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TREATMENT AND REUSE OF DAIRY MILKING FACILITY WASH WATER

By

Rebecca Anne Larson

A THESIS

Submitted to
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ABSTRACT

TREATMENT AND REUSE OF DAIRY MILKING FACILITY WASH WATER

By

Rebecca Anne Larson

Treatment and disposal of dairy milking facility wash water using lagoon storage and land application poses serious potential environmental consequences if not properly managed. Dairy wash water contains high liquid content increasing overflows, spills and runoff which contaminate surface waterways due to large concentrations of biochemical oxygen demand (BOD_5), chemical oxygen demand (COD), total solids (TS) and total suspended solids (TSS). Two aerobic suspended growth treatment units provided by Consolidated Treatment Systems Inc., were proposed to treat high strength dairy wash water to be reused for first flush of the milking facility. The Nayadic^{TM} had a gravity driven solid/liquid separation and alternatively the Multi-Flo^{TM} with a filtration mechanism for separation. Average influent values were 5,761 mg/L BOD_5, 36,528 mg/L COD, 17,809 mg/L TS and 9,758 mg/L TSS. The Nayadic^{TM} treatment unit performance at 50 gal/day ranged from 67 to 96%, 69 to 96%, (-48) to 92% and (-106) to 96% percent reductions for BOD_5, COD, TS and TSS. The Multi-Flo^{TM} was capable reaching first flush reuse levels for one month. Treatment reduction percentages for the Multi-Flo^{TM} unit at 50 gallons per day were 74 to 99%, 67 to 99%, 46 to 98%, and 63 to 99% for BOD_5, COD, TS and TSS, respectively.

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-Becky

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CHAPTER 1: INTRODUCTION

Dairy milking facilities produce over 180,000 million pounds of milk in the United States annually (USDA, 2006). Milking facilities milk each head of cattle multiple times a day, everyday, throughout the year. In order to maintain sanitary conditions and a safe product within the scope of government laws and regulations, dairies must clean and disinfect the milking parlor and all equipment after each milking event. Daily cleaning and operation of milking facilities produces a large volume of liquid waste, also known as dairy parlor wash water. This wash water is a result of the combination of fresh water, milk waste, cleaning chemicals and animal waste. Herd size, cleaning practices, milking parlor design and management of waste collection greatly influences the characteristics and quantity of wash water. Wright and Graves (1998) estimated a quantity of 3.5 to 11 gallons per day per cow. The National Agricultural Statistics Service reports 320,000 head of cattle in Michigan alone, and over 9 million head of cattle in the United States (USDA, 2006). Consequently, the volumes of milking facility wash water can be calculated at 400 million to 1.3 billion gallons annually in Michigan and a range of 11 billion to over 36 billion gallons annually in the US.

Current practices for management of the milking parlor wash water include manure storage lagoons, land application and use in alternative farming facilities, such as composting. Manure storage lagoons provide little to no treatment.

Disposal actually occurs when the content is land applied at acceptable nutrient agronomic rates. Wash water can account for 20-50% of lagoon storage volume (Livestock Wastes Subcommittee, 1985). Greater liquid content results in larger volumes of waste, increasing the likelihood of leaks, overflows, runoff and migration of undesirable solids and nutrient into ground water. In addition, land application requires extensive land management planning and is restricted by land availability and climate. The use of wash water in alternate farming facilities, such as composting, rarely requires the volume of water produced by the milking facility. Further many farms do not operate these alternative facilities. Because of the lack of options, it is reasonable to assume that farmers not using proper disposal systems are discharging the parlor wash water without proper treatment, resulting in potential negative environmental impacts.

Transport of wash water to various storage facilities and land application sites can be very costly. The Michigan State University Dairy Teaching and Research Facility (MSU dairy) spends over $10,000 a year to transport wash water to storage and application sites, or a unit amount of $0.015 per gallon. Although transportation costs vary greatly with location of storage and application sites, Michigan spends an estimated $600,000 to $2 million in transport of wash water waste annually. The lack of options for treatment and disposal can inevitably lead to expensive management decisions or improper treatment.

Disposal of wash water poses environmental risks associated with runoff and contamination of surface and ground waters due to the high concentrations of environmental pollutants. This includes high levels of oxygen demand, nutrients, solids, pathogens and fats, oils and grease (FOG). Large concentrations of nutrients cause eutrophication in surface water. High oxygen demand results in low dissolved oxygen levels, threatening the survival of aquatic species. Solids result in a reduction of lake depth, more aquatic growth due to higher water temperatures from an increase in thermal energy, resulting in eutrophication. High oxygen demand leads to aquatic death due to a lack of dissolved oxygen, increasing the solids content contributing to the eutrophication process described above. Wash water contains large pathogen concentrations posing contamination problems and presenting health risks to humans and animals. Offensive odors and other non-aesthetically pleasing characteristics are also features of dairy wash water that can lead to public dissent of dairy operations.

1.1 Thesis Statement

A systems approach is used to evaluate two typical aerobic suspended growth units with different solid/liquid separation mechanisms at a local dairy to determine their ability to treat high strength dairy milking facility wash water for reuse.

1.2 Objectives

The specific objectives of the project follow.

1. Use a systems approach to determine if aerobic treatment units are capable of treating high strength dairy wash water to an effluent quality suitable for reuse.
2. Determine which of two treatment designs, the Nayadic™ gravity driven solid/liquid separation unit or the Multi-Flo™ sock filtration unit, performs more efficiently in a highly managed system
3. Determine possible reuse applications for the effluent quality reached.
4. Determine typical operation requirements and the man hours to maintain effective treatment.

CHAPTER 2: LITERATURE REVIEW

Aerobic treatment units (ATU's) are typically used for on-site treatment of domestic household wastewater, but are also used for treatment before drip irrigation (USEPA, 2002). A premise of this research is this equipment may be applicable to treat the wash water from a small dairy. Traditionally an ATU replaces or supplements the use of a more traditional septic system. Table 1 provides pollutant removal data for various ATU systems.

Table 1: Traditional On-Site Aerobic Treatment Unit Performance

Treatment Unit	Typical Values	bioMax		Multi-Flo™	Nayadic™
Manufacturer	n/a	Durrant & Waite		Consolidated Treatment Systems Inc.	
Flow Rate (gpd)	400-1,500 (1)	338 (2)	634 (2)	500 (3)	500 (3)
Influent BOD_5 (mg/L)	100-300 (1)	554 (2)	356 (2)	150 (3)	150 (3)
Influent TSS (mg/L)	100-300 (1)	446 (2)	225 (2)	195 (3)	194 (3)
Effluent BOD_5 (mg/L)	< 25 (1)	3.2 (2)	10.1 (2)	5 (3)	6 (3)
Effluent TSS (mg/L)	< 30 (1)	20.9 (2)	14.3 (2)	5 (3)	7 (3)
Cost	$2,500-$9,000 (1)	n/a	n/a	$4,905 (3)	$4,825 (3)

1 USEPA, 2002
2 Ivery, 1995
3 Consolidated Treatment Systems Inc., 2002

Treatment mechanisms for ATU's can include aeration, suspended growth or fixed-film growth for BOD removal and clarification or filtration for TSS removal

(USEPA, 2002). Aeration provides oxygen for aerobic microorganisms to establish a colony and achieve biological treatment through microbial digestion and degradation. Additional components used to increase treatment performance include settling tanks, sand filtration, disinfection units and anaerobic treatment for denitrification (USEPA, 2002). Although many treatment units perform adequately as described in table 1, Roeder et. al., 2006, sampled 1,200 ATU's in the Florida Keys and determined 50% of the systems were producing effluent values for TSS over USEPA guidelines and 25% over BOD_5 guidelines. Performance of ATU's relies greatly on operation and maintenance, much more than traditional on-site treatment systems such as septic tanks (USEPA, 2002).

Christopherson (2003) used ATU's combining aeration, pretreatment settling and suspended growth to treat dairy wash water with positive results . Hamoda (1995) conducted a field experiment on dairy wash water treatment using sedimentation and aeration. Dong (2003) proposed and tested a system for dairy wash water reuse combining anaerobic and aerobic treatment. The design values and general parameters of each study are described below with emphasis on their relation to the treatment system used in this study, Table 2.

Table 2: Previous literature for aerobic treatment units

Research	Christopherson	Hamoda	Dong
Influent BOD_5 (mg/L)	2220	n/a	1003
Influent COD (mg/L)	3360	3200	4997
Influent TSS (mg/L)	1030	n/a	4200
Influent FOG (mg/L)	650	n/a	n/a
Reduction of BOD_5 (%)	44-94	n/a	n/a
Reduction of COD (%)	32-94	up to 94	70-75
Reduction of TSS (%)	61-82	up to 96	72-78
Reduction of FOG (%)	71-98%	n/a	n/a

Christopherson (2003) designed treatment for dairy farm wastewater ranging from 40-130 cows, and treated a range of flow rates from 95-440 gallons per day. Specifically, Christopherson used two aerobic treatment systems the FAST® and the Nibbler®. The tested Bio-Microbic, Inc., FAST® unit (at a cost of $11,000) is an aerobic fixed activated sludge unit with a honeycomb shaped media for suspended bacteria growth. Aeration is provided by a blower and a 750 gallon pretreatment settling tank is located inline. Removal rates are reported at 6 pounds of BOD_5 per day. The second unit is the Nibbler® designed by Bill Stuth and distributed by NCS Wastewater Solutions for a cost of $14,000. Floating pods are located within the unit, the number of which is determined by loading rates. The pods are plastic cages that provide housing for buoyant media with large amounts of surface area. Each pod is aerated with an airlift pump in the center. A 500 gallon septic tank and a 1000 gallon pump tank are located in series before the treatment unit. The Nibbler® is designed to remove 0.81 lbs/day of BOD_5 and rated to handle a maximum of 137.5 gallons per day.

These aerobic treatment systems have been shown to effectively remove biochemical oxygen demand (BOD_5), chemical oxygen demand (COD), total suspended solids (TSS) and FOG. Little to no removal of phosphorus and nitrogen were found. Christopherson also noted that the main source of BOD_5 is milk waste. This component should be minimized in order to maximize treatment performance.

Wash water from the milking parlor at a large dairy farm with 2500 milk cows was used in a field experiment conducted by Hamoda (1995). The preexisting treatment consisted of a two chamber sedimentation tank for each of the two milking parlors. The first chamber was for initial settling and contained a scum baffle on the surface. The second chamber received influent from the first chamber, overflow from the groundwater reverse osmosis system and effluent from the two chamber sedimentation tank from the other milking parlor. These sedimentation tanks are in effect a solid-liquid separator (Hamoda, 1995). In this study, aerobic activity was achieved using a sequencing batch reactor loaded with the dairy wash water and activated sludge from a nearby wastewater treatment plant. The sedimentation tank removed 31% COD and 53% TSS. The most effective aeration time of 12 hours was capable of removing 87% COD and 89% TSS. Hamoda (1995) recommends a primary settling tank followed by aerobic activity to achieve these effluent levels.

Hamoda (1995) recommended using the treated wash water for irrigation of Lucerne grass. However, he noted that build-up of salts and high nitrogen loading may be of concern over time. There is also a need for disinfection to prevent the migration of pathogens. Therefore, land application for discharge of the treated wash water was recommended provided storage was available during periods when irrigation is not possible.

Dairy wash water was evaluated for reuse in research on a farm in Hawaii (Dong's 2003). The COD and BOD_5 ranges were 2000 to 7000 mg/L and 500 to 1500 mg/L respectively. Dong (2003) set reuse goals of COD, nitrogen (N), phosphorus (P) and TSS concentrations at 650-700 mg/L, 70-80 mg/L N, 6-10 mg/L P and 5-8 mg/L, respectively. A small-scale system consisting of an anaerobic bioreactor paired with an aerobic treatment system was evaluated to determine if these goals were reachable. The combined system produced effluent concentrations of COD, BOD_5, N, P and TSS concentrations of 400 to 550 mg/L, 8 to 14 mg/L, 30 to 40 mg/L N, 3 to 4 mg/L P and 4-7 mg/l, respectively (Dong, 2003). The two stage process was effective in producing effluent capable of reuse.

The systems described above demonstrate that aerobic systems are capable of pollutant removal to low levels for dairy wash water. Further, it is apparent that the level of pollutants varies greatly from farm to farm.

CHAPTER 3: METHODS AND MATERIALS

The treatment system was tested at the Michigan State University Dairy Cattle Teaching and Research Facility (MSU Dairy Farm). The treatment units included the Nayadic™, a typical ATU that used suspended growth aeration and gravity solid/liquid separation, and the Multi-Flo™, a comparable suspended growth system paired with solid/liquid separation by filtration. Both are manufactured by Consolidated Treatment Systems Inc. of Franklin, Ohio. The dairy facility treatment system design, sampling and laboratory procedures along with their purpose/function are described in the subsections following.

3.1 Michigan State University Dairy Cattle Teaching and Research Facility

The Michigan State University Dairy Cattle Teaching and Research Facility actively milks between 140-160 dairy cattle twice per day, producing nearly 11,000 pounds of milk per day. The average daily accumulation of wash water is almost 1,800 gallons (as determined by examining farm hauling records). A flush system was used to clean the dairy facility during which the entire milking parlor and all milking equipment were power washed. The effluent drained through floor grates into an underground storage pit. Wash water is typically removed biweekly and transported for land application or longer term storage.

3.2 Treatment System Design

Milking facility wash water is stored in large 60,000 gallon underground tanks. For research, the wash water was transported from the underground pits via a submersible sewage pump operated on a timer. The pump is positioned atop a steel platform to maintain a distance of 1.5 feet from the bottom of the pit in order to avoid large settled solids. Flow rates from the main submerged pump were found by determining the time required to deliver five gallons. Due to variations in the flow rate caused by changes in head due to the changing volume in the underground tank, flow rates were measured a minimum of three times per week and adjusted accordingly. With a known flow rate, the timer was set to provide the specific daily volume desired for testing.

Wash water from the underground pits was first pumped into two 500 gallon settling tanks positioned in series to provide primary settling. Flow was then equally divided into two treatment lines using a Tuf-Tite™ distribution box. Equal flows were achieved by leveling the platform holding the box. Each effluent line from the distribution box entered a 500 gallon dose tank. Flow from the settling tanks through the distribution box into the dose tanks was maintained by gravity. A 0.5 horsepower pump activated by a level switch, at approximately 3 feet below the inlet line, was positioned within the dose tank to provide a controlled flow rate into each aeration system. Pumps were equipped with a blow-by and a check valve to reduce pump strain. A throttle valve on the blow-by was adjusted to allow treated effluent from the recirculation line to reenter the recirculation tank, reducing the pressure and flow rate. A general layout of all equipment is shown in Figure 3.

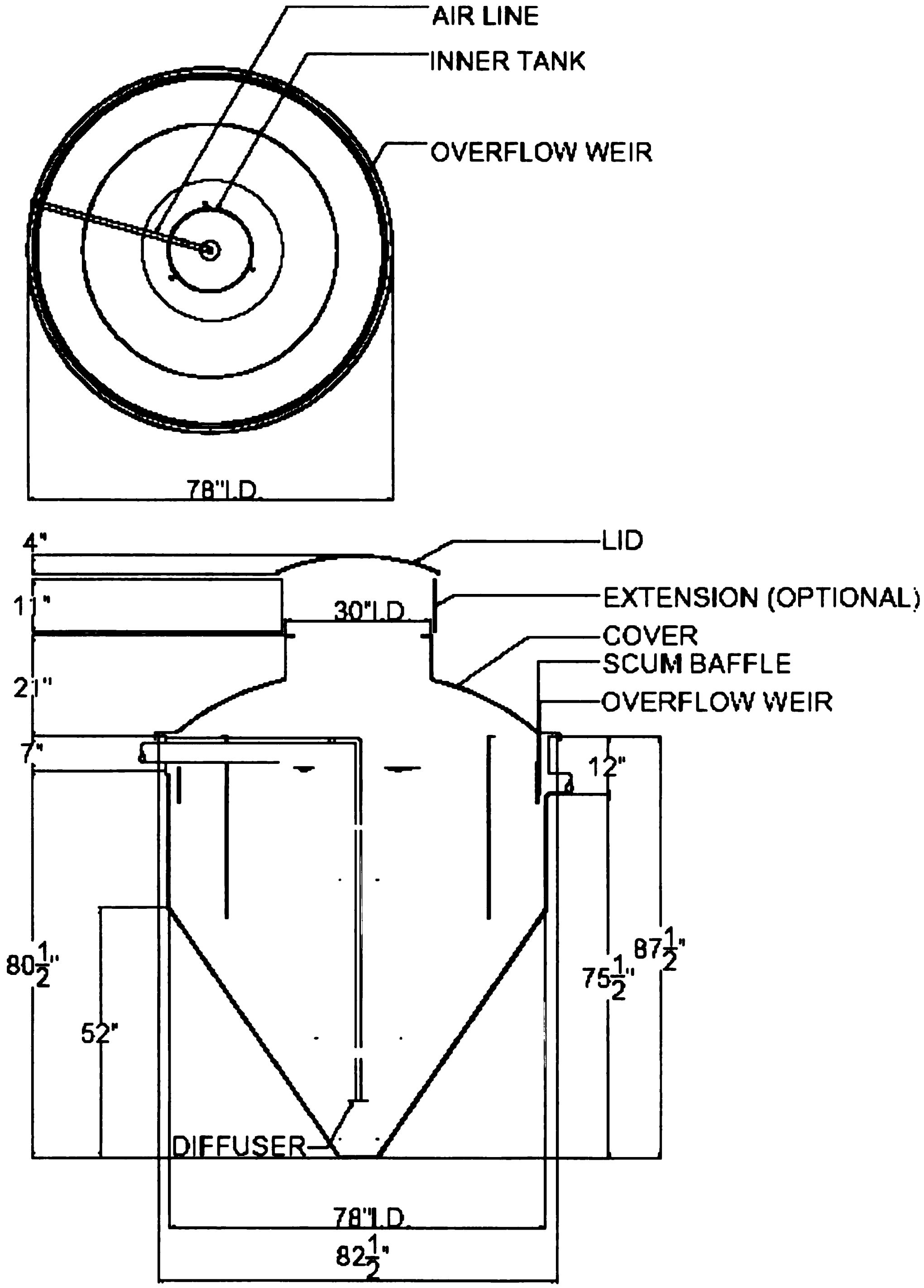
The pumps in the dose tanks provided the flow into the two aerobic treatment units, the Nayadic^{TM} and the Multi-Flo^{TM}. Further details on the two units are provided in the next section. Following the treatment units, recirculation tanks diverted a portion of treated wash water back to the dosing tanks for dilution of the primary effluent in an effort to reduce the organic loadings to the aeration units. Pumps in the recirculation tanks had an identical setup to those in the dose tanks, including level switches and flow control using a throttling valve on the blow by system. The recirculation ratio is an important system design characteristic. A 3:1 recirculation ratio of treated effluent for recirculation to that exiting the system was maintained throughout treatment. Previous research done by Safferman, 2004, on these treatment units used a 3:1 ratio for optimized treatment efficiency. The ratio followed the concept of diminishing return where an increase in the recirculation ratio did not provide a significant increase in treatment efficiency. The final treatment segment was an ultraviolet (UV) disinfection unit, provided by Salcor Inc., and detailed in a subsection below.

