EKOKAN BIOFILTRATION TECHNOLOGY PERFORMANCE VERIFICATION

REPORT FOR

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Designee for Environmental Superior Technology Determinations for the agreement between N. C. Attorney General and Smithfield Foods/Premium Standard Farms/Frontline Farmers

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May 24, 2004

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SUMMARY

Ekokan® Biofiltration Treatment System was one of the projects selected for demonstration and evaluation as a potential Environmentally Superior Technology for swine manure management under an agreement between the North Carolina Attorney General and Smithfield Foods/Premium Standard Farms/Frontline Farmers. The main objective of the technology performance verification was to determine waste treatment performance in terms of partition, conversion or removal of solids and organic matter, nutrients (nitrogen, phosphorus and potassium), and metals (e.g., copper and zinc).

The Ekokan ® LLC waste treatment system was constructed in 2002 and consisted of solids/liquid separation and biofiltration of the liquid with upflow aerated biological filters which contained fixed media. Two 45 kW (60 Hp) blowers furnished air at the bottom of the biofilters. Five finishing barns (about 4,300 finishing pigs total) were connected to the waste treatment system, and the barn pits were emptied automatically in sequence. Approximately six pits were emptied each day at normal operation. The pit discharge flowed through the solids/liquid separation basin, was then pumped to an equalization tank, and then gravity flowed through four biofilters (two series of two-stage biofilters). The treated effluent from the biofilters flowed by gravity to a storage cell which supplied liquid for pit recharge, and about half of the effluent was recirculated to the equalization tank. The biofilters also had periodic cleaning by air agitation and some liquid release (backwash), and the covered biofilters had pipes connected to the top to remove foam. The original anaerobic lagoon (for 8,000 pigs) was partitioned with plastic curtains to make three sections for: (1) anaerobic treatment of manure from 4000 pigs, (2) receiving biofilter “backwash” and separated solids, and (3) receiving biofilter effluent.

Acclimation of the system with diluted lagoon liquid began August 14, 2002. Performance data is presented for the period August 14, 2002 through June 30, 2003, at which time the system operation was terminated due to lack of additional operation funds. Due to various factors the loading from August 14, 2002 through January 5, 2003 was mainly with lagoon liquid and recirculated biofilter effluent, and lower than the design loading rate. Although the nitrite plus nitrate nitrogen concentrations were sometimes over 200 mg/L (an indication of nitrification), the performance of the system was variable during this period. The technology provider reported that they requested to use bacterial “seeding” to acclimate and start up the system, but the farm owner denied the request because of biosecurity concerns. The start up performance may have been impacted by the lack of bacterial seeding. Loading with pit releases and recirculated effluent occurred from January 6, 2003 through June 30, 2003. The performance and operation of the system was also variable during this period, but was usually loaded at design rates or higher.

The reductions in concentrations through the biofilters for the last three months of performance evaluation were generally lower than the reductions previously reported for a pilot-scale system during a similar period (April – May, 1998) with loading of 5.2 kg COD/m^3 – d (Westerman et al., 2000). The reductions in concentrations through the biofilters for April – June 2003 were generally in the indicated ranges: total ammoniacal nitrogen (TAN) 90 - 98 %, total nitrogen (TN) 10 – 20%,

suspended solids 20 – 50 %, Chemical Oxygen Demand (COD) 20 – 40 %, Biochemical Oxygen Demand (5-d) (BOD5) 40 – 70 %. Approximately 60 – 90 % of the ammonia reduction occurred in the first stage biofilters. Nitrite plus nitrate nitrogen in the effluent was 170 to 300 mg/L.

Overall, the aerated biofilters demonstrated potential for greater than 90 % reduction of ammonia in spring season, resulting in relatively high concentrations of nitrite plus nitrate nitrogen in biofilter effluent. The overall reduction of total nitrogen concentration during spring season was about 10 – 20 %. Generally, biofilter performance would be expected to improve with higher temperature and decrease with lower temperature. Continuous aeration of the biofilters resulted in an energy use of about 2,100 kWh/d.

A mass balance on each series of biofilters was estimated for six dates in the last three months of evaluation. Usually about 20 to 30% of the input mass of the various parameters was recovered in the backwash from the first stage biofilters, and about 5% was recovered from the second stage biofilters. The total solids content of the backwash varied but were usually about 0.5 to 1 %, and thus have potential for further dewatering and/or recirculation to the front of the treatment system. For the dates used in the mass balance, the B series retained more mass in the effluent (about 70% for total solids, suspended solids, total nitrogen and Chemical Oxygen Demand). This may be due to the higher loading rate to the B series. The unaccounted for mass of several parameters were 20 to 30%; this could be due to errors in flow due partially to variable storage in biofilters, errors in average concentration due to using grab samples of flows, not accounting for losses with foam, possible accumulation of some parameters within the biofilters, and possible denitrificaiton within the biofilters.

The TR solids/liquid separator used in the Ekokan system evaluation mainly separated coarse solids, and had relative small impact on Chemical Oxygen Demand or total solids loading of the biofilters. Some batch tests were conducted on six dates where the separated solids from a barn “flush” were collected, weighed and analyzed. Generally, the solids, nitrogen, phosphorus and other parameters that were analyzed for the separated solids represented a small percentage of the mass of those parameters that were input to the separator system from a barn pit “flush”, typically less than 5%. The coarse solids that were collected were about 15 - 25 % dry matter and could be land applied or blended in a compost operation.

The potential to perform on-site and off-site operational control and observe operational information by computer was demonstrated with this project. During the evaluation period, the technology provider also performed on-site inspection and operational supervision of the system, as well as data collection, almost every day. Maintenance and/or replacement of components during the evaluation period of this system included such items as the lift-station pump, float switches, and valves.

1.0 INTRODUCTION

Several technology evaluations have been conducted or are being conducted in North Carolina with swine manure under an agreement between the North Carolina Attorney General and Smithfield Foods/Premium Standard Farms/Frontline Farmers. Ekokan Biofiltration Treatment System was one of the projects selected for demonstration and evaluation in North Carolina based in part on previous success with a pilot scale evaluation at a North Carolina State University research farm (Westerman et al., 2000). The full-scale system was constructed in 2002 and acclimation of the system with diluted lagoon liquid began August 14, 2002. Performance data is presented for August 14, 2002 through June 30, 2003, at which time the system operation was terminated due to lack of operation funds. The objectives of the technology performance verification were to:

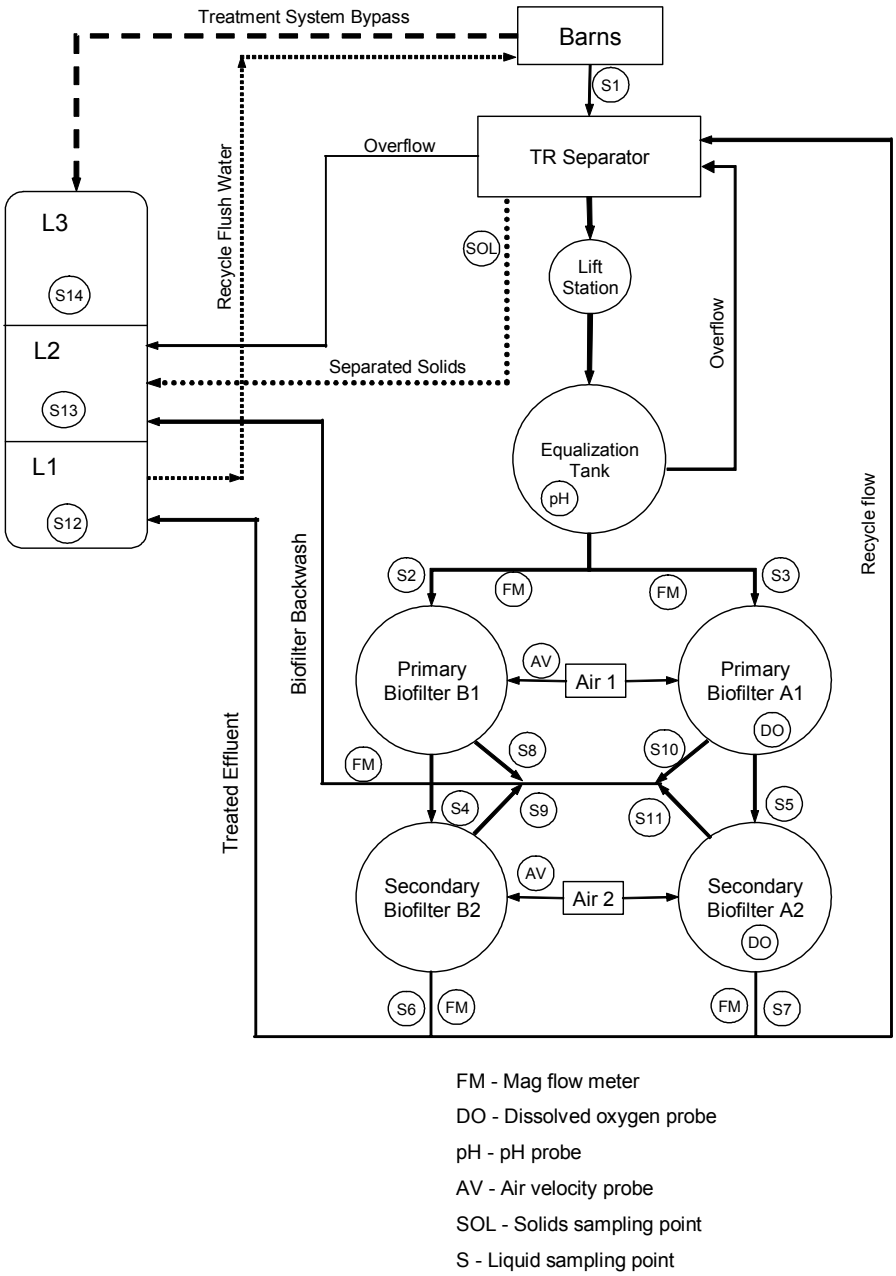
1. Determine waste treatment performance of the major components (solids/liquid separator and upflow biofiltration) in terms of partition, conversion or removal of solids and organic matter, nutrients (nitrogen, phosphorus and potassium), and metals (e.g., copper and zinc).
2. Document the operation and maintenance requirements of the system.

2.0 EKOKAN SYSTEM DESCRIPTION

The Ekokan ® LLC waste treatment system consists of solids/liquid separation and biofiltration of the liquid with upflow aerated biological filters. A picture of the system is shown in Figure 1 and a schematic diagram of material flow in Figure 2. Five finishing barns (about 4,300 finishing pigs total) are connected to the waste treatment system, and the barn pits are emptied automatically in sequence. It typically takes 60 to 90 min. to empty a barn pit, and about 3 hrs. to recharge the pit with about 76 m^3 (20,000 gal.) of recycled liquid. Thus, approximately six pits are emptied each day.

Wastewater from the barn pits is released to a solids separation unit. Coarse solids are separated from the wastewater by an inclined screen/conveyor separator (TR Separator). After the solids/liquid separation, the liquid flows by gravity to a lift station and is pumped (1.5 kW (2 hp pump)) to a 151 m^3 (40,000 gal.) equalization tank. Liquid flows from the equalization tank by gravity and passes through first-stage and second-stage aerated biofilters connected in series (two sets, or four biofilters in total), with each biofilter having 130 m^3 of plastic media in a 151 m^3 (40,000 gal.) tank. Plastic fixed media within the biofilters provides surface area for a biofilm of bacteria to perform biological degradation that results in reducing organics and odor, and conversion of ammonia to nitrate nitrogen (nitrification). Wastewater flows upward through the biofilters, and air is supplied at the bottom to provide a concurrent flow in each biofilter. Two 45 kW (60 hp) blowers provide the air. The biofilter tanks are covered, and the air and foam given off from the aerated treatment are routed through PVC pipes to exit points over the anaerobic lagoon. The time for liquid to flow through (liquid retention time) the two biofilters is less than 24 hours.

Figure 1. Ekokan Biofiltration treatment system treating manure from approximately 4300 finishing pigs.



FM - Mag flow meter

DO - Dissolved oxygen probe

pH - pH probe

AV - Air velocity probe

SOL - Solids sampling point

S - Liquid sampling point

Figure 2. Schematic of system (not to scale) and directions of material flow.

Biofilters are backwashed periodically to remove excess biosolids. A “backwash” consists of opening a valve for five minutes to release liquid from the bottom of the biofilter, with the first minute having normal aeration (1/2 of air from one 45 kW blower), and the next four minutes having twice the normal aeration (all of the air from one 45 kW blower). Treated effluent from the biofilters flow by gravity to a storage basin, which is a partitioned section (L1) of the pre-existing lagoon for storage. Liquid is pumped from the L1 section to the barns to refill the pits. Liquid recycled for flushing the barns should have lower ammonia content than typical anaerobic lagoon liquid normally used for flushing.

The flush system that is used for the five barns was changed from a pit-recharge to an “automatic” valve release flush system. The pit release valves and the recycle pump are connected to a control system, and are controlled by a computer. A barn empties and then refills before the next barn empties. The “backwash” sequence is also controlled by the computer. The first-stage biofilters are “backwashed” every six hours, while the second-stage biofilters are “backwashed” once per day. There are four flow meters, two D.O. meters, one pH meter, one water level recorder and two air velocity sensors “on line” continuously. All the meters and sensors are connected to a data acquisition system and can be accessed remotely. There is also an hour meter on the lift station pump that can be read manually.

On this farm, the anaerobic lagoon that received manure from ten barns was partitioned by plastic curtains into three sections (L1, L2, and L3), with one section (L3) much larger than the other two. Based on measurements taken on 6/25/03 when depth from the liquid surface to the lagoon bottom was near normal liquid depth of 2.5 m, the relative surface areas of L1, L2, and L3 were 12.5%, 16.4%, and 71.9% of total area, respectively (see Appendix F for more information). The L3 section received manure from five barns not connected to the EKOKAN treatment system. The L2 section received overflow from the solids separation basin, separated solids, backwashed biosolids removed from the biofilters, and foam from the 1st stage biofilters. The L1 section received the treated effluent from the biofilters and foam from the 2nd stage biofilters. Budget limitations resulted in the partitioning of the anaerobic lagoon to store separated solids, backwashed biosolids and treated effluent. A proposed alternative for handling the backwashed biosolids was to have another tank for settling solids by gravity, recycle the liquid to the treatment system and apply the biosolids to land or to a constructed drying bed that has reeds growing on it. The decanted liquid from the reed bed would be returned to the biofilter system. The separated solids from the liquid/solids separator could be land applied or composted.

The system design of the biofilters is based on loading rate of chemical oxygen demand to the 1st stage biofilters (6 kg COD/d-m^3 of biofilter media), and an aeration rate to produce adequate upward velocity in the biofilters to prevent them from clogging (25 m^3 of air per meter square of biofilter cross-section). A pilot scale demonstration/evaluation (Westerman et al., 2000) treating 8 m^3/d of supernate from settled flushed swine manure, operated at these conditions showed reductions under warm weather conditions (average about 27 °C) of 88 % of biochemical oxygen demand (BOD), 75 % of chemical oxygen demand (COD), 82 % of suspended solids (SS), 84 % of Total Kjeldahl Nitrogen (TKN), 94 % of total ammonia nitrogen (TAN), and 61 % of total nitrogen (TN). Operation during cold weather conditions (average of 10 °C) was about 50% to 70 % as effective depending upon the parameter being reduced. A mass balance indicated that about 30 % of the influent volume, 35 % of the TN, and 60 % of the total phosphorus (TP) were removed with the backwash.

3.0 TREATMENT EVALUATION PROCEDURES

The process for determination of Environmentally Superior Technologies (EST) under the N. C. Attorney General agreement includes procuring environmental performance and economic feasibility data. The environmental performance data consists of four main evaluations. One is the treatment effectiveness, which consists of taking flow measurements and other performance indicators (pH, dissolved oxygen (D.O.)) and taking samples of inputs and outputs of the treatment system in order to determine partitions and/or reductions for parameters such as nitrogen, phosphorus, copper, zinc and other parameters. The treatment effectiveness for the Ekokan system is the scope of this report. The other three environmental performance evaluations consists of measurements on pathogens (in liquid and solids as well as air measurements), odor (from liquid and solids as well as air measurements), and ammonia emission from various locations. These emissions measurements were conducted by "OPEN" group during two periods (March 31 to April 18, 2003, and June 16 to 27, 2003) and will be reported by the "OPEN" group in a separate report.

Treatment effectiveness in a biological treatment system such as the Ekokan biofiltration system, is expected to vary with temperature as shown in the Ekokan pilot-scale system evaluation (Westerman et al., 2000). Thus, biological systems do not maintain a true steady-state performance, but rather a "cyclic" performance with seasonal changes in temperature. Therefore, ideally an evaluation should include measurements during summer through winter seasons after the system has reached operational design conditions. Biological systems typically need an acclimation period to establish the microbes that perform the biological treatment. The establishment of microbes occurs more quickly during warm temperature and with "seeding" of microbes from another established biological treatment system or with commercial microbial additives. The acclimation period is typically 2-4 weeks for nitrification systems, but can vary due to the waste characteristics, the temperature, whether "seeding" is used, and other factors. With the Ekokan system, the acclimation of the system began with diluted lagoon liquid on August 14, 2002 without any "seeding" of bacteria due to biosecurity concerns of the farm. The evaluators expected the system to have a few weeks of acclimation before reaching the design loading rates of organic matter and nutrients. The evaluators planned to take measurements during the acclimation period (expected to be about one month), and continue measurements for about eleven more months to include winter and summer conditions. Measurements were taken August 14, 2002 when system start-up occurred through June 30, 2003, when the system operation was terminated due to lack of funds for operation.

Flow was recorded daily from four flow meters and also estimated from the pumping time and pumping rate of the pump in the lift station. There were two DO meters, one pH meter and one water level recorder and two air velocity sensors "on line" continuously (Figure 2). All the meters and sensors readings were recorded once a day on site by the Technology Provider who performed the daily system management. Also, all the meters and sensors were connected to a data acquisition system that could be accessed remotely.

The flow into and out of the biofilters were analyzed principally for COD, total ammonia nitrogen (TAN), nitrate+nitrite nitrogen (NO_{2+3}-N), nitrite N (NO_2-N), total solids (TS), volatile solids (VS), and suspended solids (SS). These analyses were usually done every one to two weeks. Other parameters were also measured at least once per month, such as total phosphorus (TP), copper (Cu) and zinc (Zn). Basically the same parameters were measured for the backwash liquid and the three partitioned sections of the pre-existing lagoon. Sample analyses were performed by the Environmental Analysis Laboratory, Biological and Agricultural Engineering Department, N.C. State University, except BOD was analyzed by TRITEST, Inc., a commercial laboratory in Raleigh, NC.

4.0 SYSTEM START-UP AND OPERATION

Construction of the system was completed in June 2002. Testing of the system in June 2002 resulted in excessive foaming from the uncovered biofilters, with foam overtopping the biofilters. Consequently, metal air-tight covers and foam discharge pipes were installed to control the foaming problem. On July 29, 2002 the state regulatory agency (Department of Environment and Natural Resources, DENR) gave permission for the system to operate. After some cleaning of the system, acclimation of the system began with diluted lagoon liquid (L1) on August 14, 2002, but without bacterial "seeding". By using L1 liquid and recirculating biofilter effluent to feed the biofilters, the NO_{2+3}–N concentration was over 200 mg/L in both biofilters by September 12, 2002 (Appendix A, Table A-5). Beginning October 9, 2002, some flushed manure was added in addition to the lagoon liquid for loading. The NO_{2+3}–N concentrations were variable for the next several weeks. On November 17, 2002, it appeared that liquid overflowed from the lift station between the solids/liquids separator and the equalization tank, which led to some modifications to prevent another occurrence. During the last part of November and during December 2002, a low level of loading was used to attempt to maintain some aerobic bacteria population. Ekokan resumed loading with flushed waste on January 6, 2003, and also recirculated a portion of the effluent from biofilters A2 and B2 with goal to reduce the concentration of the COD and TAN in the influent and maintain more flow between pit releases.

5.0 SYSTEM PERFORMANCE RESULTS

5.1 FLOWS, AERATION, AND COD LOADING

5.1.1 Flows into Biofilters

The daily flow rates into the system are presented in Figures 3 and 4. Figure 3 has total flow into the two 1st-stage biofilters. The flow meter for biofilter B1 had problems, and was not serviced until Feburary 25, 2003. Thus, flows from 8/14/02 to 2/25/03 were estimated from the operating time of the lift-station pump and assuming 0.757 m^3/min (200 gal./min.) flow rate. The times at which the lift-station operation "timer clock" were read varied from day to day, and "read" times were not recorded for the period 8/14/02 through 9/30/02. Thus, the estimated flows for this period are not corrected for times between readings for daily flow rate. Starting 10/1/02, the time of day when the readings were taken was recorded, thus the flows were corrected for 24-h daily flow using Equation 1. Starting 2/27/03, the flow meter readings were used for flow rates.

$$\text{Daily Flow Rate } ((m^3/d) = \frac{\text{Total metered flow } (m^3) \times 24 \text{ (h/d)}}{\text{Time between meter readings (h)}} \qquad (1)$$

The flows to the 1st -stage biofilters in total were usually between 500 and 1,000 m^3/d (Figure 3). Low flow or no flow sometimes occurred because of problems with the 1.5 kW lift-station pump, especially in spring of 2003. Flow during the periods 4/12 to 4/22 and 5/13 to 6/3 were lower due to using a 0.37 kW pump because of problems with the 1.5 kW pump. The lift-station pump was replaced with a new pump on 6/4/03. Flows into the A and B series of biofilters averaged 308 and 523 m^3/d, respectively, using the periods 2/26 to 4/11, 4/23 to 5/12, and 6/4 to 6/30 (Figure 4). The flow into the B1 biofilter was much higher than flow into the A1 biofilter, and could possibly be due to some blockage of the inlet in biofilter A1 by the support structure for the media, or simply the uneven distribution of the influent to both series of biofilters.

