Demonstration and Transfer of Selected New Technologies for Animal Waste Pollution Control

TSSWCB Project 03-10

Final Report

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***Texas Water Resources Institute is part of the Texas AgriLife Extension Service, Texas AgriLife Research, and the Texas A&M University College of Agriculture and Life Sciences**

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Executive Summary

The *Demonstration and Transfer of Selected New Technologies for Animal Waste Pollution Control* project was conducted by the Texas AgriLife Extension Service and Texas Water Resources Institute and was designed as a means for evaluating animal waste treatment methods and their ability to remove phosphorus (P) from dairy waste. A variety of factors present in the North Bosque River watershed have led to the excessive loading of P and subsequent algal growth in the water body. As a result, the Texas Commission on Environmental Quality developed two Total Maximum Daily Loads (TMDLs) for the North Bosque River mandating that P loading to the water body be reduced by at least 50 percent.

Upper portions of the North Bosque River watershed are home to numerous dairy operations that can be a source of manageable P and other nutrients to the watershed. Prior to the development of this project, dairy producers in the area were approached by different companies soliciting their respective products that ‘guaranteed’ P removal from their dairy waste and/or lagoons; however, the diary producers were not presented with scientific evidence to support these claims and were skeptical about actual results. This project was designed in response to the need for scientific evidence and evaluated the ability of four products/technologies to remove P from liquid dairy manure prior to its application on nearby fields.

The program was set up so that an unbiased, third party laboratory analyzed samples collected from dairy waste prior, during, and after treatment by each respective product or technology to provide scientifically sound information to dairy producers so they can make an informed decision about implementing a specific treatment to reduce P from their dairies. Each technology provider utilized a different approach for applying or implementing their respective treatments; the providers were allowed to demonstrate their technology without any modifications recommended by Texas AgriLife Extension Service. Specific sampling procedures and locations were not consistent between each evaluation due to the nature of the technologies; two physiochemical methods treated the waste stream to separate solids and nutrients from liquid manure while two biological treatment methods utilized microbes to treat the entire lagoon. Though each technology resulted in improvements of lagoon characteristics, only the physiochemical treatments effectively removed more than 50 percent of P present in the dairy waste.

As an addendum to the project, a demonstration was conducted to evaluate the feasibility of growing turfgrass on soils amended with byproduct from one of the physiochemical treatment evaluations. The large volume of solids remaining after treatment raised the question of how to effectively dispose of the solids in a beneficial way. The demonstration assessed the response of turfgrass growth and leachate/runoff water quality from small cylinders containing soils amended with the particular byproduct. Results showed that turf production increased as a result of the amendment and water quality was not drastically compromised.

This report summarizes the results of each demonstrated product or technology and the turfgrass growth demonstration. It highlights both positive and negative aspects of each treatment methodology so producers who consider implementing one of the technologies may have science-based findings predicting respective performance.

Project Background

In 1998, the North Bosque River segment 1226 and the Upper North Bosque River segment 1255 were deemed "impaired segments" on the *Texas Water Quality Inventory and 303(d) List*. Recent studies conducted or sponsored by the Texas Commission on Environmental Quality (TCEQ), the Texas State Soil and Water Conservation Board (TSSWCB), the Texas Institute for Applied Environmental Research (TIAER), the Texas Water Resources Institute (TWRI), and others demonstrated that high levels of phosphorus (P) and other nutrients from point and nonpoint sources degraded the water quality in the North Bosque River. Nonpoint sources such as dairy waste application fields (WAFs), and point sources such as municipal wastewater treatment plants, were identified as the major controllable sources of P in the watershed.

These findings led to the U.S. Environmental Protection Agency's (USEPA) approval of two Total Maximum Daily Loads (TMDLs) for P in the North Bosque River. In December 2002, TCEQ approved the implementation plan for the two TMDLs, and TSSWCB approved them in January 2003. The goal of these TMDLs was to achieve a reduction of total annual loading and annual average concentrations of soluble reactive P (SRP) by approximately 50 percent. It is anticipated that SRP reductions of this magnitude will reduce the potential for problematic algal growth in the North Bosque River and Lake Waco.

When this project began in 2003, there were roughly 41,000 dairy cows in the North Bosque River watershed. Runoff from production areas such as feedlots and feed lanes is regulated as point source while runoff from waste applications fields (WAFs) is not regulated, and is therefore treated as a nonpoint source. It is anticipated that the measures to control SRP loading from WAFs may include a combination of dairy regulations for land application of manure and wastewater as well as voluntary land management and stewardship programs. Several permitted dairies in the watershed use best management practices (BMPs) that reduce the nutrient content in the effluent applied to WAFs. In most cases, these include the separation of solids from liquid manure by either gravitational (settling basins) or mechanical (screen separators) methods that may remove as much as 40 percent of solids from liquid dairy manure. While separating solids does actually reduce total P (TP), as much as 90 percent of the SRP remains in the effluent to be stored in a basin or lagoon and eventually land applied to WAFs. Low-cost, highly efficient, and easy-to-adopt technologies or BMPs that will reduce TP and SRP from dairy effluent applied to WAFs will contribute significantly to the overall goal of a 50 percent reduction in annual SRP loading in the North Bosque River.

