Aerobic Treatment of Manure Lagoons showing Environmental and Economic Benefits with Eco-System Service Paybacks

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Deliverables:

- Demonstrate eco-system service paybacks for aerobic reduction of methane and nitrous oxide emissions from manure lagoons.
- Validate new Eco-System Service paybacks through demonstration on 11 farm sites across three upper Midwest states.
- Evaluate and disseminate results showing environmental, economic and on-farm benefits of aerobic lagoon treatment (liquid composting) at demonstration sites.
- Develop new NRCS practice standards for aerobic treatment and management of livestock manure.
- Attend at least one NRCS CIG showcase or comparable NRCS event during the period of the grant.

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EXECUTIVE SUMMARY

This Conservation Innovation Grant successfully demonstrated innovative and affordable aerobic treatment for animal nutrient waste lagoons to meet designated NRCS environmental priorities, including:

- ✓ **Air Quality Priorities** by avoiding the formation of severe greenhouse gasses (GHG's) such as methane and nitrous oxide in lagoons and from field application of manure, by eliminating other noxious gasses, odors and pathogens and by reducing emissions from fossil fuel consumption required for agitating and applying nutrients on farm fields.
- ✓ **Water Quality Priorities** by retaining and transforming more manure nutrients into odor- and pathogen free, crop-ready, liquid fertilizer for direct application onto crops during the growing season, thereby avoiding fall, winter and spring applications onto farm fields and avoiding the production of nitrates.
- ✓ **Soil Quality Priorities** by delivering aerobic microbial soil amendments in large quantities to reverse years of lost microbial fertility in degraded soils as well as offering the potential to reverse phosphorous and potassium tie-up in soils.

This project installed a total of 100 floating oxygenation-circulator platform (OCP) units on lagoons at 11 animal production sites in Wisconsin, South Dakota and Nebraska to manage manure from over 10 million pounds of animal body weight. This was done to demonstrate the benefits, performance and reliability of continuous re-oxygenation and complete mixing of manure lagoons. At several sites, odor and pathogen free "safe water" was recycled for barn cleaning to eliminate gas and odor from the barn.

The project intended to provide enhanced air, water and soil quality from precision aerobic manure management while adding farm revenues to help pay for these eco-system services.

- **Air Quality Goals and Objectives** Specifically the project reduced or eliminated the production of
  - ✓ Severe GHG's, especially methane and nitrous oxide from lagoons and farm fields
  - ✓ Other gas and odors such as hydrogen sulfide, ammonia and VFA's
  - ✓ Pathogens, specifically measured as E. Coli
  - ✓ GHG emissions from consumption of fossil fuel during manure management

  Direct evidence from on site observations and data from demonstration locations, lab testing of manure samples and microbial matrix analysis clearly indicates air quality goals have been achieved.
- **The project reduced severe GHG's including methane and nitrous oxide** by supplying sufficient oxygen to inactivate methanogens while avoiding excess oxygen that would

support the formation of nitrite and nitrate, precursors for nitrous oxide. Microbial Matrix Analysis consistently reported methane producing methanogens as the lowest group of microbes. This group was consistently below 300,000 CFU/g compared with other microbial groups in the 10 million to 10 billion range. Desired levels of oxygen were specifically targeted within the ± 150mV ORP range to be maintained in the lagoon by means of total lagoon circulation. This level of oxygen supply requires less energy and avoids N-conversion into undesirable nitrites and nitrates. Nitrates can be undesirable because they are difficult to control in the environment. They move easily through the soil and readily denitrify under anoxic conditions, losing valuable nitrogen to the atmosphere. From an air quality perspective, production and long term storage of nitrites and nitrates in the lagoon or in the soil promotes nitrous oxide emissions. Lab samples consistently showed nitrate at less than 0.002% and reaching 0.0003% in demonstration lagoons.

- **The project reduced ammonia gas and retained more available-N for crops** by supporting conditions favorable for converting ammonia (NH3) to ammonium (NH4+). This reduced N-loss from ammonia volitilization, reduced emissions of ammonia (NH3), hydrogen sulfide and other PM precursors while retaining more manure-N in plant available, crop ready condition for direct application onto growing crops. Manure reports consistently show higher available-N, some with NH4+ reaching as high as 95% of total-N.
- **The project eliminated odor from lagoons, field application and barn cleaning.** The most reliable measure of potential odor is Volatile Fatty Acid (VFA's) found in the lagoon. VFA's in untreated manure lagoons are typically measured between 5,000 ppm and 10,000 ppm. Research has shown that a sensitive human nose is able to detect and identify odors from liquids containing as little as 250ppm of VFA. Below this threshold, odors are undetectable. Lab samples from aerobic demonstration lagoons consistently reported VFA's at or below 100ppm – indicating that no detectable odor could be produced.
- **The project reduced or eliminated pathogens from manure lagoons**. Not always discussed as an air quality issue, pathogens can become airborne when pit fans are turned or whenever animal wastes are applied to fields. E. coli is most often used as a measure for the presence or absence of other undesirable pathogens. E. coli levels in manure are typically found between 3,000-50,000 cfu/g. In demonstration lagoon samples E. coli consistently reported below 100 cfu and often below 10cfu/g, the infectious dosage limit for humans. Important limiting factors for pathogens are UV-sunlight, oxygen, low or high pH and dilution. These conditions are supported by oxygenation circulators.
- **The project planned to develop carbon credit protocols** to supplement farm income and help pay for improved air quality and other beneficial eco-system services provided by aerobic treatment. With the collapse of US carbon markets just as the project was getting under way, new carbon credit protocols were no longer being accepted. However, it had already become apparent that other significant aerobic revenues, both savings and income

would be available from improved farm productivity, less expensive, easier and environmentally better manure handling, more recovered nitrogen in ammonium (NH_4^+) form and increased crop yield from in-season fertigation (to name a few sources). Carbon credits may return for consideration in the future, but they are not the only source of additional income available to pay for aerobic manure management.

- **Aerobic Installations were completed at 11 sites** within budgets allocated for each site. Project funds were spent as anticipated with the exception of carbon credit components which were re-allocated to pay for identification of alternative revenue streams available to farmers who elect to use aerobic manure management. As a result of a more diversified approach, project outcomes have demonstrated a strong business case for the use of aerobic lagoon treatment to improve the economics and the management of manure for enhanced air, water and soil quality and improved profitability for livestock sites.
- **Demonstrating the reliability and performance of floating oxygenation- circulator equipment** was an important outcome from this project. After more than twenty years since floating circulators first appeared, earlier equipment had developed a reputation for failure to stand up to harsh conditions on manure lagoons and for failing to provide the amount of oxygenation and circulation required by high BOD manure. As a result, many farmers who hoped for the benefits offered by affordable aerobic manure management were skeptical of the reliability and performance offered by this type of equipment. During this project, equipment problems and machine failures were almost non-existent. Machines kept running under harsh conditions. Out of the entire 100 machines installed, only two manufacturing defects were encountered and were easily corrected. Oxygen and circulation stayed within desired ranges except on those ponds where minimum treatment was lacking or field and barn trash was allowed to enter the lagoon and rag up impellers. The equipment itself delivered desired performance with little or no signs of wear after 3 years of installed use. In high wind areas, several machines took on water from wave action. This was resolved by installation of an additional water seal around the lid.
- **An extensive list of benefits and paybacks from Aerobic Manure Management emerged**. Each is explained in detail in the body of this report. The project demonstrated significant air quality and other environmental benefits from aerobic manure management – while providing additional farm income to pay for improved ecosystem services. It was important to demonstrate how benefits and paybacks offset expense for improvements in manure management practice. Example paybacks discussed immediately below illustrate some of the savings and additional income available with aerobic manure management. Positive revenue outcomes were seen from eliminating lagoon agitation, increasing nitrogen retention and availability, reducing field application costs and fossil fuel consumption as well as increasing crop yields with fertilizer application when crops need nutrients most. EC levels were consistently below 12mhos and often below 6mhos, suitable for application directly onto mature crops and sometimes onto tender young crops.

- ✓ **Agitation**: With circulators installed lagoons can be pumped at any time without further agitation. A 10,000 place (25,000 pigs/year) swine finishing barn generates about 5,000,000 gallons of waste nutrient per year. At $0.01/gallon, field application costs about $50,000 per year. Often half this cost is lagoon agitation. Eliminating agitation saves about $25,000/year or about $1.00/year/pig through the barn. Circulators cost about $0.50/pig over 10 years, providing a 100% profit each year from agitation savings.
- ✓ **Nitrogen**: Total-N in swine lagoons typically averages about 4.4lbs/1000 gallons and is usually reported in the 25%--40% ammonium range. With aerobic circulators, one large swine facility reported total manure-N at 14.2lbs/1000 gallons with 85% ammonium. Nearly three times more total nitrogen than average lagoon and 2-3 times more ammonium in crop available form. The added value of more retained nitrogen can be easily calculated at a current fertilizer N-price of $0.69/lb at that time.
- ✓ **Fertigation**: Aerobic treatment transforms raw animal waste into crop ready liquid fertilizer to be sprinkled directly onto growing crops without odor or pathogens and without plant stress or leaf yellowing. EC levels below 12mhos and often below 6mhos made this material suitable for direct application onto mature row crops and sometimes on young or tender crops. With dry matter (DM) content of demonstration lagoons less than 1%, this material can be applied by center pivots without clogging nozzles. Center pivot application typically saves the farmer between $50 and $75 per acre and eliminates both the expense and the GHG's from diesel consumption for knifing or tillage.
- ✓ **Crop yield boost**: In addition, the farmer can expect a yield boost of 20bu-40bu more corn per acre from applying the same amount of crop-ready fertilizer at times when crops need nutrients most. This can only be done when manure is transformed into aerobic crop-ready fertilizer that won't burn or yellow the plants.

