Report

Community Manure Management Feasibility Study

Dane County, WI

February 2008

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SECTION 3
TECHNOLOGY REVIEW AND SHORT LIST

3.01 LITERATURE REVIEW AND FARM VISIT SUMMARY

This study included a limited literature review to evaluate the status of various manure management technologies. It also included visits to approximately ten Dane County farms, including the cluster farms identified in Section 2 and others nearby. The review and visits focused on viable technologies for manure solids destruction and stabilization, manure solids separation, and phosphorus removal and recovery from manure. Also, several articles in the reviewed literature related to benefits of manure management technologies, such as energy generation and byproduct solids reuse. A brief summary of this literature review, including the current state of the technology for manure management, is included herein.

There is considerable interest in manure management technologies throughout the world. New technologies and methods for managing manure are under development, and significant research is being conducted on manure management at numerous universities and corporations. The literature review included is not intended to be all-encompassing but rather a summary of a range of technologies that may be viable at the current time.

A. Biological Manure Treatment

Manure stabilization is achieved through processes that further decompose the manure, which results in a waste stream that has fewer solids and, depending on the method, has reduced pathogen content. Technologies that have been used for manure stabilization include anaerobic digestion, aerobic digestion, and composting. These technologies are described in the following paragraphs.

1. Anaerobic Digestion

Anaerobic digestion (AD) involves biological decomposition of organic matter in the absence of oxygen. Several groups of facultative and strictly anaerobic bacteria convert complex manure solids into stabilized solids, methane, carbon dioxide, and water. AD is likely the most commonly used “innovative” manure management technology employed at farms today. In Wisconsin alone, there are more than 20 anaerobic digesters in use, with many more in the planning stages. In addition, AD has been used for decades to stabilize municipal wastewater solids and to treat industrial wastes.

AD systems come in a variety of forms, including:

- Covered lagoon
- Plug flow
- Complete mix
- Temperature-phased AD (TPAD)
- Slurry loop
- Anaerobic sequencing batch reactor
- Fixed, thin, or mobilized film
- Attached media
- Two-stage digester
- Floating bed

AD is also classified by operating temperature, the most common being mesophilic (86°F to 104°F) and thermophilic (120°F to 140°F). TPAD uses thermophilic digestion followed by mesophilic, and this process achieves a higher level of pathogen and volatile solids destruction in a shorter period of time compared to mesophilic alone.

Solids separation can be used upstream or downstream of AD. If used upstream, manure fibers can be removed prior to AD and used for bedding or other purposes. Removal of solids upstream as opposed to downstream may remove more TP and total nitrogen from the system because these compounds tend to become soluble during digestion. In addition, the digester will be less prone to solids accumulation if solids separation is employed upstream of AD. Solids separated after anaerobic digestion can be used for livestock bedding or compost. The liquid portion is typically land-applied on farm land. Methane ("biogas") can be used to generate heat for the digester and nearby buildings or can be used to produce electricity using engine generators, microturbines, or similar equipment.

By itself, AD does not significantly change the total mass of nutrients (N, P, and K) in the manure, although it does change the form of some nutrients. For example, organic nitrogen is converted to ammonia-nitrogen. The benefits of AD include a reduced mass of solids requiring ultimate disposal, the generation of biogas (renewable energy potential), odor reduction, the reduction of pathogens in the digested manure, and a relatively low energy requirement for the process. The drawbacks of AD include its relatively high construction cost and complexity compared to typical farm operations. Some AD systems do not produce methane in excess of that needed to heat the AD system.

2. Aerobic Digestion

AD systems require the addition of air for mixing and to provide oxygen for the decomposition of organic matter. These systems do not produce biogas. Byproducts include stabilized solids, water, and carbon dioxide. As with anaerobic systems, several forms are available, including:

- Aerated lagoons.
- Suspended growth.
- Autothermal thermophilic aerobic digestion (ATAD).

It is not known if any of these systems are in operation for manure stabilization in Wisconsin or elsewhere, although there are many systems in use for municipal and industrial sludge digestion. Aerobic digestion involves a high level of energy input for aeration and mixing, and the cost of this energy makes it less attractive for farm use. If adequate mixing and aeration are not provided, these systems will normally produce offensive odors. Autothermophillic systems typically require covers and odor control equipment. An advantage of aerobic digestion is that it is simpler to operate than AD as it does not require a biogas utilization system and related safety equipment.

Aerobic digestion does not change the total mass of P and K in the manure. It can be operated to remove some of the N through nitrification and denitrification processes, if desired.

3. Composting

Composting involves combining manure with a bulking agent, such as crop residue, yard wastes, wood chips, or sawdust, in piles, rows, or vessels. The material is periodically mixed or turned to provide the required oxygen for the aerobic degradation. Natural microbes including bacteria and fungi break down the organic material into stabilized solids, carbon dioxide, and moisture. The temperature normally increases to more than 160 degrees F during the process, which destroys pathogens and weed seeds. Composting will not reduce the P content, but it may reduce N content of the manure (through ammonia leaching or denitrification in anoxic portions of the compost). The finished material is a stabilized, organic, soil-like product that is rich in nutrients and can be used on the farm or in landscaping and gardening. The compost can also be screened to improve uniformity and value.

There are three composting sites in or near Madison that are owned by Dane County, as well as two private composting sites owned by the Bruce Company. These sites presently compost yard waste and similar materials. Wisconsin solid waste regulations (Administrative Code Chapter NR 502) do not allow composting of manure or food at these sites unless proper site design is used (for example, using an impervious surface below the composting operations). However, there are at least two manure composting sites in Wisconsin that have received variances from the impervious surface requirements and are required to perform monitoring in lieu of strictly meeting the code. One of these is located near Eau Claire, and the other is near Milwaukee in Washington County and has been operating for approximately 10 years.

The University of Illinois is presently investigating manure composting. Research and Extension programs at the University include evaluating the composting process, compost quality, and compost use in a variety of applications.

A few wastewater treatment plants in Wisconsin are exploring composting or similar processes. As one example, the Madison Metropolitan Sewerage District (MMSD) is piloting a method similar to composting known as “Metro Mix.” MMSD intends to produce a low-pathogen content sludge using TPAD. MMSD will then dewater the digested sludge using centrifuges and mix the dewatered sludge with sand and/or sawdust. This mixture, if the pathogen content is low enough, is anticipated to be suitable for residential or nursery use as a gardening or potting soil. Because of the high fiber content of digested cow manure solids, and MMSD’s potential difficulty finding inexpensive sawdust, there may be some merit to exploring the use of digested, separated manure solids in lieu of sawdust as an amendment to MMSD’s “Metro Mix.”