System components were installed on a level bed of gravel. Sampling valves were installed before and after each treatment segment for evaluation of each treatment segment's performance and for measurement and adjustment of flows. A series of drainage and overflow pipes connected the treated effluent line, overflow ports and drainage spigots to a second underground tank to avoid compromising the untreated wash water in the first underground pit. This drain system was used for cleaning and drainage of tanks and lines, overflows, transport and storage of treated effluent.

3.3 Treatment Units

Aerobic treatment systems were off the shelf designs for domestic household effluent provided by Consolidated Treatment Systems Inc. Both treatment units are suspended growth, completely mixed, extended aeration units. Although normally installed underground, the system was installed aboveground for research purposes associated with sampling, maintenance, system access and ease of removal after study completion.

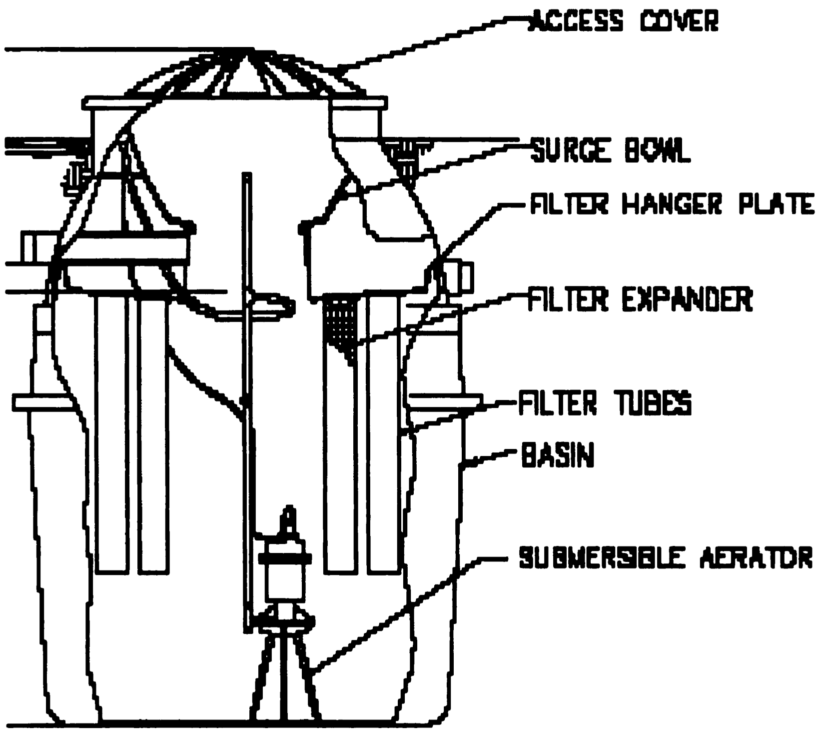
The Nayadic™ contains an inner reactor, a secondary clarifier surrounding the circular inner chamber, and a compressor for continuous aeration (Figure 1). The inner reactor functions as a completely mixed aeration basin. A diffuser, that provided 4.6 lbs/day of oxygen, is located at the bottom of the tank and forced air and wastewater through a center pipe up to the midsection of the reactor (Consolidated Treatment Systems Inc., 2002b). The diffuser provided the required aeration for biological processes and maintained a completely mixed environment. The clarifier allowed for gravity solid/liquid separation and the return of the microorganisms to the inner reactor. Floating material was kept from exiting the system in the treated water using a scum baffle. Treated water flows over a weir, ensuring even discharge.



(Consolidated Treatment Systems Inc., 2002b)

Figure 1: Nayadic™ schematic

The Multi-Flo™ was a continuously mixed, extended aeration filtration unit (Figure 2). An aerator maintained completely mixed conditions while providing 3.6 lbs/day of oxygen required for biological processes (Consolidated Treatment Systems Inc., 2002a). Solid/liquid separation is accomplished using 30 sock filters submerged in the main basin which have a nominal rating of 100 microns. Wastewater enters the center of the main basin where it is aerated, mixed and forced to travel through the filtration socks where a weir maintains equal discharge of treated effluent around the circumference of the unit. The socks also provided additional treatment as a bio-mat developed on the outside of the socks.



(Consolidated Treatment Systems Inc., 2002a)

Figure 2: Multi-Flo™ schematic

3.4 Ultraviolet Disinfection Unit

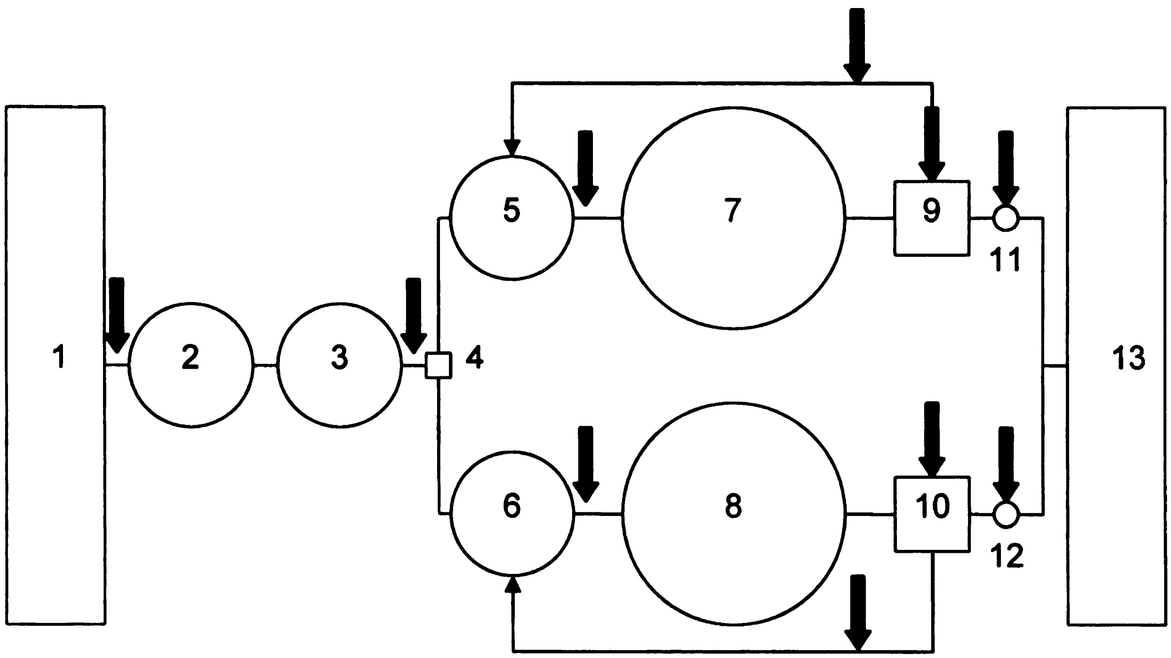
The ultraviolet (UV) disinfection unit was provided by Salcor Inc., and was designed for small aerobic treatment plants. UV light is provided throughout the length of the disinfection chamber through a sub-assembly which defines the path for proper exposure time for typical secondary treated wastewater. A quartz tube controls the lamp surface temperature while a Teflon film minimizes surface fouling. The UV system is capable of removing the fecal *coli form* bacteria to levels below the acceptable standards set by the United States Environmental Protection Agency (USEPA) for drinking water providing the total suspended solids is less than 30 mg/L.

3.5 Wash Water Analysis

Wash water treatment was characterized using water analysis parameters, including pH, alkalinity, total solids (TS), TSS, BOD_5, COD, FOG, total Kjeldahl Nitrogen (TKN), ammonia (NH_3), nitrate (NO_3), TP, DO, oxidation reduction potential (ORP), total *coli forms*, *E. Coli* and odor, which are typical for evaluation of water quality. Table 20 in appendix A provides details on the laboratory tests used their basis for analysis and associated reference method. USEPA approved or accepted practices were used whenever available.

Samples for pH, alkalinity, TS, TSS, BOD_5, COD, TKN, NH_3, and NO_3 were taken before and after each treatment segment to determine the effectiveness of each treatment process, as shown in Figure 3. Testing locations included the influent to the primary settling tank (baseline), effluent from the distribution box (distribution box), effluent from the Nayadic^{TM} and Multi-Flo^{TM} dose tanks (dose tanks), Nayadic^{TM} and Multi-Flo^{TM} treatment unit effluent (treatment units), Nayadic^{TM} and Multi-Flo^{TM} recirculation lines (recirculation) and Nayadic^{TM} and

Multi-Flo™ disinfection unit effluent (disinfection). Figure 3 displays the location of these sampling points as represented by solid black arrows.



1 Underground Tank 1
2 Settling Tank 1
3 Settling Tank 2
4 Distribution Box
5 Dose Tank Nayadic
6 Dose Tank Multi-Flo
7 Nayadic
8 Multi-Flo
9 Nayadic Recirculation Tank
10 Multi-Flo Recirculation Tank
11 Nayadic Disinfection Unit
12 Multi-Flo Disinfection Unit
13 Underground Tank 2

Figure 3: Sampling Locations

FOG, odor, ORP and DO were evaluated for the baseline influent and the treated effluent from the Nayadic™ and Multi-Flo™ only. Final FOG concentrations were sufficient to determine potential use. Treatment problems associated with high FOG concentrations could be evaluated visually. Final effluent odors were the only relevant odor data required for analysis as the system would typically be covered and buried eliminating any potential odor issues during treatment. Odors were evaluated using an odor panel. Panelists were instructed to rank samples on a scale of one to ten, ten being the most offensive. ORP and DO were used to evaluate oxygen in the treatment units only as they were the only treatment system segments to have an impact on oxygen levels. Baseline values for FOG, odor, ORP and DO were taken to ascertain the characteristics of the incoming wash water as a base for comparison.

Bacteria tests were completed for baseline samples, after treatment by the Nayadic^{TM} and Multi-Flo^{TM} and after the disinfection units. These tests were only necessary as the treatment units and UV disinfection units were the only theorized systems designed to have an impact on bacteria populations. *E. coli* will be tested specifically as it is an indicator species for bacteria. *Total Coli form* will also be monitored for the total population present.

Sampling was conducted on a weekly basis. Due to the number of samples and testing procedures requiring immediate analysis, not all parameters were obtained every week, and weekly samples were often obtained on different days within that week. Early nitrate tests indicated no nitrate concentrations within the entire system, therefore testing frequency was reduced to bi-weekly. TKN was run much more infrequently than other testing parameters due to the test time and resources required. Near the end of testing, BOD_5 samples were reduced in frequency due to unavailability of the incubator which was used for bacteria testing. A reduction in BOD testing was justified as a representative number of samples had already been analyzed, and a COD to BOD relationship could be established. Weekly samples for all other parameters and the more limited parameter tests above were able to describe the basic data trends.

3.6 Flow Rate Design

The treatment systems were designed for a household flow of 750 gallons per day. Household wastewater characteristics vary greatly from dairy milking facility wash water consequently, the equivalent hydraulic loading was determined based on the water parameters reported in previous research. The BOD_5 was determined to be 11 times higher in dairy wash water, as compared to household wastewater. The increase in BOD_5 resulted in 68 gallons per day of dairy wash water being equivalent to 750 gallons per day of household wastewater. For convenience, testing and data acquisition was conducted at 50 gallons per day of dairy wash water.

Treatment units were initially filled with waste and run at 50 gallons per day until failure. Failure for the Multi-Flo™ occurred when the socks were thoroughly clogged, restricting all flow. Failure of the Nayadic™ was more variable as even poorly treated water exited the system. When treatment levels dropped significantly as indicated by lab results or visual inspection, the Nayadic™ was designated as in failure. Reaching failure resulted in the restart of each unit. Restart entailed emptying the wash water and beginning with potable water within the treatment unit only. The Multi-Fl™ socks were removed and power washed to remove all sediment and biomat build-up before reinstalling for a system restart.

During the last three weeks of testing the flow was increased to 100 gallons to determine the treatment capabilities at greater flows. The increase in flow was determined to be applicable due to the high DO level of 5.99 mg/L in the Multi-Flo™ system after addition of the second aerator. DO levels were determined to be the limiting factor in treatment, and with increased oxygen a greater flow rate was applicable.

3.7 Reuse

Treated wash water can be reused in varying agricultural applications permitting adequate treatment is achieved. The focus reuse application for this research was the first floor flush before cleaning of the milking facility. Reuse potential was determined by the values of the water quality parameters. Accepted standards for agricultural first flush applications have not been determined by government or regulatory agencies. Table 3 provides recommended reuse water quality parameters for similar applications.

Table 3: Suggested water quality reuse values

Reuse Category	Water Parameter	Suggested Reuse Quality
Dairy Milking Parlor Floor Flushing	TCOD (mg/L)	650-700 (1)
	Nitrogen (mg/L as N)	70-80 (1)
	Phosphorus (mg/L as P)	6-10 (1)
	TSS (mg/L)	5-8 (1)
Agricultural Reuse - Food Crops Non-Commercially Processed	pH	6-9 (2)
	BOD_5 (mg/L)	≤ 10 (2)
	Turbidity (NTU)	≤ 2 (2)
	Fecal coli form (per 100 mL)	None detectable (2)
Agricultural Reuse- Food Crops Commercially Processed	pH	6-9 (2)
	BOD_5 (mg/L)	≤ 30 (2)
	TSS (mg/L)	≤ 30 (2)
	Fecal coli form (per 100 mL)	< 200 (2)
Agricultural Reuse - Non-Food Crops	pH	6-9 (2)
	BOD_5 (mg/L)	≤ 30 (2)
	TSS (mg/L)	≤ 30 (2)
	Fecal coli form (per 100 mL)	< 200 (2)
Environmental Reuse	BOD_5 (mg/L)	≤ 30 (2)
	TSS (mg/L)	≤ 30 (2)
	Fecal coli form (per 100 mL)	< 200 (2)
Dairy Milking Parlor Cleaning	pH	7.3 (3)
	Conductivity (μS/cm)	242 (3)
	Turbidity (NTU)	0.2 (3)
	TDS (mg/L)	128 (3)
	Hardness (mg/L)	88 (3)
	FOG (mg/L)	Nil (3)
	Chloride (mg/L)	58 (3)
	COD (mg/L)	24.7 (3)

1 Dong et. al, 2003
2 USEPA, 2004
3 Sarkar et. al, 2006

The reuse parameters set by Dong, 2003, most closely represented the reuse focus of this study. USEPA, 2004, suggested standards set for the most closely related fields. In general, aesthetics and the lack of bacteria and pathogens are among the most important factors for reuse in a first flush scenario. Ultimately, due to lack of standards, reuse of treated wash water is at the discretion of those farmers choosing to implement the technology.

3.8 System Enhancements

Throughout treatment various system enhancements were evaluated for their treatment effectiveness, Table 4.

Table 4: System Enhancements

Enhancement	Manufacturer	Location
Brush Filter	Sim/Tech	Settling Tank
Pressure Filter	Sim/Tech	Recirculation Lines
Aerator	Consolidated Treatment Systems Inc.	Multi-Flo^{TM} Main Basin

Three inline filters were added to the system to remove excess solids. The brush filter was inserted in a 4 inch pvc pipe located between the first and second 500 gallon settling tanks to reduce influent solids. Two pressure filters were installed in the recirculation lines to remove solids from the treated effluent before recycling to the dose tanks.

Once it was discovered that oxygen may be limiting treatment, an extra aerator was installed in the Multi-Flo^{TM} providing a total of 7.2 pounds of oxygen per day.

3.9 Monitoring

Visual inspection of the system was conducted several times per week. System maintenance was the major focus of these inspections. Maintenance was divided into two categories. The first was that seen in typical daily operation. Second was a result of research related issues only, and would not be a factor in typical implementation and operation.

CHAPTER 4: RESULTS AND DISCUSSION

Research on the operation of the treatment units continued for six months. Details concerning runtime and related operation dates can be found in Appendix B. Results for the water quality parameters, operating conditions and costs are discussed in the subsections below.

4.1 Water Quality Analysis

Water quality was determined by evaluation of alkalinity, pH, BOD_5, COD, TS, TSS, N, P, bacteria, FOG, DO, ORP and odor. Observations, trends, average values and reduction percentages were evaluated. All lab tests for alkalinity, COD, TS, TSS, N and P were duplicated. The value reported is an average. Detailed data tables are in Appendix C. The volume of data allowed for calculation of confidence intervals. General trends and reduction percentages provide proof of concept and evidence for reuse possibilities.

4.1.1 pH

An increase in pH was evident throughout the treatment process. Specifically, pH was typically between 6 and 6.5 for the baseline and distribution box samples indicating that the settling tanks had no effect. After division of the wash water into the two system lines, average pH values increased to between 7 and 8 for each treatment segment as a result of recirculated effluent (Table 5).