5.1.2 COD Loading Rates

The daily loading rates of COD expressed as kg COD/m^3 media were estimated for days when COD was analyzed for samples of biofilter input and there were also adequate flow readings from the flow meters. Data is shown in Figure 5 for Oct. 2002 through June 2003 for biofilter A1, and for March 2003 through

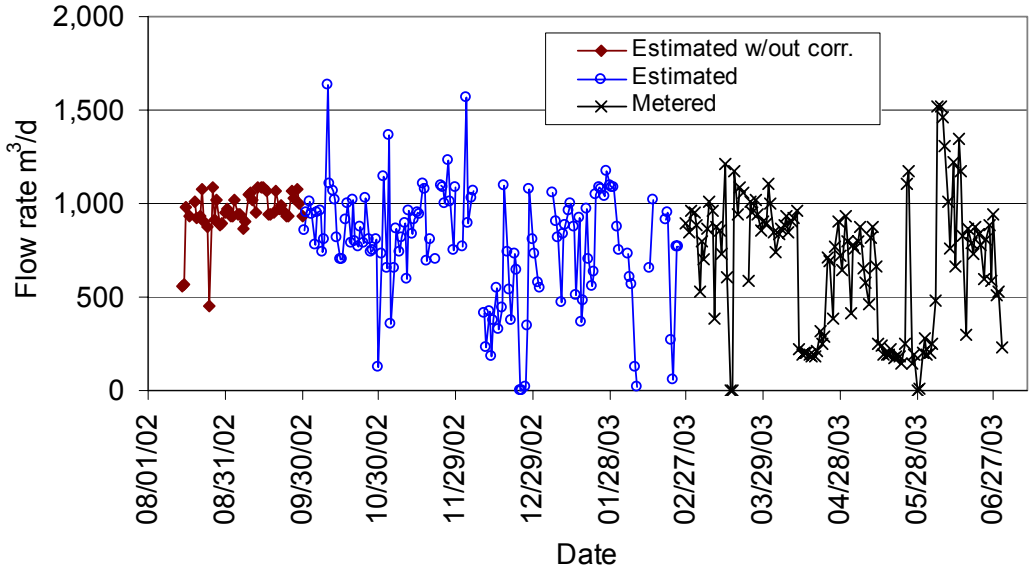


Figure 3. Flow rates into the biofilters. Includes barn flushes and various amounts of recirculated flow from biofilter effluent (typically about 50% recirculation of 2nd stage biofilter effluent after 1/6/03). For 8/14/02 – 2/25/03, flows were estimated from hours that lift-station pump operated; times that readings occurred varied from day to day and times were not recorded prior to 10/1/02.

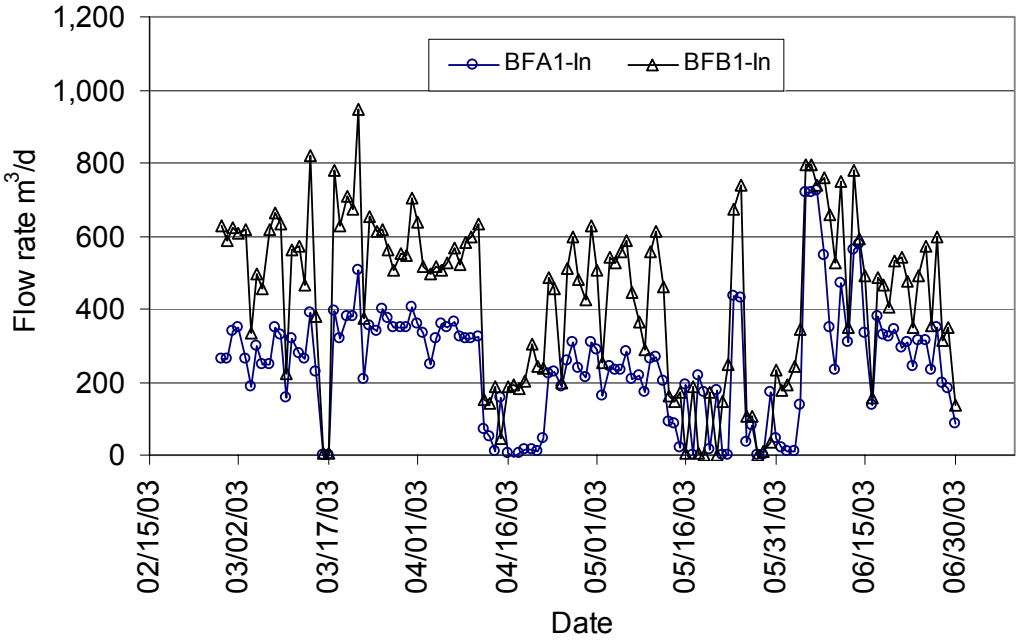


Figure 4. Flows into A1 and B1biofilters determined from flow meters. B1 typically had higher flow than A1, and cause of this difference is not known.

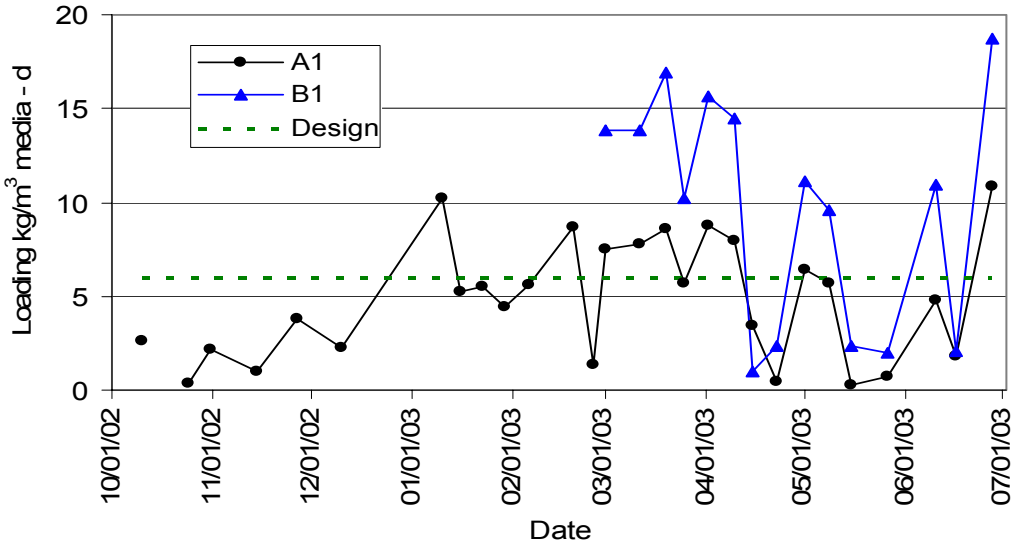


Figure 5. Daily COD loading (kg) per m^3 of media for biofilters A1 and B1.

June 2003 for biofilter B1 (data listed in Table A-1, Appendix A). The COD loading was variable. During the last four months of operation, the COD loadings for biofilters A1 and B1 were often 5 to 8 and 10 to 16 kg COD/m^3-d, respectively. Therefore, A1 was loaded near the design loading rate, but B1 was loaded at more than the design loading rate.

5.2 AIRFLOW AND DISSOLVED OXYGEN (D.O.)

Airflow to the four biofilters was continuous except during backwashes or operational problems. Velocity probes on air flow to biofilters B1 and B2 were used to estimate flow rates which were recorded daily (Figure 6). The sensor readout and calculation was limited to 28.3 m^3/min. (1000 ft^3/min.) until reset in early April 2003. Also, there is variability in the flow rates, especially for B2. The energy or power consumption at the site was relatively steady at about 2,110 kWh/d (Figure 7). Most of the power consumption was by the blowers. Therefore, much of the variability in the estimated air flow is likely due to instrument errors. The D.O. was also variable, varying between near zero and 12 mg/L (Figure 8). The D.O. probe was inserted over the top of the biofilter tank and the tank was sealed to prevent foam from escaping. Thus, it was not easy to access the probe and it was not serviced as often as needed. Some of the variability in D.O. is likely due to agitation of solids during backwashes. Overall, it is difficult to know the reliability of the D.O. readings.

5.3 TEMPERATURE AND pH

The pH was monitored in the equalization tank (EQ tank) and was normally between 8 and 9 (Figure 9). The temperature recorded by the pH probe is also shown in Figure 9, and reflects the seasonal variation over the range of about 10 °C to 30 °C. The temperature in biofilters A1 and A2 were also recorded by the D.O. probes and were normally close to that recorded in the EQ tank (Figure 10).

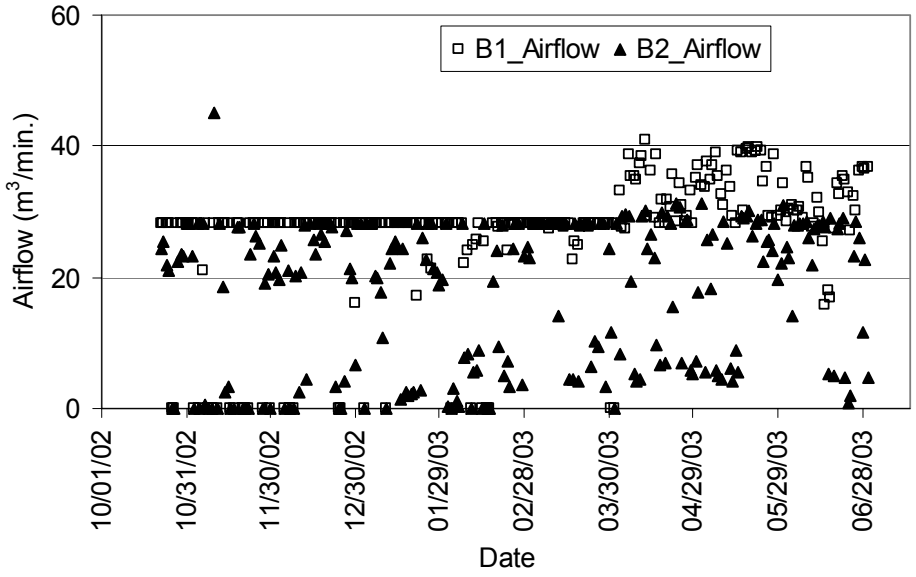


Figure 6. Airflow rates into the biofilters.

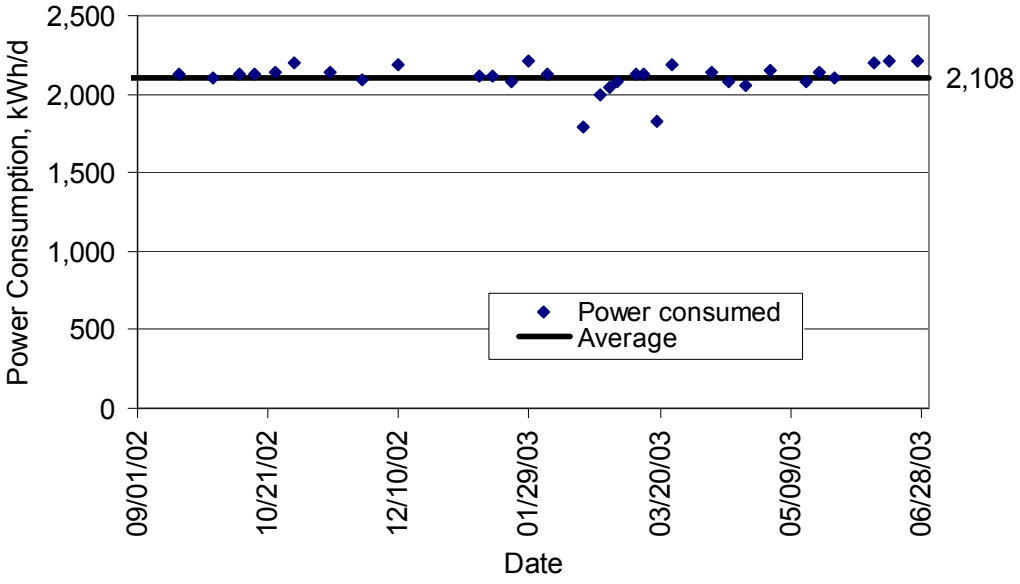


Figure 7. Power consumption.

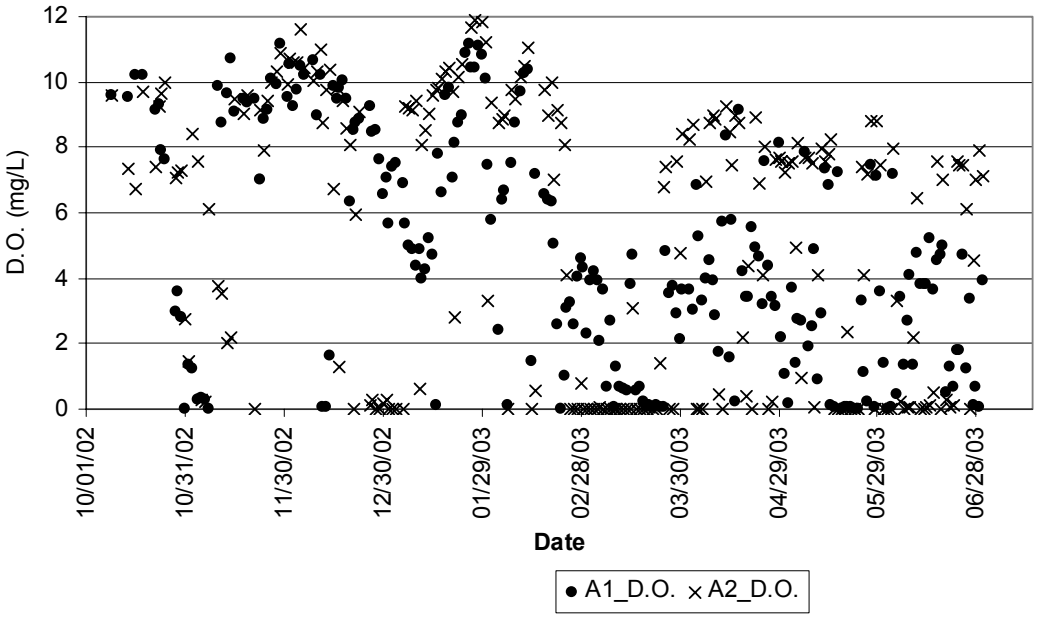


Figure 8. Daily dissolved oxygen concentrations.

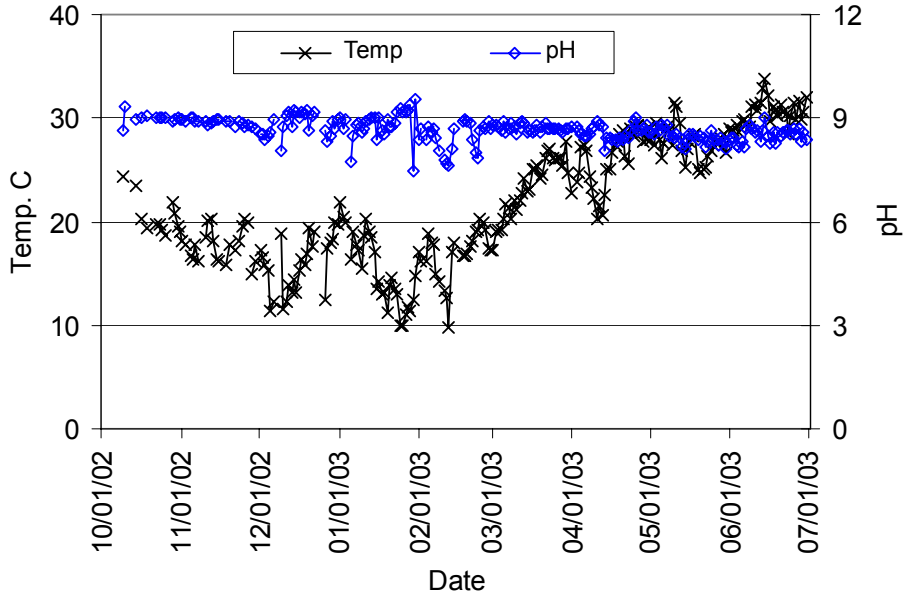


Figure 9. Temperature and pH of separated flushed manure in the Equalization Tank.

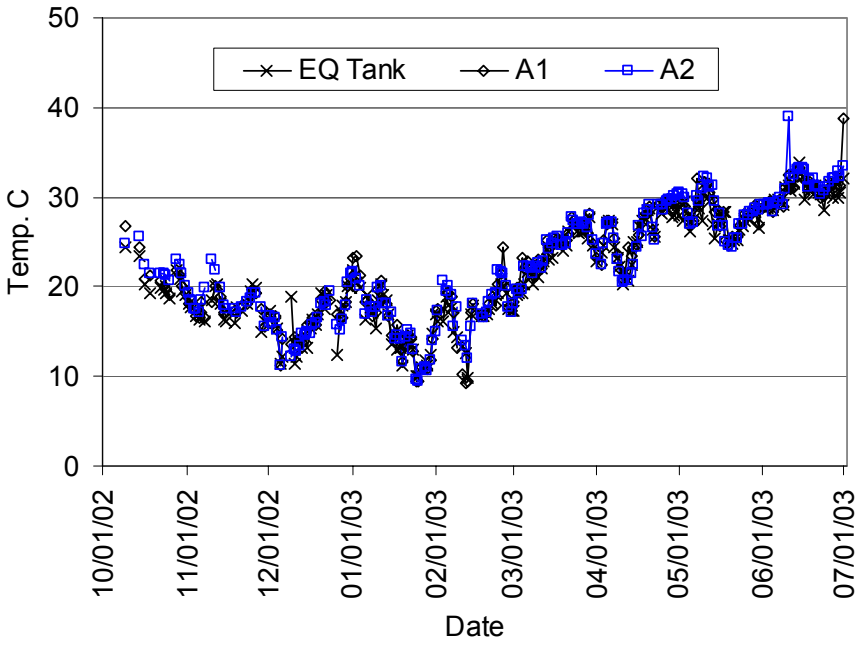


Figure 10. Temperature of the liquid in the Equalization tank and the A primary and secondary series biofilters.

5.4 PERFORMANCE OF BIOFILTERS

The input concentrations and the percent reductions in each biofilter are shown in Appendix A for parameters which were measured during the 8/14/02 through 6/30/03 period. For NO_{2+3}-N and NO_2-N, the actual concentrations are shown. Reductions were variable, likely due to start-up and acclimation and variation in operating conditions, e.g. the variable COD loading (Figure 5). Therefore, the tables in Appendix A do not show averages. Some of the parameters will be discussed more fully in this section, and monthly average reductions for some parameters will be presented for the January 2003 through June 2003 period.

5.5 COD, TAN, TKN, NO_{2+3}-N AND NO_2-N FOR THE PERIOD 8/2003 TO 6/2003

The concentrations of COD, TAN, TKN, NO_{2+3}-N and NO_2-N are shown in Figures 11 to 15, respectively, for input to biofilters and output from the second stage biofilters (A2 and B2). The COD input concentrations were less than 2,000 mg/L during the first three months when lagoon liquid was most of the loading (Figure 11). During the last six months the COD was usually between 2,000 and 4,000 mg/L, when input consisted of about 50 % flushed manure and 50 % recirculation of biofilter effluent. Tabular values of reductions for this period are shown in Table A-2, Appendix A.

The input TAN concentrations were variable, usually in the range of 100 to 500 mg/L (Figure 12). Due to nitrification in the biofilters, the TAN is reduced in effluent; thus, the recirculated biofilter effluent should have low TAN (evident for 4/2003 through 6/2003). The flushed manure volume consists mainly (probably > 90 %) of lagoon liquid used for flushing. Therefore, the input concentrations of TAN to the biofilters should be in a range similar to concentrations in the lagoon liquid used for flushing, with the low TAN in biofilter output recirculated liquid tending to offset the fresh manure TAN added to flush liquid. Tabular values of reductions for entire period are shown in Table A-3, Appendix A.

The TKN (consisting of organic N plus TAN) was not measured until 2/2003 (Figure 13). During the last five months, TKN input concentrations were variable and usually in the range of 200 to 600 mg/L. In the biofilters, there can be conversion of organic N to TAN, as well as conversion of TAN to NO_{2+3}-N (nitrification). The reductions of TKN reflect the predominance of nitrification. Tabular values of reductions are shown in Table A-4, Appendix A.

The increased concentrations of NO_{2+3}-N through the biofilters were variable, and not always consistent for the two biofilter series (Figure 14). The input concentrations were often near zero, but sometimes high because of recirculating biofilter effluent to the input. Effluent concentrations were often 200 to 400 mg/L in the last three months of operation. Tabular values of concentrations are shown in Table A-5, Appendix A.

During the evaluation period, there were variable concentrations of NO_2-N in the biofilter effluent (Figure 15). This indicates that conversion of nitrite to nitrate was not complete in the biofilters. Tabular values of concentrations are shown in Table A-6, Appendix A.

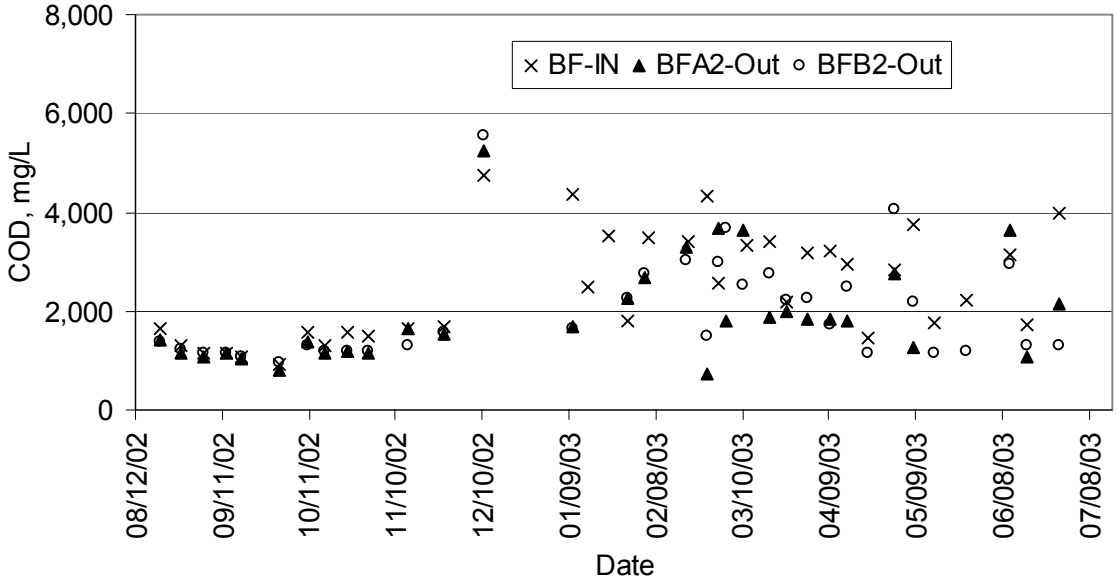


Figure 11. Chemical Oxygen Demand (COD) concentrations into and out of the biofilters.