B. Manure Thermal Treatment Processes

Thermal treatment processes have been used for manure stabilization and solids destruction at both the pilot scale and full-scale. Common combustion processes include combustion, pyrolysis, and gasification.

1. Combustion

Combustion involves the burning of solids to significantly reduce their volume. Byproducts include ash, airborne oxides of C, N, and S, and heat. The combustion heat can be used to preheat or dry the feed solids to allow combustion without the need for supplemental fuels such as fuel oil or natural gas. Drying of the manure prior to combustion is required to reduce the amount of water for autothermal combustion. Electricity can be produced by generating steam and using a steam turbine to generate electricity.

A manure combustor has been built in Brown County, Wisconsin, at the Wiese Brothers Farm, with the goals to eliminate manure spreading and generate electricity. It is a proprietary system known as Elimanure®. The Elimanure system uses a Bio-Dryer, Combustor, Bio-Steam, and a Turbine Generator to generate electricity from the steam produced in the combustion process. The system started up in late 2005. Manure is dried using waste heat from the combustion prior to feeding the solids to the combustor. The ash from this system is reported to be approximately 2 percent of the mass input. The Wiese Brothers system is currently out of service to replace the combustion chamber.

Combustion facilities have also been built for handling poultry manure. There are also numerous full-scale municipal sludge combustors in the United States, including two in Wisconsin (De Pere and Green Bay).

Bacteria and pharmaceuticals are destroyed in the combustion process. During the drying process, some nitrogen, sulfur, moisture, and carbon dioxide would be emitted to the atmosphere during this process. Nitrogen, sulfur, and carbon dioxide would also be present in the flue gas and could either be captured using air pollution control equipment or released to the atmosphere if the concentrations are below regulatory limits. The combustor ash would contain most of the P, K, calcium, and other minerals that were present in the feed solids and could potentially be used in place of lime as a soil amendment.

The combustion process may be attractive to Dane County farmers because it would condense the P so that it can be exported, possibly as a nutrient source, or landfilled. However, nitrogen would be lost and unavailable for use as a nutrient source. If cost-effective and technically feasible, the process could be combined with a technology that captures the N from the stack emissions so that it can be used as a nutrient source rather than entering the atmosphere as an air pollutant.

It may also be possible to burn a dried, pelletized manure product in home biofuel burners to generate heat or as a supplemental fuel in existing coal-fired power plants to generate electricity. However, there are no existing applications known at this time.

2. Pyrolysis

In the pyrolysis process, heat is used to convert manure into three main products: a solid (char), a liquid fuel, and a gaseous fuel. A system is under development in Wisconsin by financial backers from Cashton who purchased a pyrolysis technology firm in Australia and had the prototype shipped to Wisconsin in late 2005. This system is in the pilot stage only, and no literature could be found related to full-scale installations of this technology in the United States or abroad. The markets for the solid, liquid, and gaseous byproducts of pyrolysis are not well-defined or developed to date. Therefore, developing this technology to a level of comfort needed for this study is not as feasible as with combustion or other technologies.

3. Gasification

Gasification is similar to pyrolysis, but the emphasis is on the production of a gaseous fuel. Gasification of coal was used to produce coal gas before natural gas use became widespread. During World War II and shortly thereafter, some cars in Europe had gasification systems to make a fuel gas out of wood. There is renewed interest in this technology for cars in recent years. The literature indicates that this technology is in the pilot stage for use with cow and swine manure, including a pilot fluidized bed gasification facility at Iowa State University. Swine manure has gone through more testing than cow manure. With swine, the manure needs to be at least 40 percent dry matter prior to gasification to obtain desirable results.

C. <u>Solids Separation and Drying Technologies</u>

1. Sand and Grit Separation

There are several full-scale systems being employed for removal of sand bedding from manure and flushing water. Simple nonmechanical systems included sedimentation in lagoons or long channels to separate sand from manure. The sand particles are much denser than manure solids, and the sand tends to settle out of the liquid/manure stream fairly readily.

More active mechanical systems have been employed for grit removal at industrial and municipal wastewater treatment plants. Some of these are being implemented for sand removal at farms, including vortex grit removal and aerated grit removal. The removed sand can be further concentrated and cleaned using grit washers, grit classifiers, and grit dewatering systems. These systems produce sand suitable for reuse as bedding material.

If sand is not removed from the manure stream, its abrasiveness can damage manure handling equipment and can build up in storage tanks and digesters, reducing the effective volume of these units.

One of the farms involved in this study pilot tested a sand-removal system this year. Many attended the demonstration and results have been received. However, further interpretation from the manufacturer is necessary before reporting. The farm is investigating alternative vendors at last communication.

A sand-removal fact sheet was developed by Dane County and is available on its web page.

2. Manure Solids Separation

Solids separation and recovery can be evaluated as a stand-alone process or part of a larger manure management treatment train. It may be used in either a community system or an individual farm manure management system. Several solids separation technologies are currently in use at farms for concentrating manure solids and recovering fiber for bedding. These technologies may include one or more of the following:

- Gravity settling and thickening in tanks or lagoons.
- Stationary inclined screens.
- Vibrating screens.
- Screw presses.
- Rotary drum thickeners.
- Centrifuge thickening or dewatering.
- Belt, roller, or screw presses.
- Dissolved air flotation thickening.
- Membrane filtration (e.g., ultrafiltration, nanofiltration, reverse osmosis).

Ultrafiltration was pilot-tested by one of the farmers involved in this study and was deemed not feasible for full-scale installation because of cost, ultimate discharge issues, and feasibility.

On at least one Dane County farm, screw press separators are being used to separate solids from flushed manure for reuse as bedding. The liquid stream is discharged to a primary and secondary lagoon system into which proprietary microbes are added and a low amount of aeration employed for further treatment. The farmer and microbe supplier are testing the settled solids and liquid from the lagoons to determine if P tends to settle to the bottom of the lagoons, leaving the upper liquid layer with a lower P content for land application. Other separation technologies such as dissolved air flotation, fine screening, and higher speed centrifuges, have been tested at this farm and found to be less effective at removing P and solids from the liquid stream. Some of these technologies required a relatively high dose of polymers or chemical flocculants such as ferric sulfate, ferric chloride, or alum. Some of the technologies did not work well because of microbial slime buildup in flushing lanes or other plugging problems.

