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ENHANCED CBOD AND NITROGEN REMOVAL IN RECIRCULATING SAND FILTER WASTEWATER TREATMENT SYSTEM BY ADDITION OF PLASTIC MEDIA TO THE RECIRULATING TANK

FINAL REPORT

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16. Abstract

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Enhanced CBOD and Nitrogen Removal in Recirculating Sand Filter Wastewater Treatment System by Addition of Plastic Media to the Recirculation Tank

TDOT Welcome Center
Interstate 65-N
Ardmore, TN

Vanderbilt University
Masters of Engineering
Individual Study
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February 2001

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List of Nomenclature

CBOD – Carbonaceous biological oxygen demand is the 5-day biological oxygen demand

Meq -- milliequivalents

Recirculation ratio – In a recirculating sand filter wastewater treatment system the recirculation ratio is the number of times that the wastewater is circulated through the sand filter. A four to one ratio implies that the wastewater circulates through the sand filter five times before exiting the system. Typically, a splitter box is constructed to divide sand filter effluent so that a portion of it flows back into the recirculation tank and a portion exits the treatment plant.

RSF – Recirculating Sand Filter

TDEC – Tennessee Department of Environment and Conservation

TDOT -- Tennessee Department of Transportation

WWTP – Wastewater Treatment Plant

Abstract

An 8,000 gallon recirculation tank containing 5,400 gallons of wastewater is loaded with 758 pounds of Kaldnes polyethylene media to evaluate enhanced CBOD removal and denitrification in a recirculating sand filter system at the Giles County TDOT Welcome Center on I-65 in Ardmore, Tennessee. Media that is circulated by a Flygt mixer provides a large protected surface for the growth of bacteria that consume CBOD. Media addition can mean cost savings since the sand filter is sized based on CBOD removal per square foot. If daily flows are increasing beyond design flows the addition of media in the recirculation tank, a relatively inexpensive modification, provides an environment for CBOD removal and postpones the need for increasing the sand filter size. The recirculation ratio was adjusted to provide complete nitrification. Results show that CBOD removal does occur in the recirculation tank and that nitrification occurs in the sand filter and is limited by the alkalinity of the wastewater. Denitrifying bacteria are growing on the media. The extent of denitrification is limited by the concentration of CBOD in the influent wastewater.

Introduction

Recirculating sand filters, well suited for treatment of small wastewater flows generated by subdivisions, recreational facilities, schools, small communities and state welcome centers, have low space, energy, and maintenance requirements. They typically produce high quality effluent with CBOD and suspended solids concentrations of less than 5 mg/L and 40% total nitrogen removal. They also provide acceptable discharge to rivers, streams and soil, as well as effluent that is desirable for selected water reuse.

The main objective of this research is to evaluate the potential to increase the treatment capacity of existing recirculating sand filter wastewater treatment plants by incorporating suspended attached growth bacteria on Kaldnes plastic media in the recirculation tank. It is expected that BOD removal will occur primarily in the anoxic environment of the recirculation tank with nitrate as the electron donor, and that nitrification will occur primarily in the recirculating sand filter. Additionally, the secondary objective of this research is to evaluate expected increased total nitrogen removal or denitrification in the system. Denitrification is expected to occur in the recirculation tank as described above.

Increasing the capacity of recirculating sand filter wastewater treatment plants by incorporating Kaldnes plastic media and a mixer into the recirculation tank has excellent cost saving potential for existing and future RSF plants. Typically, the expansion of existing plants requires construction of an additional sand filter and usually an additional recirculation tank as well as possible expansion of septic tanks. The addition of Kaldnes media results in relatively minor construction efforts even if the pumping capabilities of the recirculation pumps require expansion in order to accommodate increased flows.

The existing recirculating sand filter treatment system at the TDOT I-65 Giles County Welcome Center in Ardmore, TN, consists of two septic tanks, a recirculation tank, a three-foot deep 42' by 81' sand filter and an ultraviolet disinfection unit. The 8,000-gallon recirculation tank containing 5,400 gallons of wastewater was modified by adding 758 pounds of Kaldnes polyethylene media for enhanced growth of bacteria. A Flygt mixer was also installed to provide movement and prevent clogging of media.

Process Description

Recirculating sand filters (RSF) are shallow beds of coarse sand 24 to 36 inches in depth that are sandwiched between two layers of gravel. The RSF system is provided with a surface distribution system and an under drain system. Septic tank effluent enters a recirculation tank and is subsequently applied to the surface of the sand beds via pumps in the recirculation tank for five minutes every thirty minutes. In this system the secondary septic tank and the recirculation tank are each equipped with 4 biotube filters made of 1/8" mesh polypropylene tubes housed in 12 " PVC vaults that provide two locations for additional wastewater screening.

In the RSF the treated wastewater is collected in an under drain system and returned to the recirculation tank via a splitter box that can be adjusted to recirculate wastewater the desired number of times. The effluent from the filter is commonly recirculated through the filter five times and then disinfected and discharged to surface waters or disposal fields.

A schematic drawing of the system at Giles County is shown in Figure 1 below, and an illustration of the site plan is provided in Appendix A (Figure A-1).

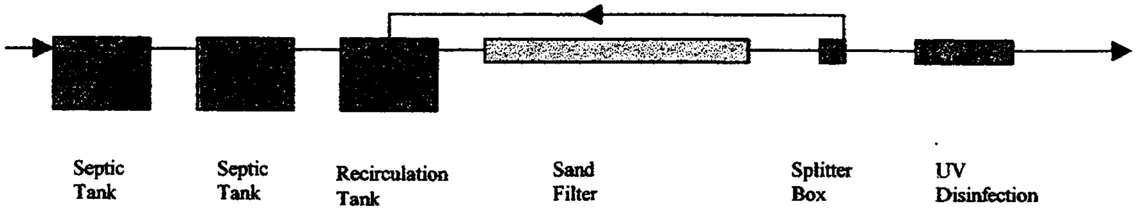

Figure 1. Diagram of Wastewater Treatment Plant--TDOT Welcome Center, Giles County, TN

Table 1 describes system parameters of the TDOT Ardmore Welcome Center, Giles County, TN:

Table 1. System Parameters

Annual average daily flow:	**4,600 gallons per day (gpd)**
Average daily flow during peak months:	**9,400 gpd**
Peak daily flow:	**17,000 gpd**
CBOD average loading:	**191 mg/L or 7.32 lbs./day**
Volumetric CBOD loading in recirculation tank:	**10.1 lbs/day*1000CF**
NBOD average loading:	**120 mg/L or 4.6 lbs./day**
Surface Area NBOD loading on the sand filter:	**616 mg/SF*day**
Combined Septic Tank Avg. Detention Time:	**3 days**
Recirculation Tank Avg. Detention Time:	**1.2 days**

Plant Modifications

The recirculation tank was modified by adding plastic media and a mixer equipped with a variable frequency drive to enable mixer speed adjustment. The 8,000 gallon recirculation tank is 13' deep by 6.5' x 12.5'. The floats that control the on/off sequence of the pumps maintain an approximate 8' 11" level of liquid in the tank creating a volume of approximately

5,400 gallons. A drawing (Figure A-2) showing modifications to the recirculation tank is provided in Appendix A.

On July 20, 2000, 930 kilograms of Kaldnes plastic media were added to the recirculation tank. Due to operational difficulties 172 kilograms of media were removed on September 8, 2000. After media removal the approximate volumetric fill of media in the recirculation tank was 25%. The Kaldnes media is 10 mm diameter X 7 mm long and has a density of 0.96 g/cm^3. The surface area is 152 ft^2/ft^3. There are 177 ft^3 of media in the tank and therefore 26,900 ft^2 of surface area.

The propeller blade mixer is a Flygt Model 4630--2.5 horsepower and is located on the bottom of the recirculation tank with the motor up and blades down. It operates at a maximum speed of 855 rpm at 60 Hz. A variable frequency drive was attached to the mixer and set ultimately at 7.5 Hz or approximately 107 rpm. A drawing of the mixer(Figure A-3) is located in Appendix A.

Sampling

Limited historic data is available for the plant and is included in the sample data spreadsheet Table B-1 in Appendix B. Baseline sampling of the recirculation tank influent and effluent and sand filter effluent was conducted beginning in November 1999. Samples in these three locations were taken measuring pH, temperature, alkalinity, ammonia, nitrate, nitrite, and total nitrogen The majority of the baseline sampling occurred the last two weeks of January. It became apparent that, even though there are no ammonia limits in the NPDES discharge permit, the concentration of ammonia in the effluent was higher than desirable (up to 39 mg/L on February 23, 2000--see sample data spreadsheet, Table B-1 in Appendix B). Historic data shows plant effluent ammonia levels between 3 and 14 mg/L, even during the winter months.

The probable cause of the high ammonia level was identified to be the unevenness of the pipe in the splitter box causing a recirculation ratio of less than the desired 4:1. TDEC and Orenco, Inc., a supplier for recirculating sand filter supplies, suggest a design recirculation ratio of 4:1 for optimum effluent quality. The splitter box was altered by slightly raising the elevation of the effluent discharge opening increasing the recirculation ratio from 3:1 to 11:1. The recirculation ratio was estimated in this study by dividing the product of the "recirculation pump-on" hours and the estimated pumping rate by the plant effluent flow as measured by the plant effluent flow meter. Figure C-1 in Appendix C presents the variation in recirculation ratio during the study.

Sampling continued biweekly and the system was allowed time to reach equilibrium. A dramatic decrease in the ammonia concentration of the plant effluent from 39 to 12 mg/ was experienced within two weeks. Subsequent effluent ammonia levels were less than 10 mg/L.

A variety of technical and logistical problems arose to be solved during the project: (1) the flexibility of controlling the speed on the mixer required the unexpected selection purchase and installation of a variable speed drive; (2) the size of the mixer required a larger diameter access riser and a concrete cut in the top of the tank; (3) unloading the media in a remote area required the rental of a back hoe; and (4) placing the mixer in the tank required the assistance of the local wrecker service. But, finally the media and mixer were added July 21,2000. Sampling continued periodically while we waited for the nitrifiers to build sufficient mass on the plastic media. Samples of media were also collected and kinectic analyses performed as part of another study.

Another minor crisis presented itself in September as the plastic media invaded the recirculation tank biofilters. All pumps and biofilters were removed and the pump vault holes that allow the flow of wastewater into the filters and pumping system were covered with nylon net with holes sized to prevent the passage of Kaldnes media, but allow the free flow of wastewater. As stated above, part of the media was removed during this time as a precaution.

From July to October the effluent pH was between 3.5 and 5, undesirably low, because the nitrifying bacteria in the sand filter were using up all of the alkalinity available in the effluent. A titration of the plant effluent was performed showing that only a small amount of alkalinity was needed to improve the effluent pH to more acceptable levels above pH 6. The titration curve is provided in Appendix C, Figure C-2. Beginning November 2, 2000 approximately 57 grams of lime were added each day to the primary septic tank to increase the alkalinity of the plant influent thus providing a more favorable environment for denitrification in the recirculation tank and a more desirable effluent pH. Sampling continued through December 2000. A spreadsheet of sample results is provided in Appendix B (Table B-1).