Table 5: Average pH concentrations

Location	Average pH 50 gal/day	95% Confidence Interval 50 gal/day (± pH)	Average pH 100 gal/day
Baseline	6.42	0.12	6.53
Distribution Box	6.24	0.37	6.39
Multi-Flo™			
Dose Tank	7.30	0.21	7.39
Treatment Unit	7.81	0.30	7.70
Recirculation	7.80	0.14	7.73
Disinfection	7.79	0.26	7.67
Nayadic™			
Dose Tank	7.59	0.34	7.49
Treatment Unit	7.97	0.09	7.59
Recirculation	7.98	0.06	7.62
Disinfection	8.03	0.07	7.57

Variation in samples was relatively low as indicated by the confidence levels. Baseline pH was much more consistent than all other treatment segment samples as represented by the low confidence interval and in Figure 4. The pH was more basic for the Nayadic™ treatment unit but not significant enough to make any real distinction. Values for pH in the dose tanks took on the characteristics of the treated effluent, as the averages are greater than the influent values from the settling tanks. There was no significant variation in pH for an increase in flow rate. Variation in pH generally followed the trends of the baseline influent pH as can be seen in Figure 4.

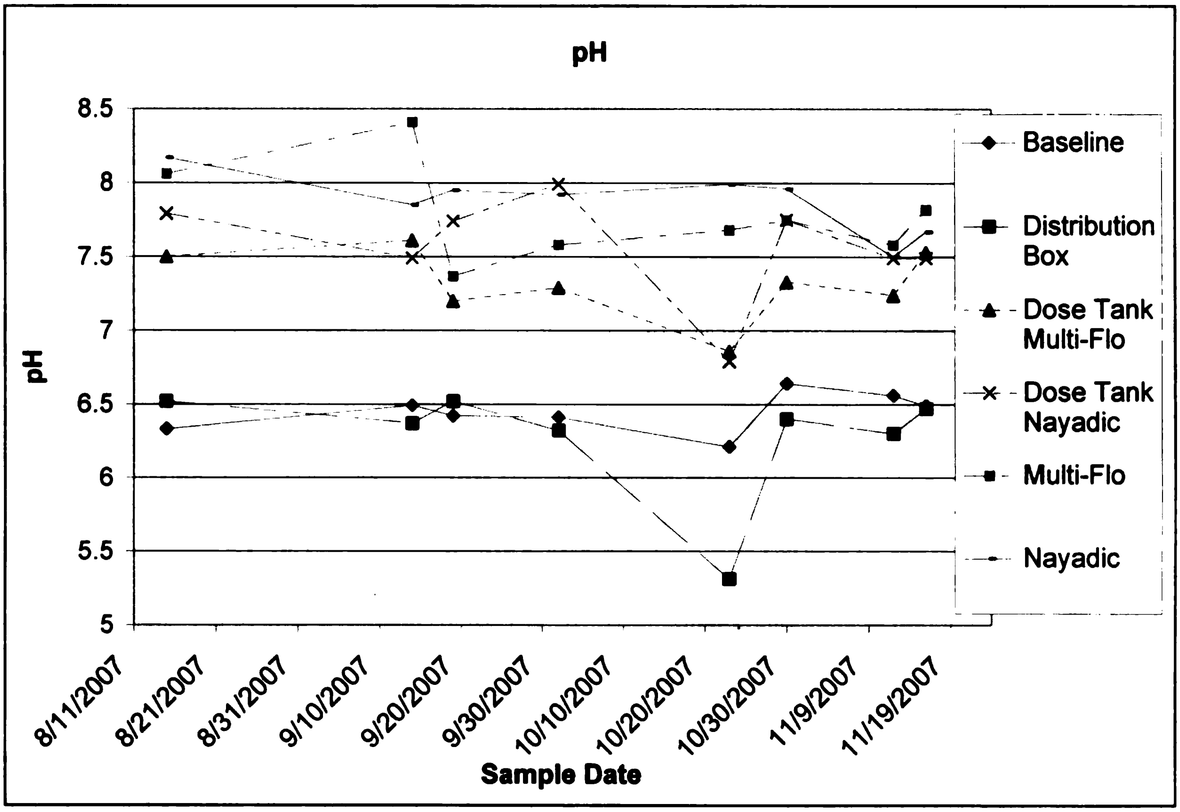


Figure 4: pH values throughout treatment

Relative maximum and minimum in the baseline samples are generally reflected throughout all treatment segments. The pH changes in the baseline influent are reflected in the treatment systems within the same day, establishing a quick pH response. There were no significant differences realized with the increased aeration in the Multi-Flo™ or with the addition of filters.

Nitrification requires pH values between 7.5 and 8.5 as those below 7.0 decrease nitrification significantly.

The pH of the treated effluent is well with ranges for water reuse and poses no problems concerning corrosion or toxicity to treatment systems, possible reuse surfaces or the environment.

4.1.2 Alkalinity

A reduction in alkalinity was observed as wash water progressed through the treatment system. Average alkalinity values and the range of reduction percentages for each treatment segment are presented in Table 6.

Table 6: Average alkalinity concentrations reduction percentages

Location	Average Alkalinity 50 gal/day (mg/L as CaCO3)	95% Confidence Interval 50 gal/day (± Alkalinity)	Percent Reduction from the Baseline
Baseline	3165	1564	
Distribution Box	1815	794	21-66%
Multi-Flo™			
Dose Tank	1006	767	66-86%
Treatment Unit	596	47	62-90%
Nayadic™			
Dose Tank	2038	756	10-62%
Treatment Unit	1853	335	3-65%

The Nayadic™ treatment unit used less alkalinity the Multi-Flo™. Alkalinity values represent bicarbonate alkalinity (HCO_3^-) as the phenolphthalein alkalinity was zero in all samples. Variations in alkalinity throughout the treatment process are directly related to the baseline wash water concentrations, as can be seen in Figure 5.

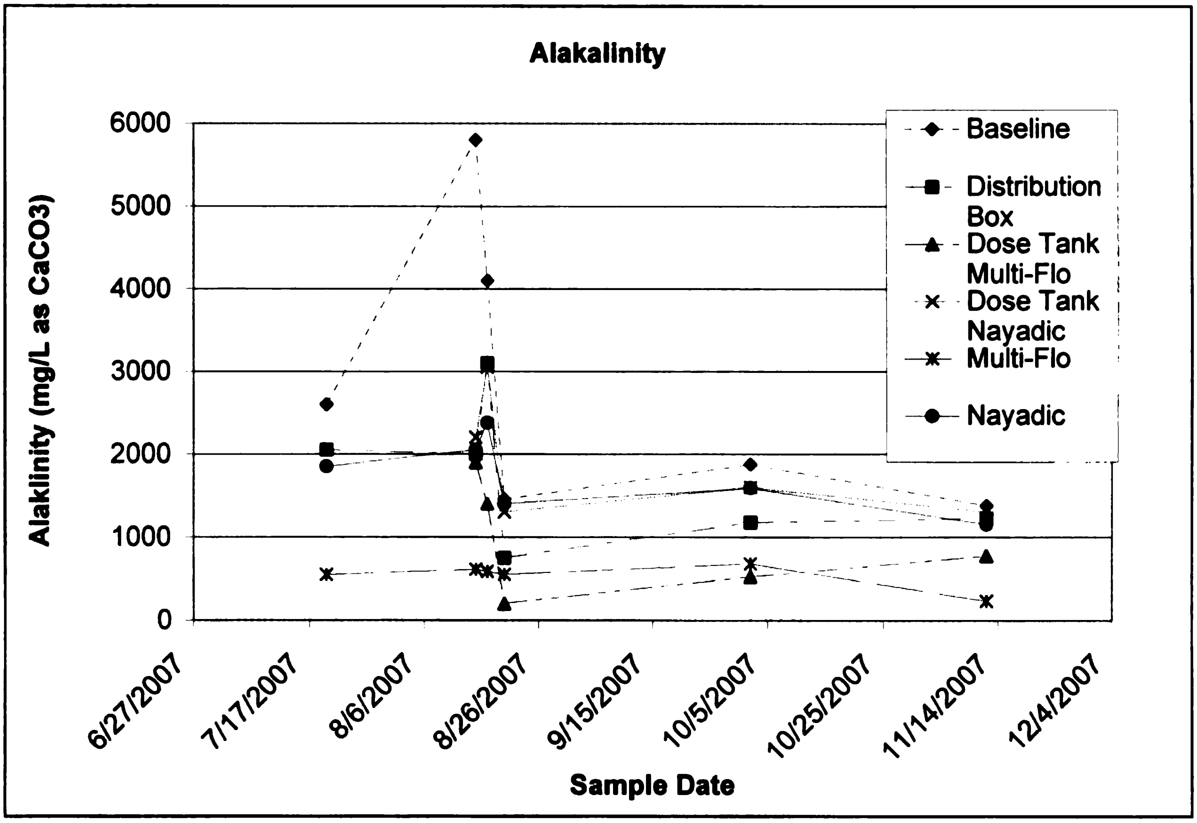


Figure 5: Alkalinity trends throughout treatment

The spikes and troughs vary similarly to the baseline throughout the treatment unit segments and indicate that alkalinity changes are rapid throughout the system. The high alkalinity concentrations in the baseline samples are reduced significantly throughout treatment due to the nitrification of ammonia to nitrate. Large amounts of alkalinity are used in the nitrification process, and as treatment occurs and ammonia is oxidized, alkalinity is used and concentrations fall as indicated in the treated samples. Reuse ability is not affected by alkalinity as all values fall within the acceptable ranges for any reuse possibilities.

4.1.3 Biochemical Oxygen Demand

Untreated wash water values had an average of 5761 mg/L BOD_5 with a range of 3353 to 7107 mg/L BOD_5. These values were more than double those reported in previous research. Reduction percentages, even at these levels, were high as can be seen in Table 7.

Table 7: Average BOD concentrations and reduction percentages

Location	Average BOD_5 (mg/L)	95% Confidence Intervals (± BOD_5)	Percent Reduction from Baseline
Baseline	5761	918	
Distribution Box	4549	1473	0-43%
Multi-Flo™			
Dose Tank	718	342	80-95%
Treatment Unit	270	261	74-99%
Nayadic™			
Dose Tank	1318	551	70-90%
Treatment Unit	700	239	67-96%

BOD_5 reduction percentages were consistent throughout the 6 month testing period. However, the Multi-Flo^{TM} unit outperformed and proved to be more consistent than the Nayadic^{TM} on a regular basis. It should be noted that lower treatment percentages resulted from the initial operation startup in which the treatment units were completely filled with untreated wash water. Treatment systems restarted with potable water reduced the loading thereby improving treatment. The Multi-Flo^{TM} unit regularly reached BOD_5 values less than 20 mg/L during the month of August, 2007, and maintained greater than a 74% reduction of BOD_5 throughout testing. For reference, the federal Clean Water Act BOD_5 surface discharge limit is 30 mg/L, unless discharging into more environmentally sensitive waters. Greater values were reflected in the table average for the Multi-Flo^{TM} due to large variation at the start of treatment testing. Higher concentrations of BOD_5 were present in the Nayadic^{TM}, but significant reduction was still achieved. Figure 6 displays the values of BOD_5 over a three month period. Significant differences among the incoming wash water and the treatment lines were observed.

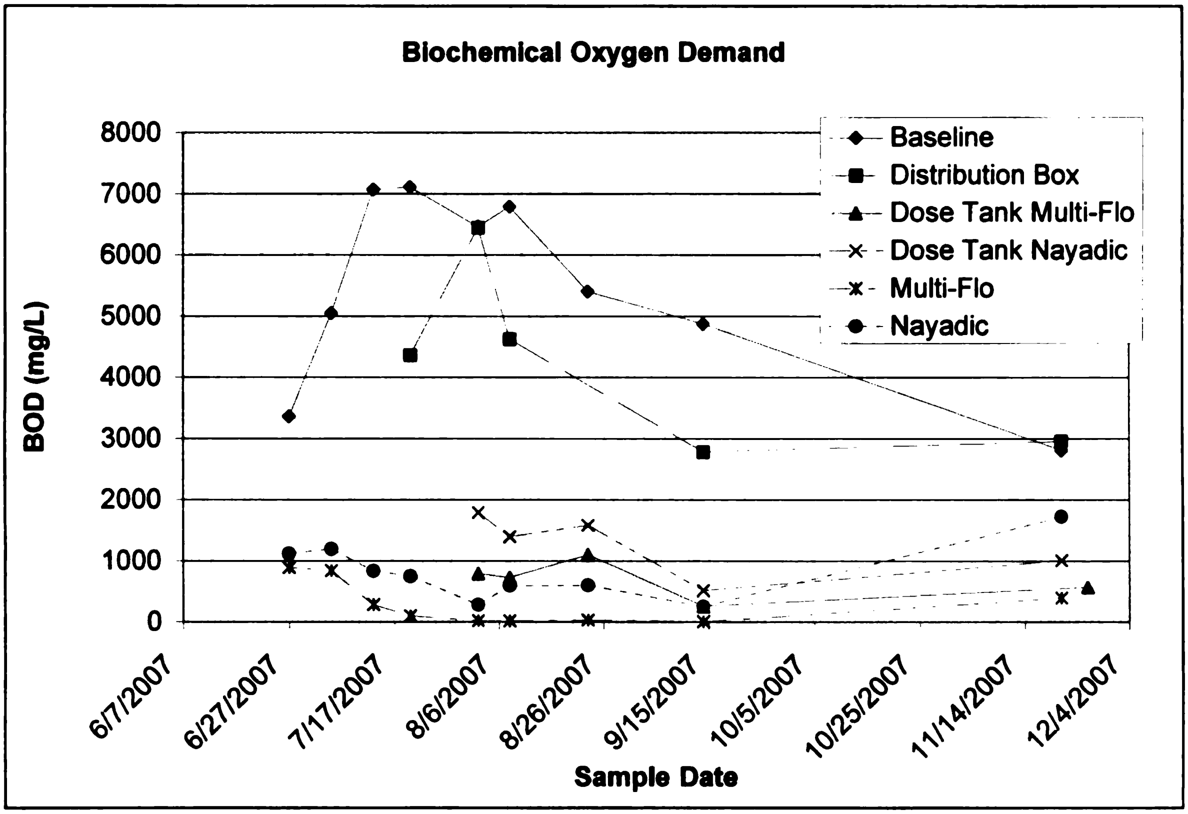


Figure 6: Biochemical oxygen demand throughout treatment

In terms of BOD_5, the Multi-Flo^{TM} was able to consistently produce very low values that fall to concentrations suitable for reuse for flushing floors and other applications. Although the Nayadic^{TM} achieved great reductions in BOD_5, the sustained levels were never close to that which would be expected for treated water.

4.1.4 Chemical Oxygen Demand

The average baseline value for COD, at 36,528 mg/L, was ten times higher than any of those reported in literature. The great increase was due to the high level of solids located within the wash water produced at the MSU dairy farm. Filtered baseline samples, or soluble COD in the wash water influent, resulted in an 84% reduction in COD values. Even with the high COD concentrations present in the influent wash water, reduction in values was substantial, as can be seen in Table 8.

Table 8: Average COD concentrations and reduction capabilities

Location	Average COD (mg/L) 50 gal/day	95% Confidence Interval (± COD value)	Percentage Reduction from Baseline 50 gal/day	Average COD (mg/L) 100 gal/day
Baseline	36528	8606		10988
Distribution Box	17065	12894	(-55)-83%	9590
Multi-Flo™				
Dose Tank	2451	1150	65-72%	3400
Treatment Unit	1094	564	77-70%	2377
Recirculation	980	1161	67-69%	3584
Nayadic™				
Dose Tank	3847	1054	17-19%	7035
Treatment Unit	3091	634	7-8%	10163
Recirculation	2565	1099	67-94%	10040

The confidence intervals show the large variability within the COD concentrations. Baseline samples varied from 9,000-63,000 mg/L while the Multi-Flo™ and Nayadic™ samples had less variation with ranges of 85-3,500 mg/L and 1,700-9,100 mg/L COD respectively. An increase in flow rate to 100 gallons per day reduced the treatment efficiency. The Multi-Flo™ was capable of producing lower numbers on a more consistent basis than those for the Nayadic™. Unlike many other parameters, the relation of peaks and troughs for treated and baseline influent COD values were not as apparent, as seen in Figure 7 (note the log scale).

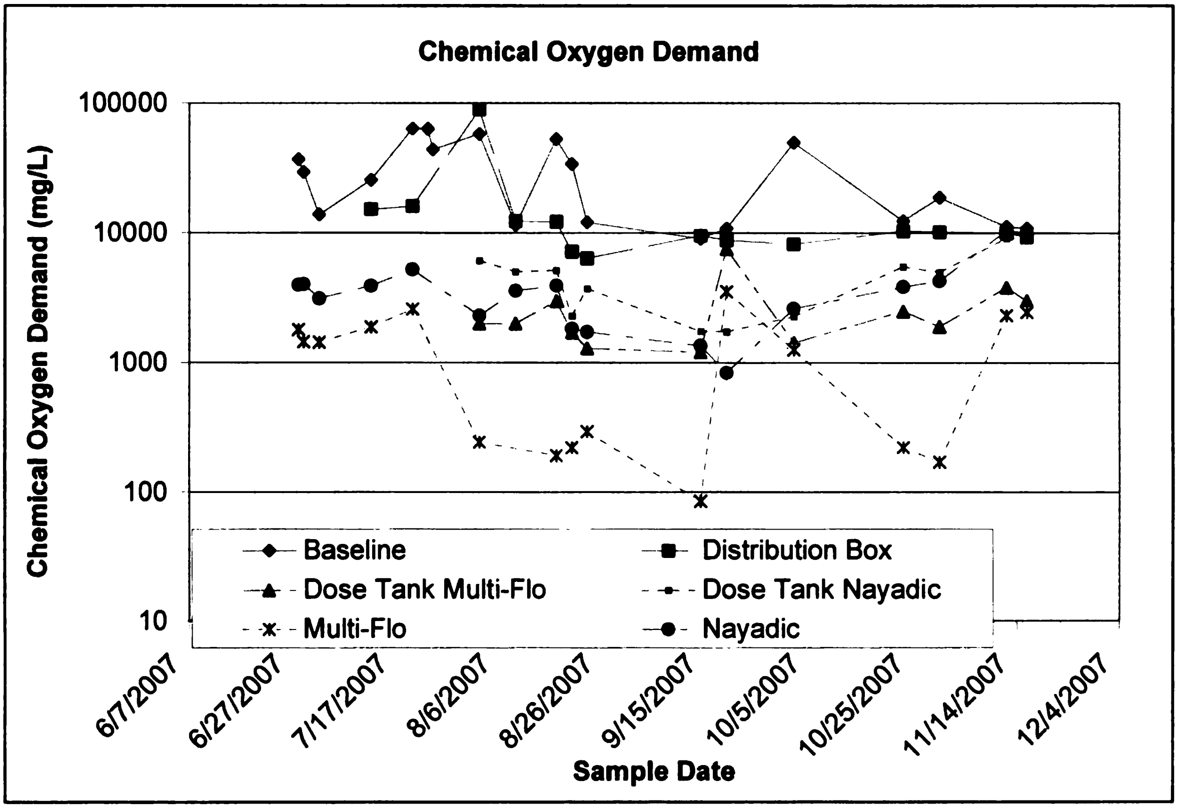


Figure 7: Chemical oxygen demand concentrations over testing span

The Multi-Flo™ dose tank and treatment unit samples had similar variations, which was attributed to dilution from recirculation of treated effluent. Reuse values for COD as outlined by Dong et. al, 2003, for cleaning milking parlor floors of 650 to 700 mg/L was reached by the Multi-Flo™ for over a month long period during August, 2007. COD values were consistent for this period but varied greatly for the remaining months of operation. Once again the Nayadic™ did not perform as well as the Multi-Flo™; therefore reuse is dependent on application and user standards. For reuse in a first flush cleaning practice COD concentrations are not as important as wash water cannot enter the environment.