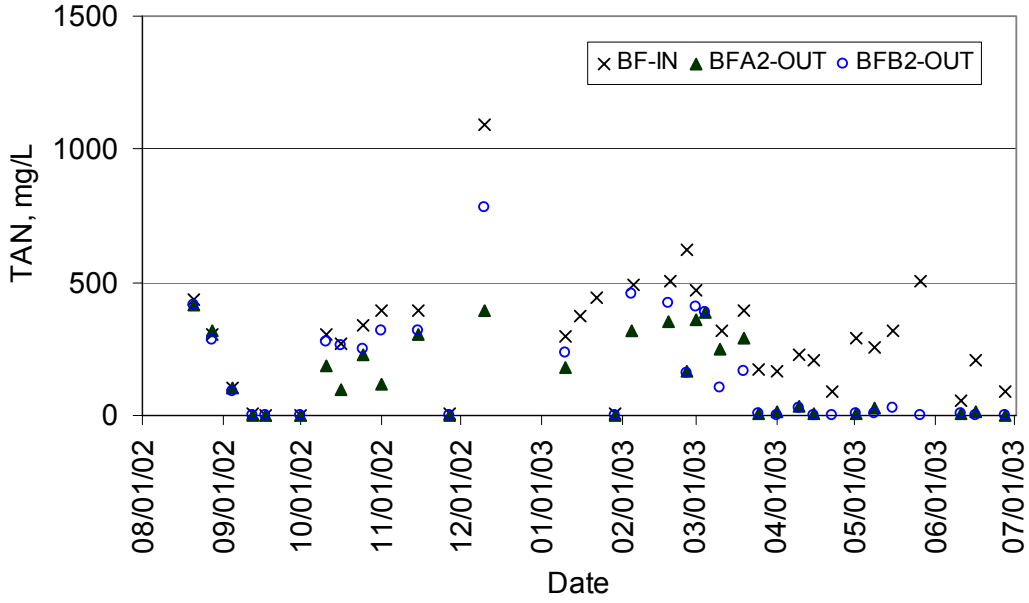


Figure 12. Total ammonium nitrogen (TAN) concentrations into and out of the biofilters.

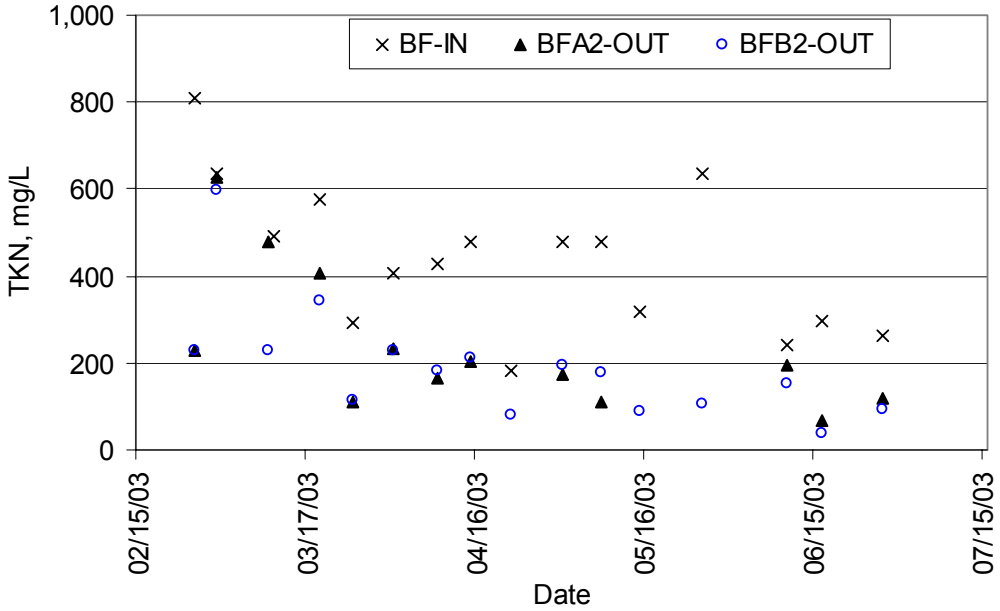


Figure 13. TKN concentrations into and out of the biofilters.

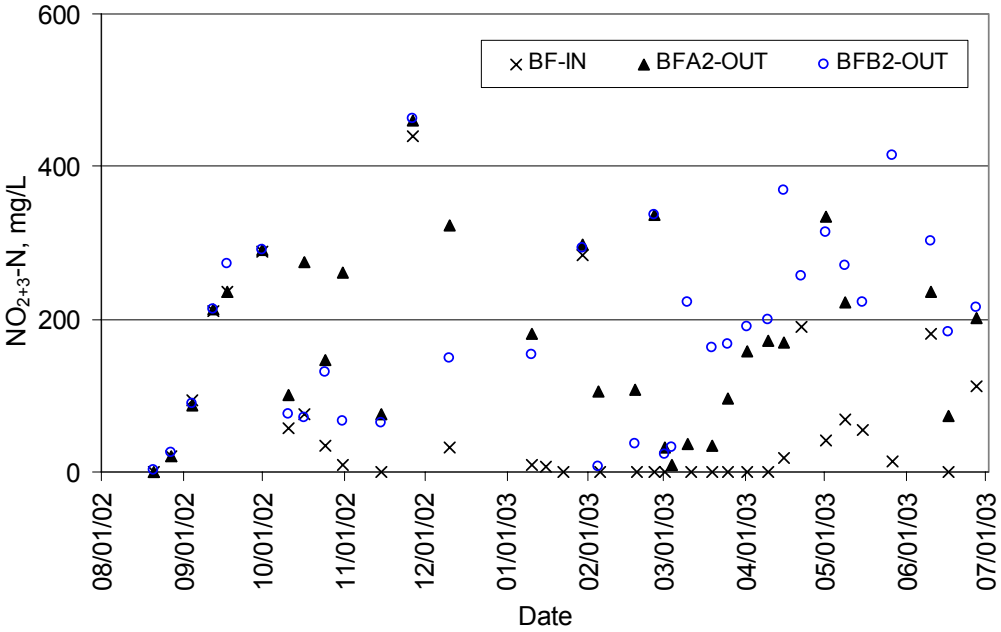


Figure 14. Nitrite-N + Nitrate-N concentrations.

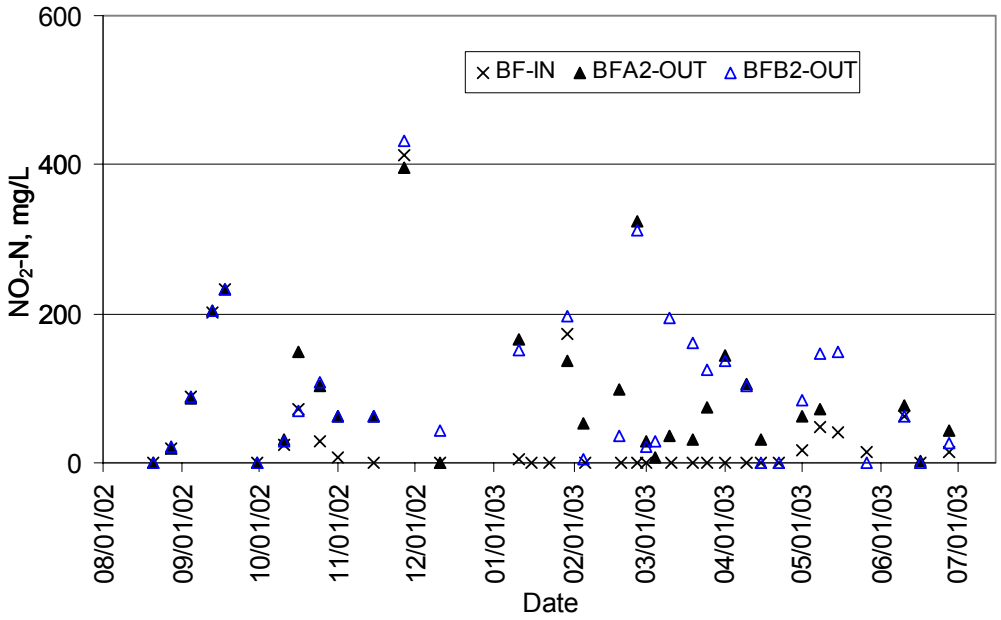


Figure 15. Nitrite-N concentrations into and out of the biofilters.

5.6 BIOFILTER PERFORMANCE DURING 1/2003 THROUGH 6/2003

During 8/2002 through 12/2002, loading of the biofilters was mostly with lagoon liquid and recirculated biofilter effluent. For 1/2003 through 6/2003, loading was with flushed manure and recirculated biofilter effluent. The last six months of operation and evaluation will be discussed in more detail regarding nitrification and oxygen demand (BOD and COD).

The TAN and $NO_{(2+3)}$-N concentrations for inflow and outflow are presented in Figures 16 and 17, respectively. Nitrification in the system was variable in January and February 2003, and improved in March with warmer weather as shown by reduction in TAN (Figure 16) and increasing trend in $NO_{(2+3)}$-N (Figure 17). The reductions in TAN were 20-40 % in March, but averaged 90 % or greater April, May and June (Table 1). The increase in concentration of $NO_{(2+3)}$-N in March 2003 were from value of 0 mg/L to about 50 and 120 mg/L in the A series and B series, respectively (Figure 17 and Table 2). The $NO_{(2+3)}$-N concentrations in output varied from 170 to 300 mg/L during April through June. The input TAN and $NO_{(2+3)}$-N concentrations varied mainly due to varying concentrations in recirculated effluent and the portion of input that was recirculated effluent which was usually about 50% of effluent, but was increased to 75% during May 24 to mid June.

The TAN reduction occurred mostly in the first stage biofilter for each biofilter series (A and B) during April through June (Figure 18). This is consistent with the pilot scale results (Westerman et al., 2000) for warm weather. The pilot scale results previously showed a larger relative contribution of the 2nd stage during cold weather compared to warm weather. The increase in $NO_{(2+3)}$-N during April to June also occurred mainly in the first stage of the biofilter series (Figure 19), consistent with the TAN reduction reflecting conversion to $NO_{(2+3)}$-N. The NO_2 -N varied (Table 2) but was a significant portion of the $NO_{(2+3)}$-N during the evaluation, especially during January through May. During June, there was still NO_2 -N (Figure 20), indicating that complete nitrification was not taking place. The pH of the liquid streams was between 7.5 and 9.0 with most values 8.0 to 8.6 (Table A-8, Appendix A).

Average monthly concentrations for inflow COD, BOD, TAN, TS, and SS are shown in Table 1. The inflow COD and BOD concentrations were usually 2000-3000 mg/L and 300-700 mg/L, respectively. The COD reductions through the biofilters were typically less than 40 %, while the BOD reductions were higher. The TS were usually between 0.6 % and 0.7 %, and showed little decrease through the biofilters. The SS in input was typically about 2,000 mg/L, and reductions were usually between 20 and 50 %.

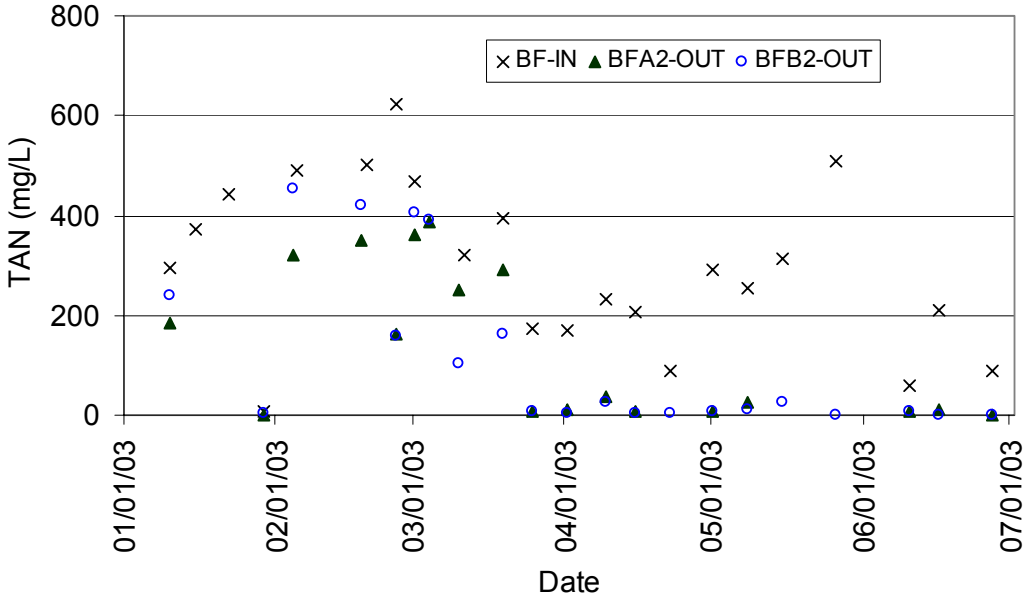


Figure 16. TAN concentrations into and out of the biofilters.

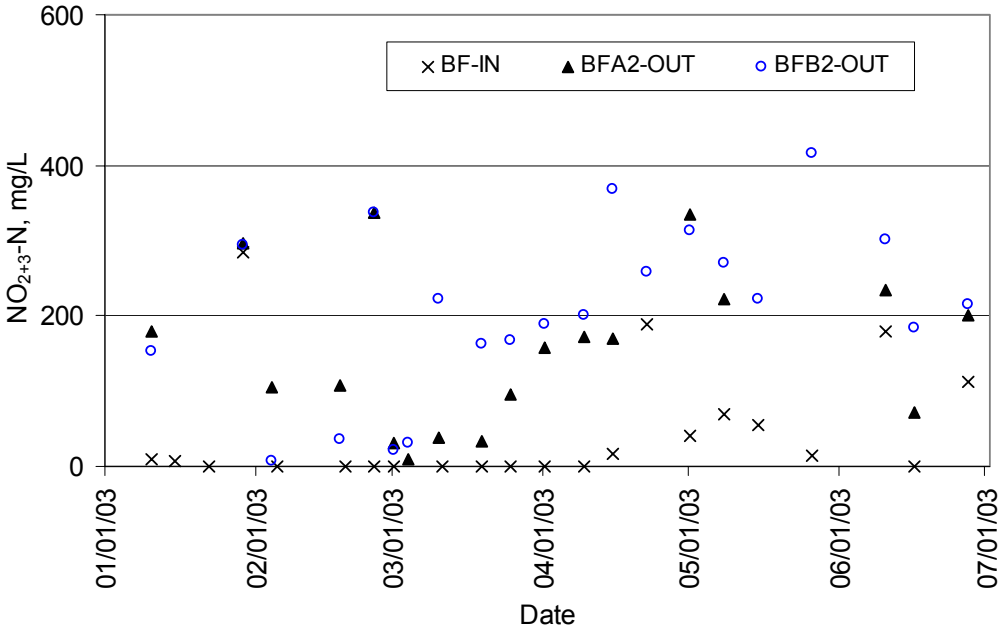


Figure 17. Nitrite-N and Nitrate-N concentrations into and out of the biofilters.

Table 1. Monthly average concentrations in liquid flowing into the biofilters and percent reductions in biofilter outflow liquid compared to BF-IN concentrations.

Parameter			% Reduction of BF-IN concentration			
		BF-IN	BFA1	BFA2	BFB1	BFB2
COD, mg/L	January	3,040	28	35	-4	35
	February	3,744	41	40	26	36
	March	2,874	13	10	9	1
	April	2,696	15	32	-1	30
	May	2,635	0	**24**	12	19
	June	1,925	-10	-18	0	3
BOD, mg/L	January					
	February			-		-
	March	332		14		0
	April	750	9	59	49	53
	May	360	57	72	55	40
	June	270	20	73	84'	69#
TAN, mg/L	January	280	40	67	11	57
	February	539	24	48	18	36
	March	339	29	23	20	37
	April	174	59	90	86	94
	May	342	81	95	83	97
	June	118	49	95	85	98
TN, mg/L	January		-	-	-	-
	February	808	35	30	34	30
	March	500	9	9	6	7
	April	425	1.4	13.7	-5.5	-0.9
	May	523	6	19	5	14
	June	364	18	19	15	10
TS, %	January	-	-	-	-	-
	February	0.70	12	9	3	10
	March	0.65	4	-2	-2	2
	April	0.67	7	14	0	7
	May	0.61	-3	0	0	-1
	June	0.61	5	1	7	5
SS, mg/L	January	-	-	-		-
	February	2,100	59	59	42	48
	March	1,788	22	-18	0	12
	April	2,070	20	**48**	-9	25
	May	1,909	-6	25	11	25
	June	2,660	36	17	34	27

All BOD values are single point observations except for April which is an average of two samples

These BOD values are not exact. Lab reported values as less than the numbers used to calculate the percent reduction.

Table 2. Monthly average nitrate and nitrite concentrations in liquid flowing in and out of the biofilters.

Parameter		BF-IN	BFA1	BFA2	BFB1	BFB2
NO_{2+3}-N	January	75	185	239	113	224
	February	0	27	184	10	127
	March	0	55	42	37	121
	April	52	127	167	204	254
	May	45	226	279	276	306
	June	98	122	170	200	234
	Average	45	124	180	140	211
NO_2^--N	January	44	124	151	83	175
	February	0	18	158	9	118
	March	0	40	36	20	106
	April	0	75	94	56	60
	May	30	163	67	170	94
	June	26	39	41	59	30
	Average	17	76	91	66	97

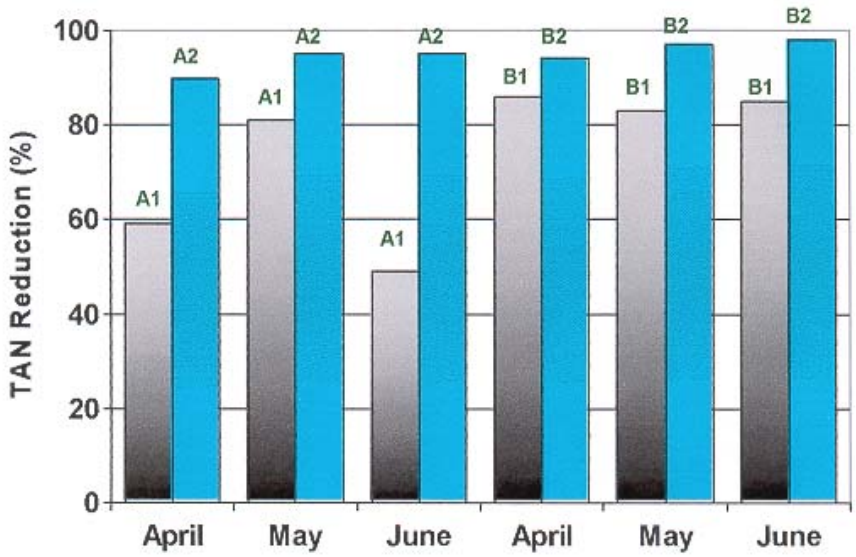


Figure 18. Average total ammonium nitrogen (TAN) reduction (%) in April, May and June 2003 for the 1st and 2nd stage of the two biofilter series.

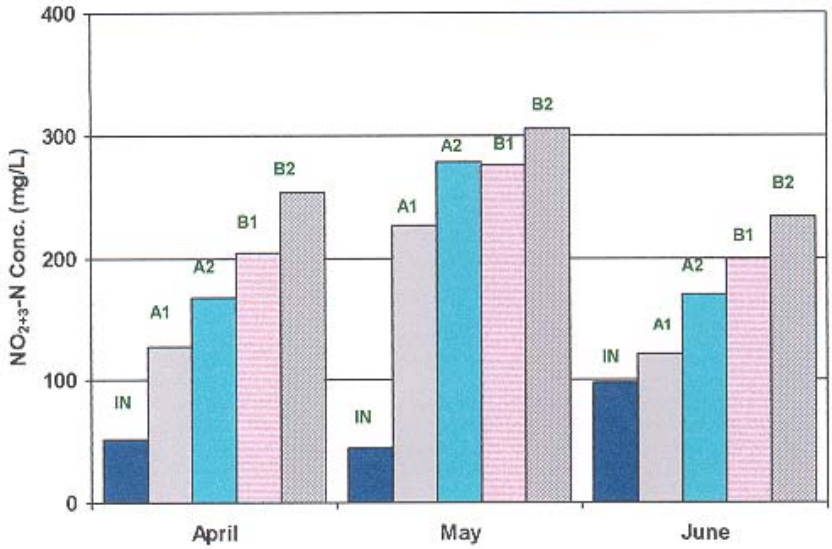


Figure 19. Average nitrate + nitrite N concentration in April, May and June 2003 for the various biofilters.

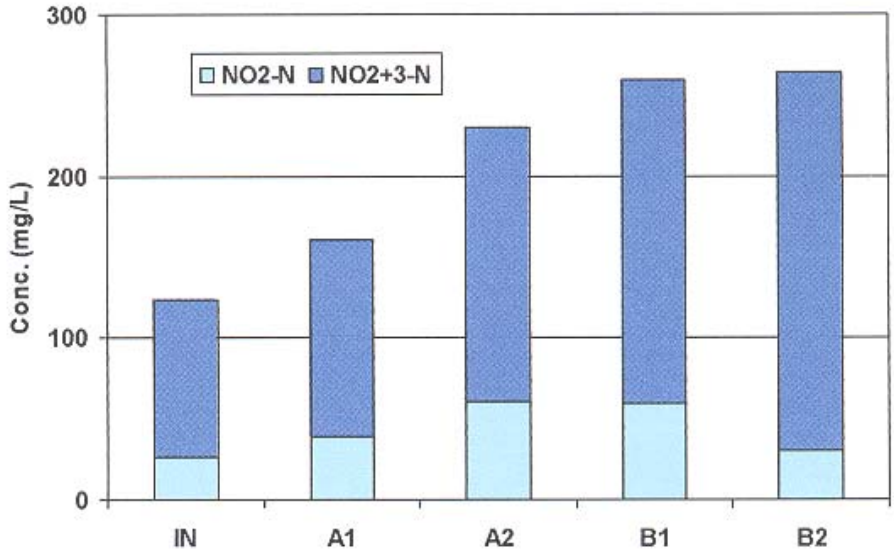


Figure 20. Average nitrite-N and nitrate + nitrite-N concentration in June 2003.

5.7 CHANGES IN LAGOON

Lagoon concentrations of various parameters were determined periodically, with the most frequent sampling being that of the L1 section that received biofilter effluent. The L2 section received separated solids and biofilter backwash, and the L3 section received flushed manure from about 4000 finishing pigs. The Control lagoon was a similar lagoon to the original lagoon (before partitions were installed), and received manure from about 8,000 finishing pigs.