The North Bosque River watershed contains areas that have concentrated numbers of dairy operations. Dairy lagoons are designed and built to catch, contain, and process water as well as certain amounts of rainwater; however, lagoons must be periodically dewatered to maintain adequate storage capacity. As a result, WAFs typically receive repeated application of effluent causing P levels to increase over time. Another factor causing repeated application of effluent to WAFs is the proximity to the lagoons. Minimizing costs is critical to the profitability of a dairy operation and as a result, application of lagoon effluent to the closest fields is preferred and expedites excessive P build-up on these fields. This practice elicits the need for practices or technologies that can reduce the level of P in lagoon effluent prior to its application to WAFs.

To address this need, the *Demonstration and Transfer of Selected New Technologies for Animal Waste Pollution Control* project (TSSWCB #03-10) was developed to evaluate the ability of selected technologies or treatment methods to remove P from dairy waste streams prior to its application to WAFs. Through this project, four technologies were evaluated and one field demonstration was conducted to evaluate the potential impacts of using residual material from one technology for beneficial on-farm uses.

The final project report briefly summarizes results of each technology demonstration and the field demonstration. Detailed information about the performance of each technology can be found in the final reports for each project. Links to each report are provided below.

Geotube® Dewatering System
http://twri.tamu.edu/reports/2009/tr345.pdf

Electrocoagulation System
http://twri.tamu.edu/reports/2009/tr346.pdf

L4DB® Microbial Treatment System
http://twri.tamu.edu/reports/2009/tr344.pdf

Wastewater Treatment Solution (WTS®) System
http://twri.tamu.edu/reports/2009/tr342.pdf

Geotube® Residual Material Demonstration
http://twri.tamu.edu/reports/2009/tr343.pdf

Project Approach

This project was developed as a methodology to provide a third party assessment of each technology demonstrated. To accomplish this goal, a Technical Advisory Committee was established to provide guidance for the project by selecting specific demonstrations to evaluate; selecting cooperating dairy facilities where technologies were demonstrated; aiding in developing protocols and procedures used in the evaluation of each technology; and assisting with the development and delivery of publications, field demonstrations, and other project outputs.

Each technology was evaluated for its efficacy to reduce total P, SRP, other nutrients, and metals by sampling and analyzing the raw and treated effluent. Cost effectiveness, treatment efficiency, and the ease of adoption for each BMP were evaluated and are presented in this report as well as each individual report. Each technology was demonstrated for a period of at least three months. A third-party analytical analysis was conducted by the lab at the Texas Institute of Applied Environmental Research (TIAER) at Tarleton State University in Stephenville, Texas. Individual sampling schemes were developed for each technology demonstrated as each treatment scenario approached the issues in differing manners. Two of demonstrations diverted the lagoon influent stream through respective treatment systems prior to entering the lagoon while two other demonstrations treated the lagoon as a whole. As such, analyzed samples were collected from the treatment system for two of the demonstrations and samples were collected directly from the lagoon during the other demonstrations.

Extensive detail about sampling methodology, the samples analyzed, results, and treatment methods are reported in each individual demonstration final report. These reports are available on-line under the “Final Reports” heading at: http://twri.tamu.edu/project-info/NewTechnologies/.

Technology Demonstrations and Methodology

Implementation of this project consists of the evaluation of four technologies demonstrated on cooperators' dairy farms by the technology providers. The four technologies demonstrated were a geotextile solids separation system, an electrocoagulation system, a microbial treatment system, and an oxygenated microbial treatment methodology.

Geotube® Dewatering System

The Geotube® dewatering system (Figure 1) was demonstrated by the Miratech Division of Ten Cate Nicolon and General Chemical Corporation. The system used a chemical pre-treatment to coagulate the solids from the lagoon effluent. The mixture was pumped into two large geotextile filtration tubes, known as Geotubes®. These tubes were placed on 6 millimeter impervious polyethylene sheeting. On the down slope end of each tube, a synthetic felt-like fabric was installed to prevent potential soil erosion from water leaving the tube. The synthetic fabric of the Geotubes® acted as a filter that trapped solids and nutrients inside of the tubes while allowing the liquid to exit the tube and return to the lagoon. A high percentage of the solids were retained as the liquid seeped from the pores in the fabric (Worley 2004). The tubes were filled to a height of approximately 5' with the mixture and were left to dewater for six months. After dewatering, the residuals were disposed of off-site. The dewatering system comprised of two 14' x 50' tubes and was set-up to treat the effluent from the primary lagoon of a 2000-head lactating cow, open-lot dairy in the Leon River watershed (which is adjacent to the Bosque River watershed). Manure from the milking parlor at this dairy was flushed into the primary lagoon. Effluent from this lagoon was then conveyed to a secondary lagoon where it was recycled and used for flushing the parlor and irrigating hay and cropland at the dairy operation.