Recirculation tank influent sampling occurred in the secondary septic tank near the effluent pipe, but before the septic tank filter. Recirculation tank effluent sampling occurred near the recirculation pumps, before the recirculation tank filter. The sand filter effluent samples were taken just prior to UV treatment. Plastic media sampling occurred just beyond the area where the septic effluent and sand filter effluent pipes are located. See Appendix A for a site drawing with sampling locations (Figure A-1).

Sample Analysis

Analysis of data samples was performed in the Vanderbilt University Civil and Environmental Engineering Laboratory. The table of methods used is included in Appendix B, Table B-2.

The following discussion describes the individual parts of the system and the physical and chemical processes that occur in them. The parameters that were measured will be examined, and evidence of changes and trends will be noted.

Recirculating Sand Filter

Treatment in the recirculating sand filter is brought about by complex physical, chemical and biological transformations. Suspended solids are removed principally by mechanical straining, straining due to chance contact with sand particles and sedimentation. Because bacteria colonize within the sand grains, auto filtration caused by the growth of bacteria further enhances the removal of suspended solids. Specific constituents are removed by chemical and physical sorption on the grains of sand. The removal of CBOD waste and nitrification, the conversion of ammonia to nitrate, is performed by microorganisms present in the sand bed and occurs in aerobic conditions. The purpose of this study is to determine if the presence of media in the recirculation tank will encourage the removal of CBOD waste in the recirculation tank rather than in the sand filter bed so that the design size of the sand filter may be reduced.

Nitrification

Nitrification is an autotrophic process (i.e., energy for bacterial growth is derived by the oxidation of nitrogen compounds). In contrast to heterotrophs, nitrifiers use carbon dioxide (inorganic carbon) rather than organic carbon for synthesis of new cells. Nitrifier cell yield per unit of substrate metabolized is smaller than the cell yield for heterotrophs. Nitrification of ammonium nitrogen is a two-step process involving two genera of microorganisms, Nitrosomonas and Nitrobacter.

Nitrification requires the presence of oxygen. Natural air circulation is provided in the sand filter by a vented under drain system without the expense of energy demanding aeration systems. The oxygen concentration in the sand filter effluent is typically greater than 5 mg/L. Periodic measurements of dissolved oxygen levels in the sand filter effluent varied between 4 and 6.3 mg/L

Nitrification occurs most efficiently when the pH of the wastewater is in the range of 7.2 to 9 (Metcalf and Eddy, p. 698). The pH of the sand filter influent varied between 6.2 and 7.5, which is on the low side of optimum. After the recirculation ratio was increased in late February, the influent pH as illustrated in Figure 2 varied between 6.3 and 6.9, which is less than desirable. The sand filter effluent pH as stated previously was between 3.1 and 5 after the recirculation ratio was increased, indicating that all of the alkalinity in the wastewater was used to maximize nitrification. A titration of the plant effluent October 19, 2000 sample indicated that only a small amount of OH^- was needed to adjust the pH of the recycle stream (0.06 meq OH^-/L wastewater). See Appendix C, Figure C-2. In order to provide increased alkalinity the addition of approximate 57 grams of lime at the influent pipe side of the primary septic tank was begun on November 2, 2000

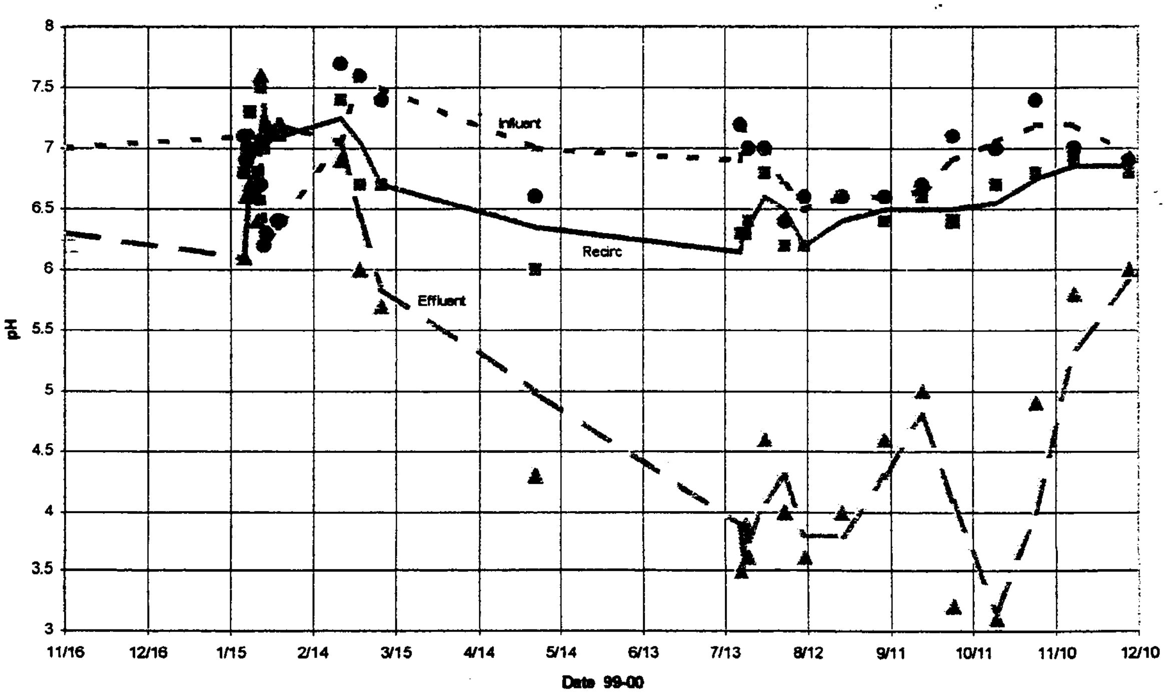

Figure 2. Comparison of Lab Measured pH in Recirculation Tank Influent, Recirculation Tank and Sand Filter Effluent Samples, Giles County Welcome Center WWTP

The temperature of the wastewater at all sampling locations, depicted in Figure 3, varied between 12 degrees C and 30 degrees C, which is relatively moderate, considerably warmer than the ambient temperature in winter and cooler in the summer. The average temperature in the system was 19 degrees C. Temperature will affect performance of nitrifying bacteria. (Metcalf & Eddy, p. 723). This factor should be given consideration if ammonia levels increase during extremely cold weather. Since the weather in Giles County tends to be moderate and the system is underground this will not typically be a limiting factor.

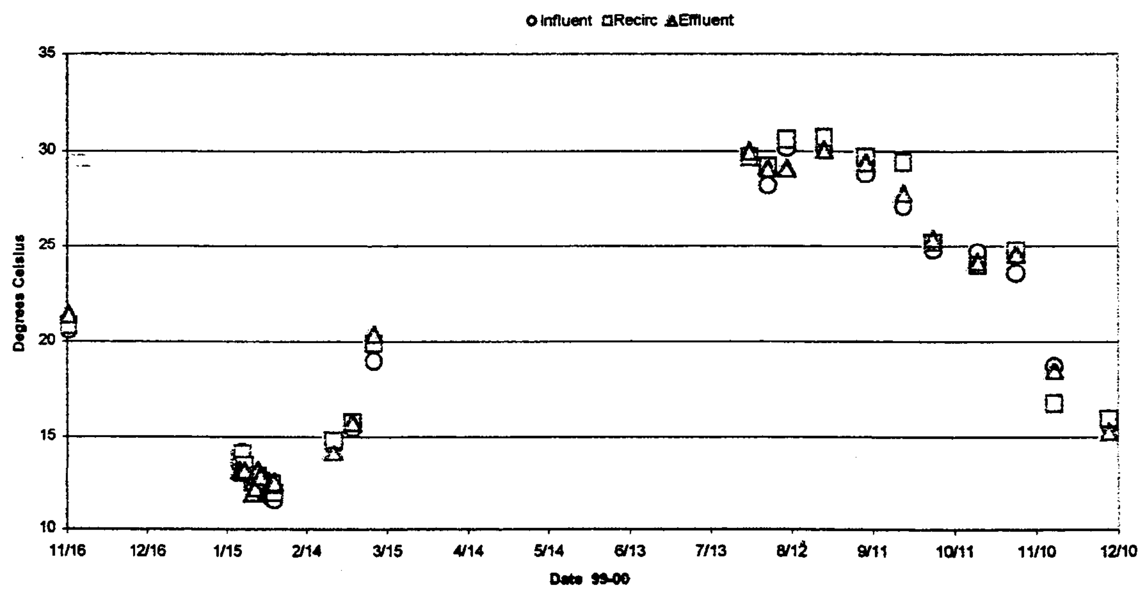

Figure 3. Comparison of Field Measured Temperature in Recirculation Tank Influent, Recirculation Tank and Sand Filter Effluent Samples, Giles County Welcome Center WWTP

Most of the conditions in the sand filter provide an environment conducive to nitrification. Ammonia, oxygen, and alkalinity are present. Most of the CBOD is expended, which is favorable since the removal of CBOD is preferential to the conversion of ammonia to nitrate.

Temperature is typically within a favorable range of 20 to 35 degrees Centigrade. The pH level was less than optimal during this study whenever the recirculation ratio was high and not enough alkalinity was available for complete nitrification. Evidence of nitrification in the sand filter can be observed from Figure 4 and in the sample data in Table B-1 by noting the difference in the average concentration of approximately 20 mg/L of ammonia in the sand filter influent (recirculation tank samples) and sand filter effluent average ammonia concentration of less than 10 mg/L.

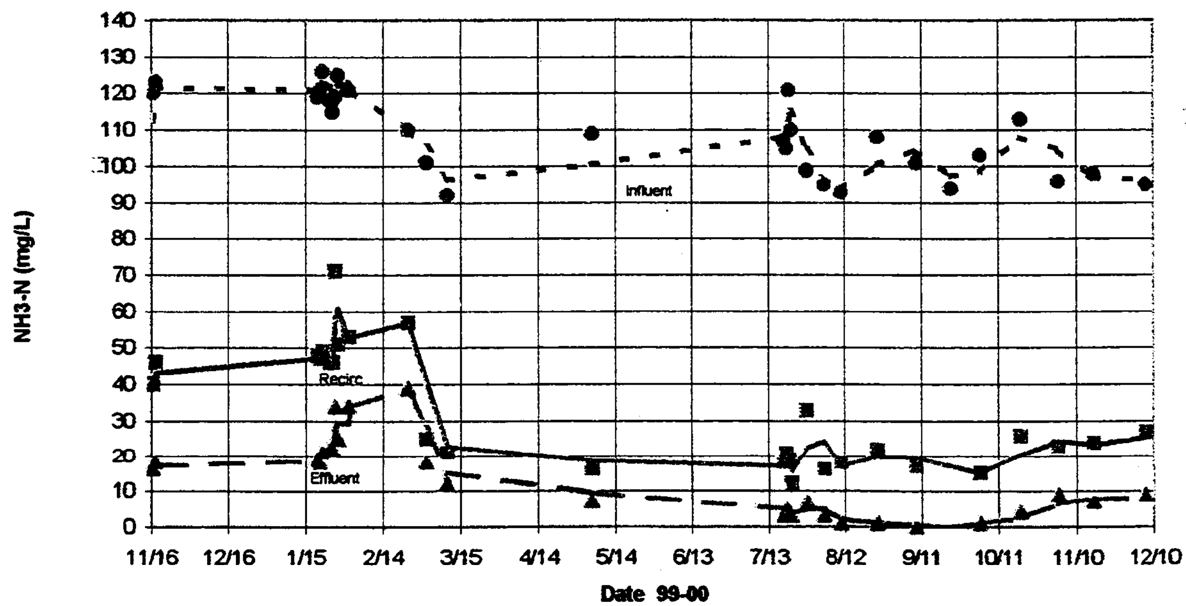

Figure 4. Comparison of Laboratory Measured Ammonia in Recirculation Tank Influent, Recirculation Tank and Sand Filter Effluent Samples, Giles County Welcome Center WWTP

The accidental finding of this study was that nitrification can be driven to completion even under somewhat adverse pH conditions. There is no formal SRT time for the sand filter, but the pumps at this location are set to pump to different zones for 5 minutes and then experience a 20-minute rest. One can assume that a zone of the filter is flooded for 5 minutes and that the wastewater quickly flows through and out. The zone then rests for 20 minutes and reaerates.