In 2007, another Dane County farmer pilot tested a solids separation system that used polymer to help remove P and increase solids concentration of separated raw manure solids. While the results of this study varied considerably, the system was able to remove up to approximately 73 percent of the solids, 73 percent of the phosphorus, 52 percent of the nitrogen, and 56 percent of the potassium from the raw manure. These removal percentages were not consistently achieved, however, and the number of samples collected was not adequate to definitively demonstrate the system's performance.

Separated solids could be used in one or more of the following ways as (a) animal bedding, (b) peat moss replacement, (c) compost, (d) dried pellets, (e) supplement in plastics, (f) supplement in fiberboard (currently being tested at the USDA Forest Products Lab), and (g) a more concentrated nutrient source for export to elsewhere in the county or beyond.

3. Manure Drying

Manure drying uses mixing, air, and sometimes heat to dry the solids following solid(s) separation or dewatering. Some processes take this step further to produce a pellet of dried manure. There are at least three manure drying systems in Wisconsin. The Wiese Brother Farm in Brown County uses air, mixing, and recovered heat from a manure combustion process to dry the manure prior to combustion. Also in Brown County, a system has been developed to dry manure using natural gas as a fuel. At the Van Der Geest Farm in Marathon County, manure is screened, dewatered in a screw press, and then dried in a three-pass system using dried manure as a fuel.

FAN Technologies has a drying system that can be used following its screw press separator. This system allows the separated solids to compost and increase in temperature, and the mixing and heat result in a relatively dry product of about 40 percent solids. Drying systems tend to be fairly capital- and operational-cost intensive, and these costs increase with the amount of moisture they remove. Drying systems have the advantage of greatly reducing the volume of the manure, making it more cost-effective to transport as a nutrient source or biofuel. Unless the system is enclosed and the emissions are captured and treated, the drying process can release N, sulfur, carbon dioxide, and moisture to the atmosphere.

D. Phosphorus Removal and Recovery

The major goal of this study is to evaluate solutions that reduce the amount of P that is returned to the Upper Lake Mendota Watershed. Many of the farmers who replied to the survey and who were subsequently interviewed indicated they had or were able to rent sufficient land for land application of manure as a nutrient source without violating county regulations or their nutrient management plan P loading limits. However, this is not true of all Dane County farmers, and additional P reductions may be required as a result of new confined animal feeding operation (CAFO) permits, Lake Mendota priority watershed project reduction goals, the Rock River total maximum daily load (TMDL) development, or revised regulations. Additionally, other factors could affect the ability to landspread manure in the future including development, land rental availability and cost, and trucking inconveniences.

1. Phosphorus Minimization in Feeds

One of the first steps that should be taken when considering removal of a specific compound from a waste stream is to investigate the source of the compound and determine whether the source can be minimized. P is an essential nutrient for bone development and maintenance and for birthing. However, P is sometimes present in the feed at levels that exceed the animals' nutritional requirements. Therefore, manure P source minimization would involve reducing the P content of the feed.

According to a Dane County area feed supplier, the P content of dairy feed has historically been unnecessarily high at about 0.48 percent. Since then, studies have shown that the P content can be lowered without detrimental effects on the animals. Currently, dietary P content for dairy cows is approximately 0.38 percent. Some of the farmers in Dane County have indicated that this feed P reduction has reduced the amount of P in manure considerably. The feed supplier also indicated that dietary supplements are being tested that could reduce the amount of protein the cows require. This, in turn, may reduce the amount of nitrogen in the feed and manure. These supplements have been used successfully in swine and poultry.

2. Phosphorus Removal

The reduction of total phosphorus (TP) from manure wastes can be achieved in one of the following ways:

a. Solids separation.

b. Chemical precipitation.

- metal salts (Fe^{3+}, Al^{3+})
- struvite [$Mg(NH_4)PO_4 \cdot 6(H_2O)$]
- vivianite [$Fe_3(PO_4)_2 \cdot 8(H_2O)$]
- hydroxyapatite [$Ca_5(PO_4)_3(OH)$]

c. Fluidized bed precipitation process for apatite or other mineral formation and removal.

d. Enhanced biological removal.

Separation of fresh manure solids may remove as much as 10 to 40 percent of the total P in manure. With the addition of polymer or chemicals, this percentage could be increased. As noted previously, one Dane County farmer plans to pilot test a polymer feed and solids separation system that is being promoted as a phosphorus removal technology. If these solids are subsequently used for animal bedding on the farm, however, some of the P will be recycled rather than removed since spent organic bedding is typically mixed and disposed of with the manure.

Chemical phosphorus removal (CPR) is achieved by the addition of chemical coagulants, typically metal salts, to precipitate dissolved phosphate (PO_4^-). This method has been pilot tested with manure and has also been used full-scale on some farms. It appears to be most widely used in combination with lagoon settling. Farmers report that they can use the higher P, heavier bottom solids as a one-time application on fields that are more remotely located, while the lower-P liquids are applied to fields that are located closer to the lagoon. This technology could be combined with a solids separation technology to reduce the volume of the high P solids even further and make longer-distance trucking more cost-effective. It should be noted that CPR using lagoons may not be as effective if the settled solids are not removed soon after they settle. If, for example, the bottom solids became anaerobic, some of the P in the settled solids may resolubilize and release into the liquid above.

Because some P becomes soluble in an anaerobic environment, the most effective means of chemical P removal from manure may occur following AD. Thus, AD could be followed by CPR and settling with the settled solids containing a high concentration of P. Alternatively, AD could be followed by solids separation and recovery, and the resultant liquid stream could be treated with CPR. Researchers at UW-Platteville performed several jar tests to examine P removal under these various treatment scenarios. Their methods and results are summarized in Appendix B.