- **Aerobic soil amendments promise to improve degraded farm fields**. Microbial Matrix Analysis of samples from aerobic demonstration lagoons reported beneficial levels of Phosphorous and Potassium Solubilizing Bacteria (PSB and KSB) among other microbial groups. After years of repeat application, heavily manured fields can become burdened by high levels of P and K tied up in the soil. PSB's and KSB's from aerobic lagoons can release soil bound nutrients back to the crops and lower the levels of P and K tied up in farm fields.
- **Control of lagoon design and operation problems** were found to be critical elements in achieving good results at demonstration sites. Recommended practice standards with operations plans to support effective aerobic manure management have been prepared and are included in the Appendix to this report. A number of problems were observed:

- ✓ ***Where lagoons were undersized*** for the number of animals using the facility, where they did not offer adequate depth or surface area for circulation, or where they did not maintain the required minimum treatment volume (MTV), aerobic processes could not keep up with incoming waste. Manure sludge and solids build up in poorly designed or poorly operated lagoons. However, aerobic circulation still delivered noticeable gas and odor reduction at all demonstration sites, despite undersized lagoons.

- ✓ ***Where foreign matter was allowed to enter the lagoon,*** circulation was reduced. For example: afterbirth, hoof wrap, bale netting, silage bag or other plastic, tumble weeds or field trash entering the lagoon will rag up impellers and reduce circulation effectiveness. Screening influent sources, practicing good barn management, using trash lanes or settling ponds and placing farm field fencing of sufficient height around the lagoon help to prevent problem materials from entering the lagoon.
- ✓ ***Where biocides, disinfectants, harsh cleaning chemicals or antibiotics*** enter the lagoon, microbial activity can be reduced or inactivated and the lagoon may cease to function aerobically. Farmers were alerted that organic cleaning products should be used. Many were already using such products. Although several farms used feed grade antibiotics, these did not cause microbial problems in the lagoon. The hypothesis is that with continuous surface exposure from bottom-to-top circulation, UV sunlight degrades antibiotic residue. The project did not have the budget to conduct AB residue testing.
- ✓ ***Where equipment failed to maintain neutral pH***, due to reduced circulation from ragged up impellers and insufficient circulation, struvite can become an issue for farms in high magnesium areas that wish to recycle safe water for barn cleaning. Increased oxygenation and circulation can bring down pH and reduce struvite formation.

- **The customers and stakeholders** to benefit from this project include the farmers, farm workers and animals, farm families, rural towns and neighbors who benefit from better air quality and improved health as well as local and global environmental benefits arising from reduced agricultural Green House Gas (GHG) emissions. Demonstrations at each of the farm sites provided an active learning environment against which other farmers may consider and evaluate the likelihood of beneficial outcomes and profitable operations using aerobic manure treatment at their farm. It is critically important that interested farmers get the opportunity to make a thorough and informed decision.
- **The project provided a detailed evaluation of the economic costs and environmental improvements** from aerobic manure management systems. Valuable lessons were learned about the likelihood of successful aerobic installations fitted to existing manure lagoons not previously designed or managed for aerobic treatment. At least two participating sites were greatly disappointed after experiencing the benefits of odor-free lagoons for six to twelve months, when unsuspected foreign materials in the lagoon were resurrected out of the receding sludge at the bottom of the lagoon and ragged up the impellers. In one case, design of the lagoon 15 years earlier included landscape netting covering the sides of the lagoon presumably for planting. After sludge had been removed by aerobic digestion, pieces of partially decomposed netting began to emerge and rag up the impellers. At another flushed dairy, herdsmen commonly disposed of afterbirth, hoof wrap, plastic bags

and straw bale netting into the flush alleys. Of course these materials would quickly rag up impellers and reduce circulation. Aerobic service at these sites had to be discontinued until foreign materials could be cleaned out of the bottom of the lagoons.

- **Federal, State, and local support** to help expand odor-free aerobic manure management are worth serious consideration. Aerobic manure management has proved successful in reducing air quality impacts, eliminating noxious gas and odor for farmers, farm workers, neighbors and animals, thus improving the environment, health and quality of life in rural areas. Currently, with narrow livestock margins, many producers lack the capital to invest in new environmental projects. Federal EQIP funds combined with state and local programs would provide financing, technical and education support to help stimulate the transition to aerobic manure management.
- **We conclude** that well-designed and well-managed oxygenation circulator treatment systems on adequately-sized hog and dairy lagoons are effective and affordable in improving air quality, and reducing nutrient losses, environmental impacts and manure management costs. Aerobic treatment systems can prove financially attractive for farmers while providing enhanced local and global environmental benefits. But there are specific requirements for design and operation of aerobic facilities. The project employed reliable and innovative technology in the form of redesigned oxygenation circulator equipment. The technology enhanced existing farm sites by reducing greenhouse gas emissions, odors, and other volatile organic compounds as well as by providing improved and lower cost manure handling and field application alternatives. This technology is recommended for common use and New Aerobic Practice Standards are suggested for NRCS consideration.

INTRODUCTION

OVERVIEW: This Conservation Innovation Grant successfully demonstrated innovative aerobic manure management using low cost and low energy, floating oxygenation-circulator platforms (OCP's) placed on manure lagoons to meet designated NRCS priorities.

The project installed OCP equipment to demonstrate, evaluate, refine and validate the conditions for success of promising aerobic technology to provide enhanced air, water and soil quality. Floating oxygenation-circulator platforms were installed on selected swine and dairy manure lagoons at 11 sites across Wisconsin, South Dakota and Nebraska. Aerobic technology transforms raw manure into odor-free, pathogen-free, crop-ready, plant-available, true liquid fertilizer with EC levels at or below 12 mhos, suitable for fertigation directly onto field crops during the growing season.

Floating oxygenation-circulators draw oxygen deficient water up from the bottom and spread it across the surface of the lagoon in contact with atmospheric oxygen and direct UV sunlight. Since water is never lifted out of the lagoon and air is not forced into the lagoon, less energy is required. Less than one horsepower is needed to manage manure from 100,000 lbs of animal body weight. At design speed, this type of equipment will induce a toroidal vortex circulation of $9m^3$/sec, about 8 million gallons of water per hour and bring over 6,000 gallons/minute to the surface. (See Appendix for full description of the mode of action for this equipment.)

Sufficient units (100) and sites (11) were set up to provide a credible demonstration of the benefits, reliability and usability of aerobic technology under varied weather conditions on different farms. Sufficient time was allowed to verify results achieved year after year and show that equipment would perform reliably beyond the initial one year warranty period. The project was extended to cover a three-year time frame.

The project team included: Wm F. Tooley, BA, MA, PhD Studies, the Project Director with over 30 years of agricultural innovation research and consulting for global Ag corporations, government agencies, NGO's, farm groups and farmer associations. John Reis, PE, NRCS-TSP and former dairy farmer has over 20 years of experience in environmental and geo-tech engineering for agriculture and has worked in manufacturing quality control. T.J. Tooley, President of Ag Systems of Wisconsin has 50 years experience with innovative agricultural systems in the US, Canada and overseas. T.J. has used and recommended aerobic manure technology for over 20 years. Kerwin Miller, Ag Tec has worked with farmers on the profit side of CAFO operations for over 30 years. Margaret Bobertz, MA, has 25 years experience in research, business and grants administration and is president of The THULE Group.

PROJECT GOALS AND OBJECTIVES: The goals and objectives of the project were designed to address NRCS-CIG priorities in the following ways:

Severe GHG reduction. Environmental benefits included reduced production of severe greenhouse gases, both methane and nitrous oxide by maintaining a balanced supply of oxygen sufficient to inactivate methanogens but not enough to support the further conversion of ammonium to nitrites or nitrates – precursors of nitrous oxide. Conversion to nitrate requires more oxygen and therefore more energy. Oxygen supply in demonstration lagoons was targeted to maintain an Oxidation Reduction Potential (ORP) range of $\pm$ 150mV.

Methane reduction. Methanogens in demonstration lagoons were found to be very low from a microbial perspective, typically below 300,000 ug/ – less than 1/100th – 1/1,000 the cfu's for other beneficial microbial groups in the same lagoon.

Odor and noxious gas reduction. In addition to methane reduction, air quality included reduction or elimination of odors and noxious gasses. Aerobic manure treatment eliminated odor from lagoons, from flushed barns and during field application. The most reliable measure of odor production is the level of Volatile Fatty Acids (VFA'S) found in the liquid. VFA's in anaerobic manure lagoons typically range between 5,000 and 10,000 ppm or higher. Research has shown that a sensitive human nose is able to detect and identify odors from lagoon liquids containing as few as 250ppm of VFA. Below this threshold, odors are undetectable. Lab samples from aerobic lagoons in this demonstration consistently reported VFA's at less than 100ppm. This level of odor production is completely undetectable.

Pathogen reduction in manure lagoons. Not always discussed as an air quality issue, pathogens become airborne when pit fans are turned or when untreated animal wastes are agitated and applied to fields or recycled to clean barns. E. coli is often used as a measure for the presence or absence of undesirable pathogens. E. coli can survive in deep anaerobic pits and undisturbed lagoons and are typically measured between 3,000-50,000 cfu/g. E. coli samples in aerobic demonstration lagoons consistently reported below 100 cfu and most often below 10cfu/g, below the infectious dosage for humans. Important limiting factors for pathogens are exposure to UV-sunlight, adequate oxygen supply, low or high pH and dilution. Conditions adverse for pathogen survival are well supported by oxygenation circulators.

Paybacks and Economic Incentives were examined as a means to pay for improved air quality and manure management. It was hoped this might be done by tapping Carbon Credit dollars and other eco-system service paybacks to make superior aerobic treatment more affordable.

With the collapse of US carbon markets early in the project, new carbon credit protocols were no longer being accepted. However, it was already apparent that significantly enhanced farm revenue, both savings and income, would be readily available from aerobic lagoon treatment.

In addition to air quality improvements, including reduced human and animal health risks from odor, pathogens and improved quality of farm life, demonstration projects showed significant revenue paybacks from enhanced farm productivity including reduced manure management costs, more retained nitrogen as crop available ammonium (NH_4^+), reuse of livestock water for barn cleaning and rescue irrigation and increased crop yield from timely fertigation. Carbon credits may reappear in the future, but they are no longer considered the major source of additional income available to the farmer from aerobic manure management practices.