Alkalinity

Increasing the recirculation ratio on February 23, 2000 brought the effluent ammonia levels down substantially to between 0 and 5 mg/L. At the same time that the ammonia levels were reduced, alkalinity in the effluent was reduced to 0, and the pH to between 3.1 and 5, as shown in Figure 6.

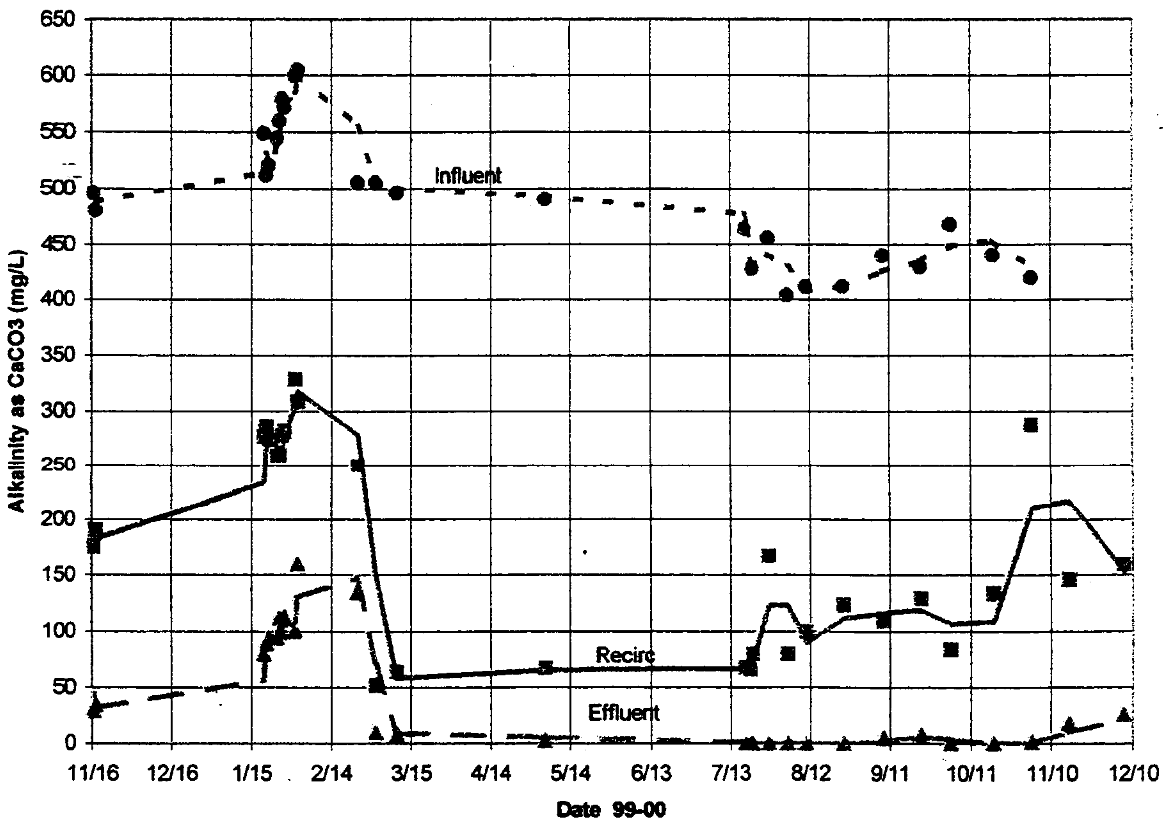

Figure 5. Comparison of Laboratory Measured Alkalinity in Recirculation Tank Influent, Recirculation Tank and Sand Filter Effluent Samples, Giles County Welcome Center WWTP

The alkalinity comparisons in Figure 6 confirm that the alkalinity needed to nitrify the ammonia present exceeds the alkalinity present. Seven grams of alkalinity is consumed per gram of NH_4-N oxidized according to the following equation:

$$NH_4^+ + 1.8\ O_2 + 0.13\ CO_2 \text{-------}\ 0.026\ C_5H_7O_2N + 0.97\ NO_3^- + 0.92\ H_2O + 1{,}97H^+$$

assumes SRT + 15 days (Rittmann and McCarty 2000)

Even when consideration is given for alkalinity produced (3.6 g alkalinity regenerated per g of NO_3^--N denitrified), alkalinity needs exceed availability thus causing a lowering of pH. Fortunately, the lowering of pH in the sand filter effluent does not prevent nitrification from occurring in the sand filter, but optimizing the presence of regained alkalinity is desirable in future studies.

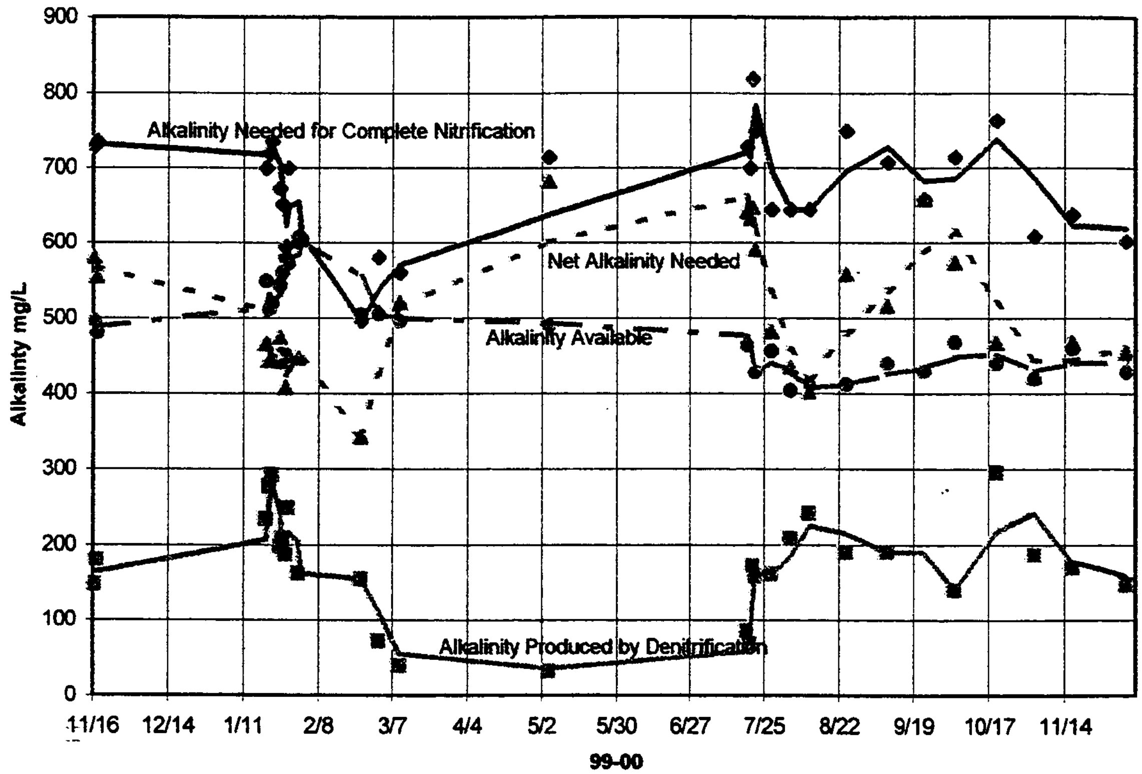

Figure 6. Comparison of Alkalinity Required and Alkalinity Available

Figure 5 shows that during late January 2000 and early February 2000, alkalinity concentrations ranged between 500 and 600 in the recirculation tank influent. The recirculation ratio was approximately 3:1 and the alkalinity in the recirculation tank varied between 250 and 300 mg/L. The actual concentration of alkalinity in the recirculation tank as depicted in Figure 9 was 40 to 70 mg/L higher than one would expect after adjusting for the dilution brought about by recirculation, indicating that denitrification was occurring. During this winter period less nitrification and more denitrification occurred, heightening the alkalinity in the recirculation tank and the effluent. After the recirculation ratio was increased substantially, nitrification increased, but concurrently alkalinity remaining in the effluent was virtually zero. The pH level in the effluent was also low and fell to 3.5 and 3.9 after a month of high recirculation ratios. The rate of denitrification was lower, down from a range of 40 to 60 per cent to a range of 10 to 20 per cent. As a result of lower denitrification rates, alkalinity was not replenished. Perhaps this occurred because the pH in the recirculation tank was lowered due to low effluent pH level, high recirculation ratios, and increased oxygen and decreased CBOD concentrations due to high recirculation ratios.

Of interest is the fact that historical sampling data shows that the alkalinity in the recirculation tank influent was higher in January and February of 1998 and lower during March and April of 1998.

Recirculation Tank

Three chemical processes of interest probably occur simultaneously in the recirculation tank--denitrification, aerobic removal of CBOD and limited nitrification. The prevailing conditions determine the favored process.

Denitrification

The purpose of this project was to encourage denitrification and thereby the removal of CBOD and nitrate in the recirculation tank by installing plastic media and a mixer in the tank. Optimal conditions for denitrification include maintaining a moderate temperature between 20 and 35 degrees Centigrade because the temperature affects removal rate of nitrate and the microbial growth rate (Metcalf & Eddy, p. 433). The importance of temperature is illustrated by the tripling of tank volume required for 10 degrees C as compared to the tank volume required for 20 degrees C (Metcalf & Eddy, p. 723). The temperature is typically moderate in the recirculation tank except possibly in the coldest winter months. Figure 3 shows temperature variations during the study.