Figure 1. Geotube® dewatering system prior to treatment

For the purposes of this demonstration, effluent was pumped from the lagoon following agitation, just as it would have been if the effluent was applied to nearby WAFs for irrigation purposes. Effluent was pumped at a rate of approximately 400 gpm through a 6" pipe and mixed with alum and a synthetic polymer as it entered into the Geotubes®. This mixture was added to the effluent to promote precipitation and flocculation of P from the waste stream.

Effluent was first pumped into the Geotubes® on March 30, 2005, and additional lagoon effluent was pumped into the Geotubes® on April 6, 2005 as well. Sampling on each date consisted of 10 sets of 15 (250 mL) grab samples that were taken during each of the sampling events. At the time of the second sampling event, there was only enough effluent seeping from one of the tubes to take 2 instead of 3 sets of effluent samples. Each set of 15 grab samples were mixed in the TIAER laboratory and analyzed as one composite sample. To assess the efficacy of the Geotubes® ability to remove P from the waste stream, samples were collected from a variety of locations. Samples were collected from the raw lagoon effluent, lagoon effluent mixed with the chemical treatment (alum and polymer), and effluent weeping from the Geotubes®. After six months of dewatering, the Geotubes® were opened and the material retained inside was sampled.

Publications describing the application and performance of this specific technology demonstration include:

Mukhtar, S., L. A. Lazenby, and S. Rahman. 2007. Evaluation of a Synthetic Tube Dewatering System For Animal Waste Pollution Control. *Applied Engineering in Agriculture* 23 (5): 669–75.

Mukhtar, S., K. Wagner, and L. Gregory. 2007. *Technologies for reducing nutrients in dairy effluent*. Texas Cooperative Extension Publication B-6196. College Station.

Mukhtar, S., K. Wagner, and L. Gregory. 2009. *Field Demonstration of the Performance of a Geotube® Dewatering System to Reduce Phosphorus and Other Substances from Dairy Lagoon Effluent.* TWRI Report No. TR-345. College Station: Texas Water Resources Institute, Texas A&M System.

Electrocoagulation System

The electrocoagulation (EC) system was demonstrated by Ecoloclean Industries, Inc. and consisted of numerous components including two mixing tanks (Figure 2), a dissolved air flotation unit, a sludge tank, the Electrocoagulation unit, a reaction tank with a mixer, two feed tanks equipped with mixers, and a final filter.

A centrifuge was added into the second system and set up to aid in removing solids from the lagoon effluent prior to it going through the EC unit. The system utilized chemical pre-treatment of alum, lime and a proprietary polymer to coagulate and separate suspended solids in the slurry pumped from the dairy lagoon. The liquid then flowed over charged iron electrodes, giving off ions that cause coagulation and precipitation of P and other metals. The configuration of the system and its components varied from event to event as a result of efforts to optimize the system. To accommodate these changes, the points at which samples were taken varied as well.

At all sampling events, samples were taken from the lagoon effluent, the lagoon effluent after the addition of the chemical pre-treatments, the effluent from the EC system, and the residual solids. Samples were also taken where the mixture exited the centrifuge after its addition to the system.

Figure 2. Mixing tank in the Electrocoagluation System

The EC system was set-up to treat 40 gpm of effluent from the secondary lagoon of a 700-head lactating cow dairy in the Bosque River watershed. Manure from the two free-stall barns at this dairy was flushed into the primary lagoon. Effluent from the secondary lagoon was recycled for flushing the barns and irrigating hay and cropland near the dairy. In total, seven sampling events were conducted during the EC demonstration between June 8, 2005 and August 2, 2005. During each sampling event except for the first one, 10 sets of 15 (250 mL) grab samples were collected and delivered to the lab at TIAER for analysis.

Publications describing the application and performance of this specific technology demonstration include:

Mukhtar, S., K. Wagner, and L. Gregory. 2007. *Technologies for reducing nutrients in dairy effluent*. Texas Cooperative Extension Publication B-6196. College Station.

Mukhtar, S., K. Wagner, and L. Gregory. 2009. *Field Demonstration of the Performance of and Electrocoagulation System to Reduce Phosphorus and Other Substances from Dairy Lagoon Effluent*. TWRI Technical No. TR-346. College Station: Texas Water Resources Institute, Texas A&M System.

L4DB® Microbial Treatment System

The L4DB® microbial treatment system demonstrated by Envirolink® LLC from Greeley, Kansas consisted of a liquid-borne microbial solution derived from milk and containing *Lactobacillus acidolphilus* and *Lactobacillus gasseri* as the active cultures. The treatment was applied by spraying a predetermined volume of the microbial solution around the perimeter of the lagoon while simultaneously agitating the lagoon with a pump and sprinkler that sprayed effluent back into the lagoon. The volume of microbial solution applied was applied based on the lagoon size, depth of water and solids in the effluent, and was adjusted as ambient temperatures and precipitation varied. When colder ambient temperatures prevailed, the lagoon received higher treatment doses due to decreased bacterial activity; months with higher precipitation totals received a smaller dose as a result of increased dissolved oxygen levels in the lagoon. Additionally, two tanks (Figure 3) were filled with lagoon effluent and treated separately in an effort to evaluate the performance of the microbial treatment under controlled conditions. One tank was used as a control and was not treated while the other was treated according to the specifications of the technology provider.