Removal of P by formation of struvite is somewhat similar to CPR. In this case, P is precipitated as magnesium ammonium phosphate ($MgNH_4PO_4*6H_2O$). Magnesium addition, ammonium addition, and/or pH adjustment are often necessary to achieve the correct ratios of compounds and conditions for struvite formation. Struvite will then precipitate as a scale onto a downstream surface. Struvite crystallizers can be used to extract the mineral through precipitation on an upflow fluidized bed. The ammonium required for struvite formation is present in fresh manure to some extent and would be present at much higher levels following AD or nonaerated lagoon storage. On the other hand, adjustment of pH may be more cost-effective if it is done upstream of digestion. One distinct advantage of struvite removal is that the resulting P is more concentrated than it is using metal salt precipitation, which would allow it to be used on nearby farms or exported as a nutrient source more easily. This process has been used in municipal wastewater treatment and swine manure management and has been pilot tested for cow manure. Manure pilot tests show a reduced P removal efficiency of approximately 50 percent while 95 percent P removal has been demonstrated in swine applications. Some studies on struvite creation in cow manure have been discontinued because the process proved cost prohibitive. pH adjustment can be difficult because of the buffering capability of manure, and P compounds may need to be modified prior to being available for struvite formation.

According to its Internet site, the Crystalactor® process utilizes a fluidized-bed crystallizer for P removal. The treatment process uses a "pellet reactor" partially filled with a suitable seed material such as sand. The wastewater is pumped in an upward direction through the reactor, fluidizing the pellet bed. In order to crystallize the target component on the pellet bed, pH-adjustment and the addition of a reagent may be required. For the Alto Dairy wastewater treatment plant installation in Wisconsin, sand was selected as the seed material and lime is used as the reagent. Calcium phosphate (apatite) crystals are formed on the sand particles. These pellets grow and move toward the reactor bottom where they are discharged from the reactor and disposed of. Fresh sand is added periodically. This process may require a relatively clean wastewater for proper operation; at Alto Dairy, for example, the Crystalactor process follows an activated sludge treatment plant and cloth disk filters, so the water entering the reactor is almost (except for P) clean enough to discharge to surface water.

Enhanced biological phosphorus removal (BPR) can be achieved by carefully controlling aerobic and anaerobic zones within an aerated mechanical waste treatment system to achieve an enhanced biological uptake of dissolved P. The P is removed from the process along with waste sludge. This sludge needs to be further processed. This technology has been used successfully at many municipal and industrial wastewater treatment plants throughout the United States. BPR generally achieves P removal with lower operation and maintenance (O&M) costs and lower sludge production than CPR, while CPR generally has a higher reliability and, in the case of manure treatment, a significantly lower capital cost. BPR could be considered as part of a full-liquid treatment process following manure solids recovery. However, this process would need to be used in conjunction with a mechanical activated sludge treatment plant, similar to the treatment system employed by MMSD, for example. Waste sludge at MMSD is further processed by AD, thickening, and land application. The high capital and long-term costs associated with building and operating such a facility reduce the viability of BPR for manure treatment. To date, we are not aware of any BPR systems employed for P removal of manure wastes.

E. Biofuel Technologies

Several biofuel technologies were found in the literature that apply to manure management. Ethanol production from manure may eventually be possible. Currently, there are no full-scale cellulosic ethanol plants in the United States, but one is being planned in Georgia. Manure may be a less desirable feedstock for such plants because of its lower cellulose content compared with grass, crop reside, or wood chips. There are installations in Texas and Nebraska that use methane produced from manure digesters to fuel ethanol production plants, and such “co-location” of facilities may be feasible in Dane County. Likewise, it may eventually be possible to cost-effectively produce biodiesel from manure. These types of systems are in the research and development stage with a few larger-scale systems. There is a pilot scale thermochemical conversion facility at the University of Illinois-Urbana that converts swine manure into crude oil. A full-scale system owned by Smithfield Foods in Utah was intended to produce methanol from manure-digester biogas and convert the methanol to biodiesel, but it is no longer operational because of lower-than-expected biogas production and other factors.

F. Byproducts and Residuals Management

The generation and use of byproducts and residuals were discussed under various technologies above. A summary and further discussion is provided in this section.

1. Liquids

The liquid manure stream that is generated following AD can be used directly as a nutrient source and applied to crops using proper management practices, either before or after P removal and/or solids removal. Digestion should remove much of the odor potential associated with the liquid. If further treatment is employed, the liquids may be suitable for use as flushing water in barns or for irrigation water at the farm or on surrounding lands. Golf courses are large irrigation water users and may be interested in highly treated liquids.

Liquids may be made suitable for a groundwater discharge if they receive a high level of treatment. Biochemical oxygen demand (BOD) and total suspended solids (TSS) would need to be reduced to approximately 50 mg/L and total nitrogen (TN) would need to be reduced to approximately 10 mg/L, either by employing an aerated lagoon or activated sludge process or a series of membranes. The groundwater discharge could be accomplished using seepage cells or unlined ponds, unlined wetlands, or infiltration galleries. Groundwater discharges tend to work best if soils are sandy such that they seep well; finding suitable soils in the Upper Mendota watershed may be difficult. A groundwater discharge would be beneficial in terms of the overall water balance in the watershed.

A Wisconsin Pollutant Discharge Elimination System (WPDES) discharge permit for a surface water discharge in the Upper Mendota watershed would be difficult to obtain because of legislation related to the Madison lakes. P would likely need to be removed to very low levels (potentially 0.05 to 0.20 mg/L), and BOD and TSS would need to be below 30 mg/L. Furthermore, it is difficult for a CAFO farm to obtain a WPDES permit for a surface water discharge because of current federal and state CAFO regulations. The Wisconsin Department of Natural Resources (DNR) staff has indicated a willingness to work with Upper Lake Mendota Watershed farms on these issues to facilitate manure management solutions that have a net environmental benefit.

2. Solids

As noted above, separated solids could be used in one or more of the following ways as (a) animal bedding, (b) peat moss replacement, (c) compost, (d) combustion material, (e) supplement in fiberboard, (f) a component of recycled plastic, and (g) a more concentrated nutrient source for export to elsewhere in the county or beyond. There is a concern about Johne's disease organisms or other bacteria in the solids. However, AD, composting, and drying at high temperatures will all destroy Johne's and other organisms.

3. Energy

Biogas produced through AD could be used in a boiler to produce steam, in a boiler to heat the digester, or in a microturbine or engine generator to generate electricity. Microturbines have been employed at a few southern Wisconsin wastewater treatment plants (WWTPs) and landfills. Electricity produced could be used on a farm, at a nearby industry such as one in the Middleton industrial park, or sold to an electric utility. Electric utilities are required by law to generate a certain percentage of their electricity from renewable sources and would be interested in such a project. If an engine generator or microturbine is used, waste heat from the unit would normally be used to heat nearby buildings and/or the digester. Since the biogas also contains carbon dioxide, reduced sulfur compounds, moisture and other nuisance compounds such as siloxanes, it often needs to be treated prior to use.