Optimal conditions also include a pH range of 7 to 8 with different optimums for different bacterial populations (Metcalf & Eddy, p. 432). The same reference suggests a range of 6.5 to 7.5 with 7 as the optimum condition using 1975 EPA study data (Metcalf & Eddy, p. 723). The pH in the recirculation tank as it is leaving the tank has tended to be in the range of 6.3 to 6.9, which is on the low side of optimum. Importantly, when the recirculation ratio is high, the plant effluent, which has a pH of between 3.6 and 6.0, mixes immediately with the plant influent, which is high in CBOD. Presumably, it is in this area of highest CBOD concentration that the conditions are most favorable for denitrification to occur, further indicating that pH adjustments should be made to optimize conditions for denitrification in the recirculation tank

The following equation represents the two-step denitrification process:

$0.15\ C_{10}H_{19}O_3N + NO_3^- + H^+$ -------- $0.105\ C_5H_7O_2N + 0.45\ N_2 + 0.15\ NH_4^+ + 0.15\ HCO_3^-$ $+ 0.81\ CO_2 + 1.13\ H_2O$ (R. E. Speece)

In this equation $C_{10}H_{19}O_3N$ represents the composition of wastewater, the electron donor or the carbon energy source. Approximately 4 g BOD_L is required for each g NO_3^-N that is denitrified. This is in addition to any BOD_L that is oxidized with oxygen as the electron acceptor. This presents a major problem to our secondary goal of increasing denitrification in the plant. The average total nitrogen concentration measured in the plant influent is 120 mg/L. This quantity of nitrogen will need a CBOD level of 480 mg/L for complete denitrification. Additionally, each time that the wastewater recirculates through the sand filter it increases the concentration of dissolved oxygen from approximately 1 mg/L to about 5 mg/L. Assuming that the recirculation ratio is at 7:1, the average ratio during the study, there is an additional need of 28 mg/L of CBOD since aerobic bacteria preferentially use CBOD. Using the average CBOD of 190 mg/L and average total nitrogen of 119 mg/L and a recirculation ratio of 7:1, the approximate maximum denitrification that is expected to occur is 34 %. This percentage increases to 37% if a recirculation ratio of 4:1 is used.

The graphing of denitrification shows that during the baseline sampling the denitrification rates varied between 40 to 55 %; during the period when recirculation rates were increased to 11:1 denitrification varied between 13-22%; and during the time that the media was present the rates varied between 18-43%. This might imply that total nitrification achieved by increasing the recirculation ratio may come at the sacrifice of denitrification whenever alkalinity is limited.

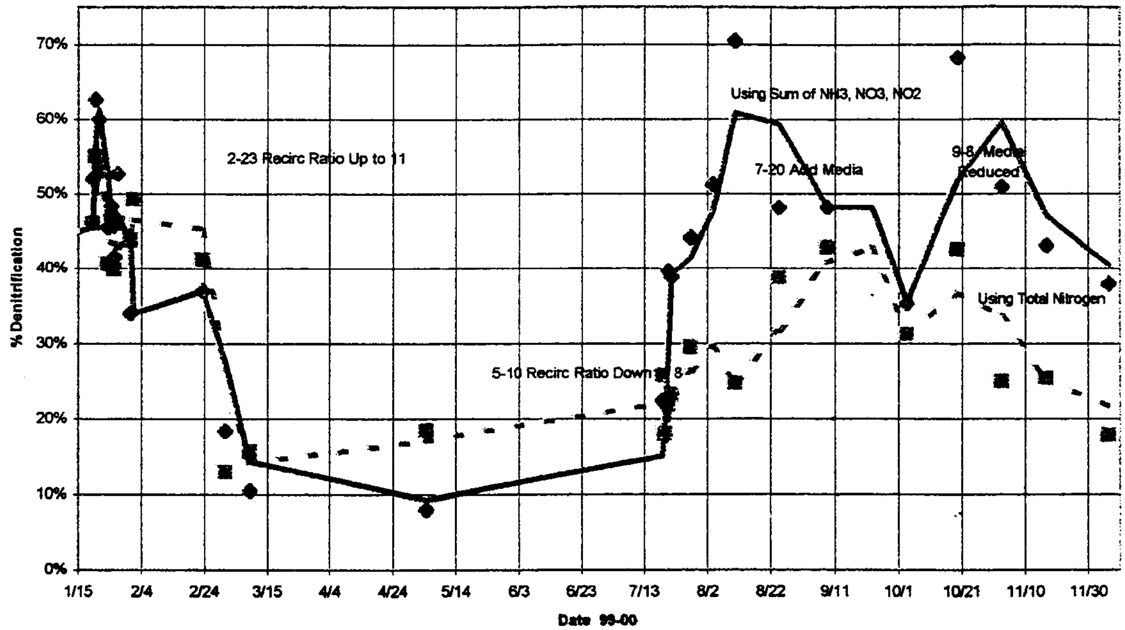

Figure 7. Estimation of denitrification occurring at Giles County Welcome Center WWTP using ratio of laboratory measured total nitrogen in recirculation tank influent and plant effluent. A similar ratio of the sum of laboratory measured ammonia, nitrate, and nitrite in the influent and effluent is also presented for comparison.

Additional evidence of the presence of denitrification can be found in the data. For example, when dilution of the substances of interest in the wastewater due to recirculation is accounted for, one can see a trend of an increase in alkalinity and a decrease in nitrate and CBOD, indicators of denitrification. More specifically, if the effluent CBOD is 5 mg/L and the influent CBOD is 200 mg/L and the recirculation ratio is 7:1, one would project a concentration of $(5*7 + 200)/8$ or 29 mg/L if no biological action occurs. The following figures show trends that indicate that nitrogen removal is occurring in the recirculation tank except during the period when the recirculation ratio was exceptionally high and denitrification was minimized.

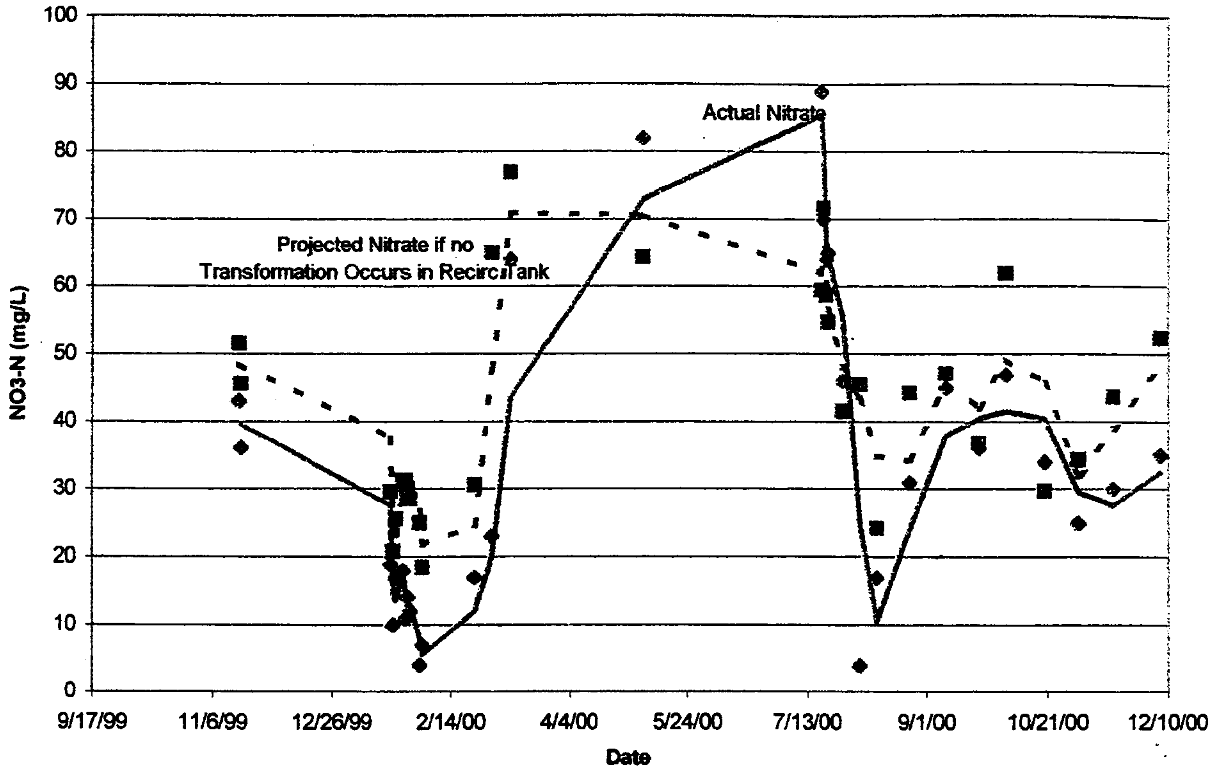

Figure 8. Comparison of the laboratory measured nitrate concentration in the recirculation tank with nitrate concentration projected assuming no biological action occurs. (Projection is calculated using recirculation tank influents and estimated recirculation ratios.)

Similarly the following figure shows that alkalinity concentrations tend to increase in the recirculation tank except during the period of very high recirculation rates, a sign that denitrification is occurring in the recirculation tank.

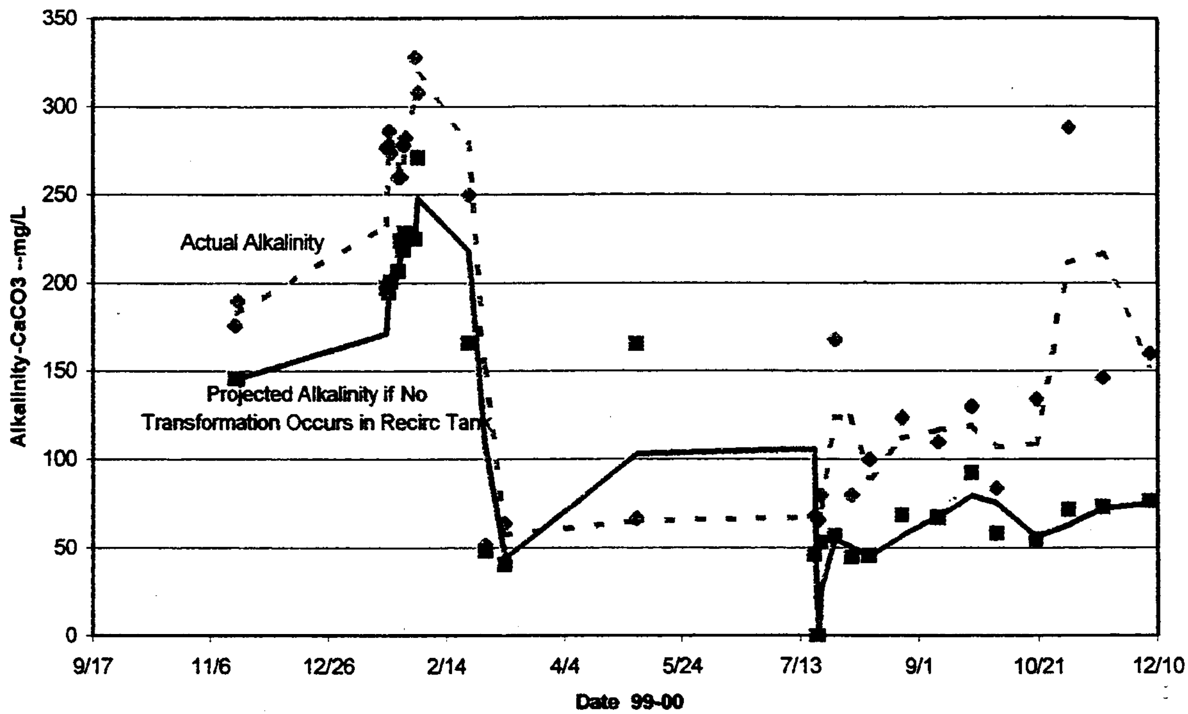

Figure 9. Comparison of the laboratory measured alkalinity concentration in the recirculation tank with alkalinity concentration projected assuming no biological action occurs. (Projection is calculated using recirculation tank influents and estimated recirculation ratios.)