This demonstration was conducted in the Bosque River watershed on a 300-head lactating cow, free-stall dairy with a single cell anaerobic lagoon. The free stall alleys were flushed four times weekly and scraped on the remaining three days of the week. Each flush utilized 10,000 to 12,000 gallons of water that flowed directly into the lagoon. In order to manage lagoon depth as needed, nearby hay fields and cropland were irrigated using a big gun irrigation system. Sampling was conducted from the lagoon, the irrigation pipeline prior to field application, and the two controlled tanks. Irrigation samples collected during each sampling event were taken from a spigot in the irrigation pipeline every three minutes for three hours yielding 60 samples. Two sets of tank and lagoon samples were collected during each sampling event.

Figure 3. Tank sampling during the L4DB® Microbial Treatment System demonstration

The first set was collected from the supernatant (the upper 2 ft of the lagoon or 1 ft of the tank) while the second set was collected from the entire profile of the lagoon and tanks. Ten sets of these samples were collected from the lagoon; nine in fixed locations and the remaining one from the irrigation pump. Two sets of samples were collected from each tank. Depth measurements were also taken to record the thickness of the dense sludge level at the bottoms of the lagoon and tanks. All samples were delivered to the TIAER laboratory for analyses.

Publications describing the application and performance of this specific technology demonstration include:

Rahman, S. and S. Mukhtar. 2008. Efficacy of Microbial Treatment to Reduce Phosphorus and other Substances from Dairy Lagoon Effluent. *Applied Engineering in Agriculture* 24 (6): 809–19.

Mukhtar, S., S. Rahman, and L. Gregory. 2009. *Field Demonstration of the Performance of the L4DB® Microbial Treatment System to Reduce Phosphorus and Other Substances from Dairy Lagoon Effluent*. TWRI Report No. TR-344. College Station: Texas Water Resources Institute, Texas A&M System.

Wastewater Treatment Solution (WTS®) System

The WTS® system was demonstrated by Ozona Environmental® LLC from Ozona, Texas. The system is a two part solution treatment that contains a microbial stimulant (WTS®) and an oxygenating additive (O2T). According to the technology provider, the system introduces and stimulates indigenous populations of microorganisms, ultimately resulting in reduced organic matter and nutrients in the wastewater. The WTS® system was initially applied directly to the lagoon (Figure 4) at a rate of 1 gal/head; thereafter, it was applied at a rate of 0.5 gal/100 head-day (3gal/day for the 600 head dairy). O2T was simultaneously applied to the lagoon at a rate of 0.1 gal/100 head-day or 0.6 gal/day. These application rates were constantly maintained using Viking injectors (Viking injector, Kyjac Inc., Nesquehoning, Pa,).

This system was demonstrated on a 600 head free-stall dairy in the Bosque River watershed that flushed and scraped its free-stall alleys. The dairy has a two lagoon system that allows for extended effluent detention time prior to the system being pumped out of the second lagoon and used as irrigation water for nearby cropland. Sampling for this demonstration was conducted in the primary lagoon at ten set locations; nine in the body of the lagoon and one at the lagoon inlet.

Figure 4. Lagoon sampling during the Wastewater Treatment Solution (WTS®) System demonstration

Two plastic tanks were also used to evaluate the treatment system under controlled circumstances. Nine sampling locations were used in each tank; including samples taken from the lagoon profile (entire depth), lagoon supernatant (upper 2 ft), tank profile, and tank supernatant (upper 1 ft). Samples collected during this demonstration were also delivered to TIAER for laboratory analysis.

Publications describing the application and performance of this specific technology demonstration include:

Mukhtar, S., S. Rahman, and L. Gregory. 2009. *Field Demonstration of the Performance of Wastewater Treatment Solution (WTS®) to Reduce Phosphorous and other Substances from Dairy Lagoon Effluent*. TWRI Report No. TR-342. College Station: Texas Water Resources Institute, Texas A&M System.

Sampling and Sample Analysis

Sampling procedures utilized to collect samples from each demonstration were consistent throughout the duration of the project. The standard method was to collect 250 mL samples from lagoon effluent prior to treatment, during, and after treatment by the respective technologies. The media sampled and its locations varied significantly between technologies due to the nature of each individual demonstration. In all four demonstrations, samples collected from individual sites were mixed to form composite samples; thus reducing the overall number of samples analyzed.

Sample analysis was conducted by the TIAER laboratory in Stephenville, Texas. This lab was chosen due to its analysis capabilities and proximity to sampling sites. Extensive analysis was conducted on each sample to evaluate the sample's pH and levels of nutrients, metals, and solids. Table 1 provides detail on individual parameters evaluated, analysis methods used, and the equipment for testing. As a result of high sample costs and limited resources, individual samples from each collection site were combined into composite samples; thus decreasing the overall number of samples analyzed, yet yielding a fair view of effluent's spatial and temporal variability.