4.1.4 Total Solids

Decreases in solids concentrations were realized throughout the treatment process. Solids in the influent had a range of 1,448 to 35,188 mg/L. Table 9 displays the average solids concentrations and confidence intervals for each sampling location. The confidence intervals again indicate large variations of total solids concentrations within the samples.

Table 9: Average TS concentrations and treatment efficiency

Location	Average TS 50 gal/day (mg/L)	95% Confidence Interval (± Total Solids)	Percent Reduction from Baseline 50 gal/day	Average TS 100 gal/day (mg/L)	Percent Reduction from Baseline 100 gal/day
Baseline	16750	5159		6407	
Distribution Box	10331	6397	(-50)-77%	6316	(-37)-17%
Multi-Flo™					
Dose Tank	2800	489	38-94%	3651	32-49%
Treatment Unit	1617	545	38-98%	3268	32-63%
Recirculation	1938	1116	52-92%		
Nayadic™					
Dose Tank	4172	671	39-89%	7018	(-45)-7%
Treatment Unit	4173	1165	(-48)-92%	7006	(-57)-11%
Recirculation	3373	1298	25-88%		

The Multi-Flo™ was capable of sustaining a total solids concentration near 1,000 mg/L for the month of August, 2007. Percent reduction for the Multi-Flo™ was maintained at over 80% for the majority of the study; only one outlying sampling event lowered this range to 46% which was during the end of the treatment run (system was approaching failure). The Nayadic™ was more variable and maintained a total solids concentration around 4,000 mg/L. Reduction percentages for the Nayadic™ were maintained on average above 70%, but had spikes that indicated very poor treatment performance at times. Concentrations within the dose tanks were diluted by the treated effluent recirculation. Dose tanks somewhat mimicked the changes in the treatment units as can be seen in Figure 8, but were more related to the baseline concentrations.

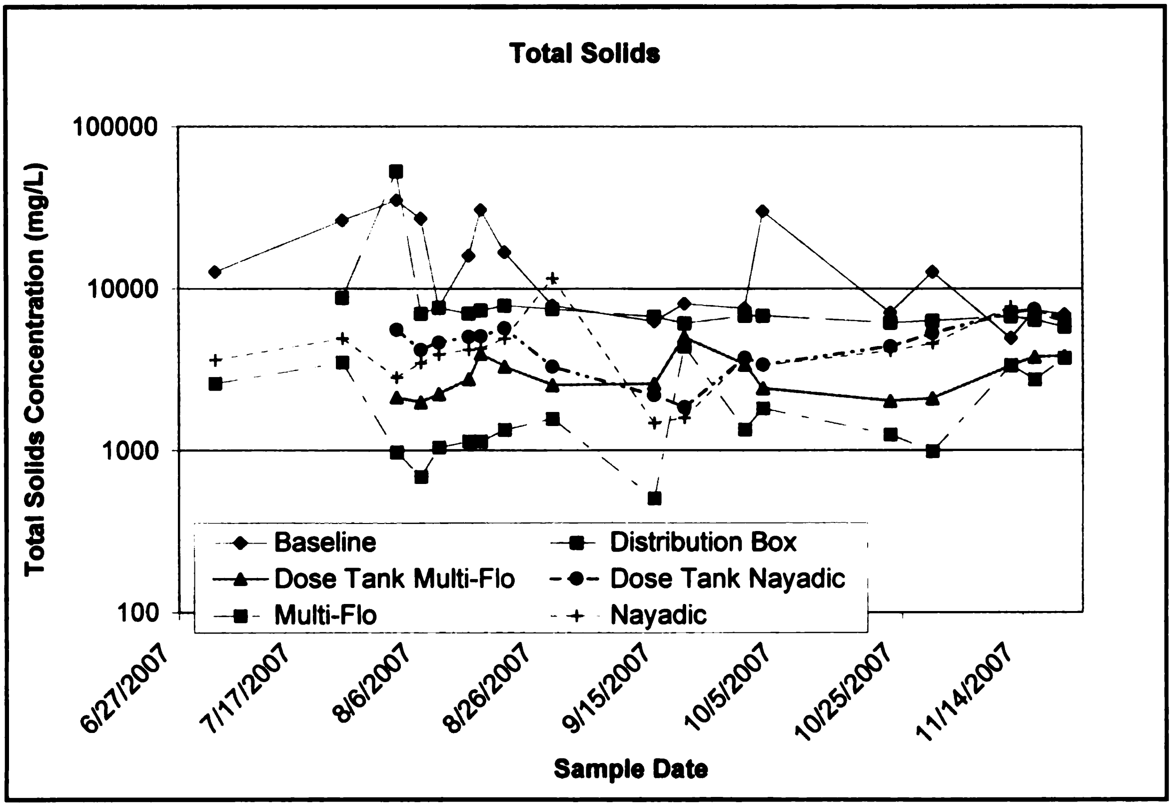


Figure 8: Total solids concentrations over time

Variability within the samples was due to management practices at the farm. Solids production varied with animal waste production, solids tracked into the milking facility and cleaning practices. The MSU dairy washed all solids into the underground tank, no solids separation resulted in very high TS and TSS relative to values reported in the literature. In an effort to decrease the solids concentrations an influent filter and recirculation filters were installed as previously explained in the methods section. Filters were successful at removing solids but clogged on an hourly basis. Various filter sizes were examined but none provided any treatment without clogging. This prevented any conclusive data collection for treatment performance at reduced solids concentrations.

4.1.5 Total Suspended Solids and Color

TSS concentrations were reduced significantly after wash water was subjected to the treatment process. Variability in the average concentration was large, as shown by the confidence intervals in Table 10.

Table 10: Average TSS concentrations and treatment efficiency

Location	Average TSS 50 gal/day (mg/L)	95% Confidence Interval (± TSS)	Percent Reduction from Baseline 50 gal/day	Average TSS 100 gal/day (mg/L)	Percent Reduction from Baseline 100 gal/day
Baseline	8725	3437		1350	
Distribution Box	1713	320	(-35)-92%	1533	(-71)-39%
Multi-Flo TM					
Dose Tank	863	465	62-98%	1167	(-24)-35%
Treatment Unit	238	308	63-99%	1083	83-90%
Nayadic TM					
Dose Tank	1103	406	68-96%	1633	75-86%
Treatment Unit	1253	1016	(-106)-96%	2033	64-89%

The Multi-Flo™ and Nayadic™ units were capable of removing more than 90% of TSS; however, these removal rates were not sustainable. TSS removal below 30 mg/L was achieved inconsistently by the Multi-Flo™ treatment unit. Spikes in each of the treatment units in Figure 9 were attributed to the rise of solids in the settling tanks, which were then transferred into the wash water entering the treatment system lines increasing the TSS.

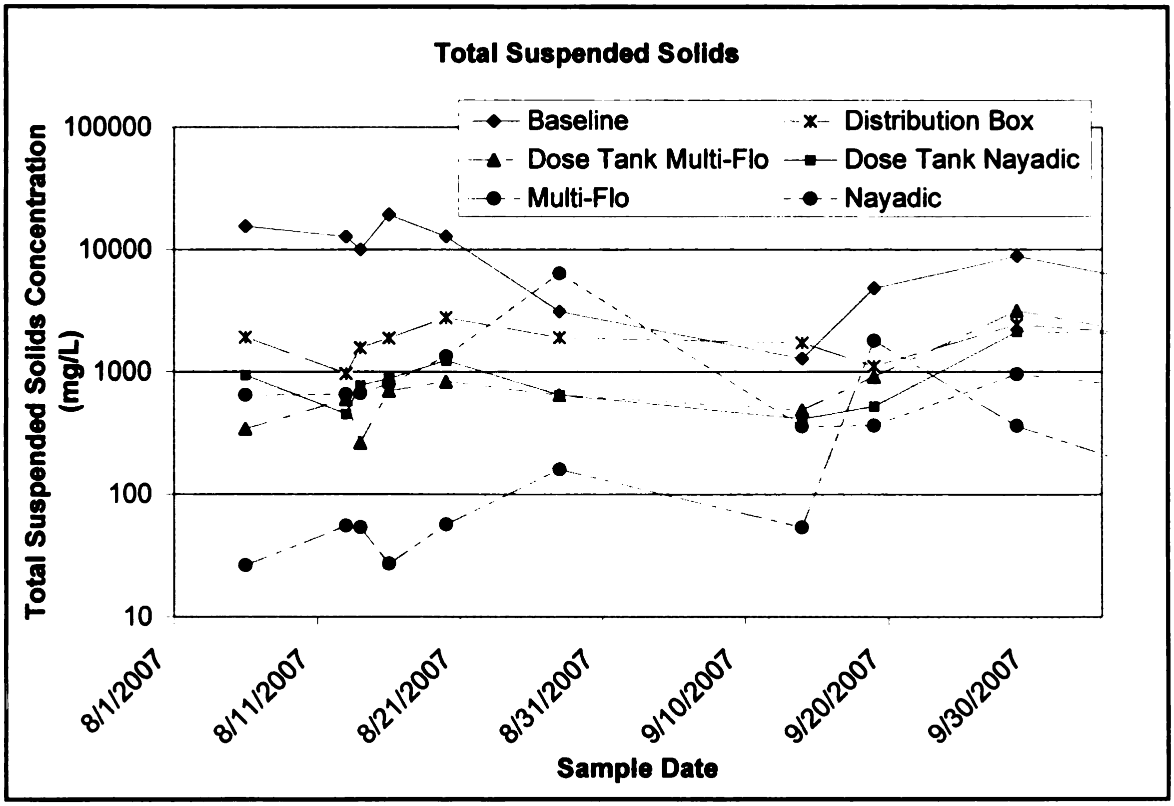


Figure 9: Total suspended solids concentration over testing span

Removal of suspended solids in the Multi-Flo™ was due not only to solids settling, but also the filter socks within the main basin. Suspended solids were present in the effluent due to wear of the socks from power washing, enlarging pore size. A small amount of build-up was present on the inside of the socks which had potential to increase the suspended solids concentration as particles were dislodged. A biomat built-up on the socks would theoretically reduce the TSS concentrations over time.

Color was a good indicator of treatment performance concerning suspended solids. Colors varied from a very light yellow for samples with little TSS, to a dark brown when there were large amounts of solids. The Multi-Flo™ was capable of reducing the color to almost clear.

TSS content poses mostly aesthetic problems concerning reuse for a first flush scenario. Solids in general can pose problems to equipment, specifically corrosion issues when used in power washers for cleaning. High TSS inhibits disinfection by the UV disinfection unit due to poor penetration. Salcor Inc. reports a value of 30 mg/L or less TSS required for proper disinfection, these values were reached infrequently. Reuse of treated wash water would require a more consistent reduction in TS and TSS.

4.1.5.1 Nitrogen

Three lab tests were conducted to determine the chemical form and concentration of nitrogen. Included was total Kjeldahl nitrogen, to determine the total organic nitrogen compounds, ammonia and nitrate. This enabled monitoring of nitrification and denitrification.

4.1.5.2 Total Kjeldahl Nitrogen

TKN is defined as the sum of nitrogen as organic nitrogen and ammonia, however, for this research only organically bound nitrogen was determined. Significant TKN reductions were observed. Confidence intervals for these samples were much lower indicating less variability, Table 11. However, there was a great reduction in the number of tests run for this parameter that could account for this decrease in variation of samples.

Table 11: Average TKN concentrations and treatment efficiency

Location	Average TKN (mg/L) 50 gal/day	95% Confidence Interval (± TKN)	Percent Reduction from Baseline
Baseline	107	18	
Distribution Box	136	54	(-17)-15%
Multi-Flo™			
Dose Tank	56	16	34-65%
Treatment Unit	14	8	83-98%
Nayadic™			
Dose Tank	90	10	14-31%
Treatment Unit	85	18	10-29%

Figure 10 shows the range of values for TKN and a general decrease in concentrations throughout the treatment process. A greater decrease occurred in the Multi-Flo™ system as compared to the Nayadic™ because conversion of organic nitrogen to ammonia is dependent on oxidizing conditions which was more characteristic of the Multi-Flo™.

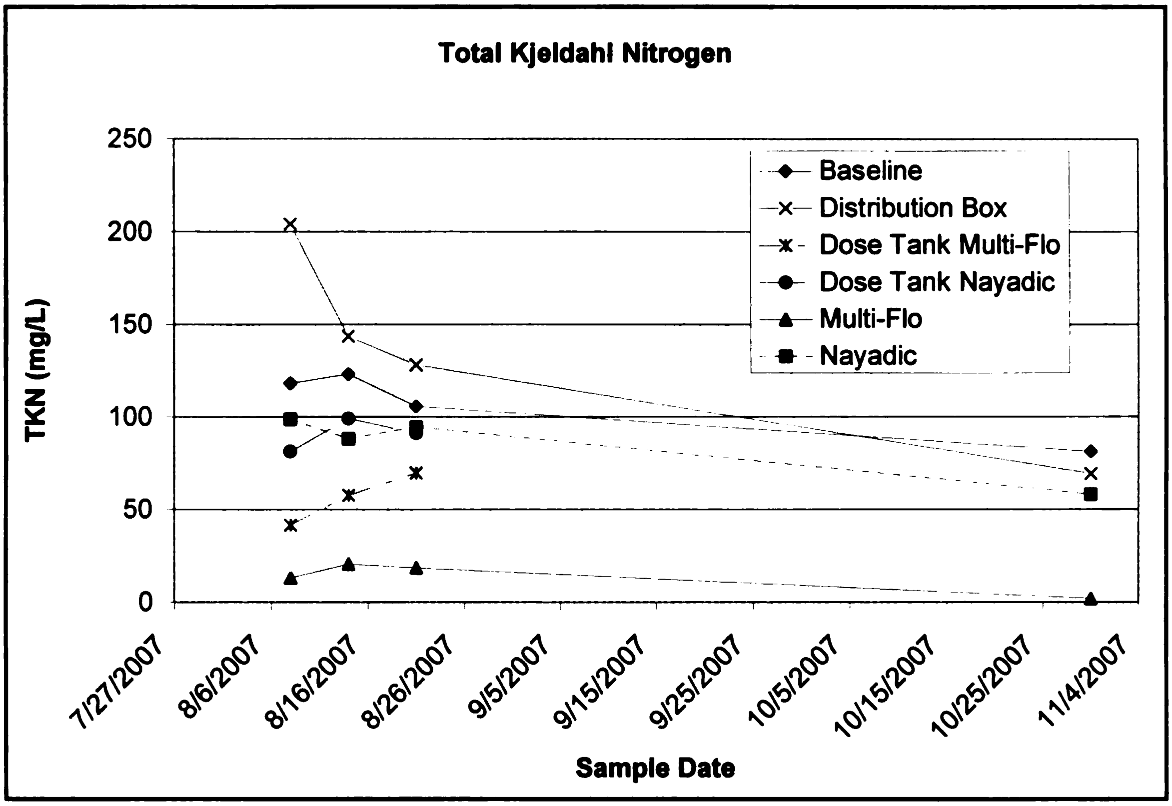


Figure 10: Total Kjeldahl nitrogen concentrations over time

Organic nitrogen accounts for around a third of the nitrogen present in the system and is converted to ammonia through decomposition by microbes. This process, known as ammonification, constantly provides more ammonia for nitrification. Further evaluation of the nitrogen processes will be discussed in the sections following.

4.1.5.3 Nitrate

Nitrate was not present in any of the samples taken throughout testing. It should be noted that due to large solid concentrations dilution was required increasing the minimum detection concentration as high as 7.5 mg/L for baseline samples and 3 mg/L for all other samples. However, because of the high organic carbon levels and low ORP, it is likely that denitrification did not allow the accumulation of nitrate.

4.1.5.4 Ammonia

Ammonia reductions were seen throughout testing with confidence intervals suggesting some variability for samples, Table 12.

Table 12: Average ammonia concentrations and treatment efficiency

Location	Average Ammonia (mg/L) 50 gal/day	95% Confidence Interval (± Ammonia)	Percent Reduction from Baseline 50 gal/day	Average Ammonia (mg/L) 100gal/day
Baseline	257	26		244
Distribution Box	245	28	(-12)-16%	251
Multi-Flo™				
Dose Tank	56	23	48-94%	65
Treatment Unit	23	24	64-100%	42
Recirculation	19	21	72-100%	43
Nayadic™				
Dose Tank	135	33	25-71%	218
Treatment Unit	128	28	23-73%	229
Recirculation	112	55	22-79%	242

The Multi-Flo™ maintained a treatment system performance over 64% for the entire data collection period. It was also capable of maintaining a consistent ammonia level below 5 mg/L for all of August, 2007. Ammonia levels in the dose tank and Nayadic™ treatment lines closely mimic the baseline, Figure 11.