SCOPE OF PROJECT TASKS: The project installed floating oxygenation-circulator platforms (OCP's) on 11 manure lagoons across Wisconsin, South Dakota and Nebraska. Oxygenation-circulators draw oxygen-deficient water from the bottom and spread it across the surface of the lagoon into direct contact with UV sunlight and oxygen. Since water is never lifted out of the lagoon, very little energy – less than one horsepower – is required to fully oxygenate manure from 100,000 lbs of animal body weight. At design speeds, this type of circulator maintain total top to bottom lagoon circulation down to more than 30' and bring over 6,000 gallons per minute to the surface.

Work Plan Tasks:

(NOTE: Tasks 1 and 10-13 could not be completed due to collapse of US carbon markets.)

1. Develop Carbon Credit Protocol
2. Identify interested farm sites
3. Estimate likely costs at each site
4. Select promising sites
5. Establish agreements with owners
6. Design aerobic installations
7. Collect prior manure reports
8. Install/start up aerobic equipment
9. Test control devices/collect data.
10. Finish 3rd Party Protocol Verification
11. Collect full CC monitoring data
12. Register sites on Climate Exchanges
13. Collect and sell Carbon Credits
14. Collect in-season lab samples
15. Assemble system performance
16. Assemble data on farm benefits.
17. Analyze and report results.
18. Develop NRCS Practice Standard.

PROJECT FACILITAION AND FUNDING: The project was funded by a grant from the NRCS-CIG Program matched by cash contributions from the equipment manufacturer, the laboratories involved in providing manure chemistry and microbial analysis and the professional staff working on this project who themselves contributed 50% of their normal fees to the project as in-kind match.

In particular, recognition goes out to Ag-Source laboratories at Bonduel and Stratford, Wisconsin and to Microbial Matrix Systems laboratory of Tangent, Oregon. Recognition and appreciation is due to Mr. David Miller, Chief Science Officer for the Iowa Farm Bureau Federation and the AgraGate Climate Credits Corporation for generous help in planning this project and in offering support for the development of aerobic carbon credit protocols.

OUTREACH EFFORTS have included open-house events as well as visits and tours at demonstration sites. NRCS staff in three states, extensions personnel, Ag teachers and institutions, key industry players, local zoning and permitting authorities, state and federal politicians, other farmers and numerous members of the general public have been introduced first-hand to the concepts and practices of aerobic manure management. In general, the interest and response has been overwhelmingly positive.

One large open house, held early on at the Oak Lane Dairy near Alexandria, SD attracted over 500 visitors from around the upper Midwest, principally South Dakota, Minnesota, and Nebraska wanting to visit an odor-free dairy. They were not disappointed. It was a hot summer day and the only cool spot was inside the barn, in the bedding shed directly adjacent to the cows and their main traffic alley. Lunch was served in this portion of the barn.

A breeze blowing through the barn and directly into the lunch area was cooled as it swept across the wet barn floors, washed every 15 minutes by an automated flush system recycling "safe water" from the aerobic manure pond. People crowded into the lunch area to keep cool and chose seats for a good view of cow activity in the barn. Animals walked past the lunch tables. Some people sat close enough to touch the cows as they walked past. The floors of the barn were spotless. The cows were clean. There were no flies and no manure odors - only the sweet smell of fresh silage in the feed alleys. Since that time, the barn has been visited by hundreds more, including scheduled bus tours, Hutterite farmers from as far away as Montana and Alberta and visitors from England, Russia, India and China. The barn is featured on YouTube at "Oak Lane 8 row – warm flush dairy" and has been visited more than 7,300 times.

Needless to say this was a significant and memorable event. Permitting agencies, local authorities, neighbors, farm families and others were strongly attracted by the appeal of odor-free agriculture. The appeal of odor free livestock production is undeniable.

During this project, Temple Grandin, world renowned livestock expert and animal care specialist, was asked her opinion of the next important frontier for improvements needed in livestock agricultural. Without a moment's hesitation she replied, "Gas and odor in the barn! Animals suffer from it. And they do not perform well."

BACKGROUND

What problem did the project intend to address?

For more than 100 years, engineers have known that aerobic treatment offers a superior pathway for the stabilization of waste and the elimination of noxious gas and odors.

Aerobic microbes provide more rapid and complete decomposition and give off only CO2 and water. They produce no bad odors, noxious gasses, PM precursors or severe GHG emissions. They work faster, even in cold climates. Each year's waste production must be ready for use in the next growing season. Aerobic microbes quickly stabilize manure nutrients into odor-free, crop-ready liquid fertilizer to provide plant available nutrients for precision application.

Until recently, however, it has always been presumed that aerobic manure treatment was too costly and energy intensive for use on the farm. This was true for older aeration technology using high horsepower blower systems. With new energy efficient oxygenation-circulator technology, energy use no longer stands in the way of on-farm aerobic manure treatment. Experience shows a single oxygenation-circulator operating at less than one horsepower can provide complete aerobic treatment for manure coming from 100,000 lbs of animal weight. This means decomposition of manure from about 70 Holstein dairy cows or 700 finisher hogs. The total cost of OCP ownership and operation is about $16 per dairy cow per year or about $0.50 per finished hog over ten years. Payback available far exceeds the cost.

Aeration-by-circulation has matured into a reliable, low cost, low energy aerobic technology. However, challenges to acceptance of this technology remain. Principle among these:

- after decades of untreated manure, the idea of odor-free lagoons is not obvious,
- expecting farmers can always pay for environmental improvements is naïve,
- attentive supervision to avoid on-farm neglect and errors is essential,
- proof that lower cost and less effort can deliver better results and more profits

A brief account of previous attempts to solve the problem

Anticipating the need for improved air quality, earlier generation aerobic circulators were installed at livestock sites in South Dakota, beginning in 2006. Installations delivered promising results - and some failures. Manure management shortcuts were taken. Mistakes were made. Equipment failed. It became apparent that better technology must be demonstrated on more different farms before acceptance could be expected. Even promising technology must offer proven payback to reward farmers and help them pay for doing the right thing.

BROWN COUNTY, SD taken Nov 30, 2006 - Circulators working on a lagoon in winter

This Three Acre, 24 Foot Deep Lagoon receives manure from 18,000 pigs in barns shown. After six months: Clear blue water. No odors. No solids.

When circulators were installed June 1st, 2006, the lagoon had 9 feet of solids in the bottom. After 5 months, solids were completely eliminated, odor and pathogens were gone. Blue water contains plant-available fertilizer ready to sprinkle on growing crops.

Pictures of dramatic success alert farmers to new possibilities. But for new aerobic technology to be accepted on the farm, several things had to happen:

1) Paybacks must be proven to provide the funds to pay for the effort.
2) On-farm trials must document success at varied farms in different locations.
3) Monitoring must ensure attentive management and avoid costly problems or mistakes.

How are manure air quality problems usually dealt with today?

On-farm manure gas, odors, GHG's and pathogens have been largely ignored. Since no effective options for overcoming these problems appeared available, odor and gas were part of doing business on the farm. Sometimes referred to as the "smell of money," farm odor and gas were generally considered a normal condition of the agricultural way of life.

Numerous partial solutions to control manure gas and odors have been tried. The outcomes from partial odor control efforts provided some reduction and limited relief from gas and odor, but offered no payback to offset the costs of that effort.

In farming terms, proposals that do not pay for themselves are non-starters. Without proven paybacks, the farmer cannot afford to incur additional costs for improved practices. Air quality issues, like many other manure management problems, have continued without solution.

Since aerobic manure management had not yet been demonstrated to achieve desired results at affordable cost, farmers did not see any real option. Farm workers, their families and neighbors as well as the farm animals themselves, were simply required to put up with gas and odor in their environment. Full aerobic manure treatment, utilizing oxygenation by circulation, now appears to provide a complete, energy efficient and affordable solution for air quality concerns and other environmental issues on the farm.

What agriculture or environmental sectors would benefit by this project?

Livestock producers, crop farmers who apply livestock manure to their fields, land owners considering livestock production to enhance farming operation and most of all farm workers, their families and rural neighbors will all benefit from more profitable and more effective gas, odor and pathogen-free manure management.

Lessons in more effective manure waste treatment and water recycling may help provide better municipal waste systems for small towns and villages at reduced cost, with improved results.

The global environment will benefit from reduced GHG emissions in agricultural operations around the world.

The consumer will benefit not only from improved air quality in general, but from lower food prices offered by better recycling of more waste nutrients, less costly methods for on-farm manure management and better re-use of water.

What natural resource issues are addressed?

1. ***Precision Nutrient Management:*** Aerobic methods decompose animal manure more rapidly and completely. Odor, pathogens and GHG's are reduced or eliminated. Crop-ready fertilizer can then be applied by center pivot, travelling gun or tanker directly onto growing crops. Farms involved can develop more precision nutrient management plans based on nutrient availability and soil sampling with more precise application of crop-ready nutrients targeted to crop yield goals and adjusted for weather and plant growth stage.

2. ***Improved Water Quality, Quantity and Reuse:*** Application of nutrients directly onto growing crops reduces the risks of leaching and runoff into aquifers or surface waters. This precision approach allows more flexible and accurate use of nutrients and avoids over-application that can occur especially when unexpected dry weather follows. Aerobic treatment supports a new paradigm that avoids injecting and storing anaerobic manure in soils or spreading un-decomposed raw manure onto wet or frozen ground. In this paradigm, in-season fertigation replaces spring or fall agitation, injection and knifing or winter spreading.

3. ***Improved Air Quality*****:** Aerobic treatment of lagoons reduces the production of severe GHG methane and nitrous oxide and reduces or eliminates pathogens, odors and noxious gasses. By avoiding long term storage of nutrients in the soil, production of nitrous oxide from manured fields can be avoided. In addition, pathogens like E. coli were reduced or eliminated from lagoons prior to field application.