Table 1. TIAER laboratory methods and equipment used for sample analysis

Parameter	**Method**	**Equipment Used**
Nitrite + +Nitrate Nitrogen	EPA 353.2 and SSSA 38-1148	Perstorp® or Lachat® QuickChem Autoanalyzer
Total Kjeldahl Nitrogen (TKN)	EPA 353.2, modified	Perstorp® or Lachat® QuickChem Autoanalyzer
Potassium	EPA 200.7	Spectro ® ICP
Calcium	EPA 200.7	Spectro ® ICP
Magnesium	EPA 200.7	Spectro ® ICP
Sodium	EPA 200.7	Spectro ® ICP
Manganese	EPA 200.7	Spectro ® ICP
Iron	EPA 200.7	Spectro ® ICP
Copper	EPA 200.7	Spectro ® ICP
Orthophosphate Phosphorus	EPA 365.2	Beckman® DU 640 Spectrophotometer
Total Phosphorus	EPA 365.4, modified	Perstorp® or Lachat® QuickChem Autoanalyzer
Total Suspended Solids	EPA 160.2	Sartorius® AC210P or Mettler® AT261 analytical balance, oven
Total Solids	SM 2540C	Sartorius® AC210P or Mettler® AT261 analytical balance, oven
Total Volatile Solids	SM 2450G	Sartorius® AC210P or Mettler® AT261 analytical balance, oven, muffle furnace
Total Volatile Solids	EPA 160.4	Sartorius® AC210P or Mettler® AT261 analytical balance, oven, muffle furnace
Potential Hydrogen	EPA 150.1 and EPA 9045A	Accument® AB15 Plus pH meter
Conductivity	EPA 120.1 and EPA 9050A	YSI® 3200 conductivity meter
Aluminum	EPA 200.7	Spectro® ICP

Demonstration Results

A general overview of performance results from each demonstration is presented and summarized in figure 5. Greater detail about individual technology performance can be found in the final reports for each demonstration (pg. 3).

Geotube® Dewatering System

Results from the three sampling events conducted during the demonstration of the Geotube® Dewatering System indicated that the system effectively removed 88 percent of SRP and 97 percent of TP. These removal rates far exceeded the 50 percent reduction goal. Additionally, the technology also removed 95 percent of the total solids from the effluent pumped through the system and was effective in removing all metals, nutrients, and solids.

Electrocoagulation System

The EC system also proved to be effective in removing TP and SRP, yielding 96 and 99.6 percent reductions respectively from the lagoon effluent. The performance of the entire system with respect to removing metals was sporadic. Only Mg was observed to have consistent reductions from each sampling event. Other metals had a wide range of reductions and increases without any apparent trends from event to event. The inconsistencies in the performance of this system for both the metals and solids is possibly linked to the changes made in the system's configuration and the changes in the chemical pre-treatment from event to event.

L4DB® Microbial Treatment System

Overall, the L4DB® treatment was somewhat effective in reducing TP, but was not effective in reducing SRP in the lagoon. Recorded levels of TP and SRP in lagoon and irrigation water varied greatly throughout the course of the demonstration and were likely due to environmental conditions and microbial degradation of sludge in the lagoon. During the one-year demonstration, TP reductions averaged 27 percent in samples collected from the lagoon profile and 52 percent from the lagoon supernatant; however, a 28 percent increase was seen in TP levels in irrigation waters. SRP levels behaved similarly showing sporadic increases and decreases in the lagoon and irrigation waters.

The L4DB® technology also yielded variable performances for other nutrients evaluated, but generally exhibited considerable reductions in metals and solids. Much of this variability was likely due to overloading of the lagoon as well as varied treatment application rates. The technology provider pre-determined the application rate for this lagoon based on experiences, but not by measuring environmental conditions of the lagoon. A general conclusion made was that most of these solids, nutrients, and metal reductions were likely due to microbial treatment, dilution of lagoon slurry due to excessive rain and runoff water, and settling of dead and degraded bacterial mass accumulated at the bottom of lagoon.

Wastewater Treatment Solution (WTS®) System

The WTS® system showed mixed results for P removal. TP levels recorded in the lagoon did not change significantly throughout the course of the demonstration; instead the values varied significantly between each sampling event. In the separate tank demonstration of the WTS® system yielded a decrease in TP of 17 percent collected from the tank profile. TP levels in tank supernatant also decreased in the treated and untreated tanks at respective rates of 60 and 55 percent. SRP levels in the lagoon and tanks showed an increasing trend over time. Generally speaking, this system was not effective at reducing P or other nutrients from the lagoon or tanks.