The TAN concentrations in the L1, L2 and L3 sections as well as in the Control lagoon decreased from about 800 mg/L in 5/2002 to about 450 mg/L by 8/2003 (Figure 21). This large decrease is more than would typically be expected due to seasonal variation, but the reason for the large decrease has not been determined. After operation of the Ekokan system began with L1 liquid as input, the TAN was usually between 300 and 400 mg/L. The TAN concentration increased some during winter, being about 400 to 450 mg/L during 1/2003 and 2/2003. For 3/2003 through 6/2003, the L1 TAN generally decreased, being less than 250 mg/L during 6/2003. The Control lagoon TAN concentration remained between 500 and 600 mg/L during the 3/2003 through 6/2003 period. The TAN concentrations in L2 and L3 also decreased during the four months of operation, with L2 TAN being somewhat greater than L1 TAN, and L3 TAN usually higher than L2 TAN. TKN was not analyzed as frequently as TAN, but had similar trends (Figure 22). Tabular values of TAN and TKN for the lagoons are in Tables B-1 and B-2, respectively, in Appendix B. In considering nitrogen available for crops when the liquid is applied to land, the L1 section can have TAN which can have some fraction lost to the atmosphere by ammonia volatilization during land application, and can also have $NO_{(2+3)}$-N which should be essentially 100 % available. The L1 liquid sometimes had $NO_{(2+3)}$-N of 20 to 50 mg/L, but usually was low during the evaluation period (Table B-3 , Appendix B). Irrigation liquid was pumped from L1, and this likely caused liquid to flow from L2 to L1 because the partition had to allow flow through.

The TP in the lagoons showed some decrease in early summer 2002 (Figure 23) similar to the TAN (Figure 19) and TKN (Figure 22). TP was not measured after 8/6/02 until 2/25/03. The L1 TP concentration decreased in May and early June 2003, but then increased, as did the L2 and Control lagoons. Tabular values of TP concentrations are shown in Table B-4, Appendix B.

The COD in all lagoons decreased during 3/2003 through 6/2003 (Figure 24). The Control lagoon had higher concentrations than the L1, L2 and L3 lagoons during this period. Tabular values of COD concentrations are shown in Table B-5, Appendix B.

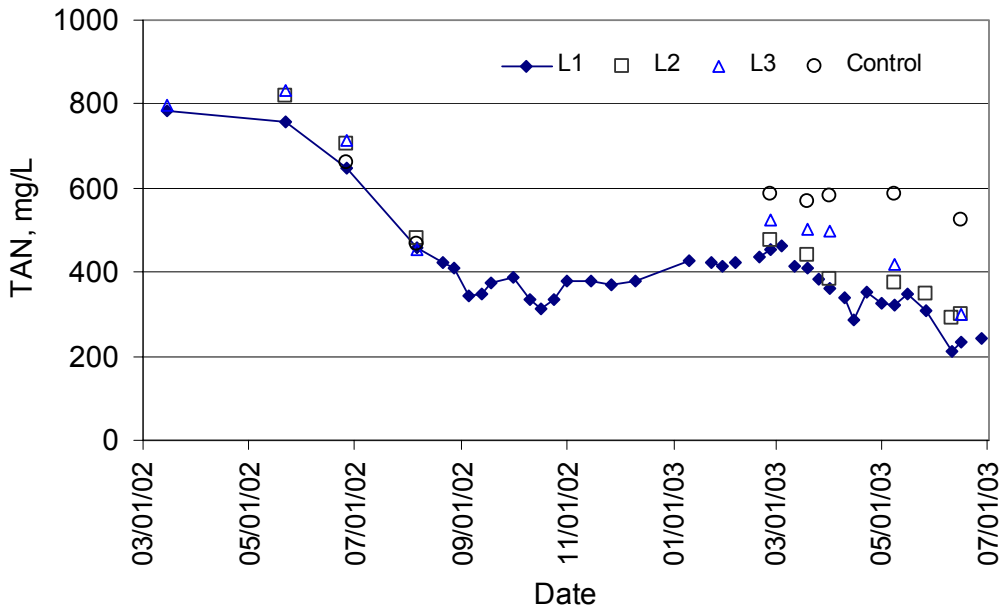


Figure 21. TAN concentration various lagoon sections.

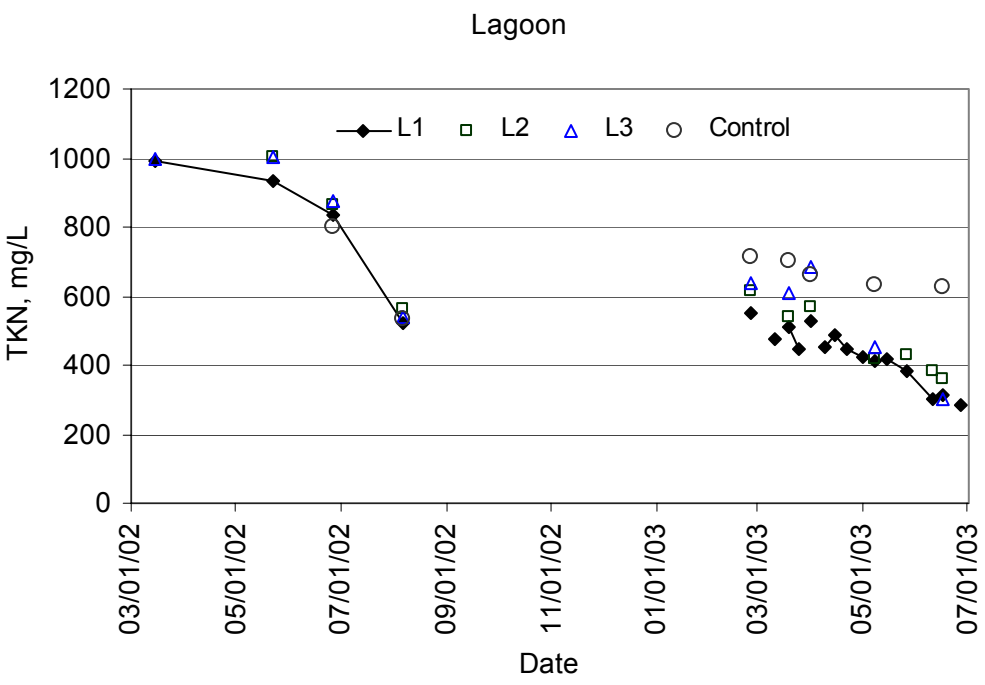


Figure 22. TKN concentrations in various lagoon sections.

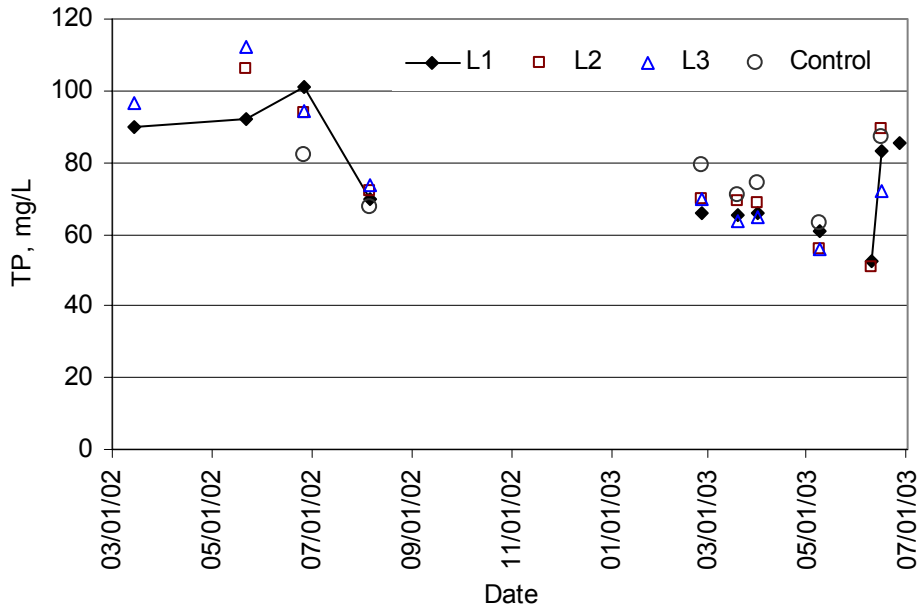


Figure 23. TP concentrations in various lagoon sections.

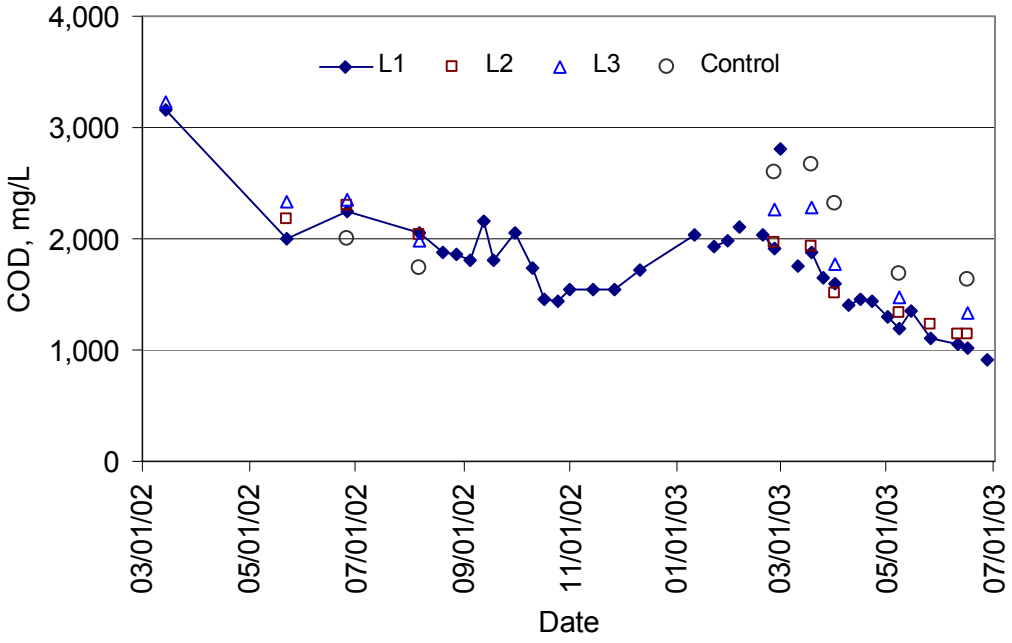


Figure 24. COD concentrations in various lagoon sections.

5.8 BIOFILTER BACKWASH

The concentrations of various parameters in the backwash from the four biofilters were variable. The TS in backwash was usually 0.5 to 0.8 % (Table C-1, Appendix C) while the SS usually was 1,000 to 5,000 mg/L but could be much higher (Table C-2, Appendix C). Part of the variability in backwash analyses no doubt resulted from taking grab samples of the backwash, which did not represent an average concentration of a particular backwash. However, the data shows that generally the backwash is about 99 % liquid and represents a wastewater that could receive a further treatment or be recycled back to the front of the treatment system. Concentrations of other parameters in the backwash are shown in Appendix C.

5.9 SOLIDS/LIQUID SEPARATION

Various types of solids/liquid separation systems could be used before the biofilters. The purpose of the solids/liquid separation is mainly to reduce organic matter loading to the biofilters and to prevent "trash" from entering the pumps and pipes of the system. The TR separator used in the Ekokan system evaluation mainly separated coarse solids, and had relative small impact on COD or total solids loading of the biofilters. Some "batch" tests were conducted on six dates where the separated solids from a "flush" were collected, weighed and analyzed. Results of these batch tests are shown in Appendix D. Generally, the solids, TKN, TP and other parameters that were collected represented a small percentage of input to the separator, typically less than 5%.

5.10 MASS BALANCE

A mass balance on each series of biofilters was estimated for six dates in 2003 (3/25, 5/1, 5/8, 6/10, 6/16 and 6/27). A summary is shown in Table 3, and the data used for the mass balance are shown in Appendix E. The mass balance shows that about 20 to 30% of the input mass of the various parameters was recovered in the backwash from the first stage biofilters, and usually about 5% was recovered from the second stage biofilters. For the dates used in the mass balance, the B series retained more mass in the effluent (about 70% for TN, SS, TS and COD) than the A series. This may be due to the high loading rate to the B series (Figure 5). Note that the unaccounted for mass of several parameters were 20 to 30%. This could be due to errors in flow due partially to variable storage in biofilters, errors in average concentration due to using grab samples of flows, not accounting for losses with foam, and possibly accumulation within the biofilters.

5.11 LAGOON SLUDGE: ACCUMULATION AND CHARACTERISTICS

The permit from the Division of Water Quality (DWQ) required monthly measurements of sludge accumulation in the cell that received separated solids and biofilter backwash (cell L2). The sludge layer thickness increased in all three cells between 5/22/02/ and 6/25/03 (Table F-1, Appendix F); however, the measurements indicated little accumulation in L2 cell during the last four months. See Appendix F for more information on sludge accumulation and sludge characteristics.

Table 3. Summary of the mass balances on the biofilter series.

A Series									
	Mass IN, kg		% retained, A1 BW		% retained, A2 BW		% retained, Effluent		Unaccounted
	Average	stdev.	Average	stdev.	Average	stdev.	Average	stdev.	%
TN	103	39	22	4	4.8	1.2	46	31	27
TP	38	25	29	25	7.3	6.5	32	17	32
Cu	0.17	0.13	19	14	2.3	1.8	36	13	43
Zn	1.15	0.73	16	14	1.2	0.5	23	21	60
SS	607	330	25	16	3.4	3.6	50	43	22
TS	1,609	558	32	16	7.4	3.7	59	29	2
COD	766	381	20	9	3.4	2.4	37	29	39
B Series									
	Mass IN, kg		% retained, B1 BW		% retained, B2 BW		% retained, Effluent		Unaccounted
	Average	stdev.	Average	stdev.	Average	stdev.	Average	stdev.	%
TN	182	75	20	18	4.7	3.3	69	30	6
TP	66	45	29	34	6.5	7.6	45	15	20
Cu	0.30	0.23	29	36	4.5	5.5	46	9	20
Zn	2.08	1.37	32	47	5.0	7.0	33	7	30
SS	1,086	620	23	38	4.7	4.5	77	48	-6
TS	2,836	1108	22	18	5.2	4.0	75	32	-2
COD	1,358	686	25	26	4.7	4.2	67	50	3

6.0 OPERATION AND MAINTENANCE

The daily operation of the system was conducted by the technology provider. This person assisted with monitoring by recording daily readings of the various parameters, and also keeping a daily log of operation. Based on the daily log, communications between the technology provider and the University evaluators, and on observations by the University technician during visits about every two weeks, a log of operation and maintenance was summarized by the University. The main operational occurrences during 1/2003 through 6/2003 are summarized in Appendix G. Problems were encountered with the lift-station pump several times, resulting in replacement of the pump 6/4/03. Problems also occurred with the float switches in the lift station and in the separator tank. There were also some problems with valves and controls. Overall, the number of problems with the system indicated that daily inspection and/or supervision is needed.

ACKNOWLEDGEMENTS

This project was funded by Smithfield Foods, Inc. under an agreement with the N. C. Attorney General and administered by Dr. Mike Williams, “designee” under the agreement, and Director of the N. C. State University Animal and Poultry Waste Management Center.

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APPENDIX A: BIOFILTERS

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Table A-1. Daily COD loading rates for biofilters A1 and B1 (kg/m^3 media-d).

Date	Flow Volume, m^3		Concentration	Mass, kg		Loading Rate	
	A1	B1	kg/m^3	A1	B1	A1	B1
08/20/02	-	-	1.65	-	-	-	-
08/27/02	-	-	1.31	-	-	-	-
09/04/02	-	-	1.15	-	-	-	-
09/12/02	-	-	1.16	-	-	-	-
09/17/02	-	-	1.08	-	-	-	-
09/30/02	-	-	0.93	-	-	-	-
10/10/02	218	-	1.57	341	-	2.6	-
10/16/02		-	1.31	-	-	-	-
10/24/02	31	-	1.59	50	-	0.4	-
10/31/02	192	-	1.49	286	-	2.2	-
11/14/02	77	-	1.65	127	-	1.0	-
11/26/02	294	-	1.70	498	-	3.8	-
12/10/02	62	-	4.74	292	-	2.2	-
01/10/03	303	-	4.38	1,325	-	10.2	-
01/15/03	274	-	2.48	680	-	5.2	-
01/22/03	206	-	3.51	722	-	5.6	-
01/29/03	319	-	1.80	572	-	4.4	-
02/05/03	207	-	3.50	725	-	5.6	-
02/19/03	333	-	3.40	1,133	-	8.7	-
02/25/03	42	-	4.33	181	-	1.4	-
03/01/03	381	698	2.57	980	1,796	7.5	13.8
03/11/03	305	541	3.33	1,016	1,800	7.8	13.8
03/19/03	327	645	3.41	1,115	2,200	8.6	16.9
03/25/03	337	611	2.18	737	1,334	5.7	10.3
04/01/03	358	640	3.18	1,139	2,036	8.8	15.7
04/09/03	321	583	3.23	1,035	1,883	8.0	14.5
04/15/03	153	43	2.94	449	125	3.5	1.0
04/22/03	44	217	1.44	63	311	0.5	2.4
05/01/03	294	511	2.82	830	1,444	6.4	11.1
05/08/03	199	332	3.75	746	1,246	5.7	9.6
05/15/03	20	176	1.76	36	311	0.3	2.4
05/26/03	42	117	2.20	93	258	0.7	2.0
06/10/03	200	451	3.15	629	1,423	4.8	10.9
06/16/03	138	159	1.72	236	272	1.8	2.1
06/27/03	357	613	3.97	1,416	2,431	10.9	18.7

Table A-2. COD concentration reduction.

Date	BF-IN mg/L	% Reduction of BF- IN concentration			
		BFA1-Out	BFA2-Out	BFB1-Out	BFB2-Out
08/20/02	1,652	23	14	16	18
08/27/02	1,310	-42	14	7	7
09/04/02	1,148	-14	6	-2	1
09/12/02	1,157	-25	-1	-2	0
09/17/02	1,075	0	3	0	0
09/30/02	925	-12	11	10	-2
10/10/02	1,566	16	11	10	17
10/16/02	1,308	3	11	6	10
10/24/02	1,588	20	25	20	26
10/31/02	1,493	18	22	13	21
11/14/02	1,646	22	0	17	21
11/26/02	1,696	6	10	5	7
12/10/02	4,740	10	-11	10	-17
01/10/03	4,376	58	62	52	62
01/15/03	2,480	-14	-	4	-
01/22/03	3,508	49	-	-70	-
01/29/03	1,796	-29	-25	-20	-26
02/05/03	3,500	-	-	0	-
02/19/03	3,400	17	-	5	-
02/25/03	4,332	57	83	63	66
03/01/03	2,572	1	-43	-8	-17
03/11/03	3,328	36	-	22	-
03/19/03	3,412	16	45	15	19
03/25/03	2,184	-9	9	-2	-1
03/31/03	3,180	22	42	8	29
04/08/03	3,228	18	43	28	47
04/09/03	2,938	41	39	-23	15
04/15/03	1,436	-	-	-40	21
04/22/03	2,824	-1	2	-3	-44
05/01/03	3,748	35	67	35	42
05/08/03	1,762	-	-	0	36
05/15/03	2,204	-	-	0	47
06/10/03	3,152	13	-16	0	6
06/16/03	1,716	-30	38	45	23
06/27/03	3968	65	46	58	67

Table A-3. TAN concentration reductions.

Date	BF-IN	% Reduction of BF- IN concentration			
	mg/L	BFA1-Out	BFA2-Out	BFB1-Out	BFB2-Out
08/20/02	437	1.8	5.3	4.6	4.6
08/27/02	303	-2.3	-5.3	1.7	7.6
09/04/02	101	6.5	-5.9	4.1	9.7
09/12/02	7.81*	NA	NA	NA	NA
09/17/02	0.05*	NA	NA	NA	NA
09/30/02	0.06*	NA	NA	NA	NA
10/10/02	303	49.5	38.3	2.0	9.2
10/16/02	269	61.7	63.7	-1.9	3.0
10/24/02	339	58.7	32.2	18.3	27.1
10/31/02	395	7.8	69.6	12.4	19.0
11/14/02	397	18.6	23.7	11.6	19.9
11/26/02	3.73*	NA	NA	NA	NA
12/10/02	1094	38.0	63.9	19.6	28.7
01/10/03	296	13.5	38.2	-5.7	19.6
01/15/03	373	59.2	-	34.3	-
01/22/03	443	40.9	-	1.4	-
01/29/03	7.74*	NA	NA	NA	NA
02/05/03	490	-	-	3.1	-
02/19/03	502	14.1	-	8.6	-
02/25/03	624	33.0	73.9	38.5	74.4
03/01/03	468	14.5	22.9	5.1	13.5
03/11/03	320	23.8	-	20.3	-
03/19/03	394	29.9	25.9	24.1	58.4
03/25/03	174	71.6	95.6	46.4	96.4
04/01/03	168	73.1	93.5	48.6	98.7
04/09/03	231	54.1	84.0	95.1	89.1
04/15/03	207	68.6	96.8	99.8	98.9
04/22/03	89.9	-	-	99.4	96.4
05/01/03	293	84.7	97.8	83.9	98.1
05/08/03	253	65.2	89.8	50.6	96.3
05/15/03	315	-	-	97.9	91.2
05/26/03	508	-	-	90.6	99.7
06/10/03	58.4	-7.5	88.9	83.7	89.0
06/16/03	209	78.7	94.2	99.9	99.8
06/27/03	88	16.7	99.0	48.6	99.4

* When BF-IN TAN concentration is below 10 mg/L, % reduction is not shown. Very low BF-IN TAN concentration implies no loading of flushed manure or lagoon liquid, but rather recycle of biofilter effluent.

Table A-4. TKN concentration reductions.

Date	BF-IN mg/L	% Reduction of BF- IN concentration			
		BFA1-Out	BFA2-Out	BFB1-Out	BFB2-Out
02/25/03	808	35.3	71.8	36.5	71.7
03/01/03	636	11.6	1.1	0.5	5.8
03/11/03	492	24.6	-	18.5	-
03/19/03	578	14.7	29.6	18.5	40.7
03/25/03	292	39.7	62.0	25.7	60.6
04/01/03	405	26.2	43.0	12.3	44.0
04/09/03	429	33.1	61.3	38.7	57.6
04/15/03	477	38.8	57.2	49.3	55.6
04/22/03	184	-	-	35.3	55.7
05/01/03	480	42.5	63.8	46.7	59.8
05/08/03	477	47.2	76.7	40.7	63.1
05/15/03	317	-	-	67.5	71.3
05/26/03	637	-	-	62.3	83.0
06/10/03	240	9.2	18.8	34.2	36.7
06/16/03	297	47.1	77.7	88.3	87.3
06/27/03	263	41.6	54.6	46.4	65.2

Table A-5. Nitrite-N + Nitrate-N concentrations.