The next figure shows the concentration of nitrite at the different sampling locations. Although not conclusive the increased levels of nitrite give another indicator that incomplete denitrification and perhaps incomplete nitrification is occurring. There is a particular indication of elevated quantities of nitrite immediately after the media was introduced into the tank.

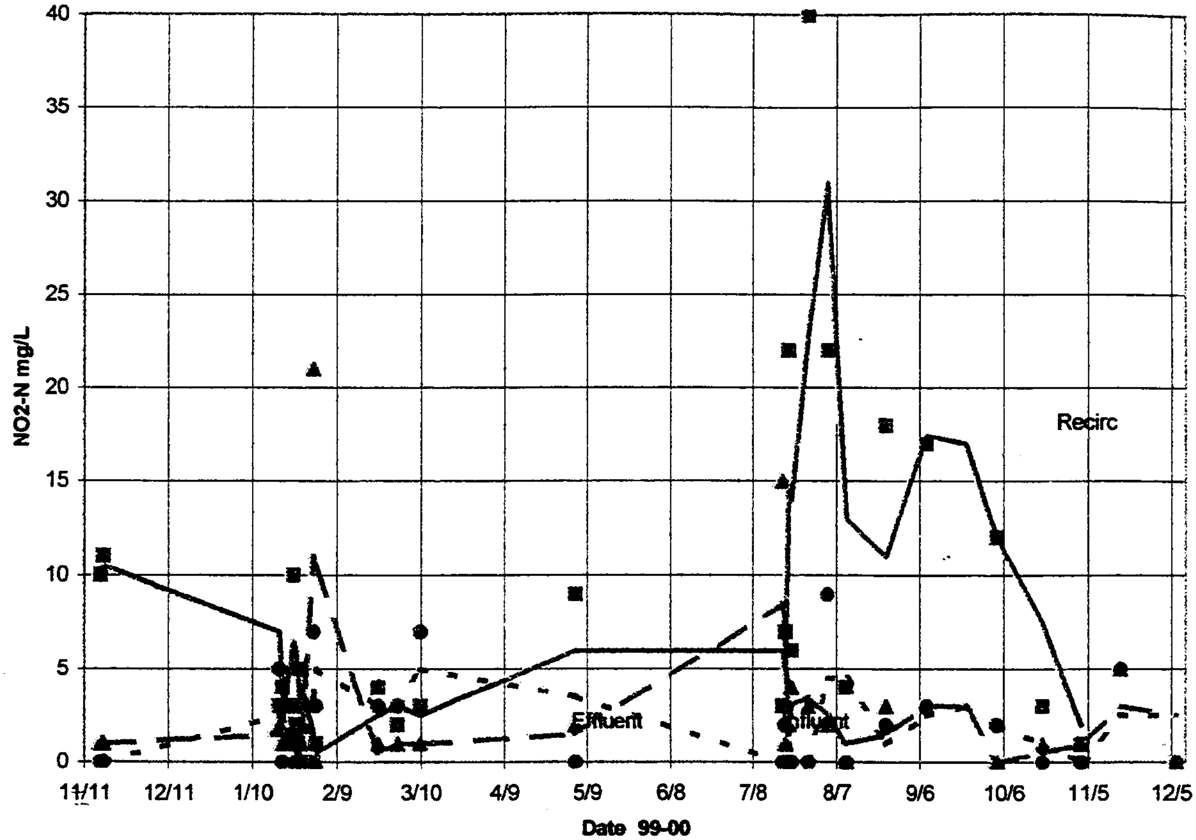

Figure 10. Comparison of Lab Measured Nitrite in Recirculation Tank Influent, Recirculation Tank and Sand Filter Effluent Samples, Giles County Welcome Center WWTP

During the study media samples were collected from the recirculation tank for kinectic studies to show the presence of denitrification bacteria. Preliminary data suggests that denitrifying organisms are present on the media. When complete this data will be presented separately.

Aerobic Removal of CBOD

As described in the paragraphs above, the aerobic removal of CBOD occurs in the recirculation tank due to the increase in oxygen concentration while the wastewater is in the sand filter. The quantity of oxygen recirculated into the recirculation tank increases as the recirculation ratio increases. This addition of oxygen into the recirculation tank needs to be minimized as much as possible so that nitrate is used as the electron donor by denitrifiers rather than the preferential use of oxygen as an electron donor by heterotrophic bacteria.

The following figure shows the projected and actual quantities of CBOD in the recirculation tank and indicates that CBOD removal does occur there.

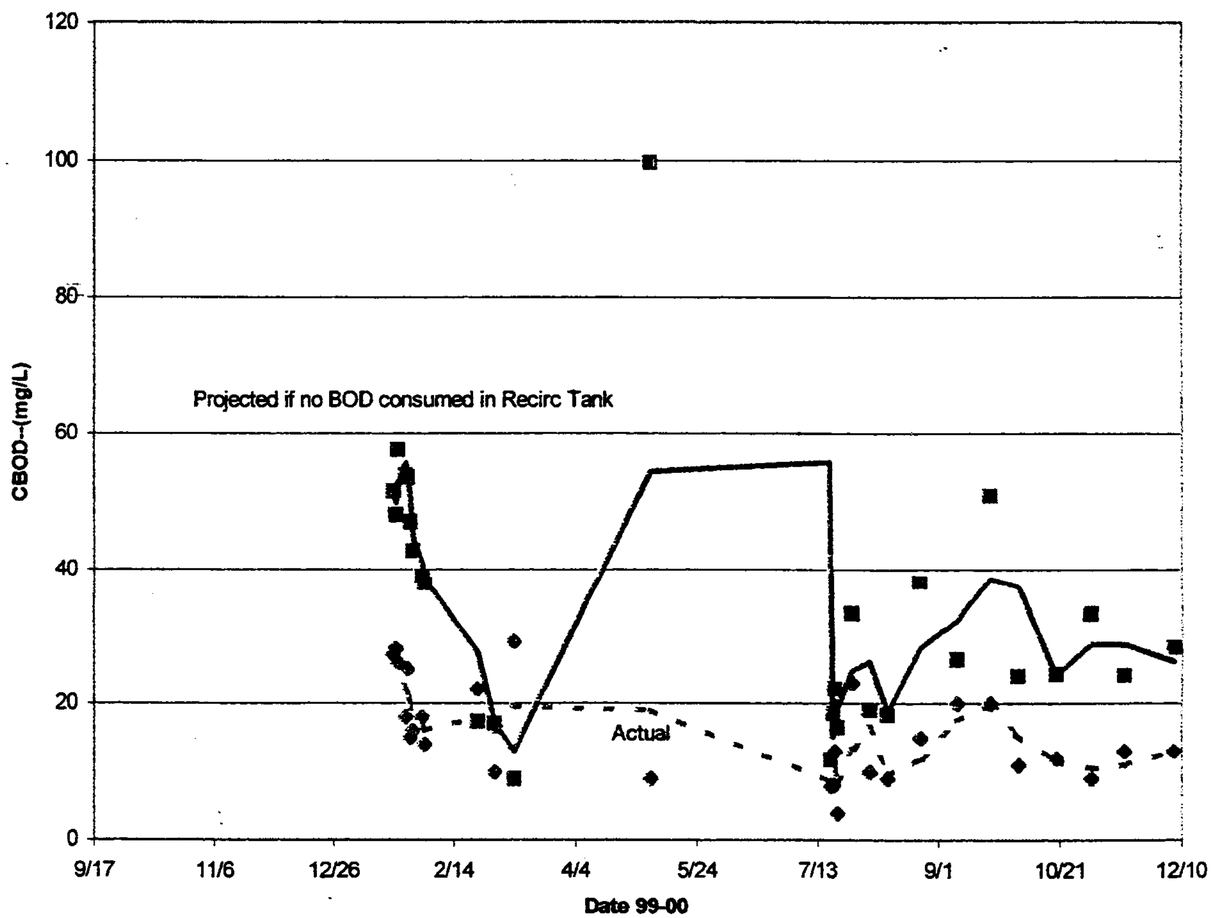

Figure 11. Comparison of the laboratory measured alkalinity concentration in the recirculation tank with alkalinity concentration projected assuming no biological action occurs. (Projection is calculated using recirculation tank influents and estimated recirculation ratios.)

Nitrification

Conditions are favorable for nitrifying bacteria in the recirculation tank of as high as 0.21 because the ratio of BOD_5 to TKN is approximately 1 in the recirculation tank and the plant effluent typically has an oxygen concentration of 5 mg/L, and all other conditions are within an acceptable range (Metcalf & Eddy, 0. 697). Figure 12 shows the actual and projected quantities of ammonia in the recirculation tank. There is no clear trend and typically the two quantities are very close. This data seems to indicate that nitrification is not occurring or is occurring minimally in the recirculation tank.

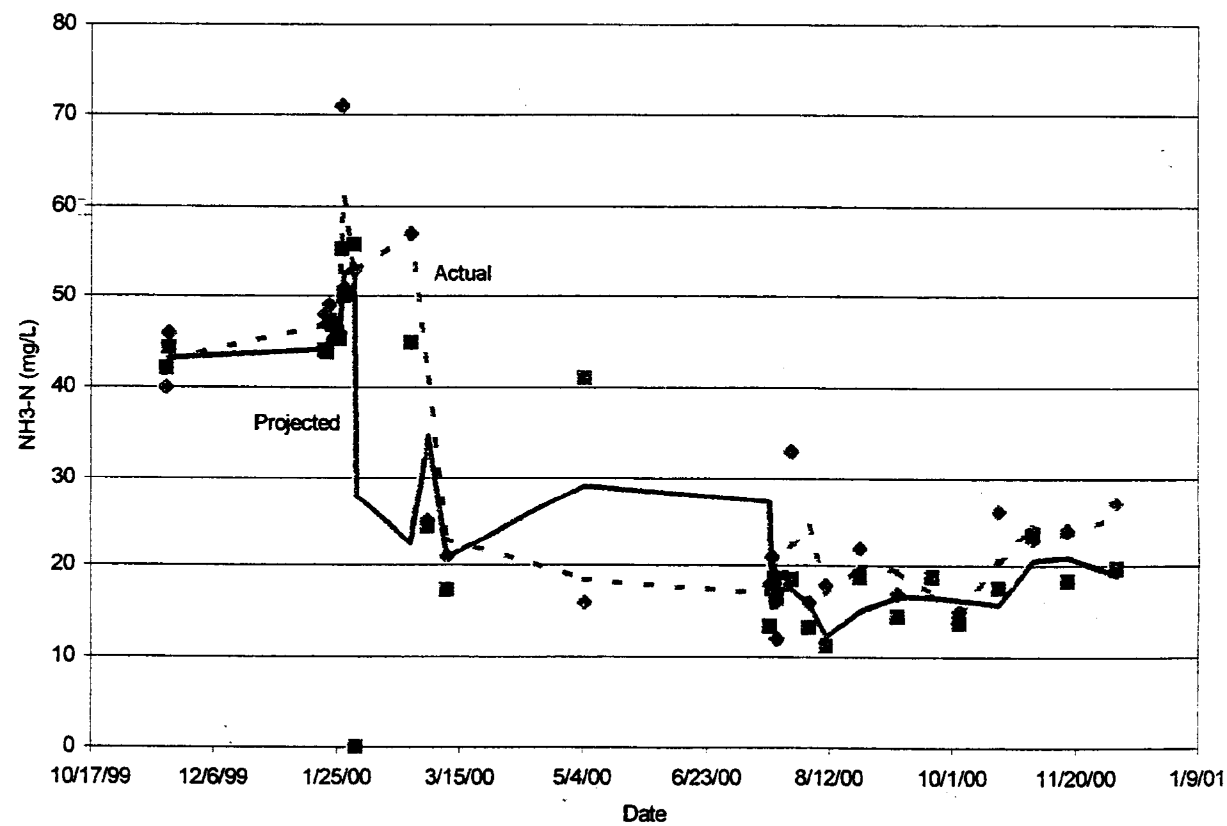

Figure 12. Comparison of the laboratory measured ammonia concentration in the recirculation tank with ammonia concentration projected assuming no biological action occurs. (Projection is calculated using recirculation tank influents and estimated recirculation ratios.)