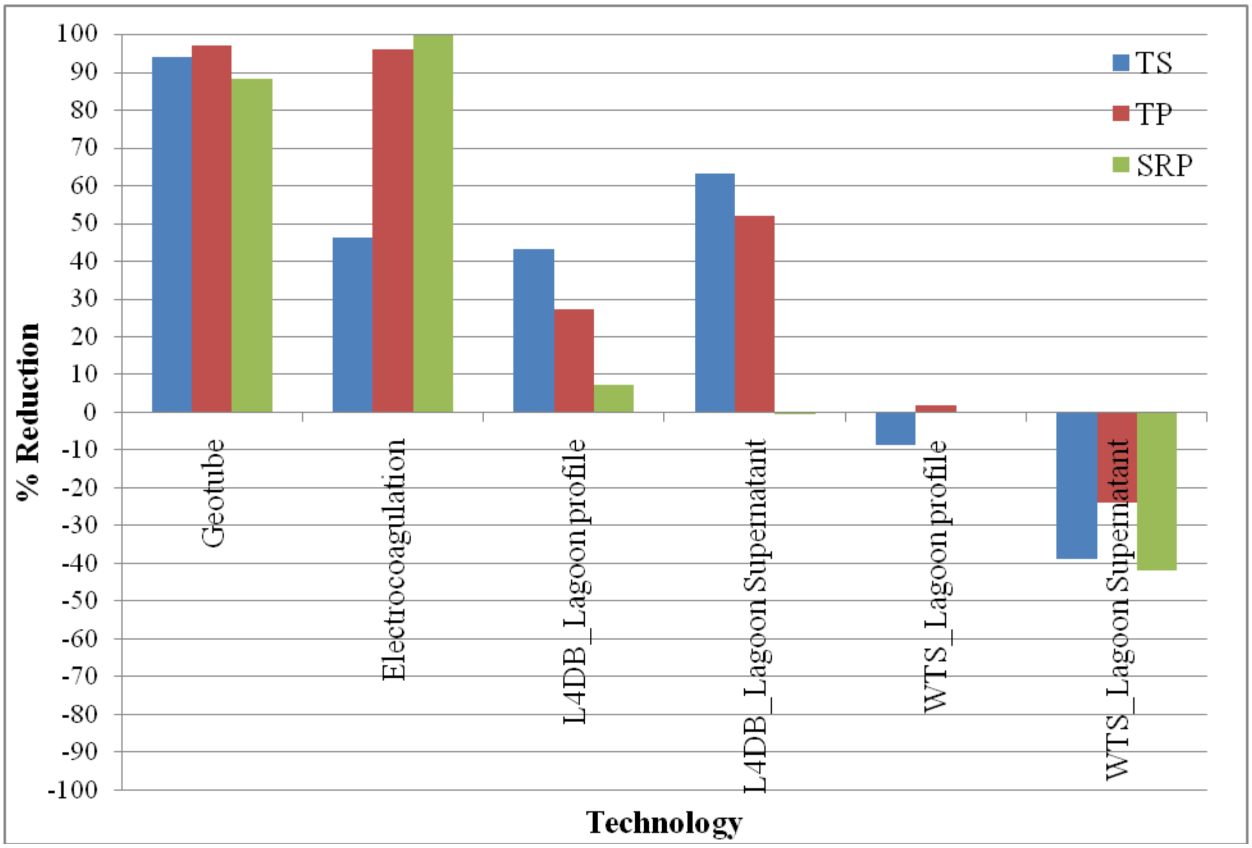

Figure 5. Efficacy of technologies on the reduction of Total Solids (TS), Total phosphorus (TP), and Soluble Reactive Phosphorus (SRP) from dairy lagoon effluent (note: a negative reduction indicates that measured levels increased during the demonstration)

Technology Costs

Costs to implement the four demonstrated technologies varied widely depending upon the method used (Figure 6). Similarly, the technology providers were unable to provide consistent cost per unit information among the technologies. The two mechanical technologies are reported in a cost per gallon and the microbial technologies are reported on a cost per head basis. All costs were converted to a cost per head per year basis to attempt to yield some level of consistency.

Geotube® Dewatering System

Treatment costs for the Geotube® Dewatering System were furnished by the technology provider as a one-time cost of $90,000 to treat 1.9 million gallons of effluent ($0.047 per gallon). Assuming this treatment would only be used once in 15 years to remove nutrient and sludge accumulations in the lagoon of a 2,000 head dairy operation, this cost equates to $3 per head per year.

Electrocoagulation System

The cost estimate for the EC system was provided by the technology provider as an average of $0.12 per gallon to treat a lagoon. This cost would be incurred to hire Ecoloclean Industries to perform the task. Assuming a similar 2,000 head dairy was treated once in 15 years, the treatment of 1.9 million gallons of lagoon effluent would cost $228,000 or $7.60 per head per year.

L4DB® Microbial Treatment System

Treatment cost information from the technology provider for the L4DB® system varied depending on a variety of dairy specific factors for which the technology provider considers when dosing the lagoon. The provider estimated that to treat the lagoon, dairies smaller than 1,000 head would cost $12 per head per year, dairies 1,001 to 7,000 head would cost between $7.20 to $10.80 per head per year, and dairies greater then 7,001 head would cost from $3.60 to $7.20 per head per year. This demonstration was conducted by treating the lagoon; therefore, a cost per gallon cannot be determined for this treatment method.

