Department of Agriculture, Trade and Consumer Protection
Division of Agricultural Development
Agricultural Development and Diversification Program (ADD)

Grant Project Final Report

Contract Number: 16052

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An Evaluation of Drying and Dewatering Technologies for Anaerobically Digested Dairy Manure

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1.0 INTRODUCTION

Tinedale Farms, LLP, in Wrightstown, Wisconsin, is a large dairy farm housing nearly 2,500 animals. These dairy cows produce nearly 50,000 gallons of manure daily with a solids content of 8-10%. Tinedale Farms traditionally used lagoons for manure storage followed by land application. In general, manure management was considered part of the cost of doing business for Tinedale Farms and other dairy farms. However, given the rapidly changing business model and increased environmental scrutiny of farm operations, particularly larger farms, these manure management costs are expected to increase substantially in the future. Several years of background work on this issue by Carl Theunis of Tinedale Farms culminated in the formation of Ag Environmental Solutions, LLC (AES). The primary focus of AES is to promote anaerobic digestion and solids separation for odor control.

The first AES anaerobic digestion project was constructed in Wrightstown, Wisconsin, at Tinedale Farms during the spring of 2001. The anaerobic digestion system was operated as a complete-mix mesophilic system until recently, when it was converted to a Temperature-phased Anaerobic Digestion (TPAD) system. It should be noted that the TPAD system is patented (U.S. Patent No. 5,746,919) by Iowa State University, although they are no longer enforcing the patent at this time. The anaerobic digestion system at Tinedale Farms has been producing biogas and generating electricity for some time. However, the effluent from the anaerobic digestion system still contains significant quantities of solids that can potentially be utilized as value-added products by Tinedale Farms or sold to others, if an appropriate manure handling and disposal system was identified.

2.0 INTENT OF THE ADD GRANT PROJECT

In addition to generating electricity from the anaerobic digestion system, AES was also extremely interested in further developing value-added products from the digested biosolids. These value-added products would not only reduce storage and land application costs for manure, but also potentially generate another source of revenue for Tinedale Farms. In an effort to pursue this opportunity further, AES applied for and was awarded an Agricultural Development and Diversification (ADD) Grant from the Wisconsin Department of Agriculture, Trade and Consumer Protection (DATCP). The two major objectives of the ADD Grant project for AES are summarized below:

1) Evaluate the technical feasibility of various types of dewatering and drying technologies on raw and digested dairy manure from Tinedale Farms.

2) Determine the economic feasibility of dewatering and drying biosolids to produce value-added products such as animal bedding and soil amendments.

The utilization of anaerobic digestion and a manure handling and disposal system in a combined process may allow manure management to go from a cost center to a profit center at Tinedale Farms and at other farms with anaerobic digestion systems in Wisconsin. Alternatively, manure handling and disposal systems could also be used on

raw manure, which would be applicable to a larger number of farms in Wisconsin, both large and small.

3.0 PROJECT PLAN OF WORK

The initial ADD grant project work plan consisted of the following tasks:

1) Complete a preliminary literature review of existing dewatering and drying technologies that would potentially be applicable for use on raw and digested dairy manure.

2) Characterize the raw and digested manure in terms of physical and chemical properties.

3) Perform pilot testing on selected manure handling and disposal systems to evaluate the suitability for full-scale implementation.

4) Select and install a suitable manure handling and disposal system and complete performance testing.

5) Complete a final report for submittal to DATCP.

Although the timeline for this project was extended several times because of the complexity of the project and several operating changes for the anaerobic digestion system, the work plan tasks listed above were ultimately completed successfully. The last six months of the project proved to be the most critical in terms of identifying a manure handling and disposal system that met the objectives of AES. It should be noted that the success achieved in the last six months of the project was only possible because AES was given an extension for the project by DATCP.

3.1 Grant funding for project activities

The funds provided by the ADD grant were utilized to address all aspects of the work plan tasks described above, including the following:

- Independent testing by a contract laboratory for the solids and nutrient content of the raw and digested manure.

- Installation and operating costs of the pilot systems, with the most notable expenses being those associated with reconfiguring the electrical system and plumbing requirements (pipes, valves, etc.) for each pilot system installation.

- Consulting services associated with experimental design and data analysis for the pilot systems, as well as completion of the final project report.