Date	BF-IN mg/L	BFA1-Out mg/L	BFA2-Out mg/L	BFB1-Out mg/L	BFB2-Out mg/L
08/20/02	0	0.5	0.63	1.09	1.16
08/27/02	20.5	25.1	19.5	25.1	24.3
09/04/02	94.6	96.7	87.7	90.4	89.1
09/12/02	210	215	214	213	214
09/17/02	236	236	236	239	273
09/30/02	288	288	290	290	290
10/10/02	56.6	165	100	62	75
10/16/02	76.1	235	274	62	72
10/24/02	35.3	236	147	105	131
10/31/02	9.87	27.5	260	44.7	66.9
11/14/02	0.13	58.4	76.3	34.6	63.3
11/26/02	440	454	461	458	463
12/10/02	32.1	348	324	154	149
01/10/03	9.2	137	180	54	154
01/15/03	6.3	164	-	109	-
01/22/03	0	153	-	0	-
01/29/03	285	285	297	289	294
02/04/03	-	54.7	106	-	7.66
02/05/03	0	-	-	0	-
02/18/03	-	-	108	-	35.9
02/19/03	0.01	25.7	-	9.22	-
02/25/03	0	0	337	20.3	337
03/01/03	0.01	11.5	32.2	0	22.2
03/04/03	-	-	8.92	-	31.3
03/10/03	-	-	37.1	-	222
03/11/03	0	61	-	56.9	-
03/19/03	0	46.5	33.5	26.5	163
03/25/03	0.25	102	96.4	66.4	168
04/01/03	0.09	144	158	97.9	190
04/09/03	0	118	172	110	200
04/15/03	17.9	119	170	328	368
04/22/03	189	-	-	281	257
05/01/03	41.3	258	334	259	314
05/08/03	69.3	194	223	170	271
05/15/03	55.3	-	-	295	223
05/26/03	13.6	-	-	378	415
06/10/03	180	193	235	270	302
06/16/03	0.03	39.9	72.7	177	184
06/27/03	113	133	201	152	215

Table A-6. Nitrite-N concentrations.

Date	BF-IN mg/L	BFA1-Out mg/L	BFA2-Out mg/L	BFB1-Out mg/L	BFB2-Out mg/L
08/20/02	0	0.47	0.61	1.06	1.13
08/27/02	18.8	22.5	18.2	23.5	22.2
09/04/02	87.7	91.2	86	89.1	88.6
09/12/02	201	203	204	204	203
09/17/02	232	233	233	236	233
09/30/02	0.11	0.06	0.04	0.04	0.03
10/10/02	24.4	34.1	31.1	28.1	28.7
10/16/02	72.9	153	150	60.7	70.2
10/24/02	29.6	69.6	103	85.7	108
10/31/02	6.66	24.5	62.5	19.6	62.8
11/14/02	0.02	51.8	63.6	16.6	63.3
11/26/02	412	429	395	424	432
12/10/02	0	82.1	0.22	55.4	43.8
01/10/03	4	136	166	47	152
01/15/03	0.02	66	-	101	-
01/22/03	0	102	-	0	-
01/29/03	173	193	136	185	198
02/04/03	-	29.2	51.9	-	5.94
02/05/03	0	-	-	0	-
02/18/03	-	-	99.6	-	35.02
02/19/03	0	24.3	-	6.25	-
02/25/03	0	0	323	19.9	313
03/01/03	0	11	29.8	0	21.2
03/04/03	-	-	7.23	-	27.6
03/10/03	-	-	37	-	194
03/11/03	0	27	-	4.85	-
03/19/03	0	45.5	32.3	26.3	161
03/25/03	0.02	76.5	74.2	48.4	124
04/01/03	0.01	131	145	87.6	138
04/09/03	0	80	106	75	103
04/15/03	0.1	13	32	61	0.02
04/22/03	0.79	-	-	0.05	0.76
05/01/03	16	148	61.9	146	83.4
05/08/03	49	177	71.2	149	146
05/15/03	41.4	-	-	212	148
05/26/03	13.4	-	-	172	0.49
06/10/03	62.5	72.6	77.2	124	62.9
06/16/03	0.01	4.42	1.89	0.02	0.28
06/27/03	14.6	39.8	43.6	51.8	25.6

Table A-7. Total nitrogen concentration reductions.

Date	% Reduction				
	BF-IN, mg/L	BFA1-Out	BFA2-Out	BFB1-Out	BFB2-Out
02/25/03	808	35	30	34	30
03/01/03	636	10	-4	-	2
03/11/03	492	12	100	7	100
03/19/03	578	7	24	14	12
03/25/03	292	5	29	3	3
04/01/03	405	-9	4	-12	-3
04/09/03	429	6	21	13	11
04/15/03	495	17	24	-15	-17
04/22/03	373	-	-	-7	9
05/01/03	521	-2	3	1	3
05/08/03	546	18	39	17	18
05/15/03	372	-	-	-7	16
05/26/03	651	-	-	5	20
06/10/03	420	2	-2	-2	-8
06/16/03	297	34	53	29	25
06/27/03	376	24	15	22	18

Table A-8. pH reductions.

Date	BF-IN mg/L	% Reduction of BF- IN concentration			
		BFA1-Out	BFA2-Out	BFB1-Out	BFB2-Out
08/20/02	8.92	-0.90	-3.14	-1.91	-2.58
08/27/02	9.4	-0.11	0.21	-0.74	-1.06
09/04/02	9.45	0.00	-0.21	-0.21	-0.42
09/12/02	9.32	-0.75	-0.54	-0.75	-1.18
09/17/02	9.12	-0.44	-0.66	-1.10	-1.10
09/30/02	9.13	-0.33	-0.66	-0.88	-1.53
10/10/02	8.75	-1.49	-4.57	-2.29	-4.57
10/16/02	8.61	2.56	-1.28	-1.05	-3.48
10/24/02	8.52	2.23	-3.29	-0.94	-3.40
10/31/02	8.46	0.83	2.84	-1.30	-3.31
11/14/02	8.36	-0.84	-3.35	-1.91	-2.03
11/26/02	8.07	3.47	2.73	0.74	0.12
12/10/02	8.5	0.71	2.00	-0.82	0.35
01/10/03	8.14	3.44	7.13	0.98	1.11
01/15/03	8.24	0.73	-	-0.36	-
01/22/03	8.24	2.43	-	-3.28	-
01/29/03	8.42	-4.28	1.43	1.78	0.48
02/05/03	8.46	-	-	-1.77	-
02/19/03	8.54	-0.59	-	-1.64	-
02/25/03	7.96	-9.30	-1.38	-9.67	-2.14
03/01/03	8.13	-1.60	-3.81	-1.97	-3.57
03/11/03	8.39	0.36	-	-0.83	-
03/19/03	8.24	-1.70	0.00	-3.64	-1.70
03/25/03	8.49	3.42	4.48	1.30	2.94
04/01/03	8.5	3.29	6.00	1.65	3.65
04/09/03	8.42	2.61	3.92	1.07	3.09
04/15/03	8.08	-1.11	1.86	1.36	0.62
04/22/03	8.13	-	-	-3.08	-1.23
05/01/03	8.35	3.71	4.43	2.28	2.99
05/08/03	8.31	1.56	1.81	-0.96	1.81
05/15/03	8.04	-	-	3.48	-4.73
05/26/03	8.38	-	-	6.80	6.56
06/10/03	8.13	0.00	0.98	0.49	-1.85
06/16/03	8.21	-2.92	-3.78	-9.26	-8.65
06/27/03	8.33	2.76	1.44	1.08	1.56

Table A-9. Total solids reductions.

Date	BF-IN mg/L	% Reduction of BF- IN concentration			
		BFA1-Out	BFA2-Out	BFB1-Out	BFB2-Out
01/22/03	0.72	15	-	-19	-
02/05/03	0.71	-	-	1	-
02/19/03	0.69	3	-	3	-
02/25/03	0.7	17	19	4	20
03/01/03	0.63	0	-17	-3	-5
03/11/03	0.65	12	-	-9	-
03/19/03	0.69	3	12	1	4
03/25/03	0.61	0	3	2	3
04/01/03	0.67	7	15	4	12
04/09/03	0.68	7	15	15	16
04/15/03	0.66	12	12	-18	-9
04/22/03	0.67	-	-	-3	10
05/01/03	0.62	-6	-13	-10	-11
05/08/03	0.72	17	28	18	17
05/15/03	0.53	-	-	0	8
05/26/03	0.57	-	-	-14	-19
06/10/03	0.65	3	-12	-5	-5
06/16/03	0.55	-4	11	11	7
06/27/03	0.64	16	6	16	13

Table A-10. Suspended solids concentration reductions.

Date	BF-IN mg/L	% Reduction of BF- IN concentration			
		BFA1-Out	BFA2-Out	BFB1-Out	BFB2-Out
01/22/03	0.72	15	-	-19	-
02/05/03	0.71	-	-	1	-
02/19/03	0.69	3	-	3	-
02/25/03	0.7	17	19	4	20
03/01/03	0.63	0	-17	-3	-5
03/11/03	0.65	12	-	-9	-
03/19/03	0.69	3	12	1	4
03/25/03	0.61	0	3	2	3
04/01/03	0.67	7	15	4	12
04/09/03	0.68	-	-	15	16
04/15/03	0.66	-	12	-18	-9
04/22/03	0.67	-	-	-3	10
05/01/03	0.62	-6	-13	-10	-11
05/08/03	0.72	17	28	18	17
05/15/03	0.53	-	-	0	8
05/26/03	0.57	-	-	-14	-19
06/10/03	0.65	3	-12	-5	-5
06/16/03	0.55	-4	11	11	7
06/27/03	0.64	16	6	16	13

Table A-11. Total phosphorus concentration reductions.

Date	BF-IN mg/L	% Reduction of BF- IN concentration			
		BFA1-Out	BFA2-Out	BFB1-Out	BFB2-Out
02/25/03	124	41	50	58	49
03/19/03	110	9	45	12	18
04/01/03	127	4	28	6	29
05/08/03	176	34	58	37	34
06/10/03	139	7	-22	-12	-12
06/16/03	116	0	3	12	0
06/27/03	206	43	34	41	40

Table A-12. Ortho phosphate-P concentration reductions.

Date	BF-IN mg/L	% Reduction of BF- IN concentration			
		BFA1-Out	BFA2-Out	BFB1-Out	BFB2-Out
04/01/03	94	1	16	-2	16
05/08/03	139	27	50	33	32
06/10/03	99	-4	-19	-17	-11
06/16/03	86	-2	-3	7	29
06/27/03	111	25	22	13	27

Table A-13. Potassium concentration reductions.

Date	BF-IN mg/L	% Reduction of BF- IN concentration			
		BFA1-Out	BFA2-Out	BFB1-Out	BFB2-Out
04/01/03	1,400	5	2	4	2
05/08/03	1,228	4	2	-2	-4
06/10/03	1,216	-3	-3	-2	-2
06/16/03	1,264	-2	2	-4	-4
06/27/03	1,222	0	-2	-6	-11

Table A-14. Sodium concentration reductions.

Date	BF-IN mg/L	% Reduction of BF- IN concentration			
		BFA1-Out	BFA2-Out	BFB1-Out	BFB2-Out
04/01/03	358	10	9	9	9
05/08/03	329	5	5	2	-1
06/10/03	279	-3	-2	-3	-10
06/16/03	354	1	6	-3	1
06/27/03	318	-5	-13	-16	-16

Table A-15. Calcium concentration reductions.

Date	BF-IN mg/L	% Reduction of BF- IN concentration			
		BFA1-Out	BFA2-Out	BFB1-Out	BFB2-Out
04/01/03	112	29	39	21	39
05/08/03	108	37	73	41	33
06/10/03	108	15	-33	-6	-9
06/16/03	62	39	52	61	42
06/27/03	96	51	26	45	44

Table A-16. Magnesium concentration reductions.

Date	BF-IN mg/L	% Reduction of BF- IN concentration			
		BFA1-Out	BFA2-Out	BFB1-Out	BFB2-Out
04/01/03	56	29	29	21	29
05/08/03	59.6	34	42	32	28
06/10/03	56	7	-5	-4	0
06/16/03	44	0	7	14	4
06/27/03	68.4	37	30	39	37

Table A-17. Copper concentration reductions.

Date	BF-IN mg/L	% Reduction of BF- IN concentration			
		BFA1-Out	BFA2-Out	BFB1-Out	BFB2-Out
02/25/03	0.88	-107	5	-14	14
03/19/03	0.8	55	91	-10	73
04/01/03	0.48	67	58	42	50
05/08/03	0.68	29	54	6	24
06/10/03	0.68	26	-32	-9	-6
06/16/03	0.34	-29	-71	59	-24
06/27/03	1	74	45	58	51

Table A-18. Zinc concentration reductions.

Date	BF-IN mg/L	% Reduction of BF- IN concentration			
		BFA1-Out	BFA2-Out	BFB1-Out	BFB2-Out
02/25/03	1.64	74	76	67	73
03/19/03	3.16	27	74	30	40
04/01/03	4.04	43	56	33	48
05/08/03	5.12	44	78	46	46
06/10/03	5.84	24	-24	5	9
06/16/03	2.40	13	52	53	15
06/27/03	5.88	71	40	63	64

Table A-19. Chloride concentration reductions.

Date	BF-IN mg/L	% Reduction of BF- IN concentration			
		BFA1-Out	BFA2-Out	BFB1-Out	BFB2-Out
04/01/03	703	1.00	1.28	1.14	0.57
05/08/03	676	0.74	-1.04	0.00	-1.18
06/10/03	617	0.00	-0.81	0.65	-0.49
06/16/03	655	0.00	1.07	0.92	-0.46
06/27/03	652	-0.61	-1.23	-0.46	-0.46

Table A-20. Volatile solids concentration.

Date	BF IN mg/L	BFA1 Out mg/L	BFA2 Out mg/L	BFB1 Out mg/L	BFB2 Out mg/L
02/04/03	-	1,600	2,100	-	2,200
02/05/03	2,300	-	-	2,400	-
02/18/03	-	-	1,800	-	1,500
02/19/03	1,900	1,600	-	1,600	-
02/25/03	2,400	1,400	1,400	2,300	1,100
03/01/03	2,079	2,000	2,700	2,200	2,300
03/10/03	-	-	1,900	-	2,000
03/11/03	2,200	1,000	-	2,500	-
03/19/03	2,000	1,802	1,300	1,900	1,800
03/25/03	1,800	1,900	1,600	1,700	1,600
04/01/03	2,400	1,898	1,636	2,100	1,700
04/09/03	2,000	1,800	1,400	1,400	1,500
04/15/03	2,300	1,900	1,700	3,100	2,500
04/22/03	2,400	-	-	2,400	1,500
05/01/03	1,800	2,200	2,500	2,300	2,400
05/08/03	2,800	1,900	1,300	1,900	1,800
05/15/03	1,400	-	-	1,300	1,000
05/26/03	970	-	-	1,950	2,278
06/10/03	2,300	2,200	2,300	2,500	2,100
06/16/03	1,400	1,700	1,200	900	1,000
06/27/03	2,300	1,600	1,900	1,600	1,700

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Table B-1. Lagoon TAN concentrations.

Date	L1 mg/L	L2 mg/L	L3 mg/L	Control mg/L
12/05/01	646	646	646	-
03/14/02	785	-	796	-
05/22/02	757	818	831	
06/26/02	649	706	714	662
08/06/02	456	478	454	466
08/20/02	421	-	-	-
08/27/02	408	-	-	-
09/04/02	345	-	-	-
09/12/02	348	-	-	-
09/17/02	376	-	-	-
09/30/02	389	-	-	-
10/10/02	333	-	-	-
10/16/02	312	-	-	-
10/24/02	333	-	-	-
10/31/02	381	-	-	-
11/14/02	378	-	-	-
11/26/02	372	-	-	-
12/10/02	381	-	-	-
01/10/03	429	-	-	-
01/22/03	422	-	-	-
01/29/03	416	-	-	-
02/05/03	422	-	-	-
02/19/03	437	-	-	-
02/25/03	453	475	523	585
03/04/03	463	-	-	-
03/11/03	416	-	-	-
03/19/03	411	440	501	568
03/25/03	385	-	-	-
04/01/03	362	382	498	582
04/09/03	339	-	-	-
04/15/03	286	-	-	-
04/22/03	351	-	-	-
05/01/03	324	-	-	-
05/08/03	322	375	420	585
05/15/03	348	-	-	-
05/26/03	307	346	-	-
06/10/03	211	290	-	-
06/16/03	233	301	299	526
06/27/03	244	-	-	-

Table B-2. Lagoon TKN concentrations.

Date	L1 mg/L	L2 mg/L	L3 mg/L	Control mg/L
12/05/01	812	812	812	-
03/14/02	992	-	995	-
05/22/02	934	1001	1002	-
06/26/02	835	862	876	799
08/06/02	522	560	538	536
02/25/03	551	616	639	712
03/11/03	474	-	-	-
03/19/03	509	542	608	704
03/25/03	446	-	-	-
04/01/03	530	569	682	662
04/09/03	450	-	-	-
04/15/03	485	-	-	-
04/22/03	447	-	-	-
05/01/03	423	-	-	-
05/08/03	412	419	451	631
05/15/03	418	-	-	-
05/26/03	384	430	-	-
06/10/03	303	384	-	-
06/16/03	314	359	301	627
06/27/03	283	-	-	-

Table B-3. Nitrate + Nitrite concentrations in the lagoon.

Date	L1 mg/L	L2 mg/L	L3 mg/L	Control mg/L
12/05/01	0	0	0	-
03/14/02	0	-	0	-
05/22/02	0	0	0	-
06/26/02	0	0	0	-
08/06/02	0	0	0	-
08/20/02	0	-	-	-
08/27/02	0	-	-	-
09/04/02	0	-	-	-
09/12/02	0	-	-	-
09/17/02	0	-	-	-
09/30/02	0	-	-	-
10/10/02	30	-	-	-
10/16/02	14.3	-	-	-
10/24/02	35.3	-	-	-
10/31/02	4.6	-	-	-
11/14/02	1.68	-	-	-
11/26/02	0	-	-	-
12/10/02	29.3	-	-	-
01/10/03	0	-	-	-
01/22/03	0	-	-	-
01/29/03	0.01	-	-	-
02/05/03	0	-	-	-
02/19/03	0.02	-	-	-
02/25/03	0	0	0	-
03/11/03	0.02	-	-	-
03/19/03	0	-	-	-
03/25/03	0	-	-	-
04/01/03	0	0	0	-
04/09/03	0.02	-	-	-
04/15/03	2.03	-	-	-
04/22/03	0	-	-	-
05/01/03	15.8	-	-	-
05/08/03	1.55	0	0	0.03
05/15/03	0.04	-	-	-
05/26/03	4.87	1.9	-	-
06/10/03	55.1	0.29	-	-
06/16/03	3.38	0.02	0	0
06/27/03	31	-	-	-

Table B-4. Lagoon TP concentrations.

Date	L1 mg/L	L2 mg/L	L3 mg/L	Control mg/L
12/05/01	97.3	97.3	97.3	-
03/14/02	89.7	-	96.4	-
05/22/02	92.3	106	112	-
06/26/02	101	93.8	94.2	82.2
08/06/02	70	72.1	73.6	67.3
02/25/03	66	69.6	69.8	79.5
03/19/03	65.3	69.1	63.9	70.9
04/01/03	66.1	68.5	64.7	74.4
05/08/03	60.7	55.6	55.6	63.1
06/10/03	52.4	51	-	-
06/16/03	83.1	89.2	72.2	87.3
06/27/03	85.64	-	-	-

Table B-5. COD concentrations in the lagoon.

Date	L1 mg/L	L2 mg/L	L3 mg/L	Control mg/L
12/05/01	2,064	2,064	2,064	-
03/14/02	3,160	-	3,220	-
05/22/02	2,000	2,180	2,330	-
06/26/02	2,252	2,300	2,344	2,004
08/06/02	2,052	2,040	1,988	1,744
08/20/02	1,884	-	-	-
08/27/02	1,858	-	-	-
09/04/02	1,802	-	-	-
09/12/02	2,162	-	-	-
09/17/02	1,806	-	-	-
09/30/02	2,054	-	-	-
10/10/02	1,742	-	-	-
10/16/02	1,464	-	-	-
10/24/02	1,446	-	-	-
10/31/02	1,548	-	-	-
11/14/02	1,544	-	-	-
11/26/02	1,546	-	-	-
12/10/02	1,722	-	-	-
01/10/03	2,040	-	-	-
01/22/03	1,924	-	-	-
01/29/03	1,984	-	-	-
02/05/03	2,100	-	-	-
02/19/03	2,040	-	-	-
02/25/03	1,920	1,972	2,264	2,592
03/01/03	2,804	-	-	-
03/11/03	1,756	-	-	-
03/19/03	1,880	1,924	2,284	2,664
03/24/03	1,648	-	-	-
04/01/03	1,600	1,504	1,772	2,308
04/09/03	1,412	-	-	-
04/15/03	1,448	-	-	-
04/22/03	1,436	-	-	-
05/01/03	1,292	-	-	-
05/08/03	1,196	1,340	1,478	1,684
05/15/03	1,348	-	-	-
05/26/03	1,114	1,226	-	-
06/10/03	1,056	1,146	-	-
06/16/03	1,024	1,132	1,328	1,628
06/27/03	908	-	-	-

Table B-6. Nitrite concentrations in the lagoon.

Date	L1	L2	L3	Control
	mg/L	mg/L	mg/L	mg/L
12/05/01	0	0	0	-
03/14/02	0	-	0	-
05/22/02	0	0	0	-
06/26/02	0	0	0	-
08/06/02	0	0	0	-
08/20/02	0	-	-	-
08/27/02	0	-	-	-
09/04/02	0	-	-	-
09/12/02	0	-	-	-
09/17/02	0	-	-	-
09/30/02	0	-	-	-
10/10/02	17.6	-	-	-
10/16/02	13.9	-	-	-
10/24/02	30.2	-	-	-
10/31/02	3.16	-	-	-
11/14/02	0.29	-	-	-
11/26/02	0	-	-	-
12/10/02	5.06	-	-	-
01/22/03	0	-	-	-
01/29/03	0.01	-	-	-
02/05/03	0	-	-	-
02/19/03	0.01	-	-	-
02/25/03	0	0	0	
03/11/03	0.02	-	-	-
03/19/03	0	-	-	-
04/09/03	0.05	-	-	-
04/15/03	0.45	-	-	-
04/22/03	0	-	-	-
05/01/03	5.04	-	-	-
05/08/03	0	0	0	-
05/15/03	0.01	-	-	-
05/26/03	0.18	0.29	-	-
06/27/03	0.01	-	-	-

Table B-7. Lagoon pH.

