EVALUATION OF AEROBIC TREATMENT UNITS IN TREATING HIGH STRENGTH WASTE FROM DAIRY MILK HOUSES

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ABSTRACT

A total of five aerobic treatment units where installed to treat milk house waste. In the fall of 2002, two Biomicrobics FAST systems and two NCS Nibbler systems were installed at four dairy farms ranging from 50-125 cows. In the summer of 2003, a Pirana unit was installed at a dairy milking 50 cows. The FAST and Nibbler units were designed with the surface discharge goal of 25 mg/L biochemical oxygen demand (BOD_5) while the Pirana unit was designed for a BOD_5 of 175 mg/L to be discharged to a drip distribution field. All of the systems include a primary treatment septic tank. In addition to system performance, design, management and economic aspects are being evaluated.

Water flow data was collected on the five farms for over one year with a range of flow rates from 636 to 2063 liters/day (L/d) (168-545 gallons per day (gpd)) or from 11.0 – 33.7 L/d/cow (3.1 – 8.9 gpd/cow). After primary treatment in a septic tank, effluent data has shown an averaged range of BOD_5 of 489- 3115 mg/L, chemical oxygen demand (COD) of 690-5080 mg/L, total suspended solids (TSS) of 218-1293 mg/L and Fats, Oils and Grease (FOG) of 89-1196 mg/L. The aerobic treatment units discharge levels for BOD_5, COD, TSS, and FOG ranged from a unit average value of 131-1584 mg/L, 256-2424 mg/L, 89-641 mg/L, and 12-267 mg/L, respectively. The range in equipment and installation cost was $11,000 - $14,500. Challenges have arisen with higher than expected organic loading.

KEYWORDS. High strength waste, aerobic treatment, waste treatment, milk, milking parlor, aeration, dairy wastes, drip distribution

INTRODUCTION

Many dairy producers handle manure as a solid and do not have environmentally sound techniques to handle their milk house wastewater. In the past, dairy producers were allowed to discharge this effluent to surface waters with little or no treatment, but recent changes in Minnesota rules and enforcement prohibit this discharge. Wastewater from dairy milk houses poses a treatment challenge because of its high organic load and chemical usage.

Milk house wastewater is typically composed of wash water used to clean the milking equipment, the pipeline, and the bulk tank on a dairy farm. It also consists of cleaning agents as well as some residual milk which remains in the pipeline, receiver jar and bulk tank after emptying. The typical cleaning regime is usually comprised of four rinses per cycle (Malcolm et al., 1998). Prior to milking, a sanitizing agent (usually sodium hypochlorite, NaOCl) is rinsed through the pipeline. Following milking, fresh water is used to remove the residual milk. A hot alkaline detergent (often containing sodium hydroxide, NaOH and NaOCl) is then rinsed through to remove fats and oils. A final acid rinse (often

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a mixture of phosphoric acid, H_3PO_4, and sulfuric acid, H_2SO_4) is employed to prevent calcium buildup. The cleaning operation obviously will produce a large volume of wastewater, which can account for up to 30% of the total wastewater volume from a dairy farm (Wright and Graves, 1998). There is a concern about high organic loads, acids, detergents and cleaners.

With funding from the US EPA 319 program through the Minnesota Pollution Control Agency a task force was formed to determine what appropriate methods where available to treat milk house wastewater. This task force has identified demonstration farms and installed milk house wastewater treatment systems on these farms.

METHODS AND MATERIALS

This project is evaluating the technical and economic aspects of three aerobic milk house wastewater systems in a cold climate. All of the treatment systems have a traditional septic tank as the first treatment process. This tank provides 24 –72 hours of detention time, allowing soaps, bedding material and milk fats to float to the top forming a scum layer and the heavier solids including floor lime, dirt and biomass to accumulate in the sludge layer. The tanks need maintenance when the scum or sludge layer is too deep (when top of sludge is within 31 cm (12 in) of the bottom of the outlet baffle or when the bottom of the scum layer is less then 8 cm (3 in) above the bottom of the outlet baffle). This will depend on the size of the tank and the use patterns, but it may need to be done annually at a minimum and bi-annually at a maximum. It is key that only residual milk from the pipelines and bulk tank enter the septic tank. Other "waste milk" is best dealt with by land applying with manure waste.