Without the ADD grant funding, it is likely that the number of system evaluated would have been reduced and Tinedale Farms may not have successfully identified the

manure handling and disposal system that was ultimately selected. Therefore, the funding provided through the ADD grant program, as well as the flexibility given by the DATCP staff administering the ADD grant program, was a critical catalyst in the successful completion of this project.

3.2 Successes of the grant

As a result of this ADD grant, a full-scale manure handling and disposal system has been installed and is currently operational at Tinedale Farms. The dried solids provided by this system have been used as animal bedding by Tinedale Farms since September of 2002, resulting in a significant cost savings for animal bedding that can be expected to be approximately $100,000 annually or $60 per cow per year. It should also be noted that the cows at Tinedale Farms appear to prefer the dried biosolids, as determined by side-by-side testing completed with the wood shavings that were previously used as animal bedding at Tinedale Farms.

Additionally, dried solids produced at Tinedale Farms using the manure handling and disposal system were successfully sold to another local dairy farm, which also found the dried biosolids to be preferable to wood shavings as an animal bedding. It should be noted that because of the positive experience using the dried biosolids from Tinedale Farms, this dairy farm recently signed a contract to purchase a manure handling and disposal system similar to that at Tinedale Farms, with the system scheduled for installation by January of 2003.

3.3 Challenges posed by the project

There were several challenges posed by this project, with the most notable being the relatively poor performance of traditional agricultural separators that were tested as part of the project. Unfortunately, this poor performance has become the status quo in the agricultural industry and facilities continue to invest substantial capital in separator systems that do not produce results consistent with the needs of the dairy industry.

The most significant issues in terms of system performance can be classified as follows:

- Solids capture rate – This can be defined as the percentage of solids in the system influent that are captured by the manure handling and disposal system.

- Solids content – This can be defined as the percentage of solids found in the dried solids produced by the manure handling and disposal system.

Although many manure separator systems were found to produce a final product that had an acceptable solids content, an analysis of the solids capture rate for these same systems found that only a small percentage of the total solids sent to the system were actually captured or removed. These results were consistent with literature that was obtained as part of the preliminary literature review for the project. From an operator standpoint, the low solids capture rate is significant for two primary reasons. First, solids that are not captured by the separator system represent a potential revenue stream that is being lost. As is the case with Tinedale Farms, solids that can be captured have the

potential to be used on-site for animal bedding or sold to other farms. The potential value of these solids can be seen in Table 1, which includes a range of solids composition and a range of bedding values.

Table 1 – Estimated Value of Captured Solids for Bedding

Composition of Separated Solids			Bedding Value		
			$25/ton	$50/ton	$75/ton
Solids %	Solids per ton (pounds)	Liquid per ton (pounds)	Revenue per pound of solids		
40	800	1200	$0.03125	$0.06250	$0.09375
45	900	1100	$0.02778	$0.05556	$0.08333
50	1000	1000	$0.02500	$0.05000	$0.07500
55	1100	900	$0.02273	$0.04545	$0.06818
60	1200	800	$0.02083	$0.04167	$0.06250

As seen in Table 1, if the final product is 50 percent solid and the value of animal bedding is $50/ton, the value of the solids (either captured or lost) is equivalent to $0.05/pound. Over the course of a year, this can represent a substantial amount of lost revenue if a poorly performing separator system is utilized. It should be noted that the value of the solids decreases as the value of the bedding decreases and as the solids content of the bedding increases, with the latter being attributed to the larger quantity of solids per ton. This high solids content actually reduced the total quantity of bedding produced daily on a weight basis.

Second, Tinedale Farms and many other facilities are actively pursuing efforts to clarify the water from separator systems for reuse at the facility or for other applications such as spray irrigation. The solids that remain in the separator effluent significantly increase the cost of further water clarification and potentially limit these reuse opportunities. If further water clarification does not take place, these solids increase the solids loading rate to the lagoons, potentially resulting in increased odor problems for the farm. Based on discussions that took place at an Odor Control Seminar in Filor, Idaho, high solids loading rates to lagoons were found to be a significant problem for many dairy producers in Idaho. Therefore, the selection of a manure handling and disposal system is extremely important from a revenue, cost, and environmental standpoint, factors which are not often considered thoroughly when a low cost manure separator system that performs poorly is purchased and installed. This not only has an adverse impact on the entire agricultural industry, but can also present difficulties to those companies, such as AES, that have developed effective manure handling and disposal systems that may have an initial capital cost somewhat higher than for traditional agricultural separator systems. Given the current economic situation in the dairy industry, it is often difficult for individual farmers to look at the long-term horizon or evaluate the true life cycle costs of such a manure handling and disposal system.

