/09	Total Phosphorus as P	2.9 ppm

Table 9: Seewald Laboratories' Parameter Results in Comparison to the NPDES Requirements						
Parameters	December Data Pre Installation	January Data Pre Installation	February Data Pre Installation	March Data Post Installation	April Data Post Installation	NPDES Permit Requirements
CBOD	5.5 ppm	6 ppm	19.5 ppm	10 ppm	<3 ppm	25 ppm or less
TSS	15.5 ppm	19 ppm	7.5 ppm	9 ppm	5 ppm	30 ppm or less
Fecal Coliforms	< 2 MPN/100 mL	< 2 MPN/100 mL	< 2 MPN/100 mL	< 2 MPN/100 mL	< 2 MPN/100 mL	200 #/100 mL geometric mean and not greater than 1,000 #/100 mL

Table 10: Mixed Liquor Sample Pre Installation of the Fixed Film Media

	27-Jan	3-Feb	5-Feb	10-Feb	12-Feb	17-Feb	19-Feb	24-Feb
D.O. ppm	5.4	0.4	0.86	1.04	0.32	0.55	0.22	3.09
Temp. °C	15.2	16.1	16	17	17.1	16.4	16.5	16
pH	7.24	6.74	6.82	6.85	6.93	6.77	6.89	6.99
Ortho. ppm	Over Range	Over Range	34.9	50.4	Over Range	Over Range	52.7	Over Range
Phos. ppm	Over Range	Over Range	Over Range	Over Range	Over Range	Over Range	Over Range	Over Range
Nitrate ppm	1.05	1.25	0.2	0.9	0.5	Under Range	0.2	0.2
Nitrite ppm	Over Range	26.51	Over Range	30.745	30.305	17.16	10.56	Over Range
TKN ppm	22	28	10.75	Under Range	Under Range	Under Range	Under Range	Under Range
MLSS ppm	3306	2473.5	4048.5	3992	3881.5	36255	4116.5	4550.5
MLVS ppm	98.02	98.2	97.9	97.9	97.9	97.9	97.9	97.8

Table 11: Mixed Liquor Sample Post Installation of the Fixed Film Media

	10-Mar	12-Mar	17-Mar	19-Mar	24-Mar	26-Mar	31-Mar	2-Apr	7-Apr	9-Apr
D.O. ppm	0.19	4.37	1	0.42	1.27	1	0.76	0.84	0.21	0.21
Temp. °C	18	17.7	18.9	18.5	18.2	18	19.4	18.9	19.1	18.6
pH	6.87	7	6.98	7.06	7.06	7.02	7.01	7.2	7.24	7.11
Ortho. ppm	110.5	46.85	56.6	70.65	39	49.2	50.25	45.3	32.35	22.5
Phos. ppm	46.6	121.5	145	130.5	124	119.5	139	133.5	119.5	36.1
Nitrate ppm	6.72	15.3	8.48	8.69	12.6	8.94	11.8	9.025	8.2	7.615
Nitrite ppm	6.27	6.45	18.1	20.65	17.35	9.65	10.3	9.25	11.05	8.1
TKN ppm	1.775	0.985	4.91	8.98	1.99	3.96	1.735	3.04	7.985	Neg. result
MLSS ppm	3536.5	4142	3937.5	4456.5	3590	3680.5	3580	3679	2866	330.5
MLVS ppm	98	98	98	97.85	98	98	98	98	98	98.6

Table 12: Chlorine Tank Effluent Pre Installation of the Fixed Film Media

	27-Jan	3-Feb	5-Feb	10-Feb	12-Feb	17-Feb	19-Feb	24-Feb
D.O. ppm	5.4	0.4	0.19	0.86	4.37	0.55	0.22	0.32
Temp. °C	15.2	16.1	18	16	17.7	16.4	16.5	17.1
pH	7.17	7.38	7.18	6.96	6.92	7.32	7.08	7.46
Ortho. ppm	28.35	30.15	17.4	28.4	17.5	15.3	21.65	19.7
Phos. ppm	29.95	32.05	18.65	30.75	19.85	16.9	22.95	30.65
Nitrate ppm	0.9	2.05	0.95	0.85	0.35	1.4	2.55	1.5
Nitrite ppm	Above Range	48.565	17.71	12.045	7.865	36.63	41.58	Tests Failed
TKN ppm	25.3	20.4	18.25	19.65	23.75	17.65	17.5	Neg. Result
TSS ppm	22.5	22.5	4	28.5	5	26.5	5	41.5
CBOD ppm	Not Tested	Not Tested	Not Tested	Not Tested	Not Tested	Not Tested	9.05	Not Tested

Table 13: Chlorine Tank Effluent Post Installation of the Fixed Film Media

	10-Mar	12-Mar	17-Mar	19-Mar	24-Mar	26-Mar	31-Mar	2-Apr	7-Apr	9-Apr
D.O. ppm	0.19	0.42	1	0.22	1.27	1	0.78	0.84	0.21	0.21
Temp. °C	16.4	18.5	18.9	16.5	18.2	18	19.4	18.9	19.1	18.6
pH	7.15	7.19	7.12	7.08	7.28	7.22	7.23	7.16	7.42	7.3
Ortho. ppm	21	20.3	28.35	21.65	20.2	22.15	20.15	26.3	26.5	18.25
Phos. ppm	22.6	21.9	30.6	22.95	21.7	24	20.75	27.95	27.85	18.9
Nitrate ppm	2.93	4.96	4.16	3.1	3.9	2.295	2.98	4.255	1.39	12.45
Nitrite ppm	12.32	15.25	10.55	9.35	11.7	4.35	5.3	7.95	4.65	17.5
TKN ppm	20.3	20	21.35	25.45	23.5	26.6	26.1	24.65	Neg. Result	Neg. Result
TSS ppm	9.5	Not Tested	20	7	7	3.5	15	17	6	6
CBOD ppm	5	Not Tested	Not Tested	Not Tested	Not Tested	9.5	Not Tested	7.5	Not Tested	8.63