Treated biogas could also be compressed and tied into a local natural gas distribution system, used by a nearby industry to partially replace natural gas, or used as a vehicle fuel. In the fall of 2007, Dane County solid waste staff visited a dairy farm in southern Michigan where methane gas from an anaerobic digestion system was being treated to purify the biogas adequately to allow it to be injected into a natural gas pipeline for commercial distribution.

G. Additional Benefits of Various Technologies

1. Addition of Other Feedstocks

A manure digester could be designed to accept material from nearby industries as well as food residuals or fats and oils to maximize the amount of biogas generated. A few area industries were contacted as part of this study. The waste from Industry No. 1 is a high-solids material that is high in organic matter but also contains high sodium and chlorides. The corporation was contacted and indicated that they currently have an outlet for this waste; however they may have a long-range need to find another method to treat or dispose of this waste. A food industry (Industry No. 2) was contacted and it has identified a few waste streams that may be viable substrates. The most likely waste stream is the scum (or "float") and sludge from its pretreatment system, which currently is land-applied. The industry also has unpackaged and packaged waste product streams that may be considered in a community system; it is currently investigating the feasibility of converting the unpackaged waste product stream into biodiesel. Industry No. 3 recently constructed a waste-grease biodiesel plant that generates a high-strength glycerin waste stream. These local industries are interested in the concept of a community system that would accept their waste streams.

The characteristics of the high strength wastes would need to be carefully evaluated for the following:

- Potential toxicity to AD or composting organisms.
- Nutrients and salt content, which may impact subsequent land application of digested liquids.
- Potential to produce significant biogas.
- Volume in proportion to the anticipated manure volumes.

Industry No. 1 and No. 3 provided general information about their waste streams, which is shown in Table 3.01-1.

	Industry No. 1	Industry No. 3
Flow, gpd	18,000	7,000
Solids		
TS	15.6-23.4%	--
VS	--	91.61%
NH_3	2,100-3,200 mg/L	non detect
P	3,600-7,100 mg/L	438 mg/L
K	8,300-10,000 mg/L	64,728 mg/L
Na	10,200-19,200 mg/L	231 mg/L

Table 3.01-1 Industrial Waste Streams

Dane County has produced estimates of food scrap generation from households, restaurants, and grocery stores within the County. Household generations, approximately half the total, amounts to about one pound per household per week. Collection would require separate storage and either an additional collection vehicle or a "piggy back" system on existing vehicles. Costs are estimated to be substantial and no Dane County communities either have such a system or are actively working to develop such system. Dane County staff has met with representatives of the trade associations for both the restaurants and the grocery stores within the County. In both cases there was very limited interest in separating food scraps for separate collection.

It may be possible to co-compost yard waste from Waunakee, Madison, or elsewhere, if composting technology is determined to be feasible.

2. Carbon Dioxide Emission Reductions

GHG emissions are an emerging concern in the United States and world because they are believed to contribute to global warming. The primary GHGs of interest for this study include methane, carbon dioxide, and nitrous oxide. Some gases are considered more harmful than others because they undergo oxidation in the atmosphere and are converted to other GHGs. Methane is one of these; it has 21 to 23 times the global GHG effect of carbon dioxide. When renewable resources such as wood or manure are burned, it is considered a "carbon neutral" activity because the source of carbon in these materials is plants within the recent past. Activities that capture carbon dioxide and remove or "retire" it for long periods of time result in a net reduction of GHGs in the atmosphere. This is known as carbon sequestration. Examples include formation of peat bogs, reforestation and reestablishment of grasslands, incorporation of carbon dioxide and biological carbon into the oceans, use of new and recycled wood in building construction, and increasing the net amount of organic matter in soil by incorporating crop residue or other methods, possibly including manure application. Landfilling of organic matter may also sequester carbon.

AD with biogas utilization is generally considered a carbon-positive process because it prevents methane from being produced during lagoon storage of manure and the generation of power replaces the use of fossil fuels. The stabilized organic solids would be reused or returned to the soil. Compared with the current Dane County farming practice of lagoon storage or pile storage of manure, which tend to release methane and nitrogen to the atmosphere, AD is expected to have a net reduction in harmful GHGs.

Combustion is sometimes considered a carbon-neutral technology if natural gas or other petroleum products are not used as a supplemental fuel. With combustion, there would be no return of organic matter to the soil and there would be an increase of carbon emissions to the atmosphere compared with AD. Drying of the manure prior to combustion will release moisture and some carbon, N, and sulfur to the atmosphere unless these emissions are captured and treated. However, capture and treatment of emissions will add significant cost to the project. It appears unlikely that combustion would result in a net reduction of GHGs compared with current Dane County farming practices.

Several entities such as the Chicago Climate Exchange (CCX) purchase and sell carbon and other GHG credits on the open market. The CCX describes itself as a "self-regulatory exchange that administers a voluntary, legally binding pilot program for reducing and trading greenhouse gas emissions in North America…." Members of the CCX include municipalities, industries, utilities, farmers, and others. Members can reduce their emissions and bank and sell their credits or can purchase project-based offsets from methane collection or carbon sequestration projects. Of particular note is CCX's Agricultural Methane Emission Offsets, which include methane collection (such as AD with energy production) at livestock operations. Offsets are currently issued at a (conservative) rate of 18.25 metric tons of carbon dioxide per ton of methane combusted. CCX prices for carbon dioxide have generally ranged from $1 to $5 per metric ton.

Other exchanges, registries, and programs are also available to obtain financial incentives for manure management projects that reduce GHG emissions, generate renewable energy, or a combination of the two. These include the Clean Development Mechanism, the California Climate Action Registry, and the Regional Greenhouse Gas Initiative. These programs, and likely others, should be evaluated if a manure AD is contemplated because the sale of credits may help offset the cost of the project. The prices for carbon dioxide credits through these programs are anticipated to be higher than through the CCX in the short-term.