After primary treatment in a septic tank the effluent flows into one of three types of aerobic treatment. The Nibbler and FAST units in this study have been installed with high strength waste from restaurants which is similar to the waste strength of effluent from milk house waste, but different in composition. In these installations, the ATUs have succeeded in bringing the waste strength down to domestic strength levels.

Monitoring of these systems is being conducted for 18 months to provide quantitative data documenting initial and long-term system performance. All wastewater samples will be analyzed for total suspended solids (TSS), biochemical oxygen demand (BOD_5), chemical oxygen demand (COD), phosphorus (P), nitrogen (ammonia, nitrate, and total Kjeldahl), pH, temperature and fats/oils/grease (FOG).

Evaluation of the aerobic systems includes monthly flow monitoring and sampling of septic/pumps tanks and the effluent after the aerobic treatment unit. In addition to the above-mentioned parameters, the dissolved oxygen (DO) concentration is measured in the effluent from the ATUs. The minimum acceptable DO in an ATU is 1 mg/L, with a range of 2-7 mg/L being desirable. Sludge depth, solids accumulation, and scum depth will be monitored in the septic, pump and aerobic tanks. Beyond wastewater analysis, data will be collected on labor requirements, general system performance, economics, and operation and maintenance.

FAST Units

Two FAST® aerobic treatment units were installed in this study. These units are developed by Bio-Microbics, Inc[3]. The FAST (Fixed Activated Sludge Treatment) wastewater treatment process is an aerobic suspended growth system with a honeycomb type media suspended in the tank. The media provides a surface for the bacteria to attach. The unit installed is a HighStrengthFAST 3.0 with a 1.5 hp electric blower providing air to the media. The aeration process agitates the effluent, providing both food and oxygen to the bacteria.

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[3] Mention of trademark, proprietary product, or vendor is for information purposes only. No endorsement is implied.

There are two different septic tank capacities being used in this study. The first (#1) uses two septic tanks each 2840 L (750 gal) in size. The second system (#2) only has one 2840 L septic tank. This was done because farm #1 had an existing watertight concrete tank. From the septic tank the effluent flows by gravity into a FAST High Strength 3.0 unit that is 10,220 L (2700 gal) is designed to remove approximately 2.7 kg (6 lb) of BOD_5 per day.
The average cost of the FAST systems, including capital and installation, in this study was $11,000.

Nibbler Units
The Nibbler® units utilized in this study were developed by Bill Stuth and are now manufactured and marketed by NCS Wastewater Solutions[4]. Each Nibbler unit contains a specified number of pods designed to match the hydraulic and biological loading of the system. Pods are injection molded plastic cages (72 cm X 72 cm X 46 cm) (28 in X 28 in X 18 in) containing buoyant high surface area media with an airlift pump mounted in the center. Each pod is capable of treating 0.37 kg/day (0.81 lbs/day) of BOD_5 loading and a maximum of 521 L (137.5 gal) per day. Each unit in this study has an 1893 L (500 gal) septic tank, a 3786 L (1000 gal) pump tank with time dosing and a Nibbler unit.
The Nibbler unit is a 13,626 L (3600 gal) septic tank containing six pods each with 0.14 m^3 (5 ft^3) of media per pod. A time controlled pump is located in the pump tank that regulates flow and provides even dosing. Air, forced by the 1.5 hp blower through a pipe manifold, flows through the airlift pumps located in the center of each pod. The airlift pump consists of a one-inch air tube that delivers air to the center of the 15 centimeters (6 in) draft type approximately 36 cm (14 in.) below the liquid surface.
There are two Nibbler units in this study, the first identified as farm #3 handling the milk house wastewater from 96 cows and the second as farm #4 with 45 cows. The average cost of the Nibbler systems in this study was $14,000 and included capital and installation.