4. ***Improved Soil Quality and Fertility*****:** Applying fully aerobic microbial material to the soil promises to return degraded soils to their full fertility and recover P & K tied up in the soil.

5. ***Improved Energy Efficiency of Land-Based Agriculture*****:** Lagoon agitation, knifing and injection of manure or tillage for incorporation are costly and energy intensive, often reaching $50-$75 per acre or more. Distribution of crop-ready nutrients by center pivot fertigation costs only about $15–$25 per application acre. It is estimated that fertigation onto growing crops using center pivots or travelling guns saves more than 75% of the fossil fuel typically associated with agitation, knifing or injection and tillage of manure and is compatible with no-till farming.

6. ***Enhanced Conservation Technology Transfer*****:** NRCS practice standards for Aerobic Manure Management have never been fully developed by the NRCS, perhaps because no affordable aerobic treatment was available. Aerobic practices have long been considered too costly for farm use. Recommended aerobic manure management practice standards in this report take agriculture one step closer to creating the knowledge and incentives for more farmers to make use of superior aerobic environmental technology for improved manure management and enhanced farm profitability.

Negative effects of manure management air and water quality problems on the environment, community, or producer's economic and personal welfare:

Most livestock producers and agricultural engineers have been guided by manure management practices used by their fathers and grandfathers over 50 years ago. In light of today's more demanding environmental expectations, traditional manure management practices pose increasingly difficult environmental challenges for livestock agriculture in their efforts to recycle animal wastes for crop nutrition. Storing raw manure in untreated lagoons starts a cascading succession of events that becomes increasingly difficult and costly and makes it impossible to achieve sustainable environmental and economic outcomes in agriculture.

Negative consequences of untreated manure storage and application include the following:

- **Noxious gases and odors** cannot be prevented. A number of these pose threats to both human and animal health.
- **Severe Green House Gas and Particulate Matter (PM) Precursors** especially methane and nitrous oxide as well as ammonia and hydrogen sulfide are emitted from untreated lagoons.
- **Human and Animal Pathogens** survive in anaerobic conditions, and are distributed by barn fans, released by agitation and carried along with manure during field application.
- **Loss of Nitrogen** from storage due to ammonia-N volatilization means increased reliance on costly and fossil fuel intensive factory nitrogen with its high carbon footprint.
- **Agitation of manure slurry** releases bursts of odor, green house gases and pathogens into the atmosphere and requires consumption of significant amounts of fossil fuel.
- **Fall, winter or spring manure applications** are common because untreated manure requires travel across the field as well as incorporation, injection or knifing into the soil which cannot be done when crops are in the fields. Off-season application stores nitrogen in the soil for a longer time and is known to produce nitrous oxide, a severe GHG. Organic nitrogen placed in the soil easily converts to nitrate which is prone to leach out or run off the field.
- **Storage of P and K in the soil** before crops arrive encourages the tie up of these nutrients making them less available during the growing season.
- **Putting high BOD manure directly into the soil** reduces soil oxygen and stresses or inactivates aerobic soil microbes and fungi needed for fertile crop production.

These undesirable events and activities are inevitable with storage of raw untreated manure and traditional forms of field application. Even with the use of anaerobic digesters, the farmer's environmental challenges in managing and storing effluent exiting from the digester remain. In fact, recent research indicates that odors and gases from highly excited post-digester anaerobic effluents may present stronger odors and worse air quality issues than manure stored without going through the digester.

Specifically, six dairy and five swine sites were selected and agreements established with owners. A total of 100 oxygenation-circulators with remote Internet control systems were installed on these manure lagoons. Each individual circulator was monitored and controlled via the Internet from a central site to ensure that units ran at design speeds and to alert service teams when attention might be needed. Circulators supplied continuous oxygenation and circulation within the lagoons providing support for aerobic decomposition while anaerobic bacteria, especially methanogens, faced a hostile environment and did not thrive.

Lagoon samples were taken during the growing season to verify that aerobic microbial counts remained high, anaerobic counts were low and methanogens counts were very low. Therefore, methane, odors, ammonia, hydrogen sulfide and other Particulate Matter (PM) precursors normally produced by anaerobic bacteria were reduced. The project prepared a new NRCS Aerobic Practice Standard that might also be considered for EPA Environmentally Superior Technologies (EST) designation.

Carbon Credit Markets – About one year after the project began, the chief science officer for *AgraGate* Climate Credits Corp, the carbon credit partner in this project reported that the Chicago Climate Exchange (CCX) had stopped accepting new carbon credit protocols due to uncertainty in US carbon markets. Even after the passage of the California Cap and Trade legislation which extended their system to other states, it was apparent that the market was not large enough to make a business case for the cost of new protocols or aggregating marketable credits from outside that state. *AgraGate is no longer developing new protocols or soliciting new carbon credits. Consultations with other carbon credit advisors reached the same conclusion. New North American carbon credit protocols were no longer viable for development at this time.*

The collapse of US Carbon Markets early in the project made the goal of developing aerobic Carbon Credit Protocols unattainable. The original purpose for carbon credits in this project was to offer farmers a way to pay for improved eco-system services and environmental improvements, especially air quality and GHG improvements. Very early in the course of this project, alternative eco-system service paybacks were identified from varied aerobic scenarios other than carbon credits. These alternative paybacks promised to far exceed the value thought likely to be available through carbon credits themselves.

Eco-system Services payback alternatives are outlined and quantified in the findings of this report. In addition, the report recommends that EPA/USDA promote aerobic BMP's and provide Practice Standards that support efficient and economical aerobic treatment.

Despite the collapse of carbon credit markets, outcomes from the project continued to signal the promise of strong success. In particular, it became apparent that new aerobic manure management technologies offer tremendous environmental benefits from the reduction of severe GHG's such as methane and nitrous oxide, along with other air quality and environmental improvements including odor reduction, water quality enhancements and degraded soil recovery. In particular, aerobic treatment offered promise for reduction of high phosphorous levels in heavily manured farm fields. It was readily apparent that significant farm efficiency and productivity enhancements were available to provide paybacks for the improvements in eco-system services available from aerobic nutrient waste management. These paybacks are itemized in a later section of this report.

Step 1. **Identify interested farm sites** – Despite the loss of carbon credit incentives, farmers still desired manure odor and gas reduction and responded positively to the invitation to participate in the project. This step was substantially completed by the fall of 2010. One new site emerged after that time. The new site offered the opportunity to test aerobic procedures and outcomes for a small, newly constructed aerobic lagoon on a 450-sow farrowing operation in Nebraska. The site is operated by a young farmer and his family who appreciate the health and quality of the life benefits of an odor-free farrowing facility. Although originally not including Nebraska, Federal and State level NRCS approval was received and paper work completed.

Step 2. **Estimate likely costs at each site** – Inspection of livestock lagoons at interested locations was interrupted by the early onset of winter and delayed by wet springs two years in a row. The principal concern for inspection is that lagoons need be of adequate size to support aerobic treatment and storage and that foreign material is not present and is prevented from entering the lagoon. Of special interest was to ensure that the farm was not using harsh chemicals, disinfectants or anti-microbials that might inhibit the growth of aerobic bacteria in the lagoon. At least one producer planned to re-size his lagoon for enhanced aerobic treatment. Average costs of installations remained within budgets anticipated.

Step 3. **Select promising sites** – Selection of all sites had been completed by fall 2011 including five dairy and one pig site in Wisconsin and four pig sites, and one other dairy in South Dakota. One small farrowing site in Nebraska was also selected. No problems were encountered documenting EQIP eligibility. After initial acceptance of participation, withdrawals were received from three other sites as a result of owners changing their minds about participation or for other reasons. For example, one large pig site under consideration simply sold their pigs and decided to exit the business due to adverse hog markets.

Step 4. **Establish agreements with owners** – Agreements were signed and returned by all participating owners. A few details were negotiated with sites where inspections indicated a need for some minor changes in manure management if aerobic treatment at those operations were to prove successful. Getting management changes at livestock facilities is never easy.

Step 5. **Design aerobic installations** – Installation designs were completed for all sites. The design for the proposed Nebraska site awaited confirmation of construction details for the new lagoon. Each site had different numbers of animals, with different lagoon arrangements and different delivery of manure from the barn. Each location required a specific design for the installation of aerobic circulators at that site. Severe crust build up was worrisome at one dairy site where straw or wood shavings are used for bedding and solid separation was not used. This type of site might require a different circulator strategy and/or different microbial inputs. Several microbial suppliers offered to provide bacteria for lignin and cellulose. As it turned out, these were not necessary. Where adequate minimum treatment volume was available in the lagoon and circulators were able to run at design speeds, circulation prevented a straw or shavings crust from forming and the lignin and cellulose materials were rapidly digested.

Step 6. **Collect and test lagoon samples** – Final aerobic manure sample testing began in the spring of 2012. Reports from all sites showed increases in crop available ammonium (NH_4+), often two-three times normal. During three consecutive months in which samples were collected at one site, ammonium increased from 40% to 90% of total N. Microbial Matrix Analysis was utilized to identify and quantify functional microbial groups that supply important eco-systems services to the soil and are supported by aerobic treatment ponds. Microbial Matrix outcomes are reported in the findings sections of this report.

Step 7. <u>Install/start up aerobic equipment</u> – All required equipment had been purchased and installed by the spring/summer of 2012, in time for testing during the final growing season. Installation procedures worked well, especially with the addition of a work barge to provide a safe platform for workers on the lagoon. Equipment has run reliably on all sites, except when Internet and power outage issues were a problem or where foreign materials had entered the lagoon and created problems with impellers ragging up. The circulators showed no signs of wear and there has been no trouble with motors burning out. Damage to a few machines and to several control systems occurred due to lightning strikes and fluctuations or surges in power supply. High winds caused slight damage when several machines took on water. On one lagoon, equipment was inoperative for the winter months after power interruptions shut down the system and repairs could not be made until the ice melted. At one dairy that had regularly experienced stray voltage issues with their power supply, circulator equipment was reset to run in manual mode to avoid the possibility of stray voltage from VFD control panels. These manual settings proved to run well for the duration of the project.