H. Concerns or Risks of Various Technologies

1. Johne's Disease

Johne's disease is a chronic wasting disease that affects animals on many dairy farms throughout the United States. The bacterium (*Mycobacterium paratuberculosis*) that causes the disease can be destroyed if sufficient time and temperature are employed. For AD, a mesophilic digester can destroy the organism in about 28 days. In a thermophilic digester and in composting, the time is reduced to hours. Destruction of the organism should be considered for any community systems that return products to the farms or any systems that result in a product to be distributed to the public.

2. Other Microbes

The management of manure must also consider the potential impact on both human and animal health. While over 100 diseases are recognized in cattle, only a few are of prime importance with respect to manure management. Dane County discussions with faculty at the University of Wisconsin School of Veterinary Medicine and a veterinarian at the Wisconsin Department of Agriculture, Trade, and Consumer Protection have led to a focus on the following:

- The environmental mastitis bacteria
- *Salmonella*
- *Escherichia coli*
- *Campylobacter*

Detailed discussion of these diseases is beyond the scope of this report.

3. Foot Bath Wastewater

Foot baths are commonly used after milking parlors to help keep animal hooves healthy. The foot bath wastewater often contains biocides. For the farms that are in the clusters studied here, the most common biocides are formaldehyde and copper sulfate. Some farms decrease their formaldehyde use in the winter because of lower ventilation rates and subsequent worker safety concerns. Biocides may be harmful to microorganisms in lagoons (e.g., if proprietary specialty microbes are added to the lagoon) and ADs. The quantity and type of biocides should be carefully reviewed to determine whether this wastewater needs to be segregated and removed from the waste stream prior to treatment.

4. Aluminum Oxide, Potassium Sulfite, and Related Compounds on Soils

Some farmers in Dane County indicated a concern with aluminum oxide (alum), potassium sulfite, and other related compounds applied to their farm fields. There is limited information in the literature about this concern. However, at least one state has aluminum limits for land application of biosolids. This should be reviewed in more detail if alum is proposed as a phosphorus removal chemical.

5. Loss of Nutrients and Organic Matter

Farmers who provide their manure to an AD or compost facility without returning digested manure to the farm or those who provide their manure to a combustion system will likely need to purchase at least some supplemental fertilizer for their feed crops. Alternatively, they may elect to reduce their land ownership and purchase feed. This may increase the total cost of operation at some farms.

Another consideration is the loss of organic matter because of the discontinuing of manure application to fields. The impact of not applying manure to fields could be large in systems where crop biomass is not conserved (systems growing primarily corn silage and soybeans and conventional tillage). In these systems, manure replaces the harvested crop residues to help build organic matter, and a decrease in solid organic matter could be expected if manure was no longer applied. However, if recovered solids are used for dairy bedding instead of harvested straw or corn stover, these residues could remain in the fields to protect soil from erosion and to help build organic matter, decreasing the need to replace harvested biomass with the manure.

3.02 ALTERNATIVES FOR STUDY

Eight alternatives have been selected for further study based on the status of technology, potential viability, and ability to meet the project goals. Specifically, each alternative discussed below is believed to meet the following objectives:

- P reduction of 40 percent, minimum.
- Proven at full-scale or at least long-term pilot scale.

Three of the alternatives are for application on individual farms and the remaining five are community solutions. Each of the alternatives is discussed in the following paragraphs.

It is noted that new technologies and methods for managing manure are under development, and significant research is being conducted worldwide on manure management. The technologies considered herein represent viable technologies at the present time.

A. Individual Farm Systems

Individual farm systems will be evaluated using a prototype farm as the basis. The prototype farm will have 500 A.U.s. The herd will be 45 percent dairy milking cows, 37 percent young stock, 7 percent dairy dry cows, and 11 percent other animals (other adult dairy, adult beef, or adult swine). The prototype farm will use straw, sand, sawdust, manure solids, rice hulls, or oat hulls for at least 85 percent of the bedding prior to the installation of manure management solutions, and it will use a scrape or push-type manure collection system. The prototype farm will have a minimum of six months of liquid manure storage, and the current maximum hauling distance for the prototype farm is 5 miles.

- F-1. Fine solids separation with polymer addition.

The raw manure would be dosed with polymer and processed through a fine solids separation unit that would result in two effluent streams. One would be a solids stream containing dewatered solids of approximately 20 to 30 percent dry matter that could be used for composting or other reuse. Solids dewatered in this manner contain anywhere from 40 to 50 percent of the P in the raw manure. Land application of treated liquid manure would provide nitrogen, phosphorus, potassium, organic matter, and trace nutrients to the land partially or wholly replacing commercial fertilizers. Alternative F-1 is shown in Figure 3.02-1.

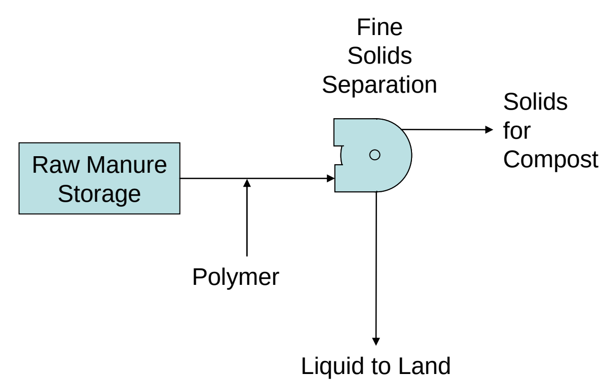

Figure 3.02-1 Alternative F-1

- F-2. Fine solids separation with ferric chloride and polymer addition.

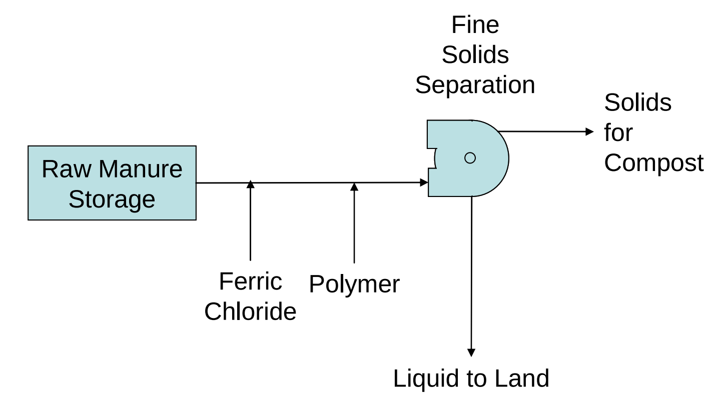

Figure 3.02-2 Alternative F-2

The raw manure would be dosed with polymer and ferric chloride before processing through a fine solids separation unit that would result in two effluent streams. One would be a solids stream containing dewatered solids of approximately 40 to 50 percent dry matter that could be used for composting or other reuse. Solids dewatered in this manner contain anywhere from 60 to 90 percent of the P in the raw manure. Land application of treated liquid manure would provide nitrogen, phosphorus, potassium, organic matter, and trace nutrients to the land partially or wholly replacing commercial fertilizers. Alternative F-2 is shown in Figure 3.02-2.