4.0 PUBLIC OUTREACH EFFORTS

A number of public outreach efforts were completed as part of this ADD grant project. These public outreach efforts are summarized in the following sections.

4.1 Literature and educational materials

The most notable literature developed as part of this project is a marketing brochure on the manure handling and disposal system installed at Tinedale Farms. A copy of this brochure, which is intended to provide a brief introduction to this new manure handling and disposal system to the agricultural community, has been included in Appendix A. The brochure includes a brief summary of each of the three major system components, as well as the advantages of the system in terms of design, operation and maintenance.

4.2 Public relations events

As part of this project a number of public relations events were conducted. On-farm tours and presentations are summarized in Table 2 and presentations at other sites are summarized in Table 3.

Table 2 – On-farm Tours and Presentations

Date	Estimated Attendance	Audience
June 2001	30	Virginia Tech University
August 2001	60	Professional Dairy Producers of Indiana
September 2001	15	National and State FFA Officers
September 2001	50	Chippewa Valley Technical School
October 2001	40	Elkhart Lake High School
August 2002	40	South Dakota Dairy Producers
August 2002	60	Richard Wagner (Quantum Dairy)

Table 3 – Presentations Off-site

Date	Estimated Attendance	Audience
October 2001	300	World Dairy Expo (AES Booth)
January 2002	150	New York Dairy Seminar
January 2002	200	Indiana Dairy Seminar
February 2002	150	Tomah, Wisconsin Dairy Seminar
March 2002	200	California Dairy Seminar
March 2002	1000	Professional Dairy Producers of Wisconsin
May 2002	500	Odor Technology Conference in Filor, Idaho
July 2002	250	Illinois Renewable Energy Conference
July 2002	400	Manure Science Review in Wapakenetta and Wooster, Ohio
December 2002	300	Pennsylvania Dairy Stakeholders Conference

As shown in Table 2 and Table 3, more than fifteen specific tours and presentations were given during the time period covered by the project. During these tours and presentations, several thousand people were made aware of the ongoing research on solids separation at Tinedale Farms. In addition to the activities in Table 2 and Table 3, numerous inquiries from other individual farmers and organizations were also answered by AES.

4.3 Additional Media outreach

In addition to the public relations events described in Table 2 and Table 3, other media outreach activities were somewhat limited because, as stated earlier, the manure handling and disposal system that was ultimately selected was not identified until the last six months of the project. Therefore, it is anticipated that a number of additional media outreach activities will be initiated in early 2003, including the following:

- Additional on-farm tours and presentations for television and radio stations
- Print advertisements in trade journals and newspapers
- Dissemination through other industry contacts such as the Professional Dairy Producers of Wisconsin and the Discovery Farms program

It is thought that these media events, in conjunction with current and future marketing materials will increase the general awareness of the effectiveness of the new manure handling and disposal system, ultimately resulting in increased equipment sales for AES. Specific sales goals for the manure handling and disposal system have been established by AES for both 2003 and 2004, which will be discussed later in this report in Section 5.6.

5.0 PROJECT RESULTS

As indicated in Section 3.0, five specific work tasks were initially identified and completed, meeting the objectives of the project. These work tasks are summarized in more detail in the following sections.

5.1 Literature review

The initial literature review completed as part of this project focused on manure separation technologies that have been traditionally used by the agricultural industry. These manure separation technologies are summarized quite well in the U.S. *EPA Agricultural Waste Management Field Handbook* (1997). A brief description of each of the most commonly used technologies can be seen in Table 4, with more detailed information available in the *Agricultural Waste Management Handbook*.