Step 8. <u>Test Monitoring Systems and Collect Data</u>. Internet systems for monitoring aerobic equipment on lagoons proved more difficult than anticipated. The installed systems provided equipment observation and stop-start-reverse-rpm control via the Internet. The problem was the lack of continuous, stable Internet service and power supply. It turns out that Internet services as well as power supply in rural areas can be spotty and often unreliable. As a result, communication was interrupted numerous times at nearly every site. Too often problems were not cured remotely and a service call was required to restore Internet observation and control.

Steps 9-13. <u>Carbon Credit Development:</u> Protocol verification, monitoring, registration and carbon credit aggregation could not be completed due to the collapse of US Carbon Markets. Other eco-system service paybacks were identified to replace the proposed carbon credit market to provide alternate sources of pay for aerobic manure treatment. Detailed discussion of eco-system service payback alternatives are found elsewhere in this report.

Step 14. <u>Lagoon Samples</u>: When available, prior manure reports were collected from farmers. It was hoped these samples would provide a rough idea of what might be considered the usual condition or starting point for that lagoon and therefore what might be accomplished. It was soon discovered, however, that the starting point for each lagoon was different each season. Nevertheless, nutrient samples were taken from time to time. In general, lagoon samples show higher Total Nitrogen levels and, in particular, higher crop availability ammonium-N. Aerobic plate counts were assessed to verify counts remain high. E. coli counts are taken to show pathogen reduction and typically reported very low or undetectable pathogens. VFA counts were taken to measure odor production potential. These typically showed VFA levels at or below 100ppm, well below detectable odor thresholds of 250ppm VFA's for the human nose. And finally Microbial Matrix Analysis verified that methanogen counts were very low.

Step 15. <u>System Performance and Reliability</u>: Of particular importance to farmers who might wish to consider aerobic manure management are results showing that the equipment itself was reliable and that the system can be kept operating year-round. Demonstration outcomes for equipment performance show that circulators themselves were very reliable and tolerant of adverse conditions found at manure lagoons. However, without proper methods in place to prevent problem materials from entering the lagoon, impeller rag up will reduce circulation. Nevertheless, demonstrations assured users of the reliability of aerobic circulators and system operations when proper steps are taken to manage materials that might enter the lagoon.

Step 16. Farm Benefits: The project provided evidence of a wide range of benefits and paybacks to farm users from aerobic manure management systems. Data on these benefits are assembled and reported in subsequent sections of this report.

Step 17. Analyze and report results: Outcomes are provided throughout this report.

Step 18. Develop NRCS Practice Standards: Recommendations for EQIP Aerobic Practice Standards are provided in the Appendix and Technology Review sections of this report.

What is innovative about the Project?

Floating oxygenation-circulator platforms (OCP's) have been around for over 20 years. A few well designed machines have provided outstanding and efficient aerobic treatment of manure. Unfortunately, 0CP's have earned a reputation for being unreliable. In addition, design standards for aerobic systems utilizing oxygenation by circulation were never well understood.

The equipment selected for this demonstration was a third generation device, designed to run economically and manufactured specifically to overcome the reputation gained by this type of equipment for unreliable service in manure lagoons. A newly patented design also claims to outperform other OCP's by creating increased oxygen transfer and increased exposure to UV sunlight at the surface of the lagoon. Nevertheless, the principal benefit demonstrated by this equipment was reliable service in harsh lagoon environments.

To overcome chronic problems with on-farm management of aerobic lagoons, innovative Internet-based monitoring systems were installed to allow each OCP unit to be observed and controlled from a central location. This allowed observers to respond to situations that might otherwise go unnoticed or untended, often for long periods of time.

Problem situations arise from widely varied sources, including pumping down too far, power failures with lack of restart, severe lagoon evaporation and loss of minimum treatment, and foreign materials entering the lagoon, ragging up impellers, and thereby reducing circulation effectiveness. Besides video observation, the remote system was capable of stop-start-reverse to clean off impellers and control rpm speed to adjust circulation in response to changing water viscosity, water temperature and microbial demand during each season of the year.

The project also proved innovative in recycling animal waste by shifting nutrient applications to the growing season and away from the traditional fall-winter-spring cycle. Aerobic nutrients in crop-ready condition can be sprayed during the growing season when crops are in the field. In addition, several sites recycled odor-free, pathogen-free "safe water" from aerobic lagoons to clean their barns and reduce in-barn gas and odor.

Compare innovative portions of the project to existing practices.
Important environmental and economic differences are apparent when innovative aerobic manure management options are compared to traditional practices.

- **Continuous lagoon circulation replaces agitation** with reduced cost, labor, equipment, fossil fuel consumption and set-up expense. Lagoon agitation normally represents about half the cost of field application. With continuous, low power aerobic mixing, manure nutrients are maintained in odor-free, pathogen-free, crop-ready, true liquid form to be sprinkled onto growing crops at any time without need of agitation. Savings from eliminating agitation alone pays back more, often two times more than the annual ownership and operating costs of aerobic lagoon circulators over a 10-year period.
- **More Crop Available Nitrogen** has typically been seen, reaching 75%-95% ammonium. Studies show anaerobic lagoons average 4.2lbs of Total-N per 1,000 gallons due to N-losses from ammonia (NH_3) volitilization. Several aerobic demonstration lagoons reported two-three times more lagoon-N, mostly converted to non-volatile, crop ready, liquid ammonium (NH_4^+). At a price of $0.69/lb, 2-3 times the available N in a typical 10 million gallon lagoon can easily add $28,980 to $57,960 of crop-ready N-value to the lagoon each year.
- **Field Application** cost can be reduced by more than 50% below typical cost of knifing and injection by eliminating tillage and fossil fuel consumption for incorporation. Manure application costs of $0.0075 - $0.0125 per gallon are common, and often reach $50 - $75 per acre (not including lagoon agitation) where 7,000 -10,000 gallons per acre are applied. Nutrient distribution by center pivot costs about $25-$35 per acre factoring in the pivot cost over 20 years. Aerobic lagoon liquid maintained in crop-ready, odor-free, pathogen-free, true-liquid form typically exhibit less than 1% dry matter for trouble free pumpability. Typical EC readings of less than 12 mhos, and often less than 6 mhos, avoid stressing or yellowing crops. Nutrient application through center pivots will save $5,000 - $10,000 per pivot in annual application cost and avoid fall, winter or spring manure applications and avoiding soil compaction.
- **Precision Crop Nutrient Applications** can avoid nutrient losses, especially leaching and run-off, caused by changing weather and drought. The biggest gamble of any fertilizer application is that the weather may change after nutrients have been applied. With less rainfall, crops utilize fewer nutrients and excess nutrients are left on fields to leach out, run off or tie up in the soil. By waiting to apply nutrients until after the crop is growing, loss of field applied manure nutrients can be reduced or avoided. Applying aerobic lagoon nutrients with ¼ - ½ acre-inch of water will ensure sufficient moisture so that nutrients are incorporated into the root zone and will be taken up by the crop. Because 75%- 95% of manure-N in aerobic demonstration lagoons had been converted into crop-ready ammonium (NH_4^+), these nutrients can be taken up immediately.
- **Crop Response and Yields** are typically increased by 10% - 20% when the same amount of crop-ready fertilizer is applied at growth stages when crops need nutrients most. Our grandfathers learned this from side-dressing. With today's genetics, however, even greater response is available from late season nutrient applications when crops may be too tall for side dressing. Late season applications are easily accomplished by spraying crop-ready aerobic lagoon nutrients directly on growing crops via fertigation. At today's $7/bu corn, late season nutrient application boost crop income by $140 to $280 per acre, using just-in-time fertigation with precision distribution at lower application cost.

- **Rescue Irrigation** has become a paramount consideration in dry land farming. Recent National Climate Assessment indicates that more rainfall is arriving in fewer weather events, usually in winter and spring, and water may disappear from the soil during increasingly hot summers before crops can utilize it. To adjust for such events where irrigation wells are not available, crop-ready lagoons can become an important source of recycled water. Increasingly, farmers are learning the value of a rescued crop. Now they can turn to crop-ready aerobic lagoon water for their irrigation source.
- **No-Till Farming** often avoids applying manure on no-till fields because it requires knifing, injection or tillage to incorporate raw manure into the soil. Tillage disturbs the no-till seed bed, damages soil tilth, disrupts microbial and fungal eco-systems and reduces soil fertility. Heavy equipment across no-till fields also causes yield robbing compaction. Utilizing aerobic lagoon water, manure nutrients in crop-ready form can be applied on no-till fields via center pivots during the growing season with no compaction or disturbance to soils. Aerobic nutrients also carry aerobic microbial supplements into the field to add additional support for the eco-systems at work in no-till fields.
- **Soil Compaction** from heavy equipment travelling over farm fields can reduce crop yields, studies show, by an estimated 20%-30%. Soil compaction is avoided by applying nutrients through center pivots or travelling guns. Spraying raw untreated manure liquids in this manner may not be well tolerated by crops, by neighbors or permitting authorities – unless the material is crop ready, odor-free and pathogen-free as demonstrated in aerobic lagoons.
- **Degraded farm fields** have lost significant soil fertility. Years of traditional tillage and commercial fertilization have had the effect of robbing soils of humus and tilth while disrupting and drying out microbial and fungal eco-systems in the soil. Placing high BOD manure in the soil robs oxygen and inactivates aerobic microbes in the soil. Heavily manured fields can become burdened with high phosphorous and potassium tie-up after years of storing manure in the soil. All three of these conditions benefit when PSB's, KSB's and other microbial soil amendments from aerobic lagoons can be field-applied without tillage and without depleting soil of oxygen and moisture.
- **Nuisance lawsuits** filed against farmers for odor and pathogens are increasing. With aerobic lagoon treatment, manure lawsuits may become a thing of the past. Currently, producers are advised to expect legal attacks and that defending against such actions can easily cost $250,000 just to fight the case. Recent court awards have mounted into the tens of millions of dollars per case. Without odor, gas or pathogen emissions from manure, there is no case to be made against farmers.