- F-3. Anaerobic digestion followed by fine solids separation with ferric chloride and polymer addition.

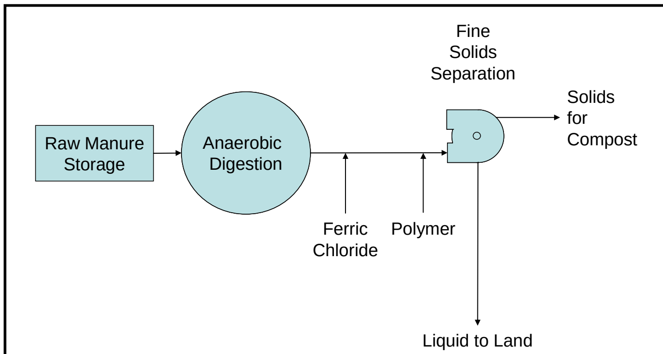

Figure 3.02-3 Alternative F-3

Raw manure would be collected and pumped to a mesophilic (86°F to 104°F) anaerobic digestion tank. Biogas generated during the anaerobic digestion process would be used to generate electricity. Solids would be separated from the digested manure after ferric chloride and polymer addition with fine solids separation. Dewatered solids would be composted or otherwise disposed. The liquid stream from the solids separation would be stored and land-applied. Treated liquid manure would provide nitrogen, phosphorus, potassium, organic matter, and trace nutrients to the land partially or wholly replacing commercial fertilizers. Alternative F-3 is shown in Figure 3.02-3.

B. Community Systems

All community alternatives must consider the means of manure transportation to the community system. Manure can be pumped or it can be trucked to a community facility. Raw manure would be difficult to pump long distances, but the liquid stream after solids separation could be successfully pumped. The Waunakee Cluster will be evaluated using the assumption that manure will be pumped to a central facility, and the Middleton Cluster will be evaluated using the assumption that manure will be hauled to a central facility. During farm visits, many farmers mentioned the inconvenience of trucking on nearby roads. They were sensitive to issues including spills, timing of manure spreading, wind direction, road conditions, road wear and tear, weekends, holidays, and community events. Pumping also has drawbacks since manure can be difficult to handle and can cause plugging and shortened equipment life.

Evaluations that include hauling manure will be evaluated for 2- and 5-mile one-way trips. This has been changed from the distances specified in the request for proposals because the farms in the Middleton Cluster are located within these distances and they correspond to the 30th and 80th percentiles of the overall reported maximum hauling distances. These distances better reflect what the farmers are currently doing.

For the purposes of this evaluation, it is assumed that sand will be separated from manure prior to delivery at the community site. Sand separation can range from settling in a lagoon to sand settling lanes to mechanical sand separation.

- C-1. Fine solids separation with polymer addition.

Raw manure would be collected at each farm and trucked or pumped to the community processing site. At the community facility, the manure would be dosed with polymer and processed through a fine solids separation unit that would result in two effluent streams, a solids stream and a liquid stream. The solids stream would be composted or disposed of otherwise. The solids stream would contain dewatered solids of approximately 20 to 30 percent dry matter. Solids dewatered in this manner contain anywhere from 40 to 50 percent of the P in the raw manure. Treated liquid manure would be pumped or trucked back to the farms to be land-applied to fields for the nutrient values (nitrogen, phosphorus, potassium, organic matter, and trace nutrients). Alternative C-1 is shown in Figure 3.02-4.

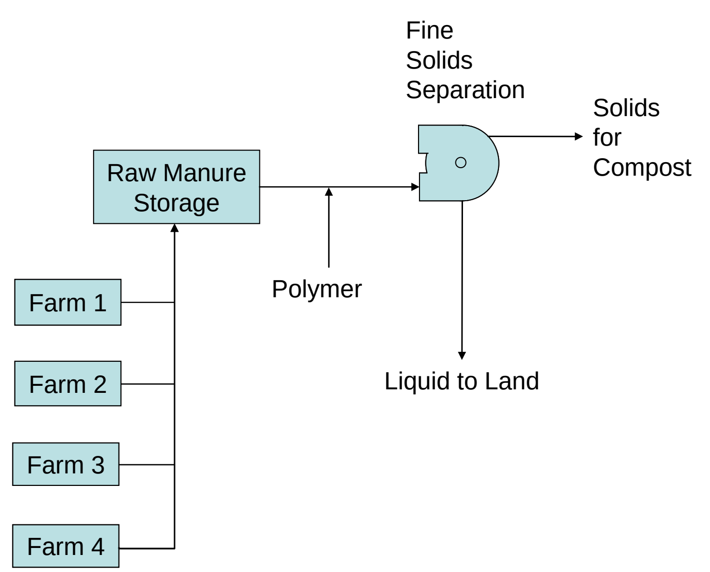

Figure 3.02-4 Alternative C-1

- C-2. Fine solids separation with ferric chloride and polymer addition.