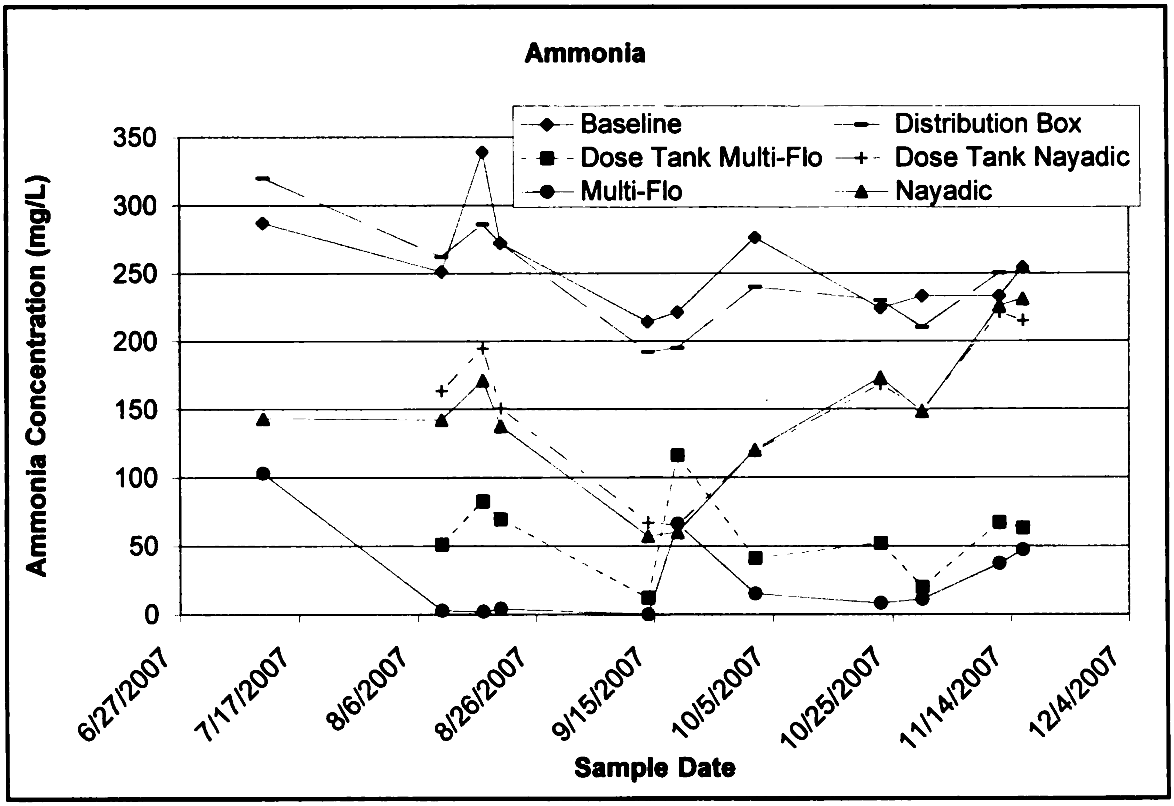


Figure 11: Ammonia concentrations over test span

The levels of ammonia in the Nayadic™ system indicated minimum nitrification. However, the low levels of ammonia in the Multi-Flo™ unit as seen in Figure 12, indicate nitrification is occurring at a rapid rate. Greater nitrification rates could be attributed to more effective oxygenation within the Multi-Flo™ unit and the lower BOD levels required before nitrification occurs.

4.1.6 Total Phosphorus

The phosphorus content in the wash water was high, indicating large amounts of manure or cleaning products. Excess manure was previously discussed as a solids waste management issue that requires a change in farm practices to improve efficiency. Phosphorus removal was less effective in the Nayadic™ system than the Multi-Flo™, Table 13.

Table 13: Average total phosphorus and treatment efficiency

Location	Average Total Phosphorus 50 gal/day (mg/L)	95% Confidence Intervals (± Total Phosphorus)	Percent Reduction from Baseline	Average Total Phosphorus 100 gal/day (mg/L)
Baseline	149	28		122
Distribution Box	133	24	(-10)-26%	118
Multi-Flo™				
Dose Tank	49	13	27-81%	85
Treatment Unit	30	11	3-72%	58
Recirculation	39	20	33-83%	65
Nayadic™				
Dose Tank	58	11	41-69%	106
Treatment Unit	45	6	43-93%	93
Recirculation	46	7	49-69%	97

Confidence intervals once again suggested some variation within the samples however, phosphorus content was more consistent in the influent wash water and treatment was not typically as variable as many other parameters.

Treatment performance for the Multi-Flo™ was in the 75-93% range throughout testing other than one outlier on September 19, 2007 which was much lower due to the system approaching failure. Failure produced a large volume of solids, resulting in high phosphorus concentrations. The Nayadic™ produced concentrations on average 1.5 times higher than the Multi-Flo™ and resulted in a greater performance inconsistency. An increase in the flow rate produced reduced treatment performance in both units. However, inconsistent performance and lack of data for flow rates of 100 gal/day require more testing for conclusive evaluations. Trends in the baseline effluent were mimicked in the distribution box, figure 12.

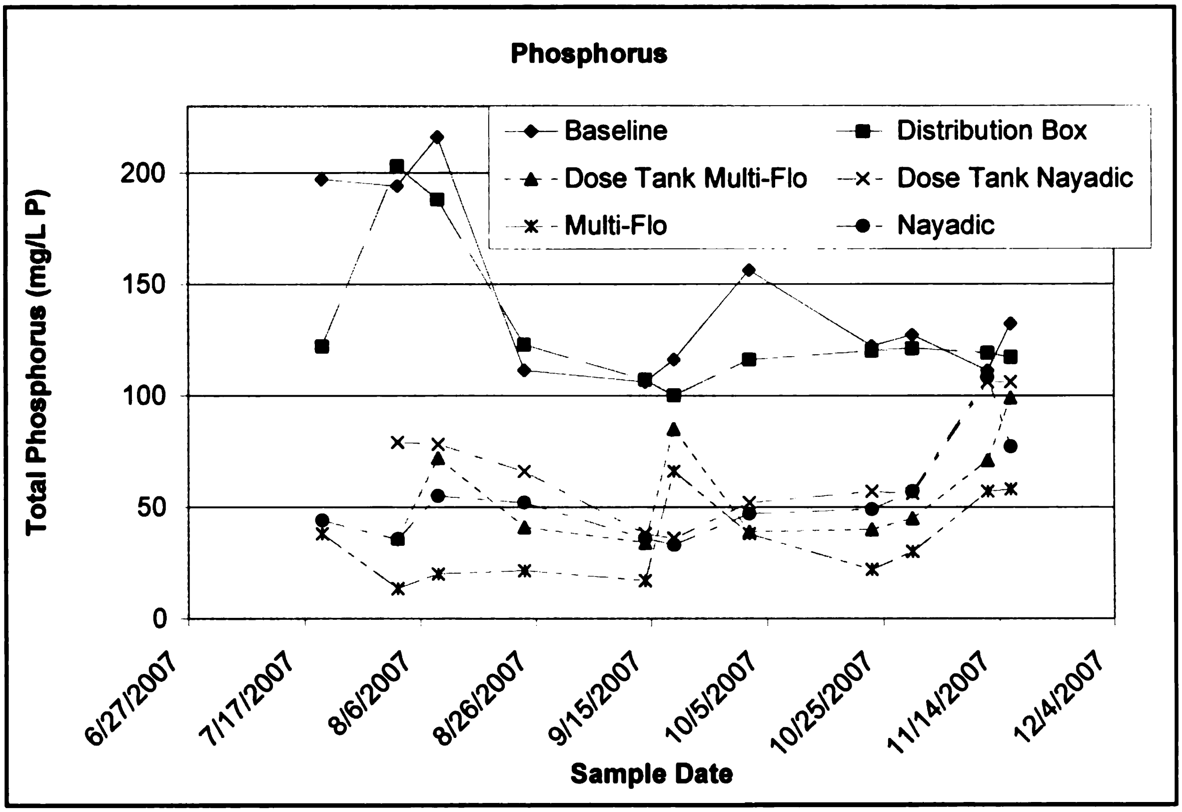


Figure 12: Phosphorus concentrations over testing span

General trends in the influent data extend to the Nayadic™ system however, these trends cannot be seen in the Multi-Flo™ system. Uptake of phosphorus by microorganisms results in biosolids with high phosphorus content, when removed eliminates large concentrations of phosphorus. Neither system achieved the reuse values for phosphorus recommended by Dong et. al (2003). Reuse of wash water is still a potential as phosphorus is tied to solids content, suggesting a management practice can reduce the concentrations.

4.1.7 Bacteria

Bacteria data for *E. coli* and *total Coli forms* were inconclusive. The few sets of valid data collected were for a flow rate of 100 gallons a day and indicated a great amount of bacteria were present throughout the system. Samples obtained after the disinfection units had very high bacteria levels, indicating no treatment, Table 14.

Table 14: Bacteria levels

Location	Sample Date	Total E. Coli (colonies/100 mL)	Total Coli forms (colonies/100 mL)
Baseline	11/14/2007	13000	80000
Baseline	11/14/2007	136000	185000
Baseline	11/16/2007	207000	245000
Multi-Flo™			
Treatment Unit	11/14/2007	5500	15500
Treatment Unit	11/14/2007	7500	21000
Treatment Unit	11/16/2007	52000	161000
Disinfection	11/14/2007	8000	16500
Disinfection	11/14/2007	6000	9500
Disinfection	11/16/2007	54000	213000
Nayadic™			
Treatment Unit	11/14/2007	12000	69000
Treatment Unit	11/14/2007	1200	45400
Treatment Unit	11/16/2007	79000	284000
Disinfection	11/14/2007	27500	86500
Disinfection	11/14/2007	5000	48500
Disinfection	11/16/2007	21000	97000

The disinfection units required a total suspended solids level below 30 mg/L for effective treatment, which were not reached in the final weeks during the 100 gallons a day flow rate. Unfortunately bacteria measurements could not be made during the 50 gallon/gay test, but if so substantial improvements would be realized.

4.1.9 Odor

An odor panel quantitatively evaluated the treatment samples. Although odor removal was achieved in both treatment systems, The Multi-Flo™ produced much lower numbers for odor indicating a more aesthetically pleasing smell, Table 15.

Table 15: Odor

Location	Average Odor Value	95% Confidence Interval (± odor value)
Baseline	7.72	0.70
Multi-Flo™	3.31	1.04
Nayadic™	5.88	0.88

4.1.10 Fats, Oils and Grease

Fats, oils and grease pose problems during treatment, as well as environmental degradation issues. Concentrations of FOG are high and variable in milking facilities due to spillage, management practices, the milk wasting rate and discharge due to quality standards. Treatment of FOG in the systems was observed, with the Multi-Flo™ removing over 90%. The Nayadic™ unit was also capable of reductions in FOG concentrations but to a lesser degree than the Multi-Flo™, Table 16.

Table 16: Fats, oil and grease data for 50 gallons per day

Location	FOG 10/23/2007 (mg/L)	FOG 10/30/2007 (mg/L)	Percent Reduction FOG 10/23/2007	Percent Reduction FOG 10/30/2007
Baseline	120	270		
Multi-Flo™	5	22	95.8%	91.9%
Nayadic™	30	190	75.0%	29.6%

Although only two samples were tested, the Multi-Flo™ unit has great FOG removal potential. Acceptable reuse concentrations will be dependent upon application. Common problems with reuse are build-up and clogging in pipes and development of a film on cleaning surfaces. The Multi-Flo™ has reduced the concentrations to levels which negate theses issues.

4.1.11 Oxidation Reduction Potential and Dissolved Oxygen

ORP and DO are indicators of the oxidizing potential of the waste water. Low ORP values indicate waste water with great potential to reduce other compounds within the treatment unit. The low ORP and DO values indicate an oxygen limiting system, Table 17.

Table 17: Average ORP and DO values

Location	Average ORP (mV)	95% Confidence Interval (± ORP)	Average DO (mg/L)	95% Confidence Interval (± DO)
Baseline	-204.3	20.5	0.81	0.42
Nayadic™	-208.5	20.1	0.63	0.21
Multi-Flo™	-93.8	158.7	3.25	2.19

The low values indicated the need for a second aerator, However, the oxygen deficiency was greater for the Nayadic™, which was consistent with the lower removal values. On October 19, 2007, the second aerator was added to the Multi-Flo™. The ORP and DO values were raised substantially to a maximum value of 104 mV and 5.99 mg/L, respectively.

4.2 Maintenance

Maintenance for operation of the treatment units required numerous man hours. The main pump had electrical, clogging and other problems that required a minimum of monthly removal and maintenance. Settling tanks required cleaning and removal of solids on a bi-weekly basis. Monthly removal and cleaning of the socks in the Multi-Flo™ was required for effective treatment. Foaming was also an issue with the Multi-Flo™ system, occurring on average after the basin was off line or refilled with water. This was due to the reduction in desired aerobic bacteria and an increase in foam producing bacteria, *Nocardia*. Easily installed anti-foaming blocks, provided by Consolidated Treatment Systems Inc., produced immediate results. One block was capable of stopping foaming for greater than a month at a cost of $5. Both treatment units need to be emptied and refilled with fresh potable water on a monthly basis. System inspection and minor leaks and repairs were required weekly. This system inspection would be reduced for systems buried and operated over a period of time. Table 18 details the average man hours required for each of the maintenance issues.

Table 18: Maintenance requirements

Maintenance Issue	Research or Typical Operation	Man Hours Required	Frequency
Main Pump Halt	Typical	2.0	Monthly/As Needed
Clean Settling Tanks	Typical	2.0	Biweekly
Remove and Clean Multi-Flo™ Socks	Typical	4.5	Monthly
Foam	Typical	0.5	Monthly/As Needed
Restart			
Empty	Typical	0.5	Monthly
Refill	Typical	2.0	Monthly
System Inspection	Typical	2.0	Weekly
System Inspection	Research	4.0	Minimum 3 Times per Week
Flow Rate Calibration	Research	1.0	Minimum 3 Times per Week
Distribution Box	Research	2.0	Implementation and Monthly
Recirculation Ratios	Research	2.0	Implementation and Monthly
Leak Repair	Research	1.0	Weekly/As Needed
Unclog Sampling Port	Research	0.5	Weekly/As Needed

Maintenance for research purposes was much more involved. The flow rate had to be calibrated three times a week. Establishing and maintaining even distribution to the two systems and the recirculation ratios were time consuming issues. Weekly maintenance included fixing leaks, dislodging clogs at sampling ports and a more detailed system inspection. Upkeep for research purposes was required daily and required numerous man hours.

CHAPTER 5: CONCLUSIONS AND RECCOMENDATIONS

5.1 Conclusions

The following conclusions were drawn from the testing results.

- Aerobic treatment units proved able to treat high strength dairy wash water waste.
- The Multi-Flo^{TM} consistently outperformed the Nayadic^{TM} for all water quality parameters.
- The Multi-Flo^{TM} reached effluent water quality standards for reuse at a flow rate of 50 gallons per day for a first flush cleaning of the dairy milking facility for one month.
- System maintenance was determined vital for proper treatment performance and can consume 21.5 man hours per month.
- An increase in water quality was realized by each of the two treatment units at a flow rate of 50 gallons of wash water per day; average values for the influent and effluent for each unit are below in Table 19.

Table19: Treatment effectiveness (50 gallons per day)

Treatment Parameter	Baseline Influent	Nayadic™ Effluent	Multi-Flo™ Effluent
pH	6.42	7.81	7.97
Alkalinity (mg/L)	3165	5038	596
Ammonia (mg/L as N)	257	128	23
BOD_5 (mg/L)	5761	700	270
COD (mg/L)	36528	3091	1094
Total Phosphorus (mg/L as P)	149	45	30
TS (mg/L)	16750	4173	1617
TSS (mg/L)	8725	1253	238
Nitrate (mg/L as N)	0	0	0
TKN (mg/L as N)	107	85	14

- A second aerator installed in the Multi-Flo™ unit proved to increase the ORP and DO levels within the tank substantially.
- Treatment is reliant on the characteristics of the wash water produced by the farm. Large amounts of solids were determined to be the main detriment to system operation and treatment performance.
- The volume of wash water treated, 50 gallons per day, does not meet production of the wash water requiring disposal. Feasibility of the treatment units will depend on improved efficiency.
- The recirculation ratio was an important design factor for treatment performance which was critical for dilution of the extremely high concentrations compared to the typical reported values.

5.2 Recommendations

Proof that the concepts and processes involved in this treatment system are capable of treating high strength dairy wash water was achieved. Further investigation of the Multi-Flo^{TM} system is warranted as it was able to achieve the reuse values for an entire month.

The Multi-Flo^{TM} system performance was based mainly on the ability of the filtration socks to provide effective solid/liquid separation, indicating the importance of solids removal on performance. A reduction in solids also has the potential to increase the effectiveness of the disinfection unit, thereby reducing bacteria levels. Further testing on the treatment units with an effective solid pretreatment or a solids reduction achieved with management practices would theoretically increase treatment performance and system life before clogging. Solid pretreatment as a result of an increase in settling can be accomplished using larger settling volumes, additional current farm sand separation technology, baffle boxes or addition of polymers. Implementing a solid scrape technique as a farm management practice prior to milking parlor cleaning has great potential to reduce the solids concentrations within the dairy wash water.

Performance of treatment systems at increased flow rates would provide vital efficiency data. Investigating a variety of flow rates would provide data for optimization, particularly in combination with the solids reduction strategies described previously. An effective increase in flow volumes would allow for greater real world application.

A simultaneous decrease in the production of wash water in combination with an increase in flow rates discussed above has the potential to be an effective treatment option. A decrease in wash water production can result from a smaller dairy (50-100 head) and more efficient cleaning practices. A decrease in water use can be sustained with use of a pressure washer or a hose instead of a flush with one large water volume. A reduction in the wasted milk and separation of solids, discussed above, also have potential to reduce wash water volume. As indicated, dairy management practices are a vital system component to reduce wash water production.

Increasing aeration is another viable option for further testing as the treatment units were oxygen limiting. Increasing the aeration to two or three aerators may enable treatment units to effectively reach reuse values for extended periods. It should be noted that an increase in aeration will not only increase performance but also increase operational costs; therefore testing with additional aeration should be supplemented with a feasibility study. An increase in effective oxygen transfer could provide the required oxygen without additional aeration. Research designed to find optimum treatment characteristics, such as water temperature, can provide operational practices to increase oxygen transfer and treatment performance.