In summary, the fate and transport of potential manure pollutants can be completely altered by affordable and innovative aerobic lagoon treatment technology.

- **Production of severe GHG methane and nitrous oxide** have been reduced or eliminated by a balanced supply of oxygen throughout the lagoon.
- **Noxious gases and odors** that affect human and animal health and impact quality of life have been largely eliminated.
- **E. coli and other pathogens** have been reduced to insignificant levels that no longer pose a threat to human or animal health.
- **Loss of nitrogen** to the atmosphere has been reduced or eliminated by converting and retaining manure-N as ammonium, avoiding ammonia gas production and volatilization. It is important to note aerobic conditions in circulated lagoons work against conversion

of ammonium to ammonia, even after the effluent is land-applied. Timing of application is also helpful, since aerobic lagoon effluent can be applied during the growing season.

- **Risk of nitrogen leaching out and phosphorous running off** manured fields can be avoided by precision application of aerobic nutrients directly onto growing crops.
- **Tie-up and accumulation of phosphorous and potassium** in the soil may be reversed by microbial solubilizers (PSB's and KSB's) as soil amendments from aerobic lagoons.
- **The necessity for fall, winter or spring application** can be completely avoided.

Marketing an alternative product:
While not intended and not formally assessed during this project, not all livestock producers are crop farmers. Many may actually have little or no crop land themselves. These producers sell (or give away) their animal nutrient to neighbors for crop fertilization. The availability of odor-free, pathogen-free, crop-ready, true liquid fertilizer, with higher ammonium levels, that is pumpable and can be applied at any time during the growing season was very attractive to nutrient users. New arrangements are being negotiated, including the use of center pivots and travelling guns to replace heavy equipment for agitation, hauling, spraying and knifing or injection of manure in fall, winter or spring. This new aerobic nutrient product appears to have greatly increased value and appeal to end users.

Describe what the producer had to do differently to accommodate the project.
Changes in manure management practice at demonstration sites were not required to accommodate aerobic treatment. However, a number of things were done differently:

- ✓ **Monitoring of lagoon conditions and maintenance of aerobic equipment** was done, not by the farmer, but by the project team. In cases where the lagoon was undersized, pumped down too far, or where evaporation during drought conditions depleted the available minimum treatment volume, water was added back into the lagoon. With summer application when growing crops need nutrients most, many farmers welcomed the immediate availability and more frequent distribution of nutrients onto crops.
- ✓ **Continuous aerobic mixing** eliminated the need for lagoon agitation. Participants found the cost, labor, set-up, fuel and equipment needed for nutrient applications were significantly reduced, in most cases cut in half. Savings from agitation alone were found to more than pay for the capital cost as well as the installation and operation of aerobic oxygenation-circulators on demonstration lagoons.
- ✓ **Crop ready nutrient applications during the growing season** did not burn or yellow tender crops. As a result, one dairyman achieved a 25% increase in alfalfa production requiring an extra cutting of alfalfa during the summer growing season.
- ✓ **Odor-free nutrient applications** had welcome outcomes. The same dairy producer was able to spray apply nutrients directly behind his neighbor's house while she sat on the porch with the breeze blowing in her face and a telephone in her lap, ready to register immediate complaints about odor. None were made.
- ✓ **Lagoons can be easily pumped**, without needing to stop often to clean the river screen. Unfortunately, after 18 hours of trouble-free pumping, the applicator failed to stop pumping, only to discover the barn would not flush until he refilled the lagoon.
- ✓ **Lagoons need to be refilled – slowly**. Low oxygen water added back into the lagoon too fast will stress the aerobic biomass and it may take several weeks before the lagoon recovers. In a flushed dairy barn, this will make the barn floors very slippery.

Supplemental bacteria were added into the flush tank and the floors soon recovered their customary non-slippery surface.

- ✓ **Field applications must be adjusted for higher first year N-availability**. In one incident, the farmer failed to adjust nutrient applications for higher levels of ammonium (NH_4^+). The over application of N was discovered when corn did not stop growing in the fall. Stalk testing showed five to ten times the nitrate typically considered excess.
- ✓ **Aerobic lagoons must be correctly sized for the number of animal units**. In another incident, one aerobic lagoon was functioning so well that the farmer directed additional manure from another barn into that lagoon along with runoff from nearby silage piles. Since the lagoon was not sized for the higher nutrient loads, solids began to build up. Hydraulic dredging was required to vacuum accumulating solids off the bottom.
- ✓ **Foreign materials and trash** must be kept out of the lagoon. The only cost effective method currently available for aerobic lagoon treatment involves the use of impellers to circulate lagoons from top to bottom. When field trash, weeds, plastic bags, bale netting, hoof wrap, afterbirth and other foreign materials enter the lagoon, they rag up impellers causing reduced circulation. Without adequate circulation, aerobic treatment will slow down or stop. Circulators had to be removed from one of the most successful dairy demonstration sites because herdsmen had allowed too much trash from the barn to be carried to the lagoon from the flush alleys, eventually inactivating aerobic circulation in that lagoon. The farm is pondering how to correct this situation.

Scheduled events and incidents

Installation and testing did not always unfold in as orderly a fashion as planned. Manure management circumstances vary widely from year to year. Although equipment was ordered and ready for delivery in the first season, late arrival of spring and the early onset of winter two years running, delayed a number of installations.

At several sites construction of new production facilities or new lagoons was underway. With weather related construction delays and other management issues, several installations were not completed until the third growing season, just in time to participate in the final rounds of testing. As a result, only the final season provided the testing reports desired for comparison of results at a number of locations. It became apparent that each season presented a different set of circumstances. Such changes made it meaningless to compare even the same location to itself from one year to another. The most informative and reliable results were obtained from comparing reviewing sample reports during the growing season, examining events that had occurred around those dates and then explaining the differences noted. Ultimately the strongest outcomes and conclusions arise from observing the absolute values of important measures such as NH_4^+, EC, VFA, pathogens, methanogens and other microbial groups.

Equipment and parts failures from manufacturing reliability or parts defects were negligible. Two units suffered minor faults from failure to adequately tighten one set screw. The incidents occurred in the same batch and simply required replacement of a pulley that ran loose.

A few units were damaged by lightning strikes or power surges normally covered by insurance. Three units took in water during high wind incidents and had to be serviced. This was corrected by retrofit of a water seal around the rim of the lid for high wind locations.

The location of project sites
Sites were chosen to avoid exposure to environmental, wildlife or culturally sensitive areas. Location descriptions and picture maps can be found in the Appendix.

Summarize what worked, didn't work and why.
In general, equipment performed as well or better than anticipated. Units continued to operate reliably through severe winters and hot summers showing almost no signs of wear of any kind during three years in the field. All of these units are still running.

Internet monitoring and remote control proved to be the most troublesome aspect of the project. Problems were largely encountered because of unreliable power and Internet service at rural locations. The combination of power outages and slow Internet recovery made it difficult to restart units and maintain connection and control. Serious consideration is being given to providing two levels of service. Manual control is being considered for problem sites and remote control only where the Internet is reliable enough to maintain communication.

Variable frequency drives at one large dairy, appeared to induce stray voltage readings in the barn. Although stray voltage was never tracked directly to circulator controls, the owner requested that remote control of the project be discontinued. Under manual control, the same equipment continued to operate faultlessly, with no stray voltage, and the site proved to be one of the most successful odor-control and manure management demonstrations.

What would be done differently in this project if it were started today? Based on experience from this project, a number of things would be done differently:

- More complete assessment, not just lagoons, but barn management practices
- More thorough instruction on operations and management of aerobic lagoons
- More complete list of what to avoid in pumping down aerobic lagoons
- Alert crop consultants to account for more available nitrogen
- Remind operators and check on how many AU's can be managed by each lagoon
- Emphasize the importance of required minimum treatment volume
- Emphasize the importance of steps to prevent trash from entering lagoons
- Instill a better farm understanding of the value provided by aerobic treatment

DISCUSSION OF QUALITY ASSURANCE

A number of steps were taken to ensure that the data from the project is valid for the demonstration analysis provided by this project:

Project site description: Sites were chosen primarily based on interest from producers and willingness to undergo some change to their lagoon operations and manure management. In addition, producers agreed to install and pay for the power required at their farm site. The lagoon had to be suitably sized for aerobic operations including sufficient volume for minimum treatment required for aerobic oxygenation. This may sometimes require more frequent application of animal waste nutrients during the growing season with replacement of treatment water after application.

Sample locations were chosen from various-sized dairy and swine operations, in central Wisconsin and east central South Dakota. Several outliers were chosen in eastern and southern Wisconsin, one in northern South Dakota and one in northwestern Nebraska. Sites were chosen in areas that represent different population density, climate and weather patterns, including highly populated areas, near Milwaukee, Green Bay, Lacrosse and Wausau/Merrill, WI as well as flood and drought prone regions like Southern Brown County and Western Charles Mix County, SD.

Sample design: Samples were planned to be taken at appropriate times during each season. Baseline samples provided before installation of oxygenation circulators relied on previous manure reports taken by the farmer or his manure consultant. Where more than one year's prior reporting was available, several years could be averaged to provide a manure chemistry baseline. Each year's report might vary somewhat. Unfortunately, previous manure reports usually did not provide micro nutrients, NH4+, pH, EC, VFA or E. coli counts. Likewise the sampling procedures for prior reports were not known.

Manure chemistry labs were asked to report the usual manure nutrient analysis plus all micro nutrients as well as ammonium and nitrate percentages and pH, and EC.

Microbial Reports included Total CFU's, Aerobic CFU's, Anaerobic CFU's, Total Coliform Count, Escherichia coli count to the limits of measurement at <10cfu/g, and Volatile Fatty Acids (VFA) in PPM including a summary total of VFA counts for an estimation of total odor potential.