Table 4 – Commonly Used Manure Separation Technologies (Adapted from U.S. EPA, 1997)

Process	Description
Gravity Separation: Sedimentation Basins	Tanks or basins used to slow wastewater and allow solids to settle by gravity, with the settled solids having high moisture content. Used for low-volume, relatively continuous flow of wastewater, such as recirculated lagoon flushwater or milkhouse washwater.
Mechanical Separation: Screens	Liquid manure passes over the screen allowing the liquid to pass through while retaining the solids. Larger openings allows more solids to pass through with the liquid, while smaller openings retain more liquid with the solids and may be more prone to plugging or binding.
Mechanical Separation: Rundown Screens	Liquid manure flows to an inclined screen, with the liquid running through the holes and the solid trapped on the surface. As the solids accumulate they move to the bottom of the screen where they are handled as solid manure.
Mechanical Separation: Vibrating Screens	Similar to stationary screens, with added horizontal and vertical vibration to move materials over the screen and reduce plugging.
Mechanical Separation: Screw Presses	Uses a straight or tapered screw, with the liquid added at one end and forced along by the rotating screw. Liquid drains through the cylinder enclosure and the solids are pushed out the end.
Mechanical Separation: Centrifugal Separators	Uses centrifugal force to separate the denser solid materials from the liquid.

It can be seen in Table 4 that the major equipment categories for typical manure separation are gravity separation and mechanical separation using screens, screw presses or centrifugal force. Each of these approaches has advantages and disadvantages in terms of capital and operating costs, solids capture rate and the solids content of the final product. For example, with screens a larger opening allows more solids to pass through with the liquid while a smaller opening retains more liquids with the solids, resulting in a lower solids content of the final products. It should also be noted that the smaller screens have also been found to be prone to plugging or blinding

and more frequent cleaning is therefore necessary. Both of these issues get at the core objectives of this project, to increase the solids capture rate while also providing a final product with a solids content that is suitable for the desired applications. The results obtained from testing several of the technologies described above will be presented in Section 5.3.

Aside from agricultural separators, a number of other types of separation equipment have been historically used in the municipal wastewater treatment industry for anaerobically digested biosolids such as those produced by the TPAD system at Tinedale Farms. A summary of these technologies can be found in Table 5.

Table 5 – Commonly Used Municipal Wastewater Separation Equipment (Adapted from Metcalf and Eddy, 1991)

Process	Description
Vacuum Filters	A vacuum is applied to a rotating drum that has three distinct zones for cake formation, cake dewatering, and cake discharge. Vacuum filtration has been used for municipal sludge dewatering for more than 60 years, but its use had declined recently because of advances in alternative dewatering equipment. Advantages include low maintenance requirements, while the disadvantages include high energy usage and increased operator attention.
Centrifuges	Solid bowl and imperforate basket centrifuges have been used for dewatering of wastewater sludges with varying degrees of success. Two methods are often used to control the fine solid discharge and increase the solids capture rate – increased residence time or chemical conditioning. Advantages include a relatively small footprint, while the disadvantages include high energy use and maintenance requirements.
Belt Filter Presses	Belt filter presses are continuous-feed sludge-dewatering devices that involve the application of chemical conditioning, gravity drainage, and mechanically applied pressure to dewater sludge. The belt filter press was introduced in the 1970s and has become one the predominant sludge-dewatering devices and have proven to be effective for almost all types of municipal wastewater sludge. Advantages include low energy requirements, low capital costs and low operating costs. Disadvantages include a hydraulically limited throughput; short media life and sensitivity to incoming sludge feed characteristics.
Recessed Plate Filter Presses	Dewatering is achieved by forcing water from the sludge under high pressure. Advantages include high concentrations of cake solids; high solids capture rate, and good filtrate clarity. Disadvantages include mechanical complexity, high chemical costs, high labor costs, and limitations on filter cloth life.

Similar to Table 4, the various types of equipment described in Table 5 have advantages and disadvantages in terms of performance, operating costs and maintenance costs. It can also be seen in Table 4 and Table 5 that there are some similarities between the various types of equipment used by agricultural and municipal wastewater facilities. For example, belt filter presses screen solids (using a fabric filter), which is then followed by the application of pressure, which would be the similar to applying pressure using a screw press.

One of the major differences between traditional agricultural separators and municipal wastewater separation equipment is the fact that the municipal equipment is typically designed to meet more rigorous operating requirements, as most municipal equipment operates continuously as opposed to the periodic operation of traditional agricultural separators. However, farm in general and larger farms in particular have the same needs as municipal wastewater plants in terms of the requirement for consist operation with minimal maintenance. Aside from the two primary objectives of this project, this also becomes another primary consideration for system selection, because the consistent long-term operation of the equipment will ultimately dictate whether the equipment is economically viable and the farmer is satisfied with the manure handling and disposal system selected.