Alternative uses for the effluent would make the system more applicable for real world implementation. For example, disposal in a leach field was viable for many of the results obtained in this test. A study of possible agriculture reuses would provide alternatives with varying reuse standards expanding not only possible applications, but treatment performance requirements.

The research conducted in this study provides solid groundwork to be extended upon in order to implement this practice and provide alternative treatment and disposal method for dairy milking facilities.

APPENDIX A

Table 20: Detailed parameter tests

Parameter	Test Basis	Hach Method #	Range	EPA Approved	Reference Method
pH	pH Meter				
Alkalinity (mg/L $CACO_3$)	Digital Titrator Titration, Phenolphthalein and Total using Sulfuric Acid Method	8203	10-4,000 mg/L CaCO3	Equivalent	Equivalent to USEPA method 310.1
TS (mg/L)	Gravimetric Methods	8271	Dilution	Yes	USEPA 160.3
TSS (mg/L)	Gravimetric Methods	8158	Dilution	Yes	USEPA 160.2
BOD_5 (mg/L)	Dilution Method	8043	Dilution	Yes	EPA 405.1; Adapted from Standard Methods for the Examination of Water and Wastewater and from Klein, R.L.; Gibbs, C. Journal of Water Pollution Control Federation, 1979, 51(9), 2257.
COD (mg/L)	Reactor Digestion Method	8000	20 to 1500 mg/L COD	Yes	EPA 410.4; Jirka, A.M.; Carter, M.J., Analytical Chemistry, 1975, 47(8), 1397 Federal Register, April 21, 1980, 45(78), 26811-26812
FOG (mg/L)	Will Be Sent To A&L Great Lakes Laboratories for Evaluation				
TKN (mg/L)	Nessler Method (Digestion Required)	8075	1-150 mg/L	Yes	EPA 351.1; Adapted from Hach, et. al., Journal of Association of Official Analytical Chemists, 70(5) 783-787 (1987); Hach, et. al., Journal of Agricultural and Food Chemistry, 33(6) 1117-1123 (1985); Standard Methods for the Examination of Water and Wastewater

Table 20 (cont'd)

NH_3 (mg/L)	Nessler Method	8038	0.02-2.50 mg/L	Yes	EPA 350.3; Adapted from Standard Methods for the Examination of Water and Wastewater 4500-NH_3 B & C.
NO_3 (mg/L)	Cadmium Reduction Method	8039	0.3-30.0 mg/L	Yes	EPA 353.2
TP	PhosVer® 3 with Acid Persulfate Digestion Method	8190	0.02 to 1.10 mg/L P	Yes	USEPA
Total *Coli form* and E. coli (colonies/100 mL)	Membrane Filtration Method	10029		Yes	USEPA
Qualitative Odor of Effluent Wastewater**	Will be Evaluated with an Odor Panel				

Table 21: Quality assurance and quality control procedures for lab analysis

QA/QC	Description	Purpose	Frequency
Duplicate	Take one sample volume and separate into two separate samples which are then prepared and analyzed using identical procedures	Determination of precision in equipment and procedures	Each Sample
Blanks	Blank or reagent water analyzed as a sample	Detection of error in a zero reading or procedure contamination	Minimum of at least once per use of equipment and once every 10 samples within each use
Standards	Known quantities of sample are analyzed to determine accuracy of equipment	Determination of accuracy of equipment and procedures	Minimum of at least once per use of equipment and once every 10 samples within each use
Calibrate pH meter	2-point pH calibration with buffers	Ensure accurate and precise readings	Every use
Calibrate Balance	Weigh appropriate range of known standards for the test to be run	Ensure accurate and precise readings	Every use
Desiccate	Use desiccate with proper indicating color	Ensures adequate functioning	Every use

Table 21 (cont'd)

QA/QC	Analysis Requiring Procedure	Acceptance Criteria	Corrective Action
Duplicate	Alkalinity, Ammonia, TKN, COD, Bacteria, Nitrate, pH, TS, TSS, TP	Relative percent difference less than 20%, take average of two values	Improve handling and precision, repeat procedure to ensure acceptance criteria is met
Blanks	Alkalinity, Ammonia, TKN, BOD_5, COD, Nitrate, TP	Less than detection limit, should produce a zero or neutral reading	Ensure proper set-up and procedure, clean equipment, check all reagents and chemicals, find the error in procedure or equipment, reanalyze until criteria met
Standards	Alkalinity, Ammonia, TKN, BOD_5, COD, TP, Nitrate	Relative percent difference less than 20%	Ensure proper set-up and procedure, clean equipment, check all reagents and chemicals, find the error in procedure or equipment, reanalyze until criteria met
Calibrate pH meter	pH	±0.05 pH units for every buffer	Clean probe, retest, replace if acceptance criteria cannot be met
Calibrate Balance	TS, TSS	Relative percent difference less than 1%	Ensure proper set-up, call service technician for repair/ recalibration
Desiccate	TS, TSS	Correct color (deep blue)	Replace or heat to proper color

APPENDIX B

Operation and System Life

System operation ran for three months from June 3, 2007 to November 26, 2007. June, 2007 was spent debugging the system and equalizing flow rates throughout. Testing began at the end of June, 2007 and continued throughout operation on a weekly basis. Table 22 provides the dates for system operation and shutdown as well as common tasks that involved a temporary system shut-down.

Table 22: System operation

Operation	Dates			
System Shut-down	25-Jul-07	3-Sep-07	9-Oct-07	31-Oct-07
System Restart	1-Aug-07	11-Sep-07	16-Oct-07	6-Nov-07
Settling Tank Cleanout	17-Jul-07	13-Aug-07	9-Sep-07	25-Sep-07
Multi-Flo™ Socks Cleaned	25-Jul-07	3-Sep-07	11-Oct-07	

Filters were installed on August 21, 2007 for the Nayadic™ recirculation and September 3, 2007 for the Multi-Flo™ recirculation line and the settling tank brush filter. The ultraviolet disinfection unit was operational on September 24, 2007. The second aerator was functional on October 19, 2007 after establishing the need for additional oxygen. An increase in flow rates from 50 gal/day to 100 gal/day was achieved on November 6, 2007. System life for the Multi-Flo™ unit was around one month, as can be seen in the clogging dates above. The

Nayadic™ could continue to treat wash water for a longer period because there was no clogging ability, but treatment performance reached failure levels after less than two weeks of operation. Reduction in pollutant concentrations, namely solids, would extend the life of the Multi-Flo™ significantly.

APPENDIX C

Table 23: pH data

Location	Sample Date	pH
Baseline	8/15/2007	6.33
Baseline	9/14/2007	6.49
Baseline	9/19/2007	6.42
Baseline	10/2/2007	6.41
Baseline	10/23/2007	6.21
Baseline	10/30/2007	6.64
Baseline	11/12/2007	6.56
Baseline	11/16/2007	6.49
Distribution Box	8/15/2007	6.52
Distribution Box	9/14/2007	6.37
Distribution Box	9/19/2007	6.52
Distribution Box	10/2/2007	6.32
Distribution Box	10/23/2007	5.31
Distribution Box	10/30/2007	6.4
Distribution Box	11/12/2007	6.3
Distribution Box	11/16/2007	6.47
Dose Tank Multi-Flo	8/15/2007	7.5
Dose Tank Multi-Flo	9/14/2007	7.61
Dose Tank Multi-Flo	9/19/2007	7.2
Dose Tank Multi-Flo	10/2/2007	7.29
Dose Tank Multi-Flo	10/23/2007	6.86
Dose Tank Multi-Flo	10/30/2007	7.33
Dose Tank Multi-Flo	11/12/2007	7.24
Dose Tank Multi-Flo	11/16/2007	7.53
Dose Tank Nayadic	8/15/2007	7.79
Dose Tank Nayadic	9/14/2007	7.49
Dose Tank Nayadic	9/19/2007	7.74
Dose Tank Nayadic	10/2/2007	7.99
Dose Tank Nayadic	10/23/2007	6.79
Dose Tank Nayadic	10/30/2007	7.75
Dose Tank Nayadic	11/12/2007	7.49
Dose Tank Nayadic	11/16/2007	7.49
Multi-Flo	8/15/2007	8.06
Multi-Flo	9/14/2007	8.41
Multi-Flo	9/19/2007	7.37
Multi-Flo	10/2/2007	7.58
Multi-Flo	10/23/2007	7.68
Multi-Flo	10/30/2007	7.75

Table 23 (cont'd)

Multi-Flo	11/12/2007	7.58
Multi-Flo	11/16/2007	7.82
Multi-Flo Disinfection	10/23/2007	7.79
Multi-Flo Disinfection	10/30/2007	7.79
Multi-Flo Disinfection	11/12/2007	7.53
Multi-Flo Disinfection	11/16/2007	7.8
Multi-Flo Recirculation	9/14/2007	7.95
Multi-Flo Recirculation	9/19/2007	7.58
Multi-Flo Recirculation	10/2/2007	7.7
Multi-Flo Recirculation	10/23/2007	7.9
Multi-Flo Recirculation	10/30/2007	7.87
Multi-Flo Recirculation	11/12/2007	7.58
Multi-Flo Recirculation	11/16/2007	7.88
Nayadic	8/15/2007	8.17
Nayadic	9/14/2007	7.85
Nayadic	9/19/2007	7.95
Nayadic	10/2/2007	7.92
Nayadic	10/23/2007	7.99
Nayadic	10/30/2007	7.96
Nayadic	11/12/2007	7.5
Nayadic	11/16/2007	7.67
Nayadic Recirculation	9/14/2007	7.87
Nayadic Recirculation	9/19/2007	7.99
Nayadic Recirculation	10/2/2007	8
Nayadic Recirculation	10/23/2007	8.07
Nayadic Recirculation	10/30/2007	7.99
Nayadic Recirculation	11/12/2007	7.54
Nayadic Recirculation	11/16/2007	7.69
Nayadic Disinfection	10/23/2007	8.06
Nayadic Disinfection	10/30/2007	7.99
Nayadic Disinfection	11/12/2007	7.5
Nayadic Disinfection	11/16/2007	7.63

Table 24: Alkalinity data

Location	Sample Date	Total Alkalinity (mg/L as CaCO3)	Percent Reduction for Treatment Segment	Percent Reduction from the Baseline
Baseline	7/20/2007	2600		
Baseline	8/15/2007	5800		
Baseline	8/17/2007	4100		
Baseline	8/20/2007	1450		
Baseline	10/2/2007	1875		
Baseline	11/12/2007	1375		
Distribution Box	7/20/2007	2050	21.2%	21.2%
Distribution Box	8/15/2007	2000	65.5%	65.5%
Distribution Box	8/17/2007	3100	24.4%	24.4%
Distribution Box	8/20/2007	750	48.3%	48.3%
Distribution Box	10/2/2007	1175	37.3%	37.3%
Distribution Box	11/12/2007	1225	10.9%	10.9%
Dose Tank Multi-Flo	8/15/2007	1900	5.0%	67.2%
Dose Tank Multi-Flo	8/17/2007	1400	54.8%	65.9%
Dose Tank Multi-Flo	8/20/2007	200	73.3%	86.2%
Dose Tank Multi-Flo	10/2/2007	525	55.3%	72.0%
Dose Tank Multi-Flo	11/12/2007	775	36.7%	43.6%
Dose Tank Nayadic	8/15/2007	2200	-10.0%	62.1%
Dose Tank Nayadic	8/17/2007	3050	1.6%	25.6%
Dose Tank Nayadic	8/20/2007	1300	-73.3%	10.3%
Dose Tank Nayadic	10/2/2007	1600	-36.2%	14.7%
Dose Tank Nayadic	11/12/2007	1300	-6.1%	5.5%
Multi-Flo	7/20/2007	550		78.8%
Multi-Flo	8/15/2007	611	67.8%	89.5%
Multi-Flo	8/17/2007	585	58.2%	85.7%
Multi-Flo	8/20/2007	552.5	-176.3%	61.9%
Multi-Flo	10/2/2007	680	-29.5%	63.7%
Multi-Flo	11/12/2007	230	70.3%	83.3%
Multi-Flo Disinfection	11/12/2007	300	-30.4%	78.2%
Multi-Flo Recirculation	10/2/2007	690	-1.5%	63.2%
Multi-Flo Recirculation	11/12/2007	300	-30.4%	78.2%
Nayadic	7/20/2007	1850		

Table 24 (cont'd)

Nayadic	8/15/2007	2050	6.8%	64.7%
Nayadic	8/17/2007	2375	22.1%	42.1%
Nayadic	8/20/2007	1400	-7.7%	3.4%
Nayadic	10/2/2007	1590	0.6%	15.2%
Nayadic	11/12/2007	1150	11.5%	16.4%
Nayadic Disinfection	11/12/2007	265	77.0%	80.7%
Nayadic Recirculation	10/2/2007	1560	1.9%	16.8%
Nayadic Recirculation	11/12/2007	340	70.4%	75.3%

Table 25: Biochemical oxygen demand data

Treatment Location	Sample Date	BOD_5 (mg/L)	Percent Reduction for Treatment Segment	Percent Reduction from Baseline
Baseline	6/27/2007	3353		
Baseline	7/5/2007	5045		
Baseline	7/13/2007	7064		
Baseline	7/20/2007	7107		
Baseline	8/2/2007	6460		
Baseline	8/8/2007	6788		
Baseline	8/23/2007	5397		
Baseline	9/14/2007	4870		
Baseline	11/21/2007	2804		
Distribution Box	7/20/2007	4357	38.7%	38.7%
Distribution Box	8/2/2007	6445	0.2%	0.2%
Distribution Box	8/8/2007	4618	32.0%	32.0%
Distribution Box	9/14/2007	2778	43.0%	43.0%
Distribution Box	11/21/2007	2953	-5.3%	-5.3%
Dose Tank Multi-Flo	8/2/2007	792	87.7%	87.7%
Dose Tank Multi-Flo	8/8/2007	729	84.2%	89.3%
Dose Tank Multi-Flo	8/23/2007	1098		79.7%
Dose Tank Multi-Flo	9/14/2007	254	90.8%	94.8%
Dose Tank Multi-Flo	11/26/2007	567	80.8%	79.8%
Dose Tank Nayadic	8/2/2007	1788	72.3%	72.3%
Dose Tank Nayadic	8/8/2007	1393	69.8%	79.5%
Dose Tank Nayadic	8/23/2007	1581		70.7%
Dose Tank Nayadic	9/14/2007	511	81.6%	89.5%
Dose Tank Nayadic	11/21/2007	1003	66.0%	64.2%
Multi-Flo	6/27/2007	886		73.6%
Multi-Flo	7/5/2007	838		83.4%
Multi-Flo	7/13/2007	279		96.0%
Multi-Flo	7/20/2007	97		98.6%
Multi-Flo	8/2/2007	16	98.0%	99.8%
Multi-Flo	8/8/2007	13	98.3%	99.8%
Multi-Flo	8/23/2007	26	97.6%	99.5%
Multi-Flo	9/14/2007	4	98.3%	99.9%
Multi-Flo	11/21/2007	391	31.0%	86.0%
Multi-Flo Recirculation	9/14/2007	30	-578.5%	99.4%

Table 25 (cont'd)

Nayadic	6/27/2007	1115		66.7%
Nayadic	7/5/2007	1189		76.4%
Nayadic	7/13/2007	831		88.2%
Nayadic	7/20/2007	749		89.5%
Nayadic	8/2/2007	275	84.6%	95.7%
Nayadic	8/8/2007	588	57.8%	91.3%
Nayadic	8/23/2007	598	62.2%	88.9%
Nayadic	9/14/2007	252	50.7%	94.8%
Nayadic	11/21/2007	1722	-71.7%	38.6%
Nayadic Recirculation	8/23/2007	583	2.4%	89.2%
Nayadic Recirculation	9/14/2007	206	18.4%	95.8%

Table 26: Chemical oxygen demand data

Treatment Unit Location	Sample Date	COD (mg/L)	Percent Reduction for Treatment Segment	Percent Reduction from Baseline Values
Baseline	6/28/2007	36528		
Baseline	6/29/2007	29240		
Baseline	7/2/2007	13744		
Baseline	7/12/2007	25456		
Baseline	7/20/2007	62997		
Baseline	7/23/2007	62774		
Baseline	7/24/2007	43633		
Baseline	8/2/2007	57300		
Baseline	8/9/2007	11430		
Baseline	8/17/2007	52375		
Baseline	8/20/2007	33700		
Baseline	8/23/2007	12025		
Baseline	9/14/2007	9000		
Baseline	9/19/2007	10750		
Baseline	10/2/2007	49200		
Baseline	10/23/2007	12300		
Baseline	10/30/2007	18650		
Baseline	11/12/2007	11150		
Baseline	11/16/2007	10825		
Distribution Box	7/12/2007	15088	40.7%	40.7%
Distribution Box	7/20/2007	15952	74.7%	74.7%
Distribution Box	8/2/2007	88830	-55.0%	-55.0%
Distribution Box	8/9/2007	12300	-7.6%	-7.6%
Distribution Box	8/17/2007	12140	76.8%	76.8%
Distribution Box	8/20/2007	7170	78.7%	78.7%
Distribution Box	8/23/2007	6360	47.1%	47.1%
Distribution Box	9/14/2007	9510	-5.7%	-5.7%
Distribution Box	9/19/2007	8740	18.7%	18.7%
Distribution Box	10/2/2007	8190	83.4%	83.4%
Distribution Box	10/23/2007	10300	16.3%	16.3%
Distribution Box	10/30/2007	10200	45.3%	45.3%
Distribution Box	11/12/2007	9920	11.0%	11.0%
Distribution Box	11/16/2007	9260	14.5%	14.5%
Dose Tank Multi-Flo	8/2/2007	2000	97.7%	96.5%
Dose Tank Multi-Flo	8/9/2007	2000	83.7%	82.5%
Dose Tank Multi-Flo	8/17/2007	2980	75.5%	94.3%

Table 26 (cont'd)