Microbial Matrix Analysis reported CFU per milligram for Active Bacteria, Active Fungi, Total Bacteria, and Total Fungi. Functional bacteria groupings included: Sporeformers, Fluorescent Pseudomonades, Chitin Utilizers, Cellulose Utilizers, PSB's (Phosphorous Solubilizing Bacteria), KSB's (Potassium Solubilizing Bacteria), Nitrifying Bacteria and Methanogens.

ORP (± 200 mV), EC (<12mhos) and pH (below 8) were typically observed during site visits. ORP is used to confirm an adequate balance of oxygen supply to demand in the lagoon. An ORP range of ± 150 was targeted to ensure adequate oxygenation for incoming BOD loadings. EC reports provided the farmer with a condition assessment of lagoon liquid which was typically below 12 mhos and suitable for application directly onto growing crops. PH levels were used to assess whether the lagoon was continuing to accumulate ammonium or if it might be shifting to off-gas ammonia. If pH levels were above 8, circulation might need to be increased. Typically lagoons did not reach pH above 8 while circulators were operating effectively. When circulators were ragged up, pH levels would rise.

Measurements were provided at the highest level of precision available from the instruments or the lab. However, all manure consultants know that the availability of a well mixed sample will greatly affect the outcomes of analysis. After circulators are installed, all samples were taken directly from the upflow stream just prior to reaching the surface. This would accurately reflect the entire contents of the lagoon. Prior to circulator installation, baseline results were taken from reports of samples normally collected by the farmer or the manure consultant at that time of field application. Often these reports appeared erratic and unreliable.

Data collected represented conditions in the lagoon at the time. Since each manure lagoon is different at varied points in time, samples and measurements truly represent what is occurring in that lagoon but are not sufficient to compare to other lagoons which may be different. From this perspective, results from each lagoon taken during field observations reflect real-life situations and can be compared in a limited fashion to samples from the same lagoon at another point in time during the same season. However, conditions may change even in the same lagoon which may be pumped and refilled several times during the growing season.

Sampling and custody procedures: Samples from lagoons where aerobic upflow oxygenation circulators were installed were taken directly in the upflow stream before it reached the surface to ensure that conditions in the entire of the lagoon and especially at the bottom would be reflected in all samples taken. This ensured that measurements were not influenced by oxygenation levels often found at the surface of any lagoon. Collection methods simply dipped from the upflow stream below the surface before the bottom water could be re-oxygenated at the surface of the lagoon. Collection was designed to provide data points during the growing season at times when lagoons would normally be tested prior to field application or at the end of the season. In addition to on site readings from ORP, EC and pH meters, standard lab sampling methods and sampling jars supplied by the lab were used to collect sample amounts specified by the lab for each procedure. Samples were delivered directly to the lab the same day or frozen and sent to the lab at the earliest possible opportunity while avoiding putting samples in transport over a weekend or holiday.

Sample analysis and quality control: Sampling was intended to reflect real life methods currently used by manure and microbial labs in support of waste management procedures needed or required of farmers prior to field application of animal nutrient wastes. . All labs used standard laboratory methods and practiced in-house quality control. Samples were normally retained for 30 days to allow for re-analysis as required or requested. No analytical procedures were conducted in the field. Meters used for on-site field measurements were only intended to alert the observer to problems that might be developing in the lagoon so that corrective action could be taken. They were not intended as part of the data collected by the project for analysis. Meters were calibrated periodically as instructed by the manufacturer.

Data reduction, analysis, review and reporting: As a demonstration project, most data reduction, analysis and reporting was intended to arise from first hand observation of the lagoon situation at the time of observation. Samples were collected and pictures taken during site visits to reinforce, refine and add verification to observations made at the site.
For example, approaching a lagoon from a downwind direction, the observer is readily able to determine at what distance from the lagoon any odor might be detected and whether the odor becomes more intense upon approaching the lagoon. For anaerobic lagoons on moderately windy days, odors might be first detected several miles from the site and would steadily intensify as the observer approaches the site. At demonstration sites, odors were typically not detectible, even when standing downwind on the berm directly beside the lagoon. ORP levels taken from the upflow stream typically read within the $\pm$ 150mV range, clearly indicating a balanced supply of oxygen in the water column. Lab samples consistently report VFA levels <100ppm, well below the 250ppm odor threshold of detection for the human nose.
Such data verify the direct observation that the lagoon was odor-free, and by extension that the lagoon was also GHG free because the same conditions that eliminate odor from the lagoon, also eliminate severe GHG's and PM precursors.

FINDINGS

Important findings from the project, besides the data collected, identified a number of ways farmers can offset the cost of improved aerobic eco-system services. Aerobic nutrient management alternatives offer promise of paybacks that far exceed what might have been expected from carbon credit payments.

Results from demonstration lagoons: Surprisingly, the paybacks itemized below greatly exceed any expectation of returns initially thought to be available from voluntary carbon credits or cap and trade legislation. This project conducted demonstration testing, assessment and measurement needed to quantify and estimate the levels of payback available from aerobic eco-system services and off-set costs of aerobic treatment in manure lagoons.

Odor Elimination: By eliminating odor, quality of farm life is improved and the risk of lawsuits and environmental penalties are reduced or eliminated. The value of reduced risk from odor lawsuit is well quantified. Legal analysts indicate CAFO operators can expect odor lawsuits to increase over the next 10 years. Lawyers estimate the cost to defend this type of lawsuit easily reaches $250,000. Where court awards follow, amounts have reached into the $10 millions. Prudent CAFO operators need to set aside at least $25,000 per year over the next ten years to build up a minimal "legal defense" fund. In addition, CAFO's will need to maintain liability insurance with award expectations in the millions of dollars if this type of lawsuit is lost. Alternatively, steps can be taken to reduce the risk of odor and nuisance related lawsuits:

- Aerobic manure treatment can reduce or completely eliminate livestock producers' risk of nuisance lawsuits from odor. Testing at demonstration sites clearly indicates that aerobic circulation on properly sized lagoons with affordable equipment installed and operating can completely eliminate all detectable odors. The most stable and reliable measure of odor from manure lagoons is the level of Volatile Fatty Acids (VFA's) found in the liquid. VFA levels found in anaerobic lagoons are typically >10,000 ppm often reaching 20,000-30,000 ppm. It is well documented that VFA's below 250 ppm are not detectable as odor to the human nose. VFA levels measured in aerobic lagoons during demonstration were always below 100ppm. Under this metric, the lagoon is incapable of producing detectable odor. These farmers would most likely be excused from odor lawsuits and not be subject to the costs of participation in defense or in court awards arising from odor lawsuits.

GHG Methane (CH4) Reduction: The methane producing microbial group, *methanogenic archaea*, requires anoxic environments to produce methane gas. There are over 50 described species of methanogens. All are obligate anaerobic organisms which thrive only in the absence of oxygen. Methanogens are sensitive to oxygen even at trace levels and cannot survive in the presence of oxygen for any prolonged time. Only one species, *methanosarcina barkeri,* possesses a superoxide dismutase enzyme (SOD) that may help it to survive contact with oxygen for somewhat longer than others.

- By maintaining controlled oxygen supply in the +/- 150 ORP range at demonstration lagoons, methanogens simply cannot thrive. These lagoons can be said to eliminate CH^4 as a GHG source from manure management systems.

There are a number of other direct and indirect ways to easily determine if lagoon methane production is being reduced or eliminated:

ORP Readings: ORP reflects the supply and demand balance of the requirement for oxygen. The ORP scale is typically -1000 mV to +1000 mV. ORP readings are sensitive to oxygen supply and change quickly when supply varies. Readings within the +/-150 range were used to signal an oxygen supply that is relatively well balanced but not excessive. To be meaningful, ORP readings must be taken from water at the bottom of the lagoon or in the up-flow stream in a vertically mixed lagoon as in our demonstration lagoons. In vertically mixed aerobic demonstration lagoons, ORP readings were taken in the oxygen depleted up-flow water just before it reached the surface. ORP readings in top water alone are not meaningful because they are always at or above the desired ORP range due to contact with atmospheric oxygen and the presence of less organic material at the surface of the lagoon. Methane is typically produced from the unmixed bottom sediment layers of anaerobic lagoons where ORP readings can easily approach -1,000. Measurement of ORP in top water samples say nothing about methane production down below.

- ORP readings taken from the up-flow waters in vertically mixed aerobic demonstration lagoons have consistently reflected a balanced oxygen supply in the $\pm$ 150mV range. This indicates there is oxygen available in the water column down to the bottom of the lagoon. Even with only trace oxygen throughout the lagoon environment, methanogens cannot thrive. We therefore conclude that a well mixed demonstration lagoon with ORP readings in the $\pm$ 150mV range will not support the production of methane. Microbial Matrix Analysis indicating low levels of methanogen CFU's verify this conclusion.

VFA Levels: Like methane, VFA's are also reduced or eliminated by adequate oxygen supply. Therefore, VFA levels can be used in aerobic lagoon settings as an easily measured surrogate for methane production. VFA levels in anaerobic manure are typically >10,000 ppm. Sensory testing has correlated VFA levels at 250 ppm in liquid manure as the threshold for human detection of odor. This means at VFA's below 250 ppm, humans cannot detect odor.

- VFA levels in aerobic lagoons at demonstration sites have consistently reported below 100 ppm. Again with sufficient oxygen to bring VFA levels low enough to prevent odor detection, there would also be too much oxygen present for methanogens to thrive and function.

Percentage of Ammonium ($NH4^+$): One goal of aerobic treatment in manure lagoons is to mineralize organic nitrogen into plant available condition using the lowest energy consumption. This means transformation of organic-N into ammonium-N, but not into nitrate which requires substantial additional oxygen.

- Lab reports from demonstration aerobic lagoons show ammonium percentages averaging 60% and reaching 85%-95% of Total-N – even when pH was above neutral. With sufficient oxygen in the lagoon to produce ammonium levels this high, there will be too much oxygen available for methanogens to thrive.

Microbial Matrix Analysis: Direct measurement of the presence of methanogens was reported by Microbial Matrix Analysis. This procedure gives a direct count of methanogen CFU's that would be viable to produce methane if the lagoon were to revert to anaerobic conditions.