Plant Effluent

The NPDES plant effluent requirements are as follows:

BOD_5 30 mg/L monthly avg.

D. O. 1.0 mg/L

Total Suspended Solids 30 mg/L

Fecal Coliform 1000/100 ml/L

Settleable Solids 1.0 ml/L

pH 6.0-9.0

Of interest in our study are the CBOD, D. O. and pH requirements. The CBOD requirement is easily met with the recirculating sand filter plant, as are the D. O. requirements. The pH requirement can be met unless the available alkalinity is inadequate for complete nitrification concurrent with diminished denitrification. The pH can also be controlled by the daily addition of lime to the septic tank.

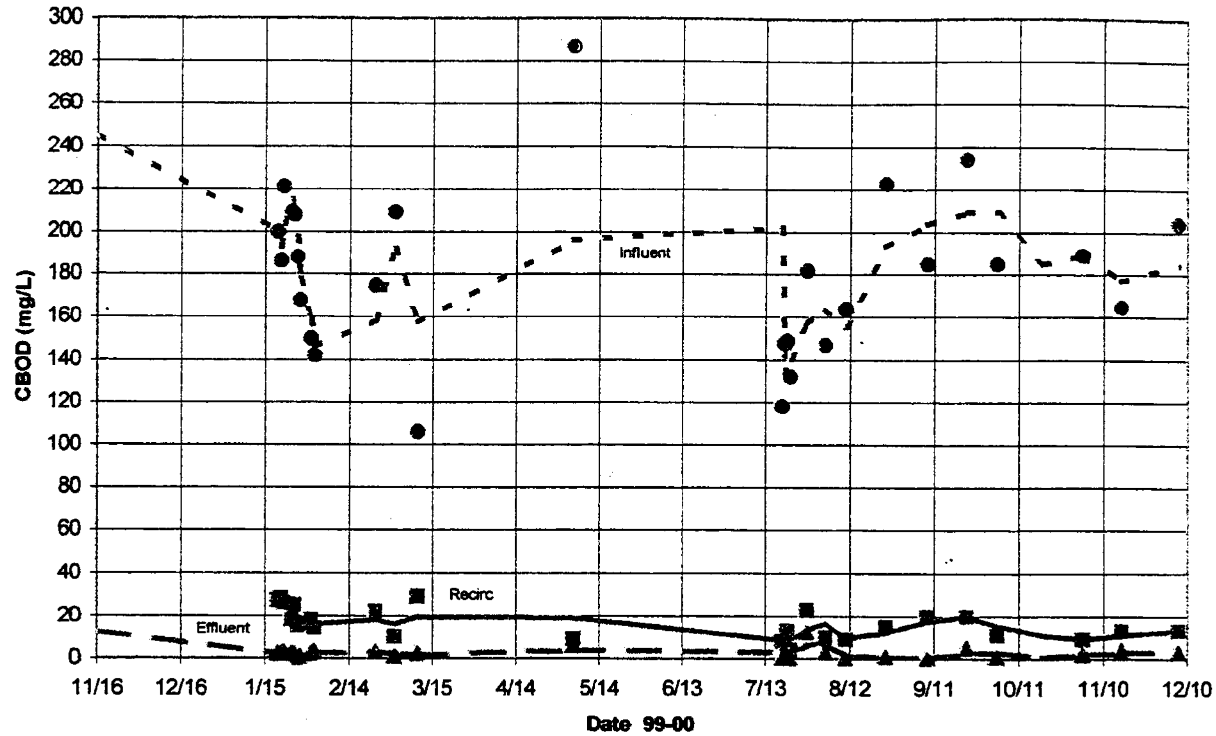

Figure 13. Comparison of Lab Measured CBOD in Recirculation Tank Influent, Recirculation Tank and Sand Filter Effluent Samples, Giles County Welcome Center WWTP

Conclusions

The main goal in this study was to promote the removal of CBOD in the recirculation tank by providing an environment conducive to denitrification and this has been accomplished. Denitrification is occurring in the recirculation tank and therefore CBOD removal does occur primarily in the recirculation tank. Additionally, evaluating the increased capacity of the sand filter is desired, but has not been accomplished and requires further analysis.

The secondary goal of the study was to increase the rate of total nitrogen removal by providing an environment conducive to denitrification. Denitrification in this process scheme is limited by CBOD concentration. There is a theoretical CBOD need of 480 mg/L for complete denitrification. In other words more carbon is needed for increased denitrification level, but increasing the concentration of CBOD is counter productive to achieving our primary purpose of CBOD removal.

A serendipitous conclusion involves increasing the recirculation ratio. Nitrification is enhanced, while denitrification is sacrificed when influent alkalinity levels are not high enough for complete nitrification. A possible explanation for this is the lowering of pH and CBOD concentration in the recirculation tank resulting from the changed proportion of plant influent and plant effluent.

These conclusions bode well for the possibility of decreasing the size of the sand filter. Further study is necessary to determine the size of the sand filter needed for nitrification only.

Recommendations for Future Study

1. Decrease the recirculation ratio while maintaining an ammonia concentration in the effluent of less than 10 mg/L. This will decrease the quantity of oxygen and increase the concentration of CBOD in the recirculation tank as well as increasing the pH slightly, promoting denitrification. Time for reaching equilibrium should be allowed after this step before any additional changes are made.

2. Gradually increase the alkalinity in the influent stream by increasing the daily quantity of lime addition, if needed. This will maximize nitrification in the sand filter and also maximize pH for denitrification where the splitter box effluent and plant influent pipe enter the recirculation tank.

3. Decrease the area of sand filter used by refraining from using one of the pumps while maintaining CBOD and ammonia effluent quality. This will show whether or not a smaller sand filter can achieve the desired effluent results.

4. Observe the process during winter periods when the tank temperatures are lower than 12 ° Centigrade to see if trends of lower nitrification and denitrification rates are detectable.

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Kati Young and Bill Hamilton, Ph. D. students at Vanderbilt University, directed sample analysis and served as advisors.

Barge, Waggoner, Sumner and Cannon, Inc., my employer, allowed me the flexibility to complete the project and provided financial support. My colleague, George Garden, Senior Engineer who pioneered the design of RSF's in Tennessee, served as advisor and encourager;

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Flygt Mixers donated the mixer.

SOS, Inc. provided a partial donation of equipment.

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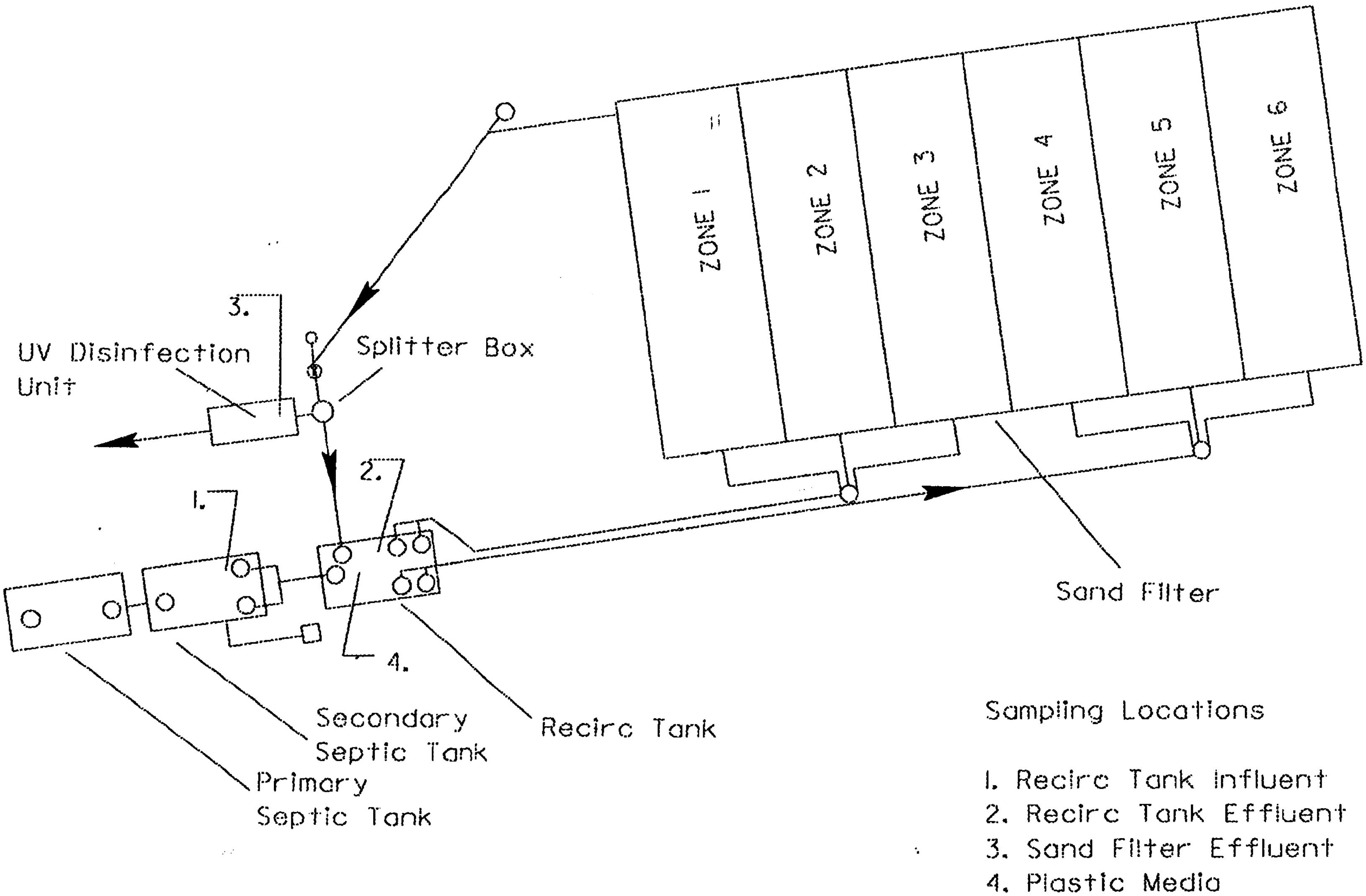
Rittman, B. E. and McCarty, P. L. 2000. *Environmental Biotechnology*, McGraw Hill