Dose Tank Multi-Flo	8/20/2007	1710	76.2%	94.9%
Dose Tank Multi-Flo	8/23/2007	1290	79.7%	89.3%
Dose Tank Multi-Flo	9/14/2007	1210	87.3%	86.6%
Dose Tank Multi-Flo	9/19/2007	7500	14.2%	30.2%
Dose Tank Multi-Flo	10/2/2007	1420	82.7%	97.1%
Dose Tank Multi-Flo	10/23/2007	2500	75.7%	79.7%
Dose Tank Multi-Flo	10/30/2007	1900	81.4%	89.8%
Dose Tank Multi-Flo	11/12/2007	3810	61.6%	65.8%
Dose Tank Multi-Flo	11/16/2007	2990	67.7%	72.4%
Dose Tank Nayadic	8/2/2007	6100	59.6%	89.4%
Dose Tank Nayadic	8/9/2007	5020	68.5%	56.1%
Dose Tank Nayadic	8/17/2007	5120	94.2%	90.2%
Dose Tank Nayadic	8/20/2007	2290	81.4%	93.2%
Dose Tank Nayadic	8/23/2007	3710	69.4%	69.1%
Dose Tank Nayadic	9/14/2007	1740	75.7%	80.7%
Dose Tank Nayadic	9/19/2007	1730	72.8%	83.9%
Dose Tank Nayadic	10/2/2007	2260	76.2%	95.4%
Dose Tank Nayadic	10/23/2007	5500	37.1%	55.3%
Dose Tank Nayadic	10/30/2007	5000	38.9%	73.2%
Dose Tank Nayadic	11/12/2007	9070	11.9%	18.7%
Dose Tank Nayadic	11/16/2007	9010	11.7%	16.8%
Multi-Flo	6/28/2007	1785		95.1%
Multi-Flo	6/29/2007	1441		95.1%
Multi-Flo	7/2/2007	1430		89.6%
Multi-Flo	7/12/2007	1872		92.6%
Multi-Flo	7/20/2007	2576		95.9%
Multi-Flo	8/2/2007	243	87.9%	99.6%
Multi-Flo	8/17/2007	191	93.6%	99.6%
Multi-Flo	8/20/2007	220	87.1%	99.3%
Multi-Flo	8/23/2007	294	77.2%	97.6%
Multi-Flo	9/14/2007	85	93.0%	99.1%
Multi-Flo	9/19/2007	3530	52.9%	67.2%
Multi-Flo	10/2/2007	1258	11.4%	97.4%
Multi-Flo	10/23/2007	221	91.2%	98.2%
Multi-Flo	10/30/2007	170	91.1%	99.1%
Multi-Flo	11/12/2007	2312	39.3%	79.3%
Multi-Flo	11/16/2007	2442	18.3%	77.4%
Multi-Flo Disinfection	10/23/2007	169	23.5%	98.6%
Multi-Flo Disinfection	10/30/2007	173	-1.8%	99.1%
Multi-Flo Disinfection	11/12/2007	3486	-50.8%	68.7%
Multi-Flo Disinfection	11/16/2007	4286	-75.5%	60.4%

Table 26 (cont'd)

Multi-Flo Recirculation	9/14/2007	371	-338.5%	95.9%
Multi-Flo Recirculation	9/19/2007	3290	6.8%	69.4%
Multi-Flo Recirculation	10/2/2007	898	28.6%	98.2%
Multi-Flo Recirculation	10/23/2007	169	23.5%	98.6%
Multi-Flo Recirculation	10/30/2007	175	-2.9%	99.1%
Multi-Flo Recirculation	11/12/2007	3460	-49.7%	69.0%
Multi-Flo Recirculation	11/16/2007	3707	-51.8%	65.8%
Nayadic	6/28/2007	3941		89.2%
Nayadic	6/29/2007	4006		86.3%
Nayadic	7/2/2007	3108		77.4%
Nayadic	7/12/2007	3888		84.7%
Nayadic	7/20/2007	5200		91.7%
Nayadic	8/2/2007	2300	62.3%	96.0%
Nayadic	8/9/2007	3570	28.9%	68.8%
Nayadic	8/17/2007	3900	23.8%	92.6%
Nayadic	8/20/2007	1820	20.5%	94.6%
Nayadic	8/23/2007	1720	53.6%	85.7%
Nayadic	9/14/2007	1352	22.3%	85.0%
Nayadic	9/19/2007	834	51.8%	92.2%
Nayadic	10/2/2007	2615	-15.7%	94.7%
Nayadic	10/23/2007	3840	30.2%	68.8%
Nayadic	10/30/2007	4270	14.6%	77.1%
Nayadic	11/12/2007	10395	-14.6%	6.8%
Nayadic	11/16/2007	9930	-10.2%	8.3%
Nayadic Disinfection	10/23/2007	4190	-9.1%	65.9%
Nayadic Disinfection	10/30/2007	4460	-4.4%	76.1%
Nayadic Disinfection	11/12/2007	9795	5.8%	12.2%
Nayadic Disinfection	11/16/2007	10510	-5.8%	2.9%
Nayadic Recirculation	8/23/2007	2260	-31.4%	81.2%
Nayadic Recirculation	9/14/2007	1160	14.2%	87.1%
Nayadic Recirculation	9/19/2007	850	-1.9%	92.1%
Nayadic Recirculation	10/2/2007	3120	-19.3%	93.7%
Nayadic Recirculation	10/23/2007	4010	-4.4%	67.4%
Nayadic Recirculation	10/30/2007	3990	6.6%	78.6%
Nayadic Recirculation	11/12/2007	9945	4.3%	10.8%
Nayadic Recirculation	11/16/2007	10135	-2.1%	6.4%

Table 27: Total Solids Data

Location	Sample Date	Total Solids (mg/L)	Percent Reduction for Treatment Segment	Percent Reduction from Baseline
Baseline	7/3/2007	12682		
Baseline	7/24/2007	26277		
Baseline	8/2/2007	35061		
Baseline	8/6/2007	27039		
Baseline	8/9/2007	7625		
Baseline	8/14/2007	15909		
Baseline	8/16/2007	30501		
Baseline	8/20/2007	16733		
Baseline	8/28/2007	7851		
Baseline	9/14/2007	6280		
Baseline	9/19/2007	8064		
Baseline	9/29/2007	7537		
Baseline	10/2/2007	29953		
Baseline	10/23/2007	7083		
Baseline	10/30/2007	12661		
Baseline	11/12/2007	4929		
Baseline	11/16/2007	7361		
Baseline	11/21/2007	6932		
Distribution Box	7/24/2007	8798	66.5%	66.5%
Distribution Box	8/2/2007	52685	-50.3%	-50.3%
Distribution Box	8/6/2007	6991	74.1%	74.1%
Distribution Box	8/9/2007	7623	0.0%	0.0%
Distribution Box	8/14/2007	7001	56.0%	56.0%
Distribution Box	8/16/2007	7334	76.0%	76.0%
Distribution Box	8/20/2007	7884	52.9%	52.9%
Distribution Box	8/28/2007	7476	4.8%	4.8%
Distribution Box	9/14/2007	6703	-6.7%	-6.7%
Distribution Box	9/19/2007	6092	24.5%	24.5%
Distribution Box	9/29/2007	6780	10.1%	10.1%
Distribution Box	10/2/2007	6804	77.3%	77.3%
Distribution Box	10/23/2007	6156	13.1%	13.1%
Distribution Box	10/30/2007	6306	50.2%	50.2%
Distribution Box	11/12/2007	6753	-37.0%	-37.0%
Distribution Box	11/16/2007	6407	13.0%	13.0%
Distribution Box	11/21/2007	5789	16.5%	16.5%
Dose Tank Multi-Flo	8/2/2007	2126	96.0%	93.9%

Table 27 (cont'd)

Dose Tank Multi-Flo	8/6/2007	1984	71.6%	92.7%
Dose Tank Multi-Flo	8/9/2007	2229	70.8%	70.8%
Dose Tank Multi-Flo	8/14/2007	2761	60.6%	82.6%
Dose Tank Multi-Flo	8/16/2007	3953	46.1%	87.0%
Dose Tank Multi-Flo	8/20/2007	3299	58.2%	80.3%
Dose Tank Multi-Flo	8/28/2007	2535	66.1%	67.7%
Dose Tank Multi-Flo	9/14/2007	2574	61.6%	59.0%
Dose Tank Multi-Flo	9/19/2007	5024	17.5%	37.7%
Dose Tank Multi-Flo	9/29/2007	3388	50.0%	55.1%
Dose Tank Multi-Flo	10/2/2007	2417	64.5%	91.9%
Dose Tank Multi-Flo	10/23/2007	2018	67.2%	71.5%
Dose Tank Multi-Flo	10/30/2007	2096	66.8%	83.4%
Dose Tank Multi-Flo	11/12/2007	3353	50.3%	32.0%
Dose Tank Multi-Flo	11/16/2007	3785	40.9%	48.6%
Dose Tank Multi-Flo	11/21/2007	3814	34.1%	45.0%
Dose Tank Nayadic	8/2/2007	5567	89.4%	84.1%
Dose Tank Nayadic	8/6/2007	4164	40.4%	84.6%
Dose Tank Nayadic	8/9/2007	4638	39.2%	39.2%
Dose Tank Nayadic	8/14/2007	5022	28.3%	68.4%
Dose Tank Nayadic	8/16/2007	5075	30.8%	83.4%
Dose Tank Nayadic	8/20/2007	5699	27.7%	65.9%
Dose Tank Nayadic	8/28/2007	3284	56.1%	58.2%
Dose Tank Nayadic	9/14/2007	2193	67.3%	65.1%
Dose Tank Nayadic	9/19/2007	1837	69.8%	77.2%
Dose Tank Nayadic	9/29/2007	3712	45.3%	50.8%
Dose Tank Nayadic	10/2/2007	3382	50.3%	88.7%
Dose Tank Nayadic	10/23/2007	4387	28.7%	38.1%
Dose Tank Nayadic	10/30/2007	5279	16.3%	58.3%
Dose Tank Nayadic	11/12/2007	7135	-5.7%	-44.8%
Dose Tank Nayadic	11/16/2007	7439	-16.1%	-1.1%
Dose Tank Nayadic	11/21/2007	6481	-11.9%	6.5%
Multi-Flo	7/3/2007	2591		79.6%
Multi-Flo	7/24/2007	3500		86.7%
Multi-Flo	8/2/2007	973	54.2%	97.2%
Multi-Flo	8/6/2007	687	65.4%	97.5%
Multi-Flo	8/9/2007	1042	53.3%	86.3%
Multi-Flo	8/14/2007	1135	58.9%	92.9%
Multi-Flo	8/16/2007	1134	71.3%	96.3%
Multi-Flo	8/20/2007	1337	59.5%	92.0%
Multi-Flo	8/28/2007	1566	38.2%	80.1%
Multi-Flo	9/14/2007	503	80.5%	92.0%
Multi-Flo	9/19/2007	4392	12.6%	45.5%

Table 27 (cont'd)

Multi-Flo	9/29/2007	1344	60.3%	82.2%
Multi-Flo	10/2/2007	1815	24.9%	93.9%
Multi-Flo	10/23/2007	1246	38.3%	82.4%
Multi-Flo	10/30/2007	984	53.0%	92.2%
Multi-Flo	11/12/2007	3353	0.0%	32.0%
Multi-Flo	11/16/2007	2738	27.7%	62.8%
Multi-Flo	11/21/2007	3713	2.6%	46.4%
Multi-Flo Recirculation	9/14/2007	835	-66.1%	86.7%
Multi-Flo Recirculation	9/19/2007	3904	11.1%	51.6%
Multi-Flo Recirculation	9/29/2007	1595	-18.6%	78.8%
Multi-Flo Recirculation	10/2/2007	2438	-34.3%	91.9%
Multi-Flo Recirculation	10/23/2007	920	26.1%	87.0%
Multi-Flo Disinfection	10/23/2007	775	37.8%	89.1%
Nayadic	7/3/2007	3618		71.5%
Nayadic	7/24/2007	4921		81.3%
Nayadic	8/2/2007	2830	49.2%	91.9%
Nayadic	8/6/2007	3470	16.7%	87.2%
Nayadic	8/9/2007	3917	15.5%	48.6%
Nayadic	8/14/2007	4198	16.4%	73.6%
Nayadic	8/16/2007	4282	15.6%	86.0%
Nayadic	8/20/2007	4934	13.4%	70.5%
Nayadic	8/28/2007	11614	-253.6%	-47.9%
Nayadic	9/14/2007	1473	32.8%	76.6%
Nayadic	9/19/2007	1589	13.5%	80.3%
Nayadic	9/29/2007	3695	0.5%	51.0%
Nayadic	10/2/2007	3345	1.1%	88.8%
Nayadic	10/23/2007	4127	5.9%	41.7%
Nayadic	10/30/2007	4577	13.3%	63.9%
Nayadic	11/12/2007	7746	-8.6%	-57.2%
Nayadic	11/16/2007	7087	4.7%	3.7%
Nayadic	11/21/2007	6184	4.6%	10.8%
Nayadic Recirculation	8/28/2007	5895	49.2%	24.9%
Nayadic Recirculation	9/14/2007	1519	-3.2%	75.8%
Nayadic Recirculation	9/19/2007	1677	-5.6%	79.2%
Nayadic Recirculation	9/29/2007	3655	1.1%	51.5%
Nayadic Recirculation	10/2/2007	3490	-4.3%	88.3%
Nayadic Recirculation	10/23/2007	4002	3.0%	43.5%
Nayadic Disinfection	10/23/2007	4107	0.5%	42.0%

Table 28: Total suspended solids data

Location	Sample date	Total Suspended Solids Concentration (mg/L)	Percent Reduction of Treatment Segment	Percent Reduction from Baseline
Baseline	8/6/2007	15420		
Baseline	8/13/2007	12650		
Baseline	8/14/2007	9950		
Baseline	8/16/2007	19200		
Baseline	8/20/2007	12680		
Baseline	8/28/2007	3090		
Baseline	9/14/2007	1265		
Baseline	9/19/2007	4790		
Baseline	9/29/2007	8780		
Baseline	10/23/2007	2500		
Baseline	10/30/2007	5650		
Baseline	11/12/2007	1050		
Baseline	11/16/2007	1300		
Baseline	11/21/2007	1700		
Distribution Box	8/6/2007	1900	87.7%	87.7%
Distribution Box	8/13/2007	960	92.4%	92.4%
Distribution Box	8/14/2007	1560	84.3%	84.3%
Distribution Box	8/16/2007	1870	90.3%	90.3%
Distribution Box	8/20/2007	2755	78.3%	78.3%
Distribution Box	8/28/2007	1885	39.0%	39.0%
Distribution Box	9/14/2007	1705	-34.8%	-34.8%
Distribution Box	9/19/2007	1100	77.0%	77.0%
Distribution Box	9/29/2007	2410	72.6%	72.6%
Distribution Box	10/23/2007	1500	40.0%	40.0%
Distribution Box	10/30/2007	1200	78.8%	78.8%
Distribution Box	11/12/2007	1800	-71.4%	-71.4%
Distribution Box	11/16/2007	800	38.5%	38.5%
Distribution Box	11/21/2007	2000	-17.6%	-17.6%
Dose Tank Multi-Flo	8/6/2007	340	82.1%	97.8%
Dose Tank Multi-Flo	8/13/2007	595	38.0%	95.3%
Dose Tank Multi-Flo	8/14/2007	260	83.3%	97.4%
Dose Tank Multi-Flo	8/16/2007	695	62.8%	96.4%
Dose Tank Multi-Flo	8/20/2007	830	69.9%	93.5%
Dose Tank Multi-Flo	8/28/2007	642	66.0%	79.2%
Dose Tank Multi-Flo	9/14/2007	485	71.6%	61.7%
Dose Tank Multi-Flo	9/19/2007	907	17.5%	81.1%

Table 28 (cont'd)

Dose Tank Multi-Flo	9/29/2007	3140	-30.3%	64.2%
Dose Tank Multi-Flo	10/23/2007	1000	33.3%	60.0%
Dose Tank Multi-Flo	10/30/2007	600	50.0%	89.4%
Dose Tank Multi-Flo	11/12/2007	1300	27.8%	-23.8%
Dose Tank Multi-Flo	11/16/2007	1100	-37.5%	15.4%
Dose Tank Multi-Flo	11/21/2007	1100	45.0%	35.3%
Dose Tank Nayadic	8/6/2007	935	50.8%	93.9%
Dose Tank Nayadic	8/13/2007	450	53.1%	96.4%
Dose Tank Nayadic	8/14/2007	770	50.6%	92.3%
Dose Tank Nayadic	8/16/2007	875	53.2%	95.4%
Dose Tank Nayadic	8/20/2007	1225	55.5%	90.3%
Dose Tank Nayadic	8/28/2007	647	65.6%	79.0%
Dose Tank Nayadic	9/14/2007	410	76.0%	67.6%
Dose Tank Nayadic	9/19/2007	518	52.9%	89.2%
Dose Tank Nayadic	9/29/2007	2100	12.9%	76.1%
Dose Tank Nayadic	10/23/2007	1900	-26.7%	78.4%
Dose Tank Nayadic	10/30/2007	2300	-91.7%	73.8%
Dose Tank Nayadic	11/12/2007	1500	16.7%	82.9%
Dose Tank Nayadic	11/16/2007	1200	-50.0%	86.3%
Dose Tank Nayadic	11/21/2007	2200	-10.0%	74.9%
Multi-Flo	8/6/2007	26	92.3%	99.8%
Multi-Flo	8/13/2007	55	90.8%	99.6%
Multi-Flo	8/14/2007	54	79.4%	99.5%
Multi-Flo	8/16/2007	27	96.1%	99.9%
Multi-Flo	8/20/2007	57	93.2%	99.6%
Multi-Flo	8/28/2007	158	75.4%	94.9%
Multi-Flo	9/14/2007	54	89.0%	95.8%
Multi-Flo	9/19/2007	1780	-96.3%	62.8%
Multi-Flo	9/29/2007	359	88.6%	95.9%
Multi-Flo	10/23/2007	44	95.6%	99.5%
Multi-Flo	10/30/2007	7	98.9%	99.9%
Multi-Flo	11/12/2007	850	34.6%	90.3%
Multi-Flo	11/16/2007	900	18.2%	89.7%
Multi-Flo	11/21/2007	1500	-36.4%	82.9%
Multi-Flo Recirculation	9/29/2007	1264	29.0%	73.6%
Nayadic	8/6/2007	641	31.4%	95.8%
Nayadic	8/13/2007	653	-45.1%	94.8%
Nayadic	8/14/2007	664	13.8%	93.3%
Nayadic	8/16/2007	789	9.8%	95.9%
Nayadic	8/20/2007	1323	-8.0%	89.6%