Date	L1	L2	L3	Control
12/05/01	8.03	8.03	8.03	-
03/14/02	7.94		7.94	-
05/22/02	8.15	8.14	8.05	-
06/26/02	8.21	8.20	8.19	8.12
08/06/02	8.26	8.24	8.23	8.15
08/20/02	8.72	-	-	-
08/27/02	8.52	-	-	-
09/04/02	8.42	-	-	-
09/12/02	8.38	-	-	-
09/17/02	8.30	-	-	-
09/30/02	8.17	-	-	-
10/10/02	8.50	-	-	-
10/16/02	8.55	-	-	-
10/24/02	8.57	-	-	-
10/31/02	8.50	-	-	-
11/14/02	8.40	-	-	-
11/26/02	8.24	-	-	-
12/10/02	8.14	-	-	-
01/10/03	8.04	-	-	-
01/22/03	8.25	-	-	-
01/29/03	8.41	-	-	-
02/05/03	8.29	-	-	-
02/19/03	8.38	-	-	-
02/25/03	8.24	8.14	8.13	8.07
03/04/03	8.08	-	-	-
03/11/03	8.22	-	-	-
03/19/03	8.24	8.23	8.21	8.11
03/24/03	8.10	-	-	-
04/01/03	8.29	8.21	8.18	8.18
04/09/03	8.24	-	-	-
04/15/03	8.21	-	-	-
04/22/03	8.34	-	-	-
05/01/03	8.50	-	-	-
05/08/03	8.55	8.37	8.38	8.33
05/15/03	8.22	-	-	-
05/26/03	8.36	8.22	-	-
06/10/03	8.47	8.48	-	-
06/16/03	8.32	8.27	8.41	8.26
06/27/03	8.35	-	-	-

Table B-8. Lagoon total solids concentrations.

Date	L1	L2	L3	Control
	%	%	%	%
12/05/01	0.58	0.58	0.58	-
05/22/02	0.59	0.56	0.61	-
06/26/02	0.68	0.65	0.66	0.52
08/06/02	0.62	0.60	0.60	0.53
01/22/03	0.61	-	-	-
02/05/03	0.63	-	-	-
02/19/03	0.58	-	-	-
02/25/03	0.57	0.57	0.58	0.53
03/11/03	0.56	-	-	-
03/19/03	0.57	0.57	0.57	0.52
03/25/03	0.55	-	-	-
04/01/03	0.54	0.54	0.55	0.53
04/09/03	0.52	-	-	-
04/15/03	0.52	-	-	-
04/22/03	0.52	-	-	-
05/01/03	0.50	-	-	-
05/08/03	0.51	0.51	0.50	0.49
05/15/03	0.50	-	-	-
05/26/03	0.47	0.48	-	-
06/10/03	0.50	0.48	-	-
06/16/03	0.48	0.49	0.49	0.49
06/27/03	0.52	-	-	-

Table B-9. Lagoon suspended solids concentrations.

Date	L1 mg/L	L2 mg/L	L3 mg/L	Control mg/L
05/22/02	363	403	457	-
06/26/02	490	480	503	497
01/22/03	608	-	-	-
02/05/03	857	-	-	-
02/25/03	533	592	513	477
03/11/03	537	-	-	-
03/19/03	526	648	507	611
03/25/03	489	-	-	-
04/01/03	637	704	675	675
04/09/03	495	-	-	-
04/15/03	571	-	-	-
04/22/03	493	-	-	-
05/01/03	410	-	-	-
05/08/03	346	420	393	546
05/15/03	447	-	-	-
05/26/03	247	273	-	-
06/10/03	519	467	-	-
06/16/03	457	547	547	722
06/27/03	512	-	-	-

Table B-10. Lagoon OP concentrations.

Date	L1 mg/L	L2 mg/L	L3 mg/L	Control mg/L
12/05/01	86	86	86	-
03/14/02	89.2	-	95.5	-
05/22/02	82.6	86.4	85.4	-
06/26/02	83.7	83.9	84.2	74.4
08/06/02	69.1	68.8	69.6	61.9
02/25/03	52.7	55.4	56.2	58
03/19/03	57	61.4	59.8	63.7
04/01/03	60.8	60.4	58.9	65.2
05/08/03	55.4	55	55	63
06/10/03	51	50.7	-	-
06/16/03	60.6	63.8	54.9	61.9
06/27/03	63.92	-	-	-

Table B-11. Lagoon potassium concentrations.

Date	L1 mg/L	L2 mg/L	L3 mg/L	Control mg/L
12/05/01	1,396	1,396	1,396	-
03/14/02	1,356	-	1,376	-
05/22/02	1,830	1,886	1,752	-
06/26/02	1,712	1,676	1,684	1,384
08/06/02	1,615	1,604	1,607	1,385
02/25/03	1,632	1,656	1,636	1,418
03/19/03	1,638	1,601	1,555	1,418
04/01/03	1,362	1,363	1,320	1,224
05/08/03	1,226	1,192	1,192	1,064
06/10/03	1,270	1,214	-	-
06/16/03	1,258	1,238	1,256	1178
06/27/03	1,168	-	-	-

Table B-12. Lagoon sodium concentrations

Date	L1 mg/L	L2 mg/L	L3 mg/L	Control mg/L
12/05/01	484	484	484	-
03/14/02	460	-	480	-
05/22/02	616	560	648	-
06/26/02	560	550	552	460
08/06/02	483	478	474	416
02/25/03	382	389	355	353
03/19/03	342	366	378	368
04/01/03	368	362	346	331
05/08/03	350	332	337	359
06/10/03	256	263	-	-
06/16/03	338	334	367	345

Table B-13. Lagoon calcium concentrations.

Date	L1 mg/L	L2 mg/L	L3 mg/L	Control mg/L
12/05/01	44	44	44	-
03/14/02	80	-	80	-
05/22/02	60	60	40	-
06/26/02	32	36	34	42
08/06/02	36	41	37	38
02/25/03	35.4	40	46.8	54
03/19/03	53	52	57	57
04/01/03	56	56	64	72
05/08/03	32	40	44	56
06/10/03	52	44	-	-
06/16/03	42	46	50	52
06/27/03	35	-	-	-

Table B-14. Lagoon magnesium concentrations.

Date	L1 mg/L	L2 mg/L	L3 mg/L	Control mg/L
12/05/01	8	8	8	-
03/14/02	10	-	12	-
05/22/02	10	12	12	-
06/26/02	8	8	10	12
08/06/02	12	14	12	16
02/25/03	9.2	10.8	9.8	8.8
03/19/03	16	19	14	15
04/01/03	16	24	16	16
05/08/03	14	15.2	12.2	15.5
06/10/03	28	20.8	-	-
06/16/03	24	24	20.4	18
06/27/03	23.1	-	-	-

Table B-15. Lagoon copper concentrations.

Date	L1 mg/L	L2 mg/L	L3 mg/L	Control mg/L
12/05/01	0.10	0.10	0.10	-
03/14/02	0.26	-	0.38	-
05/22/02	0.20	0.40	0.40	-
06/26/02	0.14	0.12	0.14	0.06
08/06/02	0.15	0.15	0.12	0.10
02/25/03	0.16	0.18	0.14	0.20
03/19/03	0.08	0.09	0.04	0.02
04/01/03	0.12	0.08	0.08	0.04
05/08/03	0.10	0.08	0.10	0.13
06/10/03	0.08	0.08	-	-
06/16/03	0.02	0.02	0.02	0.02
06/27/03	0.12	-	-	-

Table B-16. Lagoon zinc concentrations.

Date	L1 mg/L	L2 mg/L	L3 mg/L	Control mg/L
12/05/01	0.4	0.4	0.4	-
03/14/02	0.5	-	0.96	-
05/22/02	0.4	0.48	0.56	-
06/26/02	0.8	0.6	1.2	0.6
08/06/02	0.4	0.48	0.37	0.31
02/25/03	0.6	0.66	0.56	0.42
03/19/03	0.6	0.7	0.57	0.49
04/01/03	1.3	1.32	1.12	1.2
05/08/03	0.6	0.7	0.74	0.63
06/10/03	0.5	0.52	-	-
06/16/03	0.4	0.5	0.44	0.52
06/27/03	0.6	-	-	-

Table B-17. Lagoon chloride concentrations.

Date	L1 mg/L	L2 mg/L	L3 mg/L	Control mg/L
12/05/01	726	726	726	-
03/14/02	704	-	702	-
05/22/02	771	763	756	-
06/26/02	951	943	922	772
08/06/02	914	907	908	822
02/25/03	706	710	712	667
03/19/03	680	684	687	634
04/01/03	683	680	677	635
06/10/03	639	626	-	-
06/16/03	662	673	668	640
06/27/03	660	-	-	-

Table B-18. Volatile solids concentrations in lagoon liquid (mg/L).

Date	L1	L2	L3	Control
12/05/01	1,500	1,500	1,500	-
05/22/02	1,449	1,468	1,447	-
06/26/02	1,600	1,500	1,600	1,300
08/06/02	1,800	1,700	1,700	1,500
02/05/03	1,900	-	-	-
02/19/03	1,000	-	-	-
02/25/03	1,500	1,500	1,542	1,600
03/11/03	1,500	-	-	-
03/19/03	1,200	1,200	1,300	1,300
03/25/03	1,400	-	-	-
04/01/03	1,600	1,500	1,500	1,700
04/09/03	900	-	-	-
04/15/03	1,200	-	-	-
04/22/03	1,255	-	-	-
05/01/03	1,000	-	-	-
05/08/03	1,400	1,200	1,300	1,300
05/15/03	1,100	-	-	-
05/26/03	570	610	-	-
06/10/03	1,300	1,000	-	-
06/16/03	1,000	1,100	1,100	1,200
06/27/03	1,300	-	-	-

APPENDIX C: BIOFILTER BACKWASH

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Table C-1. Backwash total solids concentrations.

Date	BW A1 mg/L	BW A2 mg/L	BW B1 mg/L	BW B2 mg/L
02/05/03	-	2.45	-	-
02/18/03	-	-	0.70	-
02/19/03	0.70	-	-	-
02/25/03	-	1.35	-	0.82
02/28/03	1.12	0.74	0.77	0.83
03/10/03	0.62	1.75	1.37	0.81
03/18/03	0.73	0.77	0.74	0.71
03/25/03	0.61	1.52	0.61	0.61
03/31/03	0.60	0.86	0.62	0.60
04/08/03	-	-	-	0.62
04/09/03	0.61	1.01	0.64	-
04/15/03	0.80	0.62	0.79	0.84
05/01/03	0.74	0.77	0.90	0.78
05/08/03	0.51	0.51	0.51	0.52
05/15/03	0.69	0.84	0.60	0.73
06/10/03	3.84	0.80	0.72	0.71
06/16/03	0.51	0.47	0.57	0.52
06/27/03	0.60	0.53	0.57	0.58

Table C-2. Backwash suspended solids concentrations.

Date	BW A1 mg/L	BW A2 mg/L	BW B1 mg/L	BW B2 mg/L
02/05/03	-	21,633	-	-
02/25/03	-	11,033	-	4,133
02/28/03	-	3,517	3,833	4,500
03/10/03	1,680	15,233	9,700	4,767
03/18/03	2,620	3,517	3,023	2,500
03/25/03	1,370	12,233	1,603	1,250
03/31/03	1,083	4,945	1,871	1,321
04/08/03	-	-	-	1,750
04/09/03	2,167	8,833	2,455	-
04/15/03	4,900	2,197	5,917	5,400
05/01/03	3,247	2,553	5,778	3,153
05/08/03	457	466	442	559
05/15/03	4,533	5,883	2,378	5,800
06/10/03	21,467	4,967	4,917	4,200
06/16/03	880	188	2,456	1,301
06/27/03	2,067	1,027	2,044	1,583

Table C-3. Backwash TAN concentrations.

Date	BW A1 mg/L	BW A2 mg/L	BW B1 mg/L	BW B2 mg/L
02/05/03	-	511	-	-
02/18/03	-	-	470	-
02/19/03	443	-	-	-
02/25/03	-	333	-	451
02/28/03	459	381	465	380
03/10/03	240	442	504	262
03/18/03	338	323	339	250
03/25/03	57.6	58.6	98.2	0.11
03/31/03	84.3	11.2	102	6.96
04/08/03	-	-	-	11.5
04/09/03	103	34.3	118	-
04/15/03	32.4	16.4	2.5	3.8
05/01/03	108	8.4	111	5.7
05/08/03	0.15	3.93	4.99	1.61
05/15/03	82.4	0.2	0.93	11.1
06/10/03	68	7.09	14.1	5.5
06/16/03	38.1	15.9	110	1.23
06/27/03	71.74	4.46	46.68	0.29

Table C-4. Backwash nitrate-N + nitrite-N (NO_{2+3} -N) concentrations.

Date	BW A1 mg/L	BW A2 mg/L	BW B1 mg/L	BW B2 mg/L
02/05/03	-	0	-	-
02/18/03	-	-	0.01	-
02/19/03	18.1	-	-	-
02/25/03	-	13.6	-	32.5
02/28/03	0	7.39	0	20.4
03/10/03	59.2	0	0	35.5
03/18/03	4.48	0	1.12	102
03/25/03	72.2	0.01	38.1	147
03/31/03	85.4	45	61.4	165
04/08/03	-	-	-	200
04/09/03	112	93.3	98.6	-
04/15/03	47	153	188	274
05/01/03	196	369	189	338
05/08/03	273	197	273	260
05/15/03	143	213	276	195
06/10/03	118	233	241	287
06/16/03	101	64.8	87.7	181
06/27/03	124	177	148	234

Table C-5. Backwash nitrite-N (NO_2^- - N) concentrations.

Date	BW A1 mg/L	BW A2 mg/L	BW B1 mg/L	BW B2 mg/L
02/18/03	-	-	0	-
02/19/03	16.93	-	-	-
02/25/03	-	13.3	-	31.3
03/18/03	-	-	0.81	25
03/25/03	56.2	0.02	29.4	114
03/31/03	79.2	40.9	59.1	126
04/08/03	-	-	-	90.1
04/09/03	75.6	64.7	70.1	-
04/15/03	30.7	33.4	55.5	83.1
05/01/03	82.7	31.3	88.9	141
05/08/03	240	177	238	228
05/15/03	49.7	0.05	195	131
06/10/03	16.3	66.6	85.4	31.4
06/16/03	21.5	0.65	11	1.19
06/27/03	45.4	47.5	50.3	0.02

Table C-6. Backwash COD concentrations.

Date	BW A1 mg/L	BW A2 mg/L	BW B1 mg/L	BW B2 mg/L
02/05/03	-	26,600	-	-
02/18/03	-	-	3,650	-
02/19/03	3,460	-	-	-
02/25/03	-	12,170	-	5,070
02/28/03	10,420	3,560	4,260	4,650
03/10/03	2,090	20,100	14,100	5,510
03/18/03	3,620	4,300	3,500	3,960
03/25/03	2,430	15,800	2,710	2,550
03/31/03	2,408	6,440	2,520	2,480
04/08/03	-	-	-	3,532
04/09/03	2,488	8,600	2,856	-
04/15/03	5,196	2,688	5,184	5,896
05/01/03	3,924	3,252	6,536	4,380
05/08/03	1,226	1,096	1,244	1,426
05/15/03	5,165	5,390	3,160	4,600
06/10/03	12,260	4,510	5,525	3,560
06/16/03	1,296	672	2,244	1,536
06/27/03	2,612	1,240	2,468	1,516

Table C-7. Backwash pH.

Date	BW A1 mg/L	BW A2 mg/L	BW B1 mg/L	BW B2 mg/L
02/05/03	-	8.49	-	-
02/18/03	8.6	8.5	8.69	-
02/25/03	-	-	-	8.6
02/28/03	8.15	8.26	8.26	8.61
03/10/03	8.5	8.29	8.54	8.65
03/18/03	8.53	8.42	8.66	8.61
03/25/03	8.34	8.45	8.46	8.31
03/31/03	8.31	8.44	8.5	8.22
04/08/03	-	-	-	8.2
04/09/03	8.21	8.25	8.37	-
04/15/03	8.45	8.23	8.52	8.31
05/01/03	8.19	7.91	8.45	8.23
05/08/03	8.04	8.14	8.11	8.09
05/15/03	8.3	8.99	8.04	8.6
06/10/03	8.5	8.16	8.31	8.41
06/16/03	8.32	8.41	8.34	8.92
06/27/03	8.16	8.15	8.27	8.59

Table C-8. Backwash TKN concentrations.

Date	BW A1 mg/L	BW A2 mg/L	BW B1 mg/L	BW B2 mg/L
02/25/03	-	1102	-	748
02/28/03	1015	585	738	719
03/10/03	381	1645	1359	520
03/18/03	571	589	605	473
03/25/03	194	1222	134	235
03/31/03	344	496	361	298
04/08/03	-	-	-	198
04/09/03	292	606	321	-
04/15/03	369	245	308	391
05/01/03	351	221	458	225
05/08/03	65.9	61.6	58.2	77.8
05/15/03	253	261	128	254
06/10/03	711	237	197	167
06/16/03	40.3	44.5	208	58.6
06/27/03	208	87.65	183	84.71

Table C-9. Backwash total phosphorus concentrations.

Date	BW A1 mg/L	BW A2 mg/L	BW B1 mg/L	BW B2 mg/L
02/25/03	-	464	-	205
03/18/03	112	147	127	110
03/31/03	91.9	162	113	104
05/08/03	78.2	84.2	77	87.3
06/10/03	511	217	200	186
06/16/03	110	114	151	136
06/27/03	141	122	150	129

Table C-10. Backwash ortho phosphate concentrations.

Date	BW A1 mg/L	BW A2 mg/L	BW B1 mg/L	BW B2 mg/L
03/31/03	85.5	81.8	86.3	75.6
05/08/03	77.1	81.9	74.2	80.4
06/10/03	177	126	119	113
06/16/03	81.9	85.6	102	91.7
06/27/03	91.53	83.54	91.84	77.07

Table C-11. Backwash potassium concentrations.

Date	BW A1 mg/L	BW A2 mg/L	BW B1 mg/L	BW B2 mg/L
03/31/03	1,307	1,147	1,240	1,180
05/08/03	1,302	1,360	1,332	1,328
06/10/03	1,259	1,288	1,236	1,279
06/16/03	1,286	1,298	1,258	1,300
06/27/03	1,344	1,355	1,352	1,334

Table C-12. Backwash sodium concentrations.

Date	BW A1 mg/L	BW A2 mg/L	BW B1 mg/L	BW B2 mg/L
03/31/03	316	324	346	329
05/08/03	381	388	391	390
06/10/03	75.8	339	85.4	345
06/16/03	374	371	366	380
06/27/03	371	372	372	365

Table C-13. Backwash calcium concentrations.

Date	BW A1 mg/L	BW A2 mg/L	BW B1 mg/L	BW B2 mg/L
03/31/03	72	160	80	68
05/08/03	32	34	32	32
06/10/03	448	168	120	136
06/16/03	32	18	66	44
06/27/03	71	19	75	55

Table C-14. Backwash magnesium concentrations.

Date	BW A1 mg/L	BW A2 mg/L	BW B1 mg/L	BW B2 mg/L
03/31/03	40	53.3	32	32
05/08/03	43.2	42.2	54.8	47.6
06/10/03	140	69	68	68
06/16/03	41	43	47	41
06/27/03	50.4	45.1	50.3	39.9

Table C-15. Backwash copper concentrations.

Date	BW A1 mg/L	BW A2 mg/L	BW B1 mg/L	BW B2 mg/L
02/25/03	-	2.08	-	0.8
03/18/03	0.16	0.32	0.16	0.22
03/31/03	0.12	0.87	0.2	0.12
05/08/03	0.26	0.10	0.4	0.24
06/10/03	3.08	1.10	0.78	0.76
06/16/03	0.2	0.10	0.46	0.28
06/27/03	0.45	0.24	0.48	0.3

Table C-16. Backwash zinc concentrations.

Date	BW A1 mg/L	BW A2 mg/L	BW B1 mg/L	BW B2 mg/L
02/25/03	-	14.68	-	4.76
03/18/03	2.32	4	3.12	2.72
03/31/03	2.08	7.4	2.4	2.04
05/08/03	0.64	0.38	0.44	0.72
06/10/03	28.86	9.98	6.7	6.82
06/16/03	1.26	0.22	3.98	2.4
06/27/03	3.24	1.67	3.47	2.22

Table C-17. Backwash chloride concentrations.

Date	BW A1 mg/L	BW A2 mg/L	BW B1 mg/L	BW B2 mg/L
03/31/03	685	693	693	691
05/08/03	684	684	685	684
06/10/03	606	617	612	615
06/16/03	659	645	650	639
06/27/03	652	650	656	652

Table C-18. Volatile solids concentrations in backwash.

Date	BW A1	BW A2	BW B1	BW B2
	mg/L	mg/L	mg/L	mg/L
02/05/03	-	16,501	-	-
02/18/03	1,800	-	1,900	-
02/25/03	-	7,501	-	3,100
02/28/03	5,900	2,800	3,200	3,400
03/10/03	1,900	10,600	7,099	2,900
03/18/03	2,300	2,800	2,200	2,200
03/25/03	1,800	8,900	1,900	1,600
03/31/03	1,800	3,900	2,000	1,900
04/08/03	-	-	-	1,700
04/09/03	1,700	5,000	1,800	-
04/15/03	3,400	2,200	3,300	3,700
05/01/03	2,800	2,900	4,000	3,000
05/08/03	1,000	1,300	1,100	1,300
05/15/03	2,600	3,600	1,900	2,800
06/10/03	32,402	3,500	2,900	2,800
06/16/03	1,100	800	1,500	1,200
06/27/03	2,000	1,600	1,800	1,800

APPENDIX D: SOLIDS/LIQUID SEPARATION TESTS

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SOLIDS/LIQUID SEPARATION TESTS

The technology provider decided to convey separated solids to the L2 section of the lagoon. The solids fell from the press section (weighted plate over the solids outlet at the top of the inclined screen/conveyor) into a hopper which had an auger to move the solids to the L2 section. Therefore, it was not possible to measure the total amount of solids that were separated from the flushed manure. Therefore, batch tests were conducted for six separate flushes. For a pit release from a barn, the solids were collected for volume, weight and a sample. Samples of the separated liquid and the liquid from the press were also taken for most dates. Information and data for the separation tests are included in this appendix. In addition, data is included for grab samples that were taken at the beginning of each of the two OPEN team emissions measurement periods (samples taken 4/1/03 and 6/16/03).

SAMPLE CODES:

FM – Flushed manure; the liquid flowing from the barn pit to the separator.
SLIQ – Separated liquid; the liquid that passed through the screen of the separator.
SSLIQ – Separated solids liquid; liquid pressed from the solids at the top of the inclined conveyor before solids were discharged.
SEPSOL – Separated solids.