Wastewater Treatment Solution (WTS®) System

Cost information provided for the WTS® system indicates that treatment costs for this technology vary depending on the specific conditions at each dairy. The technology provider did indicate that costs are typically $6 per cow per year. This method was applied to a lagoon with an un-metered amount of daily inflow; therefore, a cost per gallon could not be determined.

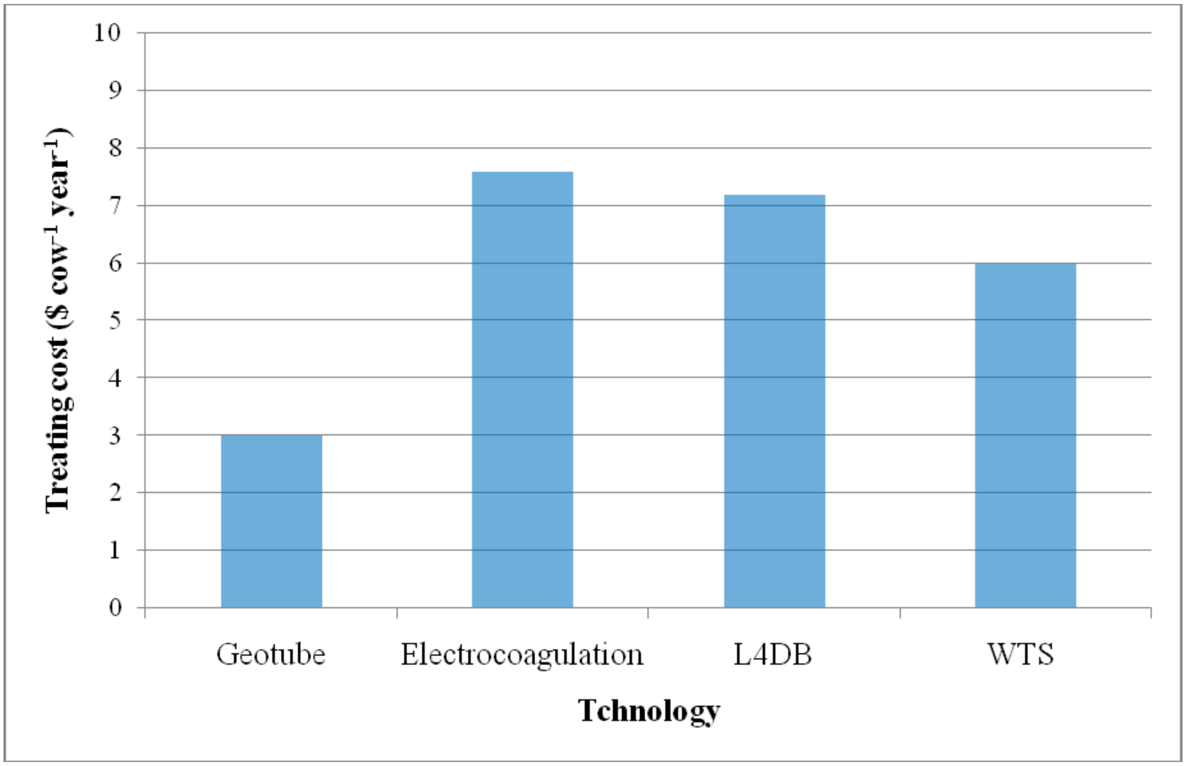

Figure 6. Estimated per cow, per year cost for treating dairy lagoon effluent using different technologies.

Geotube® Residual Material Demonstration

As an addendum to the project, a demonstration, "Cycling of Geotube® Solids from Dairy Lagoons through Turfgrass Sod," was conducted to illustrate the benefits of producing a marketable crop using residual material retained by the Geotube® Dewatering System. After treatment of the lagoon using this system, geotextiles tubes measuring 14 ft x 50 ft retain the bulk of solid material, nutrients, and metals that were removed from the dairy's lagoon. Disposing of this residual material is an economical hindrance for implementing this technology.

Through this project, faculty in the Soil and Crop Sciences and Biological and Agricultural Engineering Departments at Texas A&M University utilized this resource as a soil amendment to produce turfgrass. The goal of this project was to evaluate the sustainability of systems for cycling Geotube® solids through turfgrass production for value-added export with sod. The first objective was to evaluate turfgrass establishment using physical, chemical, and biological properties of contrasting soil textures with and without incorporation of increasing rates of Geotube® solids. The second objective was to evaluate leaching losses of nutrients from contrasting soil textures with and without incorporation of Geotube® solids during turfgrass establishment.

Project Approach and Sampling

In order to effectively conduct this demonstration, an experiment was designed to test four replications of three Geotube® solids application rates on two soil types by packing the soils into 0.25ft x 1ft polyvinyl chloride (PVC) pipe cylinders (figure 7) and amending the soils with 0, 12.5, and 25 percent Geotube® solids by volume and then sprigging with Tifway Bermudagrass. Water was initially applied to the columns from the bottom up and on the surface thereafter. On days 45 and 90 of the experiment the cylinders were irrigated so that one pore volume of water was collected as leachate to determine the impacts of Geotube® solids incorporation. Turfgrass growth was monitored and recorded prior to the harvesting of grass stems and leaves. These clippings were analyzed for nitrogen and phosphorus content by the Texas AgriLife Extension Service's Soil, Water and Forages Testing Laboratory in College Station.