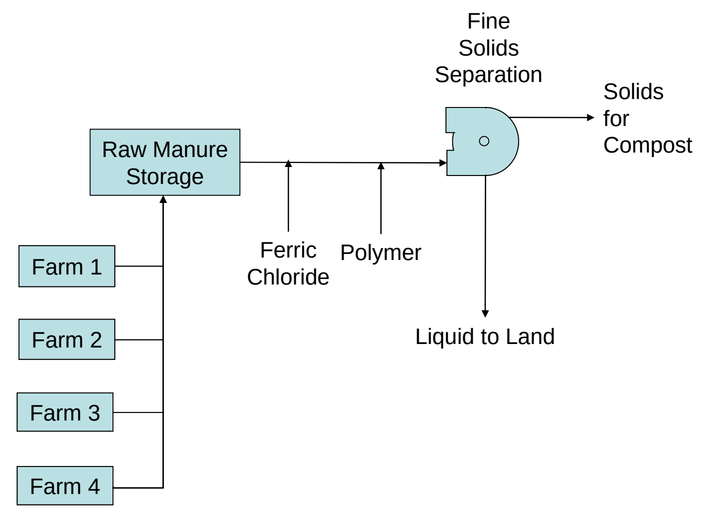

Figure 3.02-5 Alternative C-2

Raw manure would be collected at each farm and trucked or pumped to the community processing site. At the community facility, the manure would be dosed with polymer and ferric chloride before processing through a fine solids separation unit that would result in two effluent streams, a solids stream and a liquid stream. The solids stream would be composted or disposed of otherwise. The solids stream would contain dewatered solids of approximately 40 to 50 percent dry matter. Solids dewatered in this manner contain anywhere from 60 to 90 percent of the P in the raw manure. Treated liquid manure would be pumped or trucked back to the farms to be land-applied to fields for the nutrient values (nitrogen, phosphorus, potassium, organic matter, and trace nutrients). Alternative C-2 is shown in Figure 3.02-5.

- C-3. Anaerobic digestion followed by solids separation with ferric chloride and polymer addition.

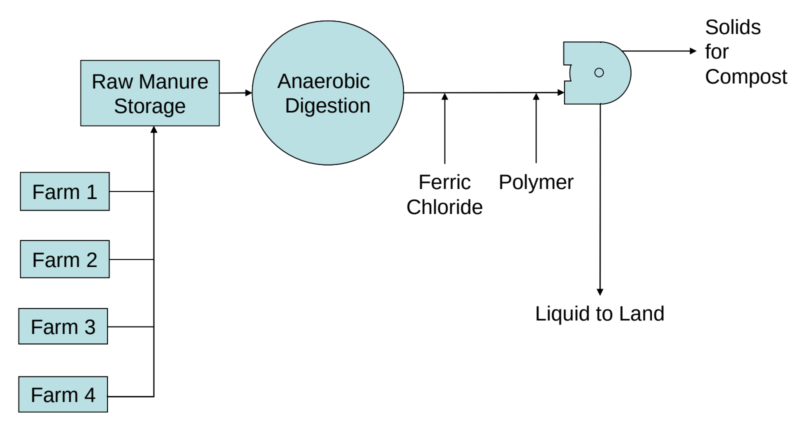

Figure 3.02-6 Alternative C-3

Raw manure at each farm would be collected and transferred to a 28-day mesophilic anaerobic digestion tank. The tank would be covered with a gas-collecting cover. Biogas generated during the anaerobic digestion process would be used to generate electricity. Solids would be separated from the digested manure with fine solids separation downstream of CPR with ferric chloride and polymer. Dewatered solids could be used for compost or other off-farm uses. Digester detention time and temperature would be selected to provide a high level of weed seed and disease-causing organism destruction because community systems need to prevent the spread of weeds and disease among different farms. Dewatered solids could be used for compost, as soil additives, or in other beneficial reuse products. Treated liquid manure would be pumped or trucked back to the farms to be land-applied to crop fields for use as a nutrient source (nitrogen, potassium, and organic matter). Alternative C-3 is shown in Figure 3.02-6.

- C-4. Fine solids separation with ferric chloride and polymer addition followed by a drier/pelletizer.

Raw manure will be treated with a community fine solids separation unit, and separated liquids will be treated with CPR as described in Alternative F-4; however, CPR will be optional for this alternative depending on the amount of P in the liquid stream. Separated solids will be processed in a drier or pelletizer. The unit will create a product that can be used as a soil additive or possibly a fuel. Farms will be able to use the treated liquid manure on their fields and be able to dispose of the P solids for beneficial reuse. This alternative is shown in Figure 3.02-7.

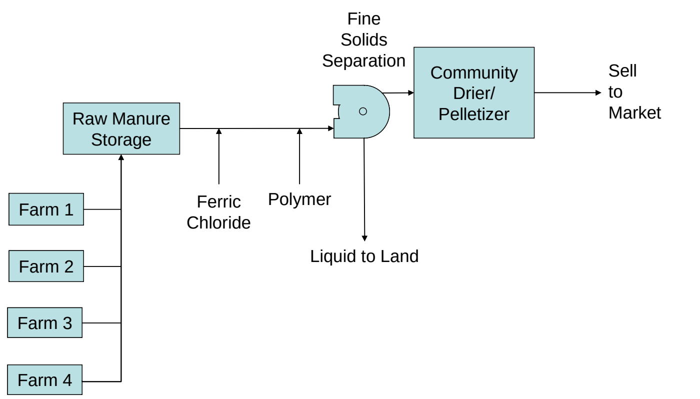

Figure 3.02-7 Alternative C-4

- C-5. Drying followed by combustion.

A portion or all of the raw manure or separated solids would be trucked or pumped to a community site where it would be stored prior to entering the dryer. In the dryer, water would be evaporated to the atmosphere. The resulting solids stream will be combusted creating ash and energy as byproducts. Some nutrients, specifically nitrogen, will be emitted to the atmosphere through the stack. The ash can be used as a soil amendment or possibly as an additive to concrete or asphalt. No byproducts will be returned to the farms, and farms will need to use other means of fertilizing. Alternative C-5 is shown in Figure 3.02-8.

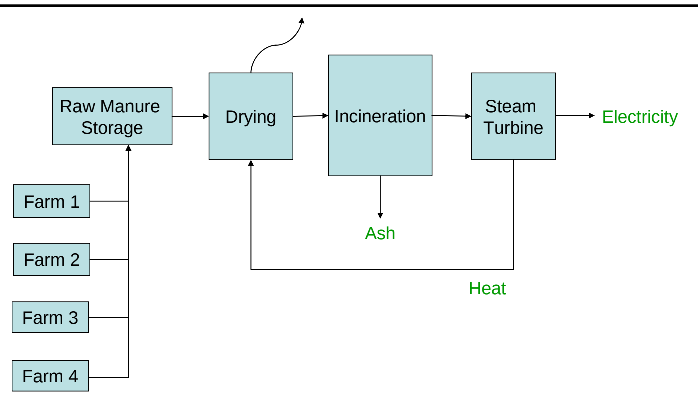

Figure 3.02-8 Alternative C-5