APPENDICES

Appendix A. Wastewater Treatment System Drawings

Site Layout

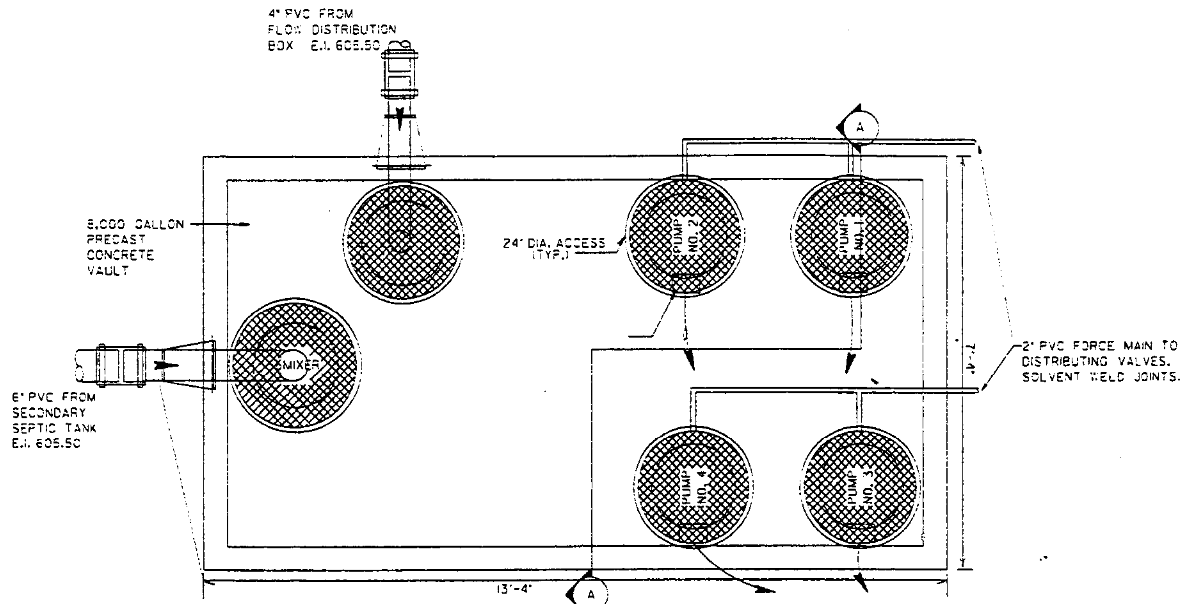
Figure A-1, Site Layout



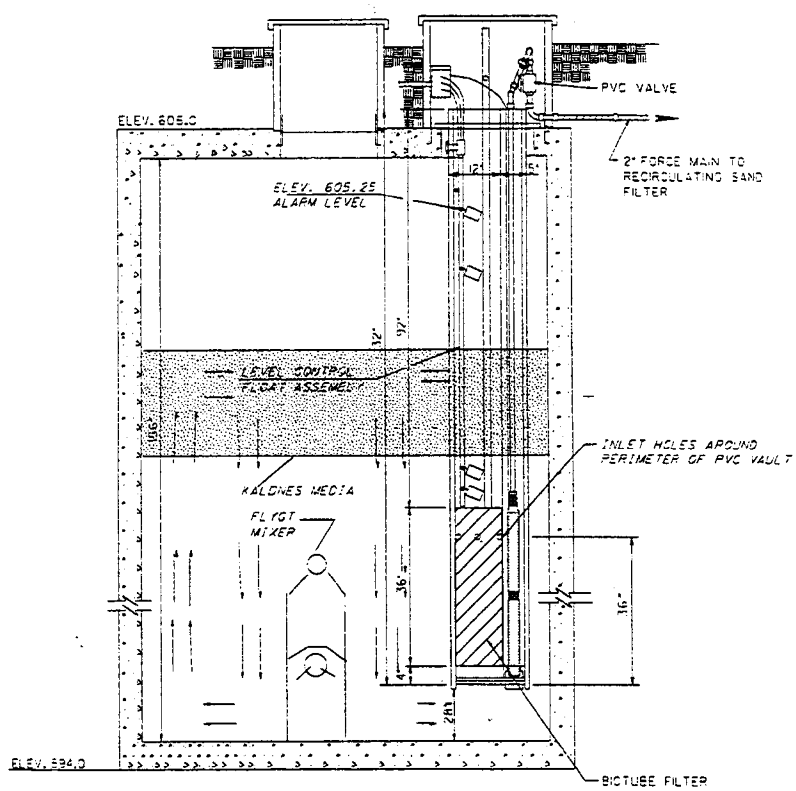
SITE LAYOUT
WASTE WATER TREATMENT SYSTEM
GILES COUNTY WELCOME CENTER
ARDMORE, TN

Recirculation Tank Modifications

Figure A-2, Recirculation Tank Modifications



RECIRCULATION TANK PLAN



RECIRCULATION TANK ELEVATION

A

SCALE: 3/4" = 1'-0"

WASTEWATER
RECIRCULATION
TANK

I-65 NORTHBOUND WELCOME CENTER
GILES COUNTY, TENNESSEE

...\1585051\giles\sheet07.dgn Dec. 08, 2000 13:21:48

Flygt Mixer

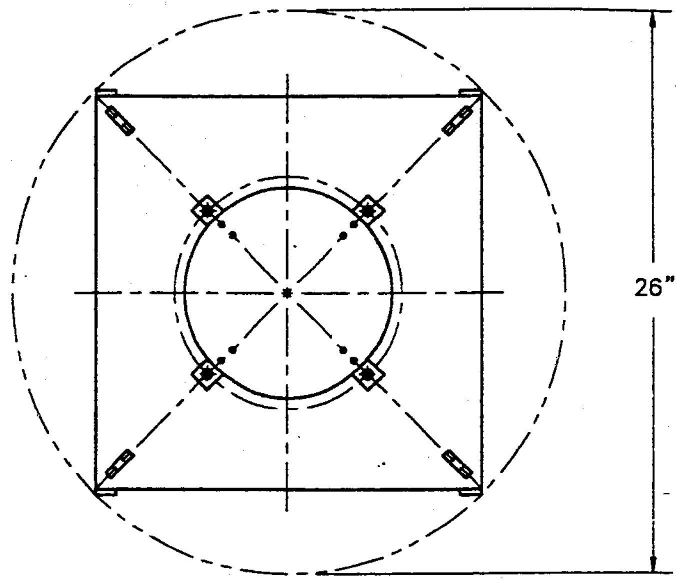
Figure A-3. Drawing of 4630/4640 Flygt Mixer

4630/4640 Porta-Cleanse

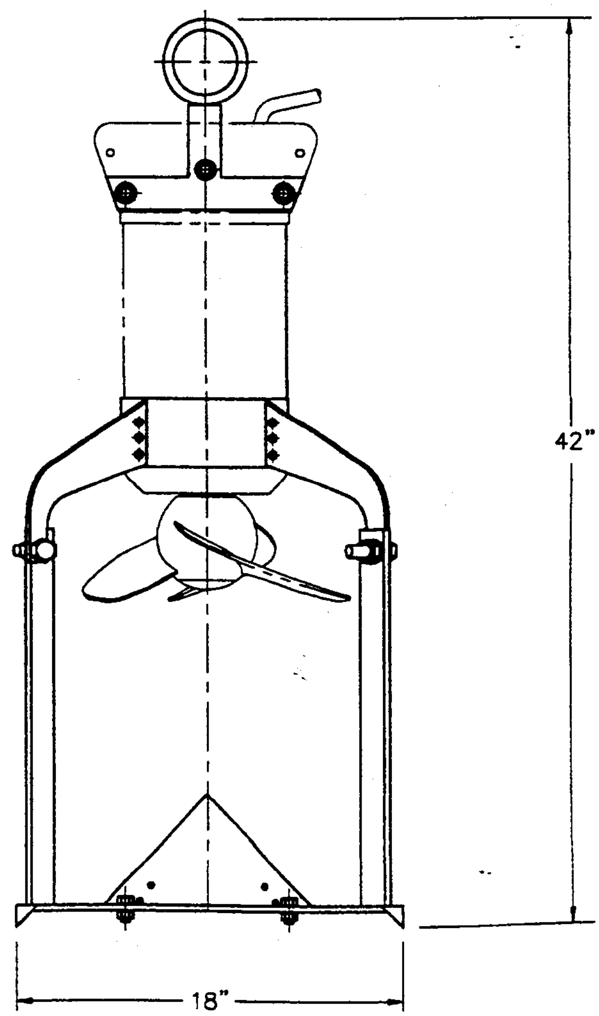
Mastless Mixer Stand

14-58 79 32 316 stainless steel

14-58 79 33 galv.steel



MIXER MODEL	BLADE ANGLE	INPUT (KW)	MAX. LIQUID TEMP.
4630.083704SF	4°	2.00	195°
4640.083704SF	4°	2.05	195°
4640.083705SF	5°	2.30	195°
4640.083706SF	6°	2.55	195°
4640.083707SF	7°	2.80	195°
4640.083709SF	9°	3.30	195°



NOTES:

1. ABOVE SELECTIONS CARRY 1.15 SERVICE FACTOR.
2. THE REMOVAL OF THE JET RING RESTRICTS BLADE ANGLE OPTIONS TO THOSE NOTED ABOVE.