In addition to these two primary references on separator systems for agricultural and municipal applications, a number of other articles were also evaluated. A listing of the references obtained for this project can be found in Section 8.0.

5.2 Manure characterization

As part of this project, AES evaluated solids separation equipment on both raw and digested manure, which were both available at Tinedale Farms. The raw manure from Tinedale Farms is a mixture of manure and parlor water, with the typical characteristics of this raw manure found in Table 6.

Table 6 -- Raw Manure Characteristics

Parameter	Units	Average
Flow Rate	gallons/day	45,000
pH		7.40
Alkalinity	mg/L as $CaCO_3$	9,000
Total Solids	%	8.10
Volatile Solids	%	6.50
Fixed Solids	%	1.60
Chemical Oxygen Demand (COD)	mg/L	140,000
Soluble Chemical Oxygen Demand (SCOD)	mg/L	50,000
Volatile Fatty Acids	mg/L	1,700

It can be seen in Table 6 that the raw manure has total solids of approximately 8 percent, which would be equivalent to approximately 30,000 pounds per day. It should

be noted that the solids content is significantly lower than for scraped manure, which is typically 12 percent or more. The volatile solids represent approximately 80 percent of the total solids, which is important because only the volatile solids will be reduced through the anaerobic digestion process. The nutrient characteristics of the raw manure from Tinedale Farms are summarized in Table 7.

Table 7 – Nutrient Characteristics of Raw Manure

Parameter	Quantity (lbs/1000 gallons)	Estimated Available Nutrients[1] (lbs/1000 gallons)	Value of Equivalent Commercial Fertilizer[2] ($/1000 gallons)
Nitrogen	29.88	8.93	$2.82
P205	7.21	3.96	$0.83
K20	17.23	12.92	$1.55
Sulfur	2.06	2.06	$0.47
TOTAL:			$5.67

[1] First year nutrient availability assuming manure will be injected or incorporated within 3 days.
[2] Assumes fertilizer values of N (urea) of $0.27/lb, P2O5 (triple superphosphate) of $0.21/lb, K2O (potash) of $0.12/lb, and S (elemental sulfur) of $0.23/lb.

It can be seen in Table 7 that the total value of the nutrients in the raw manure is $5.79, with the majority of this value coming from nitrogen. However, there is also some value associated with the phosphorus, but in many cases phosphorus is the limiting factor for land application rates and cannot be fully utilized. It should be noted that the fate of the phosphorus during the manure separation process then becomes a critical factor in the operation of the manure handling and disposal system, with several of the references found in Section 8.0 focusing specifically on this issue.

After the anaerobic digestion process, the characteristics of the manure change considerably. The characteristics of the digested manure from Tinedale Farms can be seen in Table 8.

Table 8 - Digested Manure Characteristics

Parameter	Units	Average
Flow Rate	gallons/day	45,000
pH		7.70
Alkalinity	mg/L as $CaCO_3$	12,000
Total Solids	%	5.00
Volatile Solids	%	3.50
Fixed Solids	%	1.50
Chemical Oxygen Demand (COD)	mg/L	110,000
Soluble Chemical Oxygen Demand (SCOD)	mg/L	40,000
Volatile Fatty Acids	mg/L	500

It should be noted that digested manure characteristics in Table 8 were obtained during a period when the anaerobic digestion system at Tinedale Farm was operated at mesophilic conditions. Therefore, it is expected that both the total and volatile solids in the digested manure will be somewhat lower after the system reaches steady-state conditions at thermophilic temperatures. The nutrient characteristics of the digested manure can be seen in Table 9.

Table 9 – Nutrient Characteristics of Digested Manure

Parameter	Quantity (lbs/1000 gallons)	Estimated Available Nutrients[1] (lbs/1000 gallons)	Value of Equivalent Commercial Fertilizer[2] ($/1000 gallons)
Nitrogen	26.56	9.27	$2.50
P205	9.21	5.06	$1.06
K20	21.29	5.97	$1.92
Sulfur	2.41	1.33	$0.31
TOTAL:			$5.79

[1] First year nutrient availability assuming manure will be injected or incorporated within 3 days.
[2] Assumes fertilizer values of N (urea) of $0.27/lb, P2O5 (triple superphosphate) of $0.21/lb, K2O (potash) of $0.12/lb, and S (elemental sulfur) of $0.23/lb.