Pirana/Geoflow System
Microtech/Pirana[4] developed the Pirana unit utilized in this study (#5). A 3786 L (1000 gal) septic tank is the first step in the treatment process. The effluent then flows by gravity into a second 3786 L (1000 gal) septic tank which houses the Pirana unit. The Pirana unit is composed of an inoculator/generator unit with a 0.1 hp blower with a diffuser and fixed film media with 13.9 m^2 (150 ft^2) of surface area and a bacterial pack. This unit was designed to achieve a BOD of 175 mg/L. After the Pirana unit, the effluent travels by gravity into an 1893 L (500 gal) pump tank. The pump tank contains a rotating screen filter and a 1 hp pump which doses 1000 m (3200 ft) of Geoflow[4] drip tubing. The tubing is separated into 4 zones. The tubing is 30.5 cm (12 in) deep in a clay loam soil with 46 cm (18 in) of separation to the limiting soil condition (redoximorphic features). The cost of the Pirana/Geoflow unit was $14,500 and included capital and installation. The Pirana capital and installation was $2,500, Geoflow capital and installation was $6,300 and the remainder was the septic/pump tanks, piping, electric work and labor to install totaling $5,700.

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RESULTS

Flow Data

The estimates of volume of wastewater produced the milking system and milk house have a wide range from 13 to 42 L/d/cow (3.5 to 11 gpd/cow) (Wright and Graves, 1998). Small operations tend to use less water for cleaning floors and equipment, but more water per cow. Effluent generation rate is related more to system design and management than the number of cows milked (MWPS-7, 2000). As a part of this study, flow meters were installed in water supply lines to the milk house. Average daily water flows are reported in Table 1. The water use per day does go up with the number of cows increases, but generally on a per cow basis the number does decrease.

Table 1. Flow data and system information.

Farm	Number of Cows Milked	Liters (Gal) per day	Liter (Gal) per Cow per Day	Type of Treatment System Installed	Total Septic Tank Capacity (L)	Aerobic Tanks Capacity (L)
1	41	1363 (360)	33.7 (8.9)	FAST	5680	10,220
2	130	1438 (382)	11.0 (2.9)	FAST	2840	10,200
3	96	2063 (545)	21.6 (5.7)	Nibbler	1893	13,626
4	45	784 (207)	17.4 (4.6)	Nibbler	1893	13,626
5	54	636 (168)	11.7 (3.1)	Pirana with Geoflow	3,786	3,786

Influent and Effluent Data

Limited grab samples were taken before the systems were installed to determine a baseline BOD influent value. This was done by sampling existing septic tanks when available and taking grab samples of discharge in milk house when septic tanks were not available. This data was summarized and a BOD_5 of 1100 mg/L was used as typical BOD_5 value leaving a septic tank. The data collected in the first nine months of this study has been much higher at some of the sites particularly Farm #2 and #3 (Table 2). Table 2 also shows the average influent BOD_5 value converted to kg/day. This shows a range of 654-3367 mg/L or 0.9 – 7.0 kg/day.

Controlling the amounts of milk disposed of in the clean up process is critical. Milk has a BOD_5 value of 100,000 mg/L (Wrights and Graves, 1998). Studies have indicated that over half of the solids present in milk house wastewater are of the colloidal or super-colloidal size (Millen et al., 1977). Due to the colloidal nature, septic tanks can provide minimal solids separation (Zall, 1972).

High levels of nutrients are also found in milk house waste. Cleaning chemicals and milk both contain phosphorus. Cleaning chemicals, especially detergents and acid rinses account for the majority of P in the wastewater (Sherman, 1981), with the amount on a given farm highly dependent upon daily cleaning practices.

Table 2. Average effluent data after septic tank primary treatment.