Appendix B. Data Tables

Sample Data Summary

Table B-1: Sample Data Summary

Giles County Welcome Center
Sample Data

I = Influent to Recirc Tank
R = Recirc Tank
E = Plant Effluent

Date	Year	Event	Temp Influent	Temp Recirc	Temp Effluent	pH Influent	pH Recirc	pH Effluent	Alk Influent	Alk Recirc	Alk Effluent	Ammonia Influent	Ammonia Recirc	Ammonia Effluent	Nitrate Influent	Nitrate Recirc	Nitrate Effluent	Nitrite Influent	Nitrite Recirc	Nitrite Effluent	NSUM Influent	NSUM Recirc	NSUM Effluent	NTOT Influent	NTOT Recirc	NTOT Effluent	BOD Influent	BOD Recirc	BOD Effluent	NSUM Denite	NTOT Denite	Recirc Ratio
1/23	1998	Historic Data	13		12	6.9		6.3			72	127		3			90.3				127		93.3				310		0	27%		
2/19			12		12	7.42		6.27	527		37	120		2.4			122				120		124.4				220		7	-4%		
2/21			12		12	7.55		6.4	553		50	113		6.2			137				113		143.2				226		5	-27%		
3/19									476		16	120		7.6			70				120		77.6				220		5	35%		
4/17			17		18	7		6.3	455		64	105		14.5			62				105		76.5				245		12	27%		
11/16	1999	Baseline Data	21	20.8	21.4				496	176	29	120	40	16	5	43	67	0	10	1	125	93	84							33%		3
11/17									480	190	34	123	46	18	5	36	59	0	11	1	128	93	78							39%		3
1/19	2000		13	13.8	13.1	7.1	6.8	6.1	549	277	80	119	48	19	1	19	39	5	3	2	125	70	60	137	90	74	200	27	2	52%	46%	3
1/20			14	14.1	13	6.9	7	6.6	512	286	89	121	47	18	2	10	27	0	4	1	123	61	46	140	79	63	186	28	2	63%	55%	3
1/21			13	13.4	13.1		7.3	6.7	520	274	94	126	49	21	6	17	32	3	3	1	135	69	54	121	70	57	221	26	3	60%	53%	3
1/24			13	12.5	11.9	7	6.8	6.4	544	260	94	118	46	22	2	18	41	1	10	3	121	74	66	133	83	79	209	18	2	45%	41%	3
1/25			12	12.5	12.2	6.7	7.5	7.6	560	260	112	115	46	22	5	11	40	0	2	0	120	59	62	137	94	73	208	25	2	48%	47%	3
1/26			12	12.8	13.1	6.2	7	7.1	580	278	98	119	71	34	6	14	38	0	5	1	125	90	73	133	84	80	188	15	0	42%	40%	3
1/27			12	12.5	12.8	6.3	7.1	7.2	572	282	114	125	51	25	6	12	36	0	3	1	131	66	62	135	77	73	168	16	1	53%	46%	3
1/31			12	12.4	12.4	6.4	7.1	7.2	600	328	100	121	53	34	4	4	32	7	0	21	132	57	87	121	72	68	150	18	2	34%	44%	3
2/1			12	11.9	12.5	6.4	7.1	7.2	605	308	160				5	7	23	3	1	0				128	68	65	142	14	3		49%	3
2/23		Recirc Ratio Up	15	14.8	14.1	7.7	7.4	6.9	505	250	135	110	57	39	4	17	33	3	4	1	116	78	73	148	96	87	175	22	3	37%	41%	11
3/1			16	15.8	15.8	7.6	6.7	6	505	52	10	101	25	18	5	23	70	3	2	1	109	51	89	116	103	101	209	10	1	18%	13%	12
3/9			19	19.9	20.4	7.4	6.7	5.7	496	64	8	92	21	12	6	64	82	7	3	1	105	86	94	108	88	91	106	29	2	10%	16%	14
5/4		Recirc Ratio Down				6.6	6	4.3	490	67	3	109	16	7	3	82	95	0	9	2	112	107	103	119	96	97	287	9	6	8%	16%	2
7/18						7.2	6.3	3.5	464	68	0	107	18	3	0	89	66	0	3	15	107	110	83	128	128	95	118	8	0	22%	26%	9
7/19												105	21	5	0	70	82	2	7	1	107	98	88	111	89	91	148	8	0	16%	18%	7
7/20							6.3	3.9		66	0	121	19	4	0	64	67	0	22	2	121	104	73	105	96	82	149	13	4	40%	22%	7
7/21		Media Added				7	6.4	3.6	428	80	0	110	12	3	3	65	62	0	6	4	113	83	69	112	81	86	132	4	0	39%	23%	7
7/27			30	29.7	30	7	6.8	4.6	456	168	0	99	33	7	3	46	47	0	40	3	102	119	57	98	81	69	182	23	12	44%	30%	7
8/3			28	29.2	29.1	6.4	6.2	4	404	80	0	95	16	3	9	4	50	9	22	2	113	42	55		90	81	147	10	3	51%		6
8/10			30	30.6	29.1	6.6	6.2	3.6	412	100	0	93	18	1	2	17	27	0	4	0	95	39	28	101	65	76	164	9	0	71%	25%	8
8/24			30	30.7	30.1	6.6	6.6	4	412	124	0	108	22	1	0	31	53	2	18	3	110	71	57	103	65	63	223	15	1	48%	39%	5
9/6		Media Reduced	29	29.7	29.4	6.6	6.4	4.6	440	110	5	101	17	0	6	45	54	3	17	3	110	79	57	119	65	68	185	20	0	46%	43%	6
9/22			27	29.4	27.8	6.7	6.6	5	430	130	8	94			4	36	45										234	20	5			4
10/3			25	25.2	25.4	7.1	6.4	3.2	468	64	0	103	15	1	5	47	70	2	12	0	110	74	71	96	64	66	185	11	1	35%	31%	7
10/19			25	24	24.2	7	6.7	3.1	440	134	0	113	26	4	7	34	33	0	3	1	120	63	38	115	66	66				68%	43%	7
11/2		Begin Lime Addition	24	24.8	24.6	7.4	6.8	4.9	420	288	2	96	23	9	6	25	40	0	1	1	102	49	50	96	52	72	189	9	2	51%	25%	5
11/16			19	16.8	18.5	7	6.9	5.8	460	146	18	98	24	7	6	30	49	5	14	5	109	66	62	110	89	82	165	13	4	43%	25%	7
12/6			16	16	15.3	6.9	6.8	6	428	160	26	95	27	9	13	35	58	0	4	0	108	66	67	134	95	110	204	13	3	38%	18%	7
		Average	19	20	19				490			110				34					116			119			190					

Table 1

Appendix C. Additional Figures

Recirculation Ratio

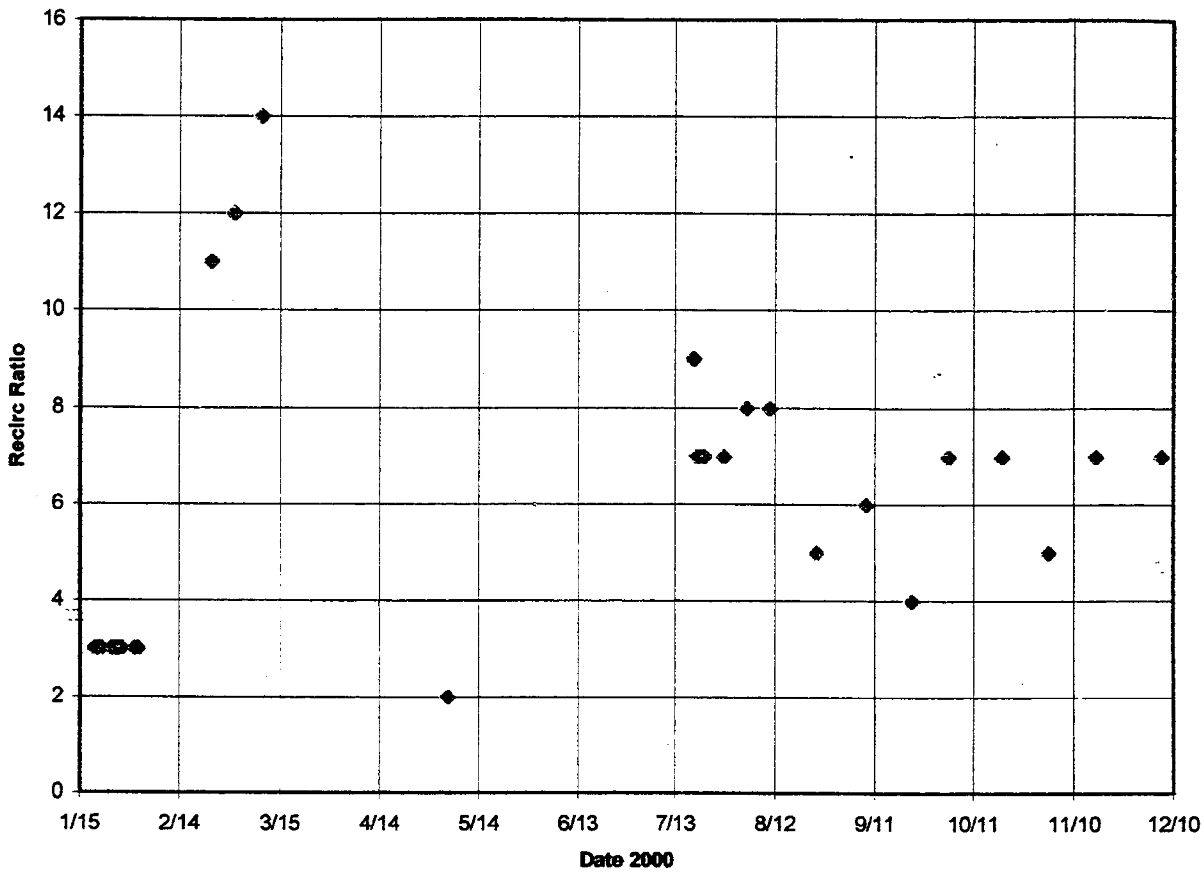


Figure C-1. Recirculation Ratio

Titration of Plant Effluent with 0.01 N NaOH

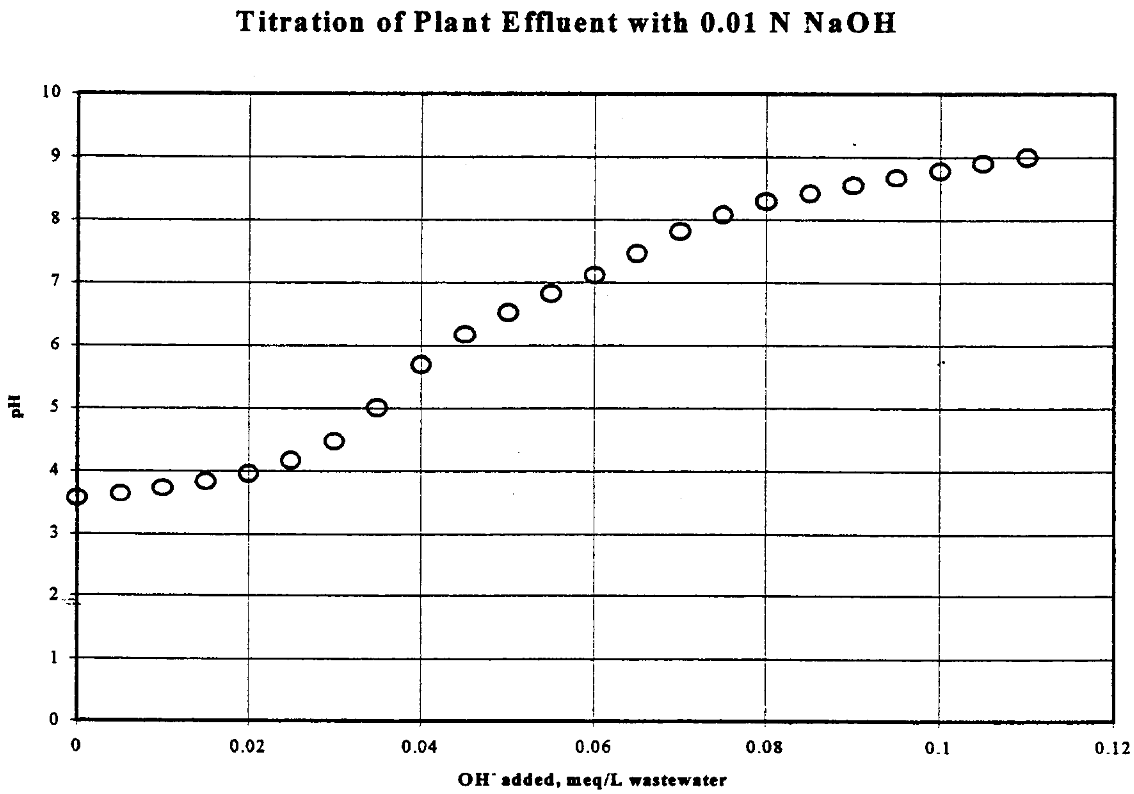


Figure C-2. Titration Curve for Plant Effluent Sample