SAMPLING PROCEDURES:

Flushed manure (FM) and separated liquid (SLIQ) samples were taken from a composite composed of one dipper taken every 5 min. during flush and collected in a bucket. The liquid from the separator press (SSLIQ) was collected in a bucket for the entire flush and sampled at the end of the flush. The solid sample (SEPSOL) was taken from various locations in the buckets or wheelbarrow which held the total amount of solids generated. The press was not on the separator for the June 2003 samples, thus SSLIQ was not collected.

FLUSH VOLUME ESTIMATES:

Flush volumes were estimated by assuming the lift-station pump time was approximately the same as the time for flushing (78, 59, 77, 77, 62 and 54 min., respectively, for the tests in chronological order) and multiplying by pump rate of 757 L/min. (200 gal./min) for the first four tests and by 833 L/min (220 gal./min) for the last two tests when a different pump was present. The pump time and flush time were compared for the fourth and sixth test and were the same, but pump times were not recorded for the other tests. Recirculation of biofilter effluent was stopped during the batch tests, but the valve was slightly open for about 15 min. of the test on 6/11/03. For the tests on 6/11/03 and 6/13/03, the flow meters on inflow to the first-stage biofilters were observed and had flow volumes about 6-7 % higher than the pumping estimate. Thus, the flush volumes are estimates, but are likely within 10 % of actual flush volume based on the information available.

RESULTS:

The moisture content of the separated solids varied from 74 to 84 % wet basis when the press was on the separator, and varied from 77 to 88 % when the press was not present. The weights of “wet” solids were about 20 kg (44 lb) with the press present, and about 70 kg (154 lb) without the press. The dry weight of solids collected was 4 to 5 kg with the press present, and about 10 kg without the press. Although the size of the pigs and the time since the last flush would affect the amounts of solids in the flush, it appears that less solids was collected when the press was present, perhaps because of retaining some solids in the “press section”. The amounts of total solids (TS) and volatile solids (VS) in the flushes were on the order of 425 kg and 140 to 220 kg, respectively. Thus, the amounts of total solids recovered (SSOL and SSLIQ) were a

small percentage of the total solids in the flush (<3 % of TS). The amounts of volatile solids recovered were also a small percentage of the volatile solids in the flush (< 5 % of VS). The amounts of nutrients and metals in the flush that were recovered were similar low percentages. Comparison of concentrations of FM and SLIQ shows higher percentages of removal on some dates than removal percentages based on solids collected. However, some dates show increased concentrations in SLIQ compared to FM, and this is likely due to the lack of being able to take representative samples of FM and SLIQ for the entire flush. Therefore, the data on separated material that is collected is judged to be more reliable than the concentration differences from grab samples that are composited.

Table D-1. Information for batch solid-liquid separation tests.

Date	Source (Barn #)	No. pigs	Avg. pig wt. (kg/pig)	Total live wt. (kg)	Time since previous flush (hr.)	Time of flush (min.)	Estimated Flush volume (L)	SEPSOL (L)	SEPSOL (kg)	SSLIQ (L)
03/14/03	1	920	66	60,700	18	78	59,050	26.5	19.1	10.6
03/14/03	2	806	81	65,300	29	59	44,660	23.7	20.4	12.3
03/17/03	3	885	71	62,840	72	77	58,290	21.8	17.1	11.4
04/01/03	3	865	80	69,200	-	-	-	-	-	-
04/29/03	5	824	84	69,220	24	67	59,050	30.3	21.0	-
06/11/03	2	867	45	39,020	36	62	51,630	67.2	64.2	N/A
06/13/03	3	902	38	34,280	20	54	44,970	76.6	74.1	N/A
06/16/03	5	843	40	33,720	-	-	-	-	-	-

Notes:

1. Grab samples were taken on 4/1/03 and 6/16/03 in conjunction with sampling for pathogens and emissions testing, and were not batch tests of solids-liquid separation.
2. On 4/29/03, SSLIQ sample was taken but volume was not recorded.
3. On 6/11/03 and 6/13/03, the press on separator was not present, so SSLIQ was not collected.

Table D-2. Solids analysis data (wet basis).

Date	Source	Liquid	Solids		pH	MC	TS	VS	TKN	TAN	$NO_{2+3}N$	TP	Na	K	Ca	Mg	Cu	Zn	% C	% N
	Barn #	Volume	Volume	Weight																
		m^3	m^3	kg		%	%	%TS	µg/g	µg/g	µg/g	µg/g	µg/g	µg/g	µg/g	µg/g	µg/g	µg/g		
03/14/03	1	59	0.026	19.05	7.68	83.9	16.1	83.4	8,026	969	1.55	4,418	-	8,530	-	-	111	1,054	7.62	0.68
03/14/03	2	45	0.024	20.32	8.27	80.6	19.4	86.1	7,944	1,021	1.65	3,140	-	8,120	-	-	69	597	9	0.81
03/17/03	3	58	0.022	17.10	8.5	76.8	23.2	84.4	7,602	481	0.95	5,922	-	6,630	-	-	57	419	10.5	0.61
04/01/03	3	-	-	-	8.15	79.4	20.7	90.1	7,769	-	-	2,513	2,225	7,395	24,850	4,220	62	515	10.3	0.69
04/29/03	5	59	0.030	21.00	8.24	73.8	26.3	91.2	12,745	658	0.3	3,195	1,750	6,960	15,250	3,880	53	432	9.69	0.85
06/11/03	2	52	0.067	64.08	8	83.6	16.4	76.9	6212	86.6	0.78	3,184	2,740	9,460	48,400	6,840	100	976	6.17	0.68
06/13/03	3	45	0.077	73.97	8.09	86.2	13.8	85.6	6433	79	0.89	2,255	2,740	10,360	30,800	7,640	101	992	6.19	0.56
06/16/03	5	-	-	-	7.71	85.8	14.3	87.9	7590	62.8	0.89	1,503	3,150	11,790	22,800	5,880	106	1,192	5.52	0.58

Table D-3. TKN and TAN.

Date	Source	TKN							TAN						
		Concentration, mg/L			Mass, kg				Concentration, mg/L			Mass, kg			
		FM	SLIQ	SSLIQ	FM	SLIQ	SSLIQ	SEPSOL	FM	SLIQ	SSLIQ	FM	SLIQ	SSLIQ	SEPSOL
03/14/03	1	728	698	6,417	43.0	41.2	0.068	0.153	599	595	1256	35.4	35.1	0.013	0.018
03/14/03	2	1,024	940	-	45.7	42.0	-	0.161	704	701	-	31.4	31.3	-	0.021
03/17/03	3	750	763	2,843	43.7	44.5	0.032	0.130	566	565	59.3	33.0	32.9	0.001	0.008
04/01/03	3	779	531	-	-	-	-	-	497	288	-	-	-	-	-
04/29/03	5	860	947	4,350	50.8	55.9	-	0.268	677	687	936	40.0	40.6	-	0.014
06/11/03	2	1,158	1,098	-	59.8	56.7	-	0.398	670	666	-	34.6	34.4	-	0.006
06/13/03	3	1,179	1,135	-	53.0	51.0	-	0.476	584	595	-	26.3	26.8	-	0.006
06/16/03	5	595	495	-	-	-	-	-	418	391	-	-	-	-	-

Table D-4. Nitrite-N and Nitrate-N and COD.

Date	Source	NO_{2+3}-N							COD					
		Concentration, mg/L			Mass, kg				Concentration, mg/L			Mass, kg		
		FM	SLIQ	SSLIQ	FM	SLIQ	SSLIQ	SEPSOL	FM	SLIQ	SSLIQ	FM	SLIQ	SSLIQ
03/14/03	1	0	0	0	0	0	0	2.95E-05	3730	3150	64000	220	186	0.678
03/14/03	2	0	1.38	-	0	6.16E-02		3.35E-05	8860	7040	-	396	314	-
03/17/03	3	0	0	-	0	0	0	1.62E-05	4470	4460	70200	261	260	0.797
04/01/03	3	0	0	-	-	-	-	-	3284	3340	-	-	-	-
04/29/03	5	0	0	0	0	0	-	6.30E-06	4600	5360	89000	272	316	-
06/11/03	2	0	0	-	0	0	-	5.00E-05	5550	4650	-	287	240	-
06/13/03	3	0.02	0	-	8.99E-04	0	-	6.58E-05	5768	4116	-	259	185	-
06/16/03	5	-	-	-	-	-	-	-	3924	2120	-	-	-	-

Table D-5. Total phosphorus and orthophosphate.

		TP							OP						
		Concentration, mg/L			Mass, kg				Concentration, mg/L			Mass, kg			
Date	Source	FM	SLIQ	SSLIQ	FM	SLIQ	SSLIQ	SEPSOL	FM	SLIQ	SSLIQ	FM	SLIQ	SSLIQ	SEPSOL
03/14/03	1	118	104	2,968	7.0	6.1	0.031	0.084	-	-	-	-	-	-	-
03/14/03	2	208	168	-	9.3	7.5	-	0.064	-	-	-	-	-	-	-
03/17/03	3	115	115	1,346	6.7	6.7	0.015	0.101	-	-	-	-	-	-	-
04/01/03	3	95	110	-	-	-	-	-	79.2	87.7	-	-	-	-	-
04/29/03	5	138	170	2,000	8.1	10.0	-	0.067	123	136	1540	7.3	8.0	-	-
06/11/03	2	224	173	-	11.6	8.9	-	0.204	139	121	-	7.2	6.2	-	-
06/13/03	3	319	272	-	14.3	12.2	-	0.167	158	153	-	7.1	6.9	-	-
06/16/03	5	168	111	-	-	-	-	-	99.2	71.7	-	-	-	-	-

Table D-6. Total and volatile solids.

Date	Source	TS							VS						
		Concentration, mg/L			Mass, kg				Concentration, mg/L			Mass, kg			
		FM	SLIQ	SSLIQ	FM	SLIQ	SSLIQ	SEPSOL	FM	SLIQ	SSLIQ	FM	SLIQ	SSLIQ	SEPSOL
03/14/03	1	6,900	6,700	67,700	407	396	0.717	3.07	2,525	2,402	48,798	149	142	0.517	2.56
03/14/03	2	9,800	8,500	-	438	380	-	3.94	4,600	3,500	-	205	156	-	3.39
03/17/03	3	7,200	7,000	85,000	420	408	0.965	3.97	2,400	2,200	63,104	140	128	0.717	3.35
04/01/03	3	6,300	6,700	-	-	-	-	-	2,300	2,500	-	-	-	-	-
04/29/03	5	7,400	7,800	76,600	437	461	-	5.52	2,800	3,200	58,599	165	189	-	5.04
06/11/03	2	7,900	7,000	-	408	361	-	10.51	3,200	2,400	-	165	124	-	8.08
06/13/03	3	9,500	8,500	-	427	382	-	10.21	4,600	3,800	-	207	171	-	8.74
06/16/03	5	6,400	5,300	-	-	-	-	-	2,200	1,400	-	-	-	-	-

Table D-7. Suspended solids and chloride concentration.

Date	Source	SS						Cl					
		Concentration, mg/L			Mass, kg			Concentration, mg/L			Mass, kg		
		FM	SLIQ	SSLIQ	FM	SLIQ	SSLIQ	FM	SLIQ	SSLIQ	FM	SLIQ	SSLIQ
03/14/03	1	1813	1320	-	107	78	-	-	-	-	-	-	-
03/14/03	2	5017	2511	-	224	112	-	-	-	-	-	-	-
03/17/03	3	2147	2211	5200	125	129	0.059	-	-	-	-	-	-
04/01/03	3	1442	2444	-	-	-	-	686	693	-	-	-	-
04/29/03	5	3683	3917	-	217	231	-	709	716	645	42	42	-
06/11/03	2	5067	2917	-	262	151	-	657	656	-	34	34	-
06/13/03	3	7300	6333	-	328	285	-	661	659	-	30	30	-
06/16/03	5	3283	1444	-	-	-	-	670	662	-	-	-	-

Table D-8. Sodium and potassium.

Date	Source	Na							K						
		Concentration, mg/L			Mass, kg				Concentration, mg/L			Mass, kg			
		FM	SLIQ	SSLIQ	FM	SLIQ	SSLIQ	SEPSOL	FM	SLIQ	SSLIQ	FM	SLIQ	SSLIQ	SEPSOL
03/14/03	1	-	-	-	-	-	-	-	1578	1414	1490	93	83	0.016	0.162
03/14/03	2	-	-	-	-	-	-	-	1117	1224	-	50	55	-	0.165
03/17/03	3	-	-	-	-	-	-	-	1184	1488	1670	69	87	0.019	0.113
04/01/03	3	320	321	-	-	-	-	-	1132	1164	-	-	-	-	-
04/29/03	5	313	309	180	18.5	18.2	-	0.037	1198	1230	1160	71	73	-	0.146
06/11/03	2	344	360	-	17.8	18.6	-	0.176	1255	1304	-	65	67	-	0.606
06/13/03	3	310	318	-	13.9	14.3	-	0.203	1210	1244	-	54	56	-	0.766
06/16/03	5	338	222	-	-	-	-	-	1184	1172	-	-	-	-	-

Table D-9. Calcium and magnesium.

Date	Source	Ca							Mg						
		Concentration, mg/L			Mass, kg				Concentration, mg/L			Mass, kg			
		FM	SLIQ	SSLIQ	FM	SLIQ	SSLIQ	SEPSOL	FM	SLIQ	SSLIQ	FM	SLIQ	SSLIQ	SEPSOL
04/01/03	3	68	84	-	-	-	-	-	32	32	-	-	-	-	
04/29/03	5	112	116	1600	6.6	6.8	-	0.320	43	46	680	2.5	2.7	-	0.081
06/11/03	2	100	76	-	5.2	3.9	-	3.102	66	53	-	3.4	2.7	-	0.438
06/13/03	3	160	140	-	7.2	6.3	-	2.278	96	76	-	4.3	3.4	-	0.565
06/16/03	5	84	58	-	-	-	-	-	42	30	-	-	-	-	-

Table D-10. Copper and zinc.

Date	Source	Copper							Zinc						
		Concentration, mg/L			Mass, kg				Concentration, mg/L			Mass, kg			
		FM	SLIQ	SSLIQ	FM	SLIQ	SSLIQ	SEPSOL	FM	SLIQ	SSLIQ	FM	SLIQ	SSLIQ	SEPSOL
03/14/03	1	0.9	0.4	11	5.31E-02	2.36E-02	1.17E-04	2.11E-03	5.9	3.05	108	3.48E-01	1.80E-01	1.14E-03	2.01E-02
03/14/03	2	0.72	0.4	-	3.22E-02	1.79E-02	-	1.40E-03	5.76	3.44	-	2.57E-01	1.54E-01	-	1.21E-02
03/17/03	3	0.24	0.24	8	1.40E-02	1.40E-02	9.08E-05	9.75E-04	2.64	2.72	102	1.54E-01	1.59E-01	1.16E-03	7.16E-03
04/01/03	3	0.12	0.16	-	-	-	-	-	1.6	2.72	-	-	-	-	-
04/29/03	5	0.48	0.56	13	2.83E-02	3.31E-02	-	1.10E-03	3.6	4.2	108	2.13E-01	2.48E-01	-	9.07E-03
06/11/03	2	1	0.56	-	5.16E-02	2.89E-02	-	6.41E-03	11	5.4	-	5.68E-01	2.79E-01	-	6.25E-02
06/13/03	3	0.8	0.84	-	3.60E-02	3.78E-02	-	7.47E-03	16	9.88	-	7.19E-01	4.44E-01	-	7.34E-02
06/16/03	5	0.48	0.18	-	-	-	-	-	5	1.38	-	-	-	-	-

APPENDIX E: MASS BALANCES FOR BIOFILTERS

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ESTIMATED MASS BALANCES FOR BIOFILTERS.

Mass balances of flow, nutrients and metals were estimated using the measured or calculated flow volumes and the concentrations from grab samples for five dates during March, May and June 2003. The inflow, outflow and backwash volumes were measured by the flow meters. By subtracting outflow from inflow, an estimated backwash volume could be calculated. Comparing the calculated backwash volume with the measured volume sometimes showed differences of 75,000 to 115,000 L. The reason for this could not be determined with certainty, but part of the difference could be due to the variation in storage of liquid in the biofilters. When a backwash occurs, the level of liquid in the biofilter tank is lowered below the overflow level. Depending on when the meters are read and when backwashes occur, the amount of liquid stored in each biofilter at a particular time can be different. Thus, this introduces some error in the mass balance.

The volumes of flushes were estimated normally using 75,700 L per flush. This is an estimate based on measuring some levels of liquid in the barn, and using the barn pit slope and the barn dimensions to estimate volume of liquid in the pit. For a particular barn, the time between flushes could vary. Also, the manure excretion per day varies with the size of pig and number of pigs. Therefore, the volume of each flush varied, but the volumes were not measured with a flow meter. The volumes of flush are not really needed in the mass balances for the biofilters because flows in and out of the biofilters were measured, but flush volumes are needed to estimate the amount of recirculated biofilter effluent by difference. Estimates of recirculated effluent as a percentage of effluent volume were 71 %, 40 % and 59 % on three different dates. For two dates, the flush volumes were not known, and on one date the estimated recirculation was slightly negative.

The details of calculations for mass balances are shown in the tables in this appendix. Means and standard deviations of the concentrations for the dates which have values are also shown. The summaries for the 6 dates are shown in Table 3 in the body of the report.

Table E-1. Estimated flush volumes and metered inflow and outflow volumes in the biofilters.

Date	Estimated Flush Volume, m^3						Inflow			Outflow			B/wash	Calculated		
														B/wash	Recirc.	% recirc.
	House 1	House 2	House 3	House 4	House 5	Total	A1	B1	Total	A2	B2	Total		In - Out	In -Flush	
03/25/03	76	34	76	76	76	336	337	611	948	273	589	862	197	86	612	71
05/01/03	-	-	-	-	-	-	294	511	805	228	496	724	158	82	-	-
05/08/03	-	-	-	-	-	-	199	332	531	91	236	327	156	204	-	-
06/10/03	76	76	76	76	93	395	200	451	651	179	460	639	134	12	256	40
06/16/03	76	76	76	-	76	303	138	159	296	35	46	81	207	215	-6	-8
06/27/03	151	76	76	-	151	454	357	613	970	280	600	880	197	90	515	59

Table E-2. Nitrogen in the A series.

Date	A1 In				A2 Out				A1 BW				A2 BW				% Retained		
	TKN	NO_{2+3}-N	Flow	Mass	TKN	NO_{2+3}-N	Flow	Mass	TKN	NO_{2+3}-N	Flow	Mass	TKN	NO_{2+3}-N	Flow	Mass	BW A1	BW A2	Effluent
	mg/L	mg/L	m^3	kg	mg/L	mg/L	m^3	kg	mg/L	mg/L	m^3	kg	mg/L	mg/L	m^3	kg			
03/25/03	292	0.25	337	99	111	96.4	273	57	194	72.2	79	21	-	0.01	20	-	21	-	-
05/01/03	480	41.3	294	153	174	334	228	116	351	196	63	35	221	369	16	9.3	23	6	76
05/08/03	477	69.3	199	109	111	223	91	30	65.9	273	62	21	61.9	197	16	4.0	19	4	28
06/10/03	240	180	200	84	195	235	179	77	-	-	-	-	-	-	-	-	-	-	-
06/16/03	297	0.03	138	41	66.1	72.7	35	5	40.3	101	83	12	44.5	64.8	21	2.3	29	6	12
06/27/03	263	113	357	134	119	201	280	90	208	124	79	26	87.65	177	20	5.2	19	4	67
Average	342	67	254	103	129	194	181	62	172	153	73	23	104	162	18	5.2	22	5	46
std. dev.	108	70	88	39	47	96	100	40	125	81	10	8	80	141	2	3.0	4	1	31

Table E-3. Total phosphorus in the A series.

Date	A1 In			A2 Out			A1 BW			A2 BW			% Retained		
	Conc.	Flow	Mass	Conc.	Flow	Mass	Conc.	Flow	Mass	Conc.	Flow	Mass	BW A1	BW A2	Effluent
	mg/L	m^3	kg	mg/L	m^3	kg	mg/L	m^3	kg	mg/L	m^3	kg			
05/08/03	176	199	35	74.4	91	7	78.2	62	5	84.2	16	1.31	14	4	19
06/10/03	139	200	28	170	179	31	-	-	-	-	-	-	-	-	-
06/16/03	116	138	16	112	35	4	110	83	9	114	21	2.36	57	15	24
06/27/03	206	357	74	135	280	38	141	79	11	122	20	2.40	15	3	51
Average	159	223	38	123	147	20	110	75	8	107	19	2.02	29	7	32
std. dev.	40	94	25	40	107	17	31	11	3	20	3	0.62	25	7	17

Table E-4. Total solids in the A series.

Date	A1 In			A2 Out			A1 BW			A2 BW			% Retained		
	Conc.	Flow	Mass	Conc.	Flow	Mass	Conc.	Flow	Mass	Conc.	Flow	Mass	BW A1	BW A2	Effluent
	mg/L	gal.	kg	mg/L	gal.	kg	mg/L	gal.	kg	mg/L	gal.	kg			
03/25/03	6100	337	2,058	5900	273	1,610	6,100	79	481	-	-	-	23	-	78
05/01/03	6200	294	1,823	7000	228	1,597	7,400	63	469	7,700	16	122	26	7	88
05/08/03	7200	199	1,433	5200	91	474	5,100	62	318	5,100	16	79	22	6	33
06/10/03	6500	200	1,298	7300	179	1,310	-	-	-	-	-	-	-	-	-
06/16/03	5500	138	757	4900	35	171	5,100	83	423	4,700	21	97	56	13	23
06/27/03	6400	357	2,284	6000	280	1,683	-	-	-	5,300	20	104	-	5	74
Average	6,317	254	1,609	6,050	181	1,141	5,925	72	423	5,700	18	101	32	7	59
std. dev.	556	88	558	952	100	653	1,090	11	74	1,356	3	18	16	4	29

Table E-5. Total suspended solids in the A series.

Date	A1 In			A2 Out			A1 BW			A2 BW			% Retained		
	Conc.	Flow	Mass	Conc.	Flow	Mass	Conc.	Flow	Mass	Conc.	Flow	Mass	BW A1	BW A2	Effluent
	mg/L	m^3	kg	mg/L	m^3	kg	mg/L	m^3	kg	mg/L	m^3	kg			
03/25/03	1230	337	415	970	273	265	1,370	79	108	-	20	-	26	-	64
05/01/03	1580	294	465	2320	228	529	3,247	63	206	2,553	16	40	44	9	114
05/08/03	3767	199	750	527	91	48	457	62	28	466	16	7	4	1	6
06/10/03	3333	200	666	3783	179	679	-	-	-	-	-	-	-	-	-
06/16/03	1425	138	196	714	35	25	880	83	73	188	21	4	37	2	13
06/27/03	3222	357	1,150	2089	280	586	2,067	79	163	1,027	20	20	14	2	51
Average	2,426	254	607	1,734	181	355	1,604	73	116	1,059	18	18	25	3	50
std. dev.	1,132	88	330	1,245	100	283	1,096	10	70	1,056	2	17	16	4	43

Table E-6. Copper in the A series.