Recall that this sample comes from a well mixed water column rising directly from the bottom of the lagoon – where methanogens are most likely to survive in uncirculated lagoons.

- ❖ Direct Microbial Matrix Analysis conducted on samples taken from aerobic demonstration lagoons indicates methanogen CFU's were among the lowest microbial groups found. The highest counts for methanogen groups were in the 100,000-300,000 range. The lab commented that it took an extended time to culture these samples. As a consequence, the findings were most likely produced from latent cultures or spores and not from active microbials producing methane at the time of sampling.

GHG Nitrous Oxide (N_2O) Reduction: N_2O occurs during the process of nitrification and denitrification in oxygen-poor soils and in marine environments, such as lagoons in which denitrifying bacteria respire Nitrite (NO_3^-). Nitrite is always identified as a link in all common Nitrous Oxide (N_2O) production pathways.

- ❖ Nutrient testing in aerobic (controlled oxygen) demonstration lagoons shows that up to 95% of total lagoon-N is converted to ammonium (NH_4+). The remaining N is typically organic-N waiting to be converted to ammonium. Without surplus oxygen available, little if any nitrite or nitrate is formed – typically less than 0.01%. Therefore, it can be concluded that Nitrous Oxide (N_2O) is most likely not formed in the "controlled oxygen" environments maintained at aerobic demonstration lagoon sites.

However, once lagoon material is applied to the soils of farm fields, things might be different. Nitrous oxide can be produced naturally when resting in the soil for a long period of time and undergoing the microbial processes of nitrification, denitrification and nitrifier denitrification. The following pathways are known:

- ❖ *aerobic autotrophic nitrification, the stepwise oxidation of ammonia (NH_3) to nitrite (NO_2^-) and to nitrate (NO_3^-) (e.g., Kowalchuk and Stephen, 2001),*
- ❖ *anaerobic heterotrophic denitrification, the stepwise reduction of NO_3^- to NO_2^-, nitric oxide (NO), N_2O and ultimately N_2, where facultative anaerobe bacteria use NO_3^- as an electron acceptor in the respiration of organic material in the condition of insufficient oxygen (O_2) (e.g. Knowles, 1982), and*
- ❖ *nitrifier denitrification, which is carried out by autotrophic NH_3–oxidizing bacteria and the pathway whereby ammonia (NH_3) is oxidized to nitrite (NO_2^-), followed by the reduction of NO_2^- to nitric oxide (NO), N_2O and molecular nitrogen (N_2) (e.g., Webster and Hopkins, 1996; Wrage et al., 2001).*
- ❖ *Other N_2O production mechanisms include heterotrophic nitrification (Robertson and Kuenen, 1990), aerobic denitrification by the same heterotrophic nitrifiers (Robertson and Kuenen, 1990), fungal denitrification (Laughlin and Stevens, 2002), and non-biological process chemodenitrification (e.g. Chalk and Smith, 1983; Van Cleemput and Baert, 1984; Martikainen and De Boer, 1993; Daum and Schenk, 1998; Mørkved et al., 2007).*

Of note, each of the pathways described above requires the presence of ammonia (NH3), nitrite or nitrate as precursors to nitrous oxide formation. Nitrous Oxide (N_2O) emissions are reported to be further exacerbated by N-residence in the soil over a prolonged period of months. Over time, soil chemical and physical properties can change and affect the production of N_2O such as the availability of nitrites and nitrates, soil pH, organic matter availability, oxygen availability, soil type, and climate related soil properties such as soil temperature and soil water content (e.g., Mosier, 1994; Bouwman, 1996; Beauchamp, 1997; Yamulki et al., 1997; Dobbie and Smith, 2003; Smith et al., 2003; Dalal et al., 2003). In any short term, N_2O does not form in the soil.

- Testing shows nutrients in aerobic demonstration lagoons are mostly plant available and in condition to be applied directly onto crops during the growing season. N from aerobic demonstration lagoons often reaches 85%-95% crop available ammonium (NH_4+) by midsummer. Aerobic lagoons are maintained in true liquid form, suitable for sprinkling onto crops via center pivot or travelling gun during the growing season when plants need nutrients most. With sprinkler applications, only a few days to a week pass after application before crop uptake occurs. The choice to apply aerobic nutrient material by fertigation directly onto growing crops will, in all likelihood reduce or completely eliminate nitrous oxide (N_2O) formation in farm fields that results from Manure-N being stored in the soil over an extended time. With short term residence in the soil, it is extremely unlikely that plant available ammonium (NH4+) can be reduced to nitrous oxide. Without soil residence preconditions, nitrous oxide cannot form.

Air Quality for Improved Human and Animal Health: One of the direct outcomes from reduced gas and odor production on the farm is improved human and animal health. For example, studies done by land grant colleges as far back as the 1970's consistently showed 12.5%-15% higher feed costs and 10% more days to market when pigs were raised in the stress of gas and odor produced from manure stored in the basement of pit barns. More recent studies indicate humans in these environments can also experience health problems.

- Quantifying 15% of today's feed bill indicates the cost of gas and odor in the barn can be estimated in lost feed conversion at about $15/finisher. This means nearly $45,000 more profit per year in feed savings from a 1,000 pig place finish barn as a result of eliminating gas and odor from the barn. With aerobic treatment of lagoons, in-barn odor reduction is easy to accomplish at very low cost using odor-free aerobic safe-water from lagoons to recycle through the barn to regularly recharge pits, continuously remove manure and eliminate gas and odor production in the barn. Several demonstration sites chose to clean their barns with odor-free recycled lagoon water.

Pathogen Reduction: A widespread concern regarding confined animal feeding is the potential for human and animal pathogen distribution when manure is applied to fields. Research has shown that pathogens can survive in the deeper reaches of under-barn pits and anaerobic lagoons for an extended length of time. Concerns arise when barn fans are turned on and draw pathogens out of the manure pit or when manure pits and anaerobic lagoons are agitated, releasing pathogens into the atmosphere. Concern would increase if these pathogens were to be sprayed into the atmosphere via irrigation pivots or travelling guns.

- As a surrogate for other pathogens, E. coli testing was conducted on samples of water from well-mixed aerobic demonstration lagoons. With continuous vertical mixing, the entire content of the lagoon is frequently exposed to UV sunlight on the surface of the lagoon for about 5-15 minutes during every daylight hour. This amount of daily UV radiation is sufficient to inactivate even the most tenacious pathogens. Results of E. coli testing from samples taken out of aerobic demonstration lagoons typically measured E. coli at less than 100 CFU's and often less than 10 CFU's in aerobic lagoon samples. E. coli reductions are noted after only a few weeks of continuous vertical mixing.

N Recovery and Retention: Loss of nitrogen from lagoons and manured fields is a significant nutrient management and air quality problem – and a cost to farmers. Volatilization of ammonia or other N-gases during manure storage in the lagoon leads to low manure-N in nutrients applied to the field. Low-N retention encourages heavier manure application per acre which in turn increases the likelihood of phosphorous tie-up in manured fields. Low manure-N reduces P uptake and can deposit left over phosphorous in the soil. Excess soil phosphorous can then enter aquifers, waterways, streams and lakes due to run-off from drain tile.

- Aerobic treatment of animal waste lagoons recovers and retains more crop available manure-N for application onto farm fields. While the typical anaerobic swine lagoon is estimated to average about 4.2 lbs of N per 1000 gallons, aerobic demonstration lagoons have reached 14.4 lbs of N per 1,000 gallons despite intentional dilution to about 1% dry matter. Equally important, up to 95% of N in aerobic demonstration lagoons has been converted to crop available ammonium (NH_4+) in a true liquid form with EC levels that permit it to be sprinkled directly onto growing crops at any time. With more N available, nutrients do not have to be applied as heavily. This in turn results in lower P applied to fields and less likelihood of phosphorous tie-up in the soil.

Phosphorous Reduction: EPA studies indicate that many manured fields are near or have reached their 200ppm phosphorous limit. Because many soils are also low in aerobic PSB's (Phosphorous Solubilizing Bacteria), they are unlikely to release soil bound phosphorous for crop uptake and this situation is unlikely to correct itself. In addition, Mycorrhizal and other fungi which help to transport phosphorous to plant roots are weakened or destroyed by application of high BOD manure that robs oxygen from heavily manured soils. Mycorrhizae are also damaged by disruption that occurs with manure injection, knifing and soil desiccation which can result from extensive field tillage followed by dry weather. As a result, manure phosphorous continues to tie-up in soils where eco-system services are inadequate to solubilize and transport phosphorous back to the crop.

- Aerobic treatment supports the growth of PSB's in the lagoon and offers the promise of returning these PSB's to the field to enhance the natural microbial matrix of the soil. Microbial Matrix Analysis of Aerobic demonstration ponds reported PSB's in the 2 million to 10 billion cfu/g range. Importantly, aerobic nutrient applications also do not deplete the soil of oxygen and do not deplete the aerobic microbial matrix required for good crop fertility. When applied with ¼ to ½ inch of water, aerobic nutrients do not volatilize and do not require physical injection, knifing or tillage for incorporation. The net result of aerobic lagoon treatment is a system which can return PSB's and other beneficial microbial groups to the soil, will not rob the soil of oxygen, does not require disruptive tillage for incorporation, and supports the growth and performance of Mycorrhizal fungi by reducing tillage and by wetting the fields more often during dry summer months. At 200ppm, farm fields might hold 800 lbs of phosphorous, tied up in the first foot of topsoil. At today's phosphorous prices, releasing only 10% of this soil-bound phosphorous back to the crops would return about $50 per acre of nutrient value to the farmer each year and reduce the soil P-load by up to 80 lbs/year – depending on how much new phosphorous is applied.

Potassium K-Uptake: Research is beginning to emerge from Winfield/Croplan and others to indicate that many, if not most crops, especially alfalfa and high performance stacked genetics, regularly suffer from yield-limiting potassium deficiencies. At