It can be see in Table 9 that the nutrient levels very similar to those found in Table 7. Research has shown that the anaerobic digestion process has only a minimal impact on the nutrient levels, primarily changing the form of the nitrogen and its subsequent availability, with little impact on the phosphorus levels. It should be noted that the reduction in phosphorus for the raw manure in Table 7 can likely be attributed to a reduction in the amount of phosphorus in the feed ration for the dairy cows.

5.3 Pilot testing

The pilot testing conducted at Tinedale Farms as part of this project was done over an extended period of time, with a number of different systems and system configurations being evaluated. Several systems were only installed for a very short period of time and not thoroughly evaluated. This was because it became readily apparent with these systems that the solids capture rate was extremely low (very little dried solids produced) or the solids content of the separated solids was not adequate (weeping of the finished product) to meet the needs of AES. A general summary of the longer-term pilot testing that was conducted, primarily on three separation systems, can be found in Table 10.

Table 10 – Summary of Pilot Testing

Dates	Type of Equipment – Description
Summer, 2001	Screw-press type, cylinder separator – This single step process utilized one piece of equipment for dewatering.
Fall, 2001	Screen system followed by a screw press – This setup provided for screening of the manure in the first step followed by dewatering in the second step.
Summer and Fall,	Rotating screen, screw press, and dissolved air flotation – This setup

2002	provided for screening of the manure in the first step followed by dewatering in the second step with water reuse from the dissolved air flotation system.

It should be noted that there was a significant gap in the pilot testing schedule between the fall of 2001 and the summer of 2002, as AES evaluated data from the first two trials and searched for other types of equipment that would be suitable. At this point, it was determined that it would be necessary to look outside the agricultural industry for alternative types of equipment that had been used in municipal and industrial applications. It should be noted that AES was not entirely familiar with these technologies, which made it difficult to accurately assess the potential of these systems. Again, the flexibility provided by DATCP staff during this period of time was extremely crucial in the identification of the final manure handling and disposal system that was evaluated, which was ultimately the system installed by AES at Tinedale Farms.

5.4 Summary of Results

Based on the results of the pilot testing from Table 10, it was determined that the traditional agricultural separators tested did not meet the needs of AES. In most cases, the solids capture rate was consistently in the range of 20 to 30 percent. This was consistent with literature from the industry which reported removal rates for total solids of only 20 to 35 percent, with removal rates for nutrients even lower (Baker 1993; Moore 1989). It should also be noted that the first AES pilot testing done in the summer of 2001 indicated that phosphorus had a tendency to be squeezed out of the solids for the screw-press type, cylinder separator, which was not desirable. Therefore, this lead AES to the two step process that utilized screens followed by a screw press, which was evaluated in the fall of 2001. During this phase of the pilot testing, it was determined that the phosphorus was more likely to remain with the solids if the manure was screened prior to being sent to the screw press. However, although more phosphorus remained with the solids, the solids capture rate for the second system that was tested was not significantly higher than for the screw-press type, cylinder separator, even though several different system configurations were utilized along with various systems operating parameters.

It should be noted that higher removal rates for both total solids and nutrients can be achieved by clumping the fine and colloidal particles together, through the processes of coagulation and flocculation, prior to mechanical removal (Calgon Corporation 1994). However, there have been some concerns with whether this can be done cost effectively on dairy farms because of the cost of the cationic polymers (McKenney).

The final system that was pilot tested was from meri Papertec Inc. of Appleton, Wisconsin, which has extensive experience with separation technologies in the pulp and paper industry. This system consisted of a rotating screen followed by a screw press, as well as a dissolved air flotation system for water recovery and utilization for screen cleaning. As with the other two step systems, such as system tested in the fall of 2001, several different system configurations were utilized along with various systems operating parameters. The most notable parameters for the meri Papertec system were

the manure flow rate (gpm), screw press setting (bars), screw press speed setting (rpm), and the rotating filter speed (rpm).