Parameter	Range of Data in Literature*	Farm #1 Avg	Farm #2 Avg	Farm #3 Avg	Farm #4 Avg	Farm#5
Treatment System		FAST	FAST	Nibbler	Nibbler	Pirana
Number of septic tanks	1-2	2	1	1	1	1
Retention time in ATU (days)		7.5	7.1	6.6	17.4	6.0
BOD_5 (mg/L)	84 - 9700	489	3115	2755	1329	754
BOD_5 (kg/day)	na	0.5	4.5	4.8	1.1	Na
COD (mg/L)	1500 - 3100	690	5080	4122	1930	1116
TSS (mg/L)	525 - 7787	218	1293	1093	436	303
FOG (mg/L)	NA	89	1196	572	384	135
pH	6.0	6.7	6.1	6.2	6.2	7.0
Total Phosphorus (mg/L)	33 – 99	61	49	82	31	42
Ammonia (mg/L)	29 – 146	23	18	77	55	24
TKN (mg/L)	45 – 445	33	130	141	104	39
Nitrite+Nitrate (mg/L)	0.08 – 2.0	0.2	1.0	0.7	0.4	0.3

Allen et al., 1973; Loehr et al., 1969; Millen et al., 1977; USDA-SCS, 1992; and Teague and Gross, 2001.

Treatment System Observations and Data

The performance of the units has been highly correlated to the waste strength of the influent. As seen in Table 3, there has been a wide range of average values after treatment in the ATUs. At Farm #1 and #4, the ATUs have reached the treatment goal of 25 mg/L. The DO values in all the ATUs have all been above 1 mg/l with the average value being 2 mg/L indicating an aerobic environment.

Changes in use and operation are needed at Farm #2 and #3 to lower the organic load into the units. In both situations, excess waste milk may be entering the systems. These units are also serving larger heard operations with higher flows. If the producers are unable to lower the inflow waste strength more capacity may be added to the in septic tanks, ATUs or a soil treatment systems could be added. More work needs to be done to understand the variation in waste strength and the affects of different management practices including cleaning regimes.

Table 3. Average effluent data after ATU.

Parameter	Farm #1 Avg	Farm #2 Avg	Farm #3 Avg	Farm #4 Avg	Farm#5*
Treatment System	FAST	FAST	Nibbler	Nibbler	Pirana
BOD_5 (mg/L)	131	574	1584	112	174
BOD_5 (kg/day)	0.14	0.8	2.8	0.1	0.1
BOD_5 removal (kg/day)	0.37	3.7	2.0	1.0	0.4
BOD_5 designed removal (kg/day)	2.7	2.7	3.0	3.0	Na
BOD_5 removal (%)	73	82	42	92	77
COD (mg/L)	256	1524	2424	462	301
COD removal (%)	63	70	41	75	73
TSS (mg/L)	89	491	641	176	142
TSS removal (%)	60	62	41	53	53
FOG (mg/L)	13	69	267	12	3
FOG removal (%)	85	94	53	95	98
pH	7.7	7.6	7.1	7.8	7.5
Total Phosphorus (mg/L)	29	40	81	27	30
Total Phosphorus removal (%)	53	19	1	17	29
Ammonia (mg/L)	16	26	91	38	16
Ammonia removal (%)	31	none	None	11	31
TKN (mg/L)	25	123	148	59	37
TKN removal (%)	23	5	None	12	7
Nitrite+Nitrate (mg/L)	0.7	0.7	0.5	0.5	2.6

Other challenges arose during the first year of the study. A problem developed at all of the FAST and Nibbler systems with the airline in the spring of 2003 due to frost heaving. The FAST systems both experienced problems during the summer of 2003. The blower housing in each case started to melt and the blowers had bearing problems and had to be replaced. Farm #3 (Nibbler) has had odor issues related to insufficient oxygen levels in the aerobic treatment unit tank.

CONCLUSION

A demonstration and research project has been successfully initiated in Minnesota to evaluate effective aerobic treatment options for milk house wastewater treatment for small to mid sized dairy producers. The systems being evaluated include two FAST ATUs, two Nibbler ATUs, and Pirana/Geoflow system. The systems all show promise in decreasing the pollutant load from a milk house waste stream. Further work needs to be performed to determine if use patterns can be changed and if surface discharge is a practical solution.

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