Table 28 (cont'd)

Nayadic	8/28/2007	6353	-881.1%	-105.6%
Nayadic	9/14/2007	355	13.4%	71.9%
Nayadic	9/19/2007	363	30.0%	92.4%
Nayadic	9/29/2007	948	54.9%	89.2%
Nayadic	10/23/2007	500	73.7%	94.3%
Nayadic	10/30/2007	1200	47.8%	86.3%
Nayadic	11/12/2007	1000	33.3%	88.6%
Nayadic	11/16/2007	1900	-58.3%	78.4%
Nayadic	11/21/2007	3200	-45.5%	63.6%
Nayadic Recirculation	8/28/2007	3720	41.4%	-20.4%
Nayadic Recirculation	9/14/2007	288	18.9%	77.2%
Nayadic Recirculation	9/19/2007	349	3.7%	92.7%
Nayadic Recirculation	9/29/2007	3927	-314.4%	55.3%

Table 29: Total Kjeldahl nitrogen data

Location	Sample Date	TKN (mg/L)	Percent Reduction of Treatment Segment	Percent Reduction from Baseline
Baseline	8/8/2007	118		
Baseline	8/14/2007	123		
Baseline	8/21/2007	105.5		
Baseline	10/30/2007	81		
Distribution Box	8/8/2007	204	-72.9%	-72.9%
Distribution Box	8/14/2007	143.5	-16.7%	-16.7%
Distribution Box	8/21/2007	128	-21.3%	-21.3%
Distribution Box	10/30/2007	69	14.8%	14.8%
Dose Tank Multi-Flo	8/8/2007	41.5	79.7%	64.8%
Dose Tank Multi-Flo	8/14/2007	57.5	59.9%	53.3%
Dose Tank Multi-Flo	8/21/2007	69.5	45.7%	34.1%
Dose Tank Nayadic	8/8/2007	81	60.3%	31.4%
Dose Tank Nayadic	8/14/2007	99	31.0%	19.5%
Dose Tank Nayadic	8/21/2007	91	28.9%	13.7%
Multi-Flo	8/8/2007	13	68.7%	89.0%
Multi-Flo	8/14/2007	20.5	64.3%	83.3%
Multi-Flo	8/21/2007	18.5	73.4%	82.5%
Multi-Flo	10/30/2007	2		97.5%
Nayadic	8/8/2007	98.5	-21.6%	16.5%
Nayadic	8/14/2007	88	11.1%	28.5%
Nayadic	8/21/2007	94.5	-3.8%	10.4%
Nayadic	10/30/2007	58		28.4%

Table 30: Nitrate data

Location	Sample Date	Amber Color	Final Nitrate
Baseline	8/6/2007	No	0
Baseline	8/17/2007	No	0
Baseline	8/21/2007	No	0
Baseline	10/23/2007	No	0
Baseline	11/12/2207	No	0
Distribution Box	8/6/2007	No	0
Distribution Box	8/17/2007	No	0
Distribution Box	8/21/2007	No	0
Distribution Box	10/23/2007	No	0
Distribution Box	11/12/2207	No	0
Dose Tank Multi-Flo	8/6/2007	No	0
Dose Tank Multi-Flo	8/17/2007	No	0
Dose Tank Multi-Flo	8/21/2007	No	0
Dose Tank Multi-Flo	10/23/2007	No	0
Dose Tank Multi-Flo	11/12/2207	No	0
		No	
Dose Tank Nayadic	8/6/2007	No	0
Dose Tank Nayadic	8/17/2007	No	0
Dose Tank Nayadic	8/21/2007	No	0
Dose Tank Nayadic	10/23/2007	No	0
Dose Tank Nayadic	11/12/2207	No	0
Multi-Flo	8/6/2007	No	0
Multi-Flo	8/17/2007	No	0
Multi-Flo	8/21/2007	No	0
Multi-Flo	10/23/2007	No	0
Multi-Flo	11/12/2207	No	0
Multi-Flo Disinfection	11/12/2207	No	0
Multi-Flo Recirculation	10/23/2007	No	0
Multi-Flo Recirculation	11/12/2207	No	0
Nayadic	8/6/2007	No	0
Nayadic	8/17/2007	No	0
Nayadic	8/21/2007	No	0
Nayadic	10/23/2007	No	0
Nayadic	11/12/2207	No	0
Nayadic Disinfection	11/12/2207	No	0

Table 30 (cont'd)

Nayadic Recirculation	10/23/2007	No	0
Nayadic Recirculation	11/12/2207	No	0

Table 31: Ammonia data

Location	Sample Date	Ammonia (mg/L)	Percent Reduction by Treatment Segment	Percent Reduction from Baseline
Baseline	7/11/2007	287		
Baseline	8/10/2007	251		
Baseline	8/17/2007	339		
Baseline	8/20/2007	272		
Baseline	9/14/2007	214		
Baseline	9/19/2007	221		
Baseline	10/2/2007	276		
Baseline	10/23/2007	224		
Baseline	10/30/2007	233		
Baseline	11/12/2007	233		
Baseline	11/16/2007	254		
Distribution Box	7/11/2007	320	-11.5%	-11.5%
Distribution Box	8/10/2007	262	-4.4%	-4.4%
Distribution Box	8/17/2007	286	15.6%	15.6%
Distribution Box	8/20/2007	272	0.0%	0.0%
Distribution Box	9/14/2007	192	10.3%	10.3%
Distribution Box	9/19/2007	195	11.8%	11.8%
Distribution Box	10/2/2007	240	13.0%	13.0%
Distribution Box	10/23/2007	230	-2.7%	-2.7%
Distribution Box	10/30/2007	210	9.9%	9.9%
Distribution Box	11/12/2007	250	-7.3%	-7.3%
Distribution Box	11/16/2007	251	1.2%	1.2%
Dose Tank Multi-Flo	8/10/2007	51	80.5%	79.7%
Dose Tank Multi-Flo	8/17/2007	83	71.2%	75.7%
Dose Tank Multi-Flo	8/20/2007	70	74.4%	74.4%
Dose Tank Multi-Flo	9/14/2007	12	93.8%	94.4%
Dose Tank Multi-Flo	9/19/2007	116	40.5%	47.5%
Dose Tank Multi-Flo	10/2/2007	41	82.9%	85.1%
Dose Tank Multi-Flo	10/23/2007	52	77.4%	76.8%
Dose Tank Multi-Flo	10/30/2007	20	90.5%	91.4%
Dose Tank Multi-Flo	11/12/2007	67	73.2%	71.2%
Dose Tank Multi-Flo	11/16/2007	63	74.9%	75.2%
Dose Tank Nayadic	8/10/2007	164	37.6%	34.9%
Dose Tank Nayadic	8/17/2007	195	32.0%	42.6%
Dose Tank Nayadic	8/20/2007	151	44.7%	44.7%
Dose Tank Nayadic	9/14/2007	67	65.1%	68.7%

Table 31 (cont'd)

Dose Tank Nayadic	9/19/2007	65	66.7%	70.6%
Dose Tank Nayadic	10/2/2007	119	50.4%	56.9%
Dose Tank Nayadic	10/23/2007	168	27.0%	25.0%
Dose Tank Nayadic	10/30/2007	149	29.0%	36.1%
Dose Tank Nayadic	11/12/2007	221	11.6%	5.2%
Dose Tank Nayadic	11/16/2007	215	14.3%	15.4%
Multi-Flo	7/11/2007	103		64.2%
Multi-Flo	8/10/2007	3	94.6%	98.9%
Multi-Flo	8/17/2007	2	97.7%	99.4%
Multi-Flo	8/20/2007	4	94.1%	98.5%
Multi-Flo	9/14/2007	0	100.0%	100.0%
Multi-Flo	9/19/2007	66	43.1%	70.1%
Multi-Flo	10/2/2007	15	63.4%	94.6%
Multi-Flo	10/23/2007	8	84.6%	96.4%
Multi-Flo	10/30/2007	11	45.0%	95.3%
Multi-Flo	11/12/2007	37	44.8%	84.1%
Multi-Flo	11/16/2007	47	25.4%	81.5%
Multi-Flo Disinfection	10/23/2007	6	25.0%	97.3%
Multi-Flo Disinfection	10/30/2007	11	0.0%	95.3%
Multi-Flo Disinfection	11/12/2007	38	-2.7%	83.7%
Multi-Flo Disinfection	11/16/2007	55	-17.0%	78.3%
Multi-Flo Recirculation	9/14/2007	0	0.0%	100.0%
Multi-Flo Recirculation	9/19/2007	61	7.6%	72.4%
Multi-Flo Recirculation	10/2/2007	16	-6.7%	94.2%
Multi-Flo Recirculation	10/23/2007	6	25.0%	97.3%
Multi-Flo Recirculation	10/30/2007	11	0.0%	95.3%
Multi-Flo Recirculation	11/12/2007	38	-2.7%	83.7%
Multi-Flo Recirculation	11/16/2007	48	-2.1%	81.1%
Nayadic	7/11/2007	143		50.2%
Nayadic	8/10/2007	142	13.1%	43.4%
Nayadic	8/17/2007	171	12.1%	49.6%
Nayadic	8/20/2007	138	8.6%	49.4%
Nayadic	9/14/2007	57	14.9%	73.4%
Nayadic	9/19/2007	60	7.7%	72.9%
Nayadic	10/2/2007	120	-0.8%	56.5%
Nayadic	10/23/2007	173	-3.0%	22.8%
Nayadic	10/30/2007	148	0.7%	36.5%
Nayadic	11/12/2007	226	-2.3%	3.0%
Nayadic	11/16/2007	231	-7.4%	9.1%

Table 31 (cont'd)

Nayadic Disinfection	10/23/2007	158	8.7%	29.5%
Nayadic Disinfection	10/30/2007	182	-23.0%	21.9%
Nayadic Disinfection	11/12/2007	232	-2.7%	0.4%
Nayadic Disinfection	11/16/2007	239	-3.5%	5.9%
Nayadic Recirculation	9/14/2007	45	21.1%	79.0%
Nayadic Recirculation	9/19/2007	54	10.0%	75.6%
Nayadic Recirculation	10/2/2007	117	2.5%	57.6%
Nayadic Recirculation	10/23/2007	164	5.2%	26.8%
Nayadic Recirculation	10/30/2007	182	-23.0%	21.9%
Nayadic Recirculation	11/12/2007	227	-0.4%	2.6%
Nayadic Recirculation	11/16/2007	256	-10.8%	-0.8%

Table 32: Phosphorus data

Location	Sample Date	Daily Average Total Phosphorus (mg/L P)	Percent Reduction from Baseline Values	Percent Reduction for Treatment Segment
Baseline	7/20/2007	197		
Baseline	8/2/2007	194		
Baseline	8/9/2007	216		
Baseline	8/24/2007	111		
Baseline	9/14/2007	106		
Baseline	9/19/2007	116		
Baseline	10/2/2007	156		
Baseline	10/23/2007	122		
Baseline	10/30/2007	127		
Baseline	11/12/2007	111		
Baseline	11/16/2007	132		
Distribution Box	7/20/2007	122	38%	38%
Distribution Box	8/2/2007	203	-5%	-5%
Distribution Box	8/9/2007	188	13%	13%
Distribution Box	8/24/2007	123	-10%	-10%
Distribution Box	9/14/2007	107	-1%	-1%
Distribution Box	9/19/2007	100	14%	14%
Distribution Box	10/2/2007	116	26%	26%
Distribution Box	10/23/2007	120	2%	2%
Distribution Box	10/30/2007	121	5%	5%
Distribution Box	11/12/2007	119	-7%	-7%
Distribution Box	11/16/2007	117	11%	11%
Dose Tank Multi-Flo	8/2/2007	36	81%	82%
Dose Tank Multi-Flo	8/9/2007	72	67%	62%
Dose Tank Multi-Flo	8/24/2007	41	63%	67%
Dose Tank Multi-Flo	9/14/2007	34	68%	68%
Dose Tank Multi-Flo	9/19/2007	85	27%	15%
Dose Tank Multi-Flo	10/2/2007	39	75%	66%
Dose Tank Multi-Flo	10/23/2007	40	67%	67%
Dose Tank Multi-Flo	10/30/2007	45	65%	63%
Dose Tank Multi-Flo	11/12/2007	71	36%	40%
Dose Tank Multi-Flo	11/16/2007	99	25%	15%
Dose Tank Nayadic	8/2/2007	79	59%	61%
Dose Tank Nayadic	8/9/2007	78	64%	59%
Dose Tank Nayadic	8/24/2007	66	41%	46%
Dose Tank Nayadic	9/14/2007	38	64%	64%

Table 32 (cont'd)

Dose Tank Nayadic	9/19/2007	36	69%	64%
Dose Tank Nayadic	10/2/2007	52	67%	55%
Dose Tank Nayadic	10/23/2007	57	53%	53%
Dose Tank Nayadic	10/30/2007	56	56%	54%
Dose Tank Nayadic	11/12/2007	106	5%	11%
Dose Tank Nayadic	11/16/2007	106	20%	9%
Multi-Flo	7/20/2007	38	81%	
Multi-Flo	8/2/2007	14	93%	63%
Multi-Flo	8/9/2007	20	91%	72%
Multi-Flo	8/24/2007	22	81%	47%
Multi-Flo	9/14/2007	17	84%	50%
Multi-Flo	9/19/2007	66	43%	22%
Multi-Flo	10/2/2007	38	76%	3%
Multi-Flo	10/23/2007	22	82%	45%
Multi-Flo	10/30/2007	30	76%	33%
Multi-Flo	11/12/2007	57	49%	20%
Multi-Flo	11/16/2007	58	56%	41%
Multi-Flo Disinfection	10/23/2007	23	81%	-5%
Multi-Flo Disinfection	10/30/2007	27	79%	10%
Multi-Flo Disinfection	11/12/2007	67	40%	-18%
Multi-Flo Disinfection	11/16/2007	95	28%	-64%
Multi-Flo Recirculation	9/14/2007	35	67%	-106%
Multi-Flo Recirculation	9/19/2007	78	33%	-18%
Multi-Flo Recirculation	10/2/2007	37	76%	3%
Multi-Flo Recirculation	10/23/2007	21	83%	5%
Multi-Flo Recirculation	10/30/2007	24	81%	20%
Multi-Flo Recirculation	11/12/2007	57	49%	0%
Multi-Flo Recirculation	11/16/2007	72	45%	-24%
Nayadic	7/20/2007	44	75%	
Nayadic	8/2/2007	36	71%	-50%
Nayadic	8/9/2007	55	50%	-200%
Nayadic	8/24/2007	52	31%	-48%
Nayadic	9/14/2007	36	45%	-2%
Nayadic	9/19/2007	33	44%	-16%
Nayadic	10/2/2007	47	24%	-11%
Nayadic	10/23/2007	49	15%	2%
Nayadic	10/30/2007	57	55%	-49%
Nayadic	11/12/2007	108	69%	-152%
Nayadic	11/16/2007	77	71%	-90%

Table 32 (cont'd)

Nayadic Disinfection	10/23/2007	58	52%	-18%
Nayadic Disinfection	10/30/2007	65	59%	-14%
Nayadic Disinfection	11/12/2007	118	7%	-9%
Nayadic Disinfection	11/16/2007	104	31%	-35%
Nayadic Recirculation	8/24/2007	57	49%	-9%
Nayadic Recirculation	9/14/2007	34	68%	6%
Nayadic Recirculation	9/19/2007	38	67%	-15%
Nayadic Recirculation	10/2/2007	48	69%	-2%
Nayadic Recirculation	10/23/2007	49	60%	0%
Nayadic Recirculation	10/30/2007	52	59%	9%
Nayadic Recirculation	11/12/2007	103	7%	5%
Nayadic Recirculation	11/16/2007	91	31%	-18%

Table 33: Odor panel data

Location	Sample Date	Panelist 1	Panelist 2	Panelist 3	Panelist 4	Average
Baseline	9/14/2007	8	10	6	7	7.75
Baseline	9/29/2007	8	8	6	5	6.75
Baseline	10/2/2007	9	9	9	10	9.25
Baseline	10/23/2007	7	10	6	10	8.25
Baseline	10/30/2007	6	10	1	7	6
Baseline	11/12/2007	9	9	7	5	7.5
Baseline	11/16/2007	9	9	9	7	8.5
Baseline	11/21/2007	8	9	7	7	7.75
Multi-Flo	9/14/2007	1	1	2	1	1.25
Multi-Flo	9/29/2007	2	3	2	1	2
Multi-Flo	10/2/2007	2	7	6	6	5.25
Multi-Flo	10/23/2007	1	3	4	1	2.25
Multi-Flo	10/30/2007	1	5	2	2	2.5
Multi-Flo	11/12/2007	6	6	1	3	4
Multi-Flo	11/16/2007	4	3	8	5	5
Multi-Flo	11/21/2007	4	5	1	7	4.25
Nayadic	9/14/2007	2	3	6	6	4.25
Nayadic	9/29/2007	3	7	4	8	5.5
Nayadic	10/2/2007	3	3	5	7	4.5
Nayadic	10/23/2007	3	9	3	5	5
Nayadic	10/30/2007	4	10	9	8	7.75
Nayadic	11/12/2007	5	10	1	9	6.25
Nayadic	11/16/2007	4	10	3	9	6.5
Nayadic	11/21/2007	6	8	7	8	7.25

Table 34: ORP and DO data

Location	Sample Date	ORP (mV)	DO (mg/L)
Baseline	9/29/2007	-222	0.36
Baseline	10/5/2007	-218	0.53
Baseline	10/30/2007	-201	1.08
Baseline	11/9/2007	-176	1.26
Baseline	11/12/2007	-196	1.03
Multi-Flo	9/29/2007	-165	3.03
Multi-Flo	10/5/2007	-272	0.52
Multi-Flo	10/30/2007	-42	5.99
Multi-Flo	11/9/2007	104	3.44
Multi-Flo	11/12/2007	-94	0.75
Nayadic	9/29/2007	-221	0.69
Nayadic	10/5/2007	-215	0.34
Nayadic	10/30/2007	-220	0.86
Nayadic	11/9/2007	-178	0.64
Nayadic	11/12/2007	-142	0.9

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