Extensive testing of this system indicated that it was possible to consistently achieve a solids capture rate of 60 to 70 percent while also producing a final dried product that was 35 to 55 percent solids for both raw manure and digested manure. Therefore, this system addressed the two primary issues identified in terms of system performance. In terms of nutrients, it was determined that the filtrate from the screw press contained approximately 30 to 40 percent of the phosphorus of the influent, with the remainder found in the solids. As shown in Table 11, this would substantially increase the amount of liquid that could be applied per acre by Tinedale Farms on a phosphorus basis.

Table 11 – Application Rates for Separation System Filtrate

Crop Type	Application Rate	Gallons per Acre
Corn – Grain	55 pounds per acre	21,854
Corn – Silage	80 pounds per acre	31,788
Soybeans	35 pounds per acre	13,907
Alfalfa	59 pounds per acre	23,443

It can be seen in Table 11 the application rates are relatively high for the manure treated using the meri Papertec system. In fact, the application rates are approximately 300 percent higher than what Tinedale Farms would typically be allowed without solids removal prior to land application because only 30 to 40 of the phosphorus remains in the filtrate. Therefore, the manure handling and disposal system not only produces valuable animal bedding, but also significantly reduces the potential costs of land application.

Although coagulation and flocculation with cationic polymers has been considered to be cost prohibitive for the dairy industry, the high rate of solids removal with the meri Papertec system may lend itself to smaller cationic polymer usage rates, which would be limited to the filtrate from the rotating screen. As noted previously, this could further increase the capture rate of both solids and nutrients, with an economic determination made on the basis of the polymer cost versus the value of the solids captured and the cost reduction associated with the reduced levels of phosphorus in the filtrate. Although the ADD grant will be ending on December 31, 2002, further research is planned in this area and will be shared with the dairy industry through appropriate channels.

5.5 System selection

The final manure handling and disposal system selected and installed by Tinedale Farms was the system from meri Papertec Inc. The system has three primary components, which are summarized below:

- Thickening – The first step in the process utilizes an “elephant” filter that consists of a paired disc design with filter fabric. The filter fabric is continually cleaned by utilizing backwash showers, with optional spray pipes utilized to

avoid plugging when lower quality spray waters are used. The filter does not require a vacuum; therefore the filter can be installed at any location. The paired disc design and filter fabric ensures easy installation and maintenance, with the discs available in twin and triple layers for "small" fabric and stainless steel for "big" fabric. The elephant filter can be seen in Figure 1.

Figure 1 – Elephant Filter for Thickening

- Pressing – The second step in the process utilizes a screw press. This screw press achieves a discharge solids percentage between approximately 35 to 55 percent. It can be used as a stand-alone dewatering press for manure or as the second step in the process following thickening. The screen plate sections are available in different perforations to adapt to the specific manure being treated and the modular design is adaptable to specific installation requirements for tonnage, feed consistency, etc. The screw press can be seen in Figure 2.

Figure 2 – Screw Press for Pressing

- Clarification – The final step in the process utilizes a dissolved air flotation system. This system uses a direct expansion system (DES) to create micro bubbles and the tangential distribution system (TDS) drives the flow into a tangential direction for better flow velocity distribution. Rotating scrapers remove sediments and residuals from the bottom and walls, allowing self-cleaning operation. The dissolved air flotation system can be seen in the foreground of Figure 3.

Figure 3 – Dissolved Air Flotation for Clarification

The final system installed by AES at Tinedale Farms can be seen in Figure 4. The elephant filter and the screw press are both located on the platform, with a simple conveyor design utilized to transfer the dried solids from the screw press to the pile seen in the foreground of Figure 4. The dried solids are then transferred from the pile to a storage area using a front-end loader.

Figure 4 – System Installation at Tinedale Farms

5.6 Business Impacts

As a result of this ADD grant project, Tinedale Farms expects to reduce animal bedding costs by approximately $100,000 annually or $60 per cow per year. Based only on bedding savings by Tinedale Farms, the manure handling and disposal system would have a payback of approximately three years. Additionally, animal bedding produced from the manure handling and disposal system was successfully sold to another local dairy farm resulting in additional revenue for AES of approximately $10,000, plus the sale of an additional manure handling and disposal system. Based on the demonstrated effectiveness of the manure handling and disposal system identified through this project and the subsequent partnership established between AES and meri Papertec, it is expected that AES will have 10 sales of complete systems in 2003 and 20 sales in 2004. This would result in revenue of several million dollars for AES, and a significant reduction in animal bedding costs for those farms that purchase these systems. All of these impacts can be directly linked with the awarding of the ADD grant to AES by DATCP, as well as flexibility demonstrated by DATCP staff throughout the project.