Date	A1 In			A2 Out			A1 BW			A2 BW			% Retained		
	Conc.	Flow	Mass	Conc.	Flow	Mass	Conc.	Flow	Mass	Conc.	Flow	Mass	BW A1	BW A2	Effluent
	mg/L	m^3	kg	mg/L	m^3	kg	mg/L	m^3	kg	mg/L	m^3	kg			
05/08/03	0.68	199	0.135	0.31	91	0.028	0.26	62	0.016	0.1	16	0.002	12	1.15	21
06/10/03	0.68	200	0.136	0.9	179	0.162	-	-	-	-	-	-	-	-	-
06/16/03	0.34	138	0.047	0.58	35	0.020	0.2	83	0.017	0.1	21	0.002	35	4.43	43
06/27/03	1	357	0.357	0.55	280	0.154	0.45	79	0.035	0.24	20	0.005	10	1.32	43
Average	0.675	223	0.169	0.585	147	0.091	0.303	75	0.023	0.147	19	0.003	19	2.30	36
std. dev.	0.270	94	0.132	0.242	107	0.077	0.131	11	0.011	0.081	3	0.002	14	1.84	13

Table E-7. Zinc in the A series.

Date	A1 In			A2 Out			A1 BW			A2 BW			% Retained		
	Conc.	Flow	Mass	Conc.	Flow	Mass	Conc.	Flow	Mass	Conc.	Flow	Mass	BW A1	BW A2	Effluent
	mg/L	m^3	kg	mg/L	m^3	kg	mg/L	m^3	kg	mg/L	m^3	kg			
05/08/03	5.12	199	1.019	1.11	91	0.101	0.64	62	0.040	0.38	16	0.006	4	0.58	10
06/10/03	5.84	200	1.166	7.22	179	1.296	-	-	-	-	-	-	-	-	-
06/16/03	2.4	138	0.331	1.16	35	0.041	1.26	83	0.104	0.22	21	0.005	32	1.38	12
06/27/03	5.88	357	2.099	3.53	280	0.990	3.24	79	0.255	1.67	20	0.033	12	1.57	47
Average	4.810	223	1.154	3.255	147	0.607	1.713	75	0.133	0.757	19	0.014	16	1.18	23
std. dev.	1.644	94	0.728	2.874	107	0.632	1.358	11	0.110	0.795	3	0.016	14	0.52	21

Table E-8. COD in the A series.

Date	A1 In			A2 Out			A1 BW			A2 BW			% Retained		
	Conc.	Flow	Mass	Conc.	Flow	Mass	Conc.	Flow	Mass	Conc.	Flow	Mass	BW A1	BW A2	Effluent
	mg/L	m^3	kg	mg/L	m^3	kg	mg/L	m^3	kg	mg/L	m^3	kg			
03/25/03	2,184	337	737	1,988	273	542	2,430	79	192		20		26		
05/01/03	2,824	294	830	2,756	228	629	3,924	63	249	3,252	16	52	30	6	76
05/08/03	3,748	199	746	1,250	91	114	1,226	62	76	1,096	16	17	10	2	15
06/10/03	3,152	200	629	3,644	179	654	-	-	-	-	-	-	-	-	-
06/16/03	1,716	138	236	1,056	35	37	-	-	-	-	-	-	-	-	16
06/27/03	3,968	357	1,416	2,128	280	597	2,612	79	206	1,240	20	24	15	2	42
Average	2,932	254	766	2,137	181	429	2,548	71	181	1,863	18	31	20	3	37
std. dev.	876	88	381	962	100	277	1,104	9	74	1,205	2	18	9	2	29

Table E-9. Nitrogen in the B series.

Date	B1 In				B2 Out				B1 BW				B2 BW				% Retained		
	TKN	NO_{2+3}-N	Flow	Mass	TKN	NO_{2+3}-N	Flow	Mass	TKN	NO_{2+3}-N	Flow	Mass	TKN	NO_{2+3}-N	Flow	Mass	BW A1	BW A2	Effluent
	mg/L	mg/L	m^3	kg	mg/L	mg/L	m^3	kg	mg/L	mg/L	m^3	kg	mg/L	mg/L	m^3	kg			
03/25/03	292	0.25	611	178	115	168	589	167	134	38.1	79	14	235	147	20	8	8	4	93
05/01/03	480	41.3	511	267	193	314	496	251	458	189	63	41	225	338	16	9	15	3	94
05/08/03	477	69.3	332	182	176	271	236	105	58.2	273	62	21	77.8	260	16	5	11	3	58
06/10/03	240	180	451	190	152	302	460	209	197	241	-	-	167	287	-	-	-	-	-
06/16/03	297	0.03	159	47	37.8	184	46	10	208	87.7	83	25	58.6	181	21	5	52	11	22
06/27/03	263	113	613	230	91.55	215	600	184	183	148	79	26	84.71	234	20	6	11	3	80
Average	342	67	446	182	128	242	404	154	206	163	73	25	141	241	18	7	20	5	69
std. dev.	108	70	176	75	58	62	219	85	135	90	10	10	78	70	2	2	18	3	30

Table E-10. Total phosphorus in the B series.

Date	B1 In			B2 Out			B1 BW			B2 BW			% Retained		
	Conc.	Flow	Mass	Conc.	Flow	Mass	Conc.	Flow	Mass	Conc.	Flow	Mass	BW A1	BW A2	Effluent
	mg/L	m^3	kg	mg/L	m^3	kg	mg/L	m^3	kg	mg/L	m^3	kg			
05/08/03	176	332	58	116	236	27	77	62	4.80	87.3	16	1.36	8	2	47
06/10/03	139	451	63	156	460	72	-	-	-	-	-	-	-	-	-
06/16/03	116	159	18	116	46	5	151	83	12.52	136	21	2.82	68	15	29
06/27/03	206	613	126	123	600	74	150	79	11.81	129	20	2.54	9	2	58
Average	159	389	66	128	335	45	126	75	9.71	117	19	2.24	29	7	45
std. dev.	40	192	45	19	244	34	42	11	4.27	26	3	0.77	34	8	15

Table E-11. Total solids in B series.

Date	B1 In			B2 Out			B1 BW			B2 BW			% Retained		
	Conc.	Flow	Mass	Conc.	Flow	Mass	Conc.	Flow	Mass	Conc.	Flow	Mass	BW A1	BW A2	Effluent
	mg/L	m^3	kg	mg/L	m^3	kg	mg/L	m^3	kg	mg/L	m^3	kg			
03/25/03	6100	611	3,725	5900	589	3,475	6,100	79	481	6,100	20	120	13	3	93
05/01/03	6200	511	3,171	6900	496	3,420	9,000	63	570	7,800	16	124	18	4	108
05/08/03	7200	332	2,393	6000	236	1,416	5,100	62	318	5,200	16	81	13	3	59
06/10/03	6500	451	2,934	6800	460	3,127	-	-	-	-	-	-	-	-	-
06/16/03	5500	159	873	5100	46	237	5,700	83	473	5,200	21	108	54	12	27
06/27/03	6400	613	3,922	5600	600	3,358	5,700	79	449	5,800	20	114	11	3	86
Average	6,317	446	2,836	6,050	404	2,505	6,320	73	458	6,020	18	109	22	5	75
std. dev.	556	176	1,108	695	219	1,358	1,540	10	91	1,069	2	17	18	4	32

Table E-12. Suspened solids in the B series.

Date	B1 In			B2 Out			B1 BW			B2 BW			% Retained		
	Conc.	Flow	Mass	Conc.	Flow	Mass	Conc.	Flow	Mass	Conc.	Flow	Mass	BW A1	BW A2	Effluent
	mg/L	m^3	kg	mg/L	m^3	kg	mg/L	m^3	kg	mg/L	m^3	kg			
03/25/03	1230	611	751	1063	589	626	1,603	79	127	1,250	20	25	17	3	83
05/01/03	1580	511	808	2380	496	1179	-	63	-	3,153	16	50	0	6	146
05/08/03	3767	332	1,252	4889	236	1154	442	62	28	559	16	9	2	1	92
06/10/03	3333	451	1,505	3317	460	1525	-	-	-	-	-	-	-	-	-
06/16/03	1425	159	226	1003	46	47	2,456	83	204	1,301	21	27	90	12	21
06/27/03	3222	613	1,974	1467	600	880	2,044	79	161	1,583	20	31	8	2	45
Average	2426	446	1,086	2353	404	902	1,636	73	130	1,569	18	28	23	5	77
std. dev.	1132	176	620	1525	219	517	869	10	75	962	2	15	38	5	48

Table E-13. Copper in the B series.

Date	B1 In			B2 Out			B1 BW			B2 BW			% Retained		
	Conc.	Flow	Mass	Conc.	Flow	Mass	Conc.	Flow	Mass	Conc.	Flow	Mass	BW A1	BW A2	Effluent
	mg/L	m^3	kg	mg/L	m^3	kg	mg/L	m^3	kg	mg/L	m^3	kg			
05/08/03	0.68	332	0.226	0.52	236	0.123	0.4	62	0.025	0.24	16	0.004	11	2	54
06/10/03	0.68	451	0.307	0.72	460	0.331	-	-	-	-	-	-	-	-	-
06/16/03	0.34	159	0.054	0.42	46	0.020	0.46	83	0.038	0.28	21	0.006	71	11	36
06/27/03	1	613	0.613	0.49	600	0.294	0.48	79	0.038	0.3	20	0.006	6	1	48
Average	0.675	389	0.300	0.538	335	0.192	0.447	75	0.034	0.273	19	0.005	29	4	46
std. dev.	0.270	192	0.234	0.129	244	0.146	0.042	11	0.008	0.031	3	0.001	36	5	9

Table E-14. Zinc in B series.

Date	B1 In			B2 Out			B1 BW			B2 BW			% Retained		
	Conc.	Flow	Mass	Conc.	Flow	Mass	Conc.	Flow	Mass	Conc.	Flow	Mass	BW A1	BW A2	Effluent
	mg/L	m^3	kg	mg/L	m^3	kg	mg/L	m^3	kg	mg/L	m^3	kg			
05/08/03	5.12	332	1.702	2.76	236	0.651	0.44	62	0.027	0.72	16	0.011	2	1	38
06/10/03	5.84	451	2.636	5.34	460	2.456	-	-	-	-	-	-	-	-	-
06/16/03	2.4	159	0.381	2.04	46	0.095	3.98	83	0.330	2.4	21	0.050	87	13	25
06/27/03	5.88	613	3.603	2.14	600	1.283	3.47	79	0.273	2.22	20	0.044	8	1	36
Average	4.810	389	2.081	3.070	335	1.121	2.630	75	0.210	1.780	19	0.035	32	5	33
std. dev.	1.644	192	1.373	1.546	244	1.013	1.914	11	0.161	0.922	3	0.021	47	7	7

Table E-15. COD in the B series.

Date	B1 In			B2 Out			B1 BW			B2 BW			% Retained		
	Conc.	Flow	Mass	Conc.	Flow	Mass	Conc.	Flow	Mass	Conc.	Flow	Mass	BW A1	BW A2	Effluent
	mg/L	m^3	kg	mg/L	m^3	kg	mg/L	m^3	kg	mg/L	m^3	kg			
03/25/03	2,184	611	1,334	2,212	589	1,303	2,710	79	214	2,550	20	50	16	4	98
05/01/03	2,824	511	1,444	4,064	496	2,014	6,536	63	414	4,380	16	69	29	5	139
05/08/03	3,748	332	1,246	2,170	236	512	1,244	62	77	1,426	16	22	6	2	41
06/10/03	3,152	451	1,423	2,952	460	1,358	-	-	-	-	-	-	-	-	-
06/16/03	1,716	159	272	1,316	46	61	2,244	83	186	1,536	21	32	68	12	22
06/27/03	3,968	613	2,431	1,312	600	787	2,468	79	194	1,516	20	30	8	1	32
Average	2,932	446	1,358	2,338	404	1,006	3,040	73	217	2,282	18	41	25	5	67
std. dev.	876	176	686	1,049	219	695	2,032	10	122	1,260	2	19	26	4	50

APPENDIX F: LAGOON SLUDGE ACCUMULATION AND CHARACTERISTICS

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SLUDGE ACCUMULATION IN THE LAGOON SECTIONS AND SLUDGE CHARACTERISTICS.
The permit from DWQ required monthly measurements of sludge accumulation in the cell receiving separated solids and biofilter backwash (cell L2). Sludge layer thickness was also measured for the lagoon before partitions were installed, and 2 or 3 times in the cells L1 (receiving biofilter effluent and source of liquid recycled for flushing and for irrigation) and L3 (receiving flushed manure from about 4000 finishing pigs).

The lagoon dimensions that were provided by the farm as part of the site information were 193 m long by 105 m wide (634 ft. x 344 ft.) at the inside top edge of the berm, with 3:1 side slope, a maximum depth at normal/maximum liquid level of 2.53 m (8.3 ft.), and a total volume of 44,824 m^3 (1,582,724 ft^3). Dimensions for the lagoon that were measured on 6/25/03 for approximately the normal liquid level were 193 m long by 104.8 m on the north end and 107.9 m on the south end. Dimensions of the cells were: L1 -104.8 m (344 ft.) by 17.1 m (56 ft.) on the east side and 32.9 m (108 ft.) on the west side (not rectangular); L2 – 104.8 m (344 ft.) by 32.9 m (108 ft.); and L3 – 107.9 m (354 ft.) by 146.3 (480 ft.) on east side and 130.4 m (428 ft.) on the west side.

Sludge layer thickness was determined by using a capped PVC pole to determine depth to the bottom of the lagoon (the soil surface at the bottom), and using a Sludge Gun (infrared sensor) to determine the top surface of the sludge layer. Difference between depth to bottom and depth to top of sludge layer was the thickness of the sludge layer.

Table F-1. Sludge layer thickness (cm) in lagoon sections.

Date	Lagoon	L3	L2	L1
12/5/01	33	-	-	-
5/22/02	-	39	43	40
2/19/03	-	-	70	-
3/25/03	-	-	76	61
4/22/03	-	-	67	-
5/20/03	-	-	76	-
6/25/03	-	57	76	68

Notes:

1. Initial survey of lagoon on 12/5/01 before partitions were installed was average of 12 points in a grid. Ten of the points which were lined up with centers of the 5 barns on each side of the lagoon remained the same for sludge surveys of L3 after the lagoon was partitioned.
2. After partitions were installed, the number of points sampled in a grid for each section was 6 points each for L1 and L2, and 10 points for L3.

RESULTS FOR SLUDGE ACCUMULATION:

All cells show increased sludge from 5/22/02 to 6/25/03. The measurements in L2 for the last 4 mo. indicate little accumulation during this period. A more detailed sludge survey would be needed to calculate accurate volumes and rates of sludge accumulation.

SLUDGE CHARACTERISTICS:

Sludge samples were taken 12/5/01, 5/22/02 and 6/25/03 with an Ekman sludge sampler. The concentrations of several parameters in the sludge are shown in Table F2 in units of microgram per gram (µg/g) (wet basis), except TS is % by weight, VS is % of TS, and pH is pH units. Sludge samples had approximately 10 % TS, and TKN and TP concentrations of approximately 6,000 µg/g. The samples from 6/25/03 appeared to show higher concentrations generally for L2 cell which received separated solids and backwash.

Table F-2. Concentrations of parameters analyzed for in the sludge.

Date	Source	Parameter														
		TKN	TAN	NO_{2+3}-N	TP	OP	COD	pH	TS	VS	Na	K	Ca	Mg	Cu	Zn
		mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	%	%TS	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
12/05/01	LAG	6356	1586	.	6556	3713	130100	7.2	9.94	54.52	412	1360	3627	2533	140	226
05/22/02	L1	6315	1913	0	6376	4161	92600	7.48	10.93	51.78	412	1360	2800	3120	129	232
05/22/02	L2	6317	1924	0	5996	4134	96800	7.57	10.13	54.29	471	1640	2000	2560	134	268
05/22/02	L3	5768	1459	0	6236	3184	84400	7.22	10.95	52.23	416	1667	3200	3520	128	184
06/25/03	L1	5618	1909	0	7256	4627	92600	7.37	9.47	54.38	320	1560	3900	2780	61	242
06/25/03	L2	6310	1790	0	9056	5097	121400	7.43	10.72	52.43	340	1650	4800	3210	77	306
06/25/03	L3	5435	1900	0	6722	4392	90800	7.34	10.19	55.05	330	1510	4000	2560	66	257

APPENDIX G: OPERATION LOG – JANUARY 2003 TO JUNE 2003.

2003
Jan 1 – sump pump failed (no flushes for 3 days)
Jan 4 – replaced pump and returned to normal operation
Jan 5 – houses stopped flushing after #1 finished during the night
Jan 9 – sump pump intermittent overnight
Jan 17 – recycle pump on but valve to house closed so it deadheaded overnight (7 BW with no feed)
Jan 22 – BW turned off to allow tanks to refill but don't know when turned back on
Jan 25 – fresh water lines to flush valves froze and busted (repaired on 1/28 but had no feed for 3 days)

Feb 7 – sump float switch stuck and no flushes overnight
Feb 8 – sump pump broke (no BW or flushes for 4 days)
Feb 12 – replaced sump pump
Feb 22, 23, 24, & Mar 3 – float switch in sump stuck and no flushes overnight but BW continued so level down in all biofilters

Mar 9 – float switch in separator tank stuck and didn't turn on separator so 4 houses flushed and flowed to lagoon
Mar 15 thru 17 – float in separator tank stuck so flushes flowed to lagoon

April 2 – computer crashed
April 3 – replaced computer with laptop, house 5 alarm stopped flushes overnight
April 4, 5, 6, & 7 – house 4 alarm stopped flushes overnight
April 11 – sump pump broke
April 12 – started back-up pump(stopped backwashes)
April 15 – house 4 alarm stopped flushes overnight
April 22 – installed main sump pump and returned to normal operation
(April 22, 26, 29), (May 1, 2, 4, 5, 9, 10, 14, 16, & 26), (June 4, 16, &18) – house 4 alarm stopped flushes overnight (BW continued)

May 13 – sump pump started having reduced flow
May 14 – started back-up pump
backwash turned off
May 15 – one minute backwash on all biofilters
feed to B side cut off to get some flow to A side
May 17 – feed to B side cut off at 7:00 pm
18 – B side cut off
19 – B side opened at 6pm
- main pump turned off and removed from sump
20 – B side shut at 12 pm
21 – B side opened (time ?)
23 – Installed rebuilt pump in lift station at 3pm
24 – Recirculation at 75 – 80 %
25 – Turned on automatic backwashes in the am

- backwash turned off and backup pump turned on
26 – recirculation left at 75 – 80 %

27 – stopped flow to B side
28 – back-up pump tripped breaker (no flow while tripped)
- reset breaker and closed B side
29 – back-up pump tripped again (cleaned trash from impeller and restarted)
- one minute backwash on all 4 biofilters
30 – shut B side

June 1 – B side opened
4 – new Teel pump had 460 volt overload protection installed and was installed in sump
5, 6 – house 4 skipped in flush cycle because of valve problem
7 – house 1 flush valve stuck open overnight so water continued to run through house
- back wash on each biofilter (time?)
8 – house 1 flush valve stuck open again
9 – house 1 skipped in flush cycle
- one minute backwash on each biofilter
- recirculation at 75 – 80 %
11 – five minute backwash on all biofilters
12 – #2 flush valve stuck open at 6am
- no flushing for several hours because of fire that damaged well
- #1 flush valve repaired
- backwash on all 4 biofilters
13 – replaced #2 flush solenoid valve
14 – returned backwash to automatic at 11pm
21 – equalization tank drained for 10 minutes
- extra 5 minute backwash on A2
- recirculation decreased a little(½ inch rotation of valve)
22, 23 – missing log sheets
25 – recirculation decreased from ≈ 50% to ≈ 15-20%
26 - #2 refill valve stuck and no flushes for ≈ 5 hours
28 - #2 refill valve stuck again
29 – missing
30 - #2 refill valve stuck again

APPENDIX H: PICTURES OF TREATMENT SYSTEM.

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Figure H-1. Aerial view of the Farm and treatment system.

Figure H-2. Picture of the EKOKAN treatment system showing the biofilters and the barns.

Figure H-3. End view of a barn showing the location of a pit outlet for flushed manure.

Figure H-4. Automatic flush valve in the pit outlet.

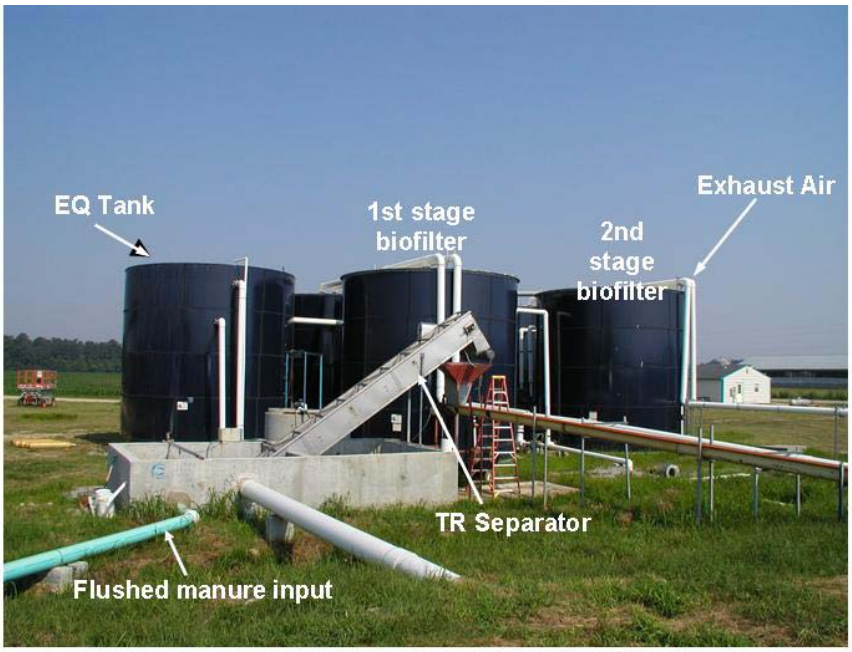

Figure H-5. Components of the treatment system.

Figure H-6. Plastic media for biofilters.

Figure H-7. Biofilter media support frame and the TR separator.