Figure 7. Turfgrass response to Geotube® residual material demonstration sample design

Results

The results of this experiment indicated that under these laboratory conditions, incorporating Geotube® solids into soils used to produce turfgrass had no detrimental effects on production or major impacts on leachate collected from the cylinders. In this demonstration, turfgrass production increased as Geotube® solids application rates increased in both evaluated soils. Results also showed that alum and polymers in the Geotube® solids did not negatively affect turf production.

Analysis of the soils amended with 0, 12.5, and 25 percent Geotube® solids showed decreasing trends in bulk density and gravimetric water content (likely due to increased organic matter from the Geotube® residuals and biomass production, respectively) while total organic carbon, total nitrogen, and total phosphorus increased as Geotube® solids levels increased.

Leachate analysis indicated that both nitrogen and phosphorus levels increased as Geotube® solids application rates increased; however, these increases provided nutrients needed to establish and produce quality turfgrass sod. Nitrate levels in the leachate did reach problematic proportions and may pose water quality threats to shallow groundwater during turfgrass establishment when nitrogen uptake is at its lowest levels.

Observed improvements in turfgrass productivity and soil properties combined with low leaching losses of SRP at high soil pH were indicative of the potential benefits of Geotube® solids incorporation in soils used to produce turfgrasses. Increases in Tifway bermudagrass clipping yields during establishment and maintenance provided evidence that incorporated, volume-based rates of Geotube® solids were an excellent source of inorganic and organic sources of P and N. In addition, the organic carbon incorporated through volume-based rates of solids reduced soil bulk density. Despite benefits to turfgrass and soil properties, the rates of Geotube® solids need to be managed to prevent detrimental effects on groundwater quality. High nitrate concentrations in the volume-based rates applied in the present study exceeded Tifway bermudagrass requirements during establishment, which contributed to high nitrate concentrations in soil and leachate. In contrast, leaching loss of dissolved reactive P from soil amended with the Geotube® solids was low even though volume-based rates increased total, soil-test, and water-extractable P to concentrations above plant requirements. Under the high soil pH conditions in the present study, the alum and/or polymers added during solids separation in the Geotube® could have limited solubility of reactive inorganic P forms even after the solids were incorporated in soil. Although leaching loss of soluble reactive P from volume-based rates of Geotube® solids was not problematic, observed leaching losses of inorganic N and organic P forms indicated rates less than 12.5 percent by volume may be necessary during turfgrass establishment.

Overall, the Geotube® demonstration proved the feasibility and highlighted the benefits of utilizing this residual material to produce value-added crops.

Conclusions

The *Demonstration and Transfer of Selected New Technologies for Animal Waste Pollution Control* project has successfully completed the evaluation of four dairy waste treatment methodologies, a demonstration utilizing byproduct from one of the treatments, and published educational information for dairy producers in the North Bosque River and surrounding watersheds; providing science-based information to dairy producers considering implementing one of the evaluated methods for removing P from dairy waste.

Findings from these evaluations showed that the physiochemical methods (Geotube® and Electrocoagulation) effectively remove 88 percent or more P from dairy waste; however, their costs were such that treatment would only be feasible once every 10 to 15 years. Microbial treatment products failed to perform as well as the other two technologies, but they did show some beneficial reductions in P and other effluent constituents. Lagoon effluent treated with the L4DB® system showed TP reductions of 27 and 52 percent from the lagoon profile and lagoon supernatant while effluent treated with the WTS® system yielded mixed results. Samples collected from the lagoon and tanks showed TP reductions of 17 and 60 percent respectively while SRP increased over time in both environments. The evaluation of turfgrass grown on soil amended with residual material from the Geotube® demonstration proved that this material is an effective soil amendment for stimulating the growth of turfgrass without significant detrimental impacts to ground or surface water quality.

Perhaps the most important findings from this study are that viable means do exist to reduce P in dairy waste by 50 percent or more; however, some claims by solicitors may not be accurate or may even be misleading. Anyone considering implementing a treatment to reduce P in animal waste should be cautious when making their decision. Costs for these treatment methods vary widely and should also be taken into consideration.

Throughout the course of the evaluations, project personnel also learned that specifically evaluating the effects of the microbial treatment methods is difficult in both lagoon and tank environments. Weather and variable manure loading impacts play an important role in the actual make-up of effluent held within lagoons and have the potential to skew the effects of microbial treatment. As a result, extended evaluations covering several years and seasons is a preferred method for more accurately assessing the effectiveness of microbial treatment methods.

Ultimately this project accomplished its goals by providing scientifically proven information on the function and effectiveness of each demonstrated treatment method to area dairy producers. A secondary benefit of this study is that dairy producers have reported fewer solicitations by companies trying to sell their product or service to reduce P in dairy waste.