6.0 BENEFITS TO THE AGRICULTURAL INDUSTRY

Throughout the course of eighteen months of testing a variety of separators, AES has compiled data showing an alarming lack of efficiency when looking at the total solids recovery from typical agricultural separator systems. Most of the separator systems tested had a solids capture rate in the range of 20 to 30 percent. This lack of efficiency for separator system results in both economic and environmental consequences for dairy producers. However, this poor performance has become the status quo in the agricultural industry and facilities continue to invest substantial capital in separator systems that do not produce results consistent with the needs of the dairy industry. Using this knowledge, AES set out to assemble and test a separator system that would improve solids recovery and by doing so also improve odor control and nutrient recovery.

As a result of the testing completed as part of this project, a joint-venture relationship has been established between AES and meri Papertec. AES and meri Papertec have assembled a manure handling and disposal system that will consistently capture 60 to 70 percent of the solids from raw manure or digested manure. The resulting effluent from this proprietary process is also very low in phosphorus, as shown in Table 11, and will significantly reduce the odor problems associated with the high solids loading of lagoons. For those dairy producers using a flush system, the flush water can be reused without the addition of fresh water, greatly reducing the total volume of water that must be disposed. The effluent from the system is also low in phosphorus and can be irrigated on cropland for the nitrogen content needed for the growing crop, resulting in a significant reduction in cost and soil compaction.

The most significant benefits of the AES/meri manure handling and disposal system are summarized below:

- Minimization of odors
- Reduction in hauling costs
- Suitability of recovered water for irrigation because of low nitrogen and phosphorus levels
- Suitability of recovered solids for bedding (eliminating the need for wood shavings), composting, fertilizer, and open market sales

The AES/MERI manure handling and disposal system represents the latest breakthrough in manure separation technology and is affordable, particularly when the economic value of the solids that can be captured are considered, as shown in Table 1, along with the many benefits described above. Therefore, the widespread utilization of this new technology can potentially reduce the environmental issues associated with dairy manure, while also having a positive impact on the bottom line of the typical dairy farm in Wisconsin.

7.0 SUMMARY OF INFORMATION GAINED AND CONCLUSIONS

Through the testing completed as part of this project and ongoing discussions with other dairy producers, it became evident that few choices were available for the separation of dairy manure and the separator technologies that were available did not meet expectations. AES has now assembled a system that will improve solids recovery and by doing so also improve odor control and nutrient recovery. A summary of the most significant information gained by AES during the course of this ADD grant project is summarized below:

- Traditional agricultural separators are often ineffective because of low solids capture rates that can range from 20 to 30 percent.
- Dairy producers are often left with few choices for separator systems and separator technologies have not changed substantially for many years.
- Phosphorus is a significant issue and some separators, such as screw-press type, cylinder separators, appear to push the phosphorus toward the filtrate, potentially limiting land application rates.
- Both raw manure and digested manure can be separated effectively, although there are some differences that need to be accounted for.
- There are fewer fines in digested manure, which allows a larger screen size to be utilized while still obtaining comparable solids capture rates.
- Separated solids from raw or digested manure can be used effectively as animal bedding, although it is appears to be better to use the animal bedding as soon as possible after it is produced.
- The technology developed can be sized for practically any size farm to achieve odor control.

Although the ADD grant will be completed on December 31, 2002, additional information continues to be obtained through the ongoing operation of the manure handling and disposal system at Tinedale Farms. It is expected that additional information will be also become available as the second AES system becomes operational in January of 2003 and with each subsequent installation.

Although there were a number of challenges encountered throughout this project, the end result has been the development of a manure handling and disposal system that meets the needs of AES and should also meet the needs of the dairy industry in Wisconsin. Again, these results would not have been possible without the ADD grant and the cooperation of staff at DATCP. It is anticipated that the benefits to AES and the State of Wisconsin will far exceed the investment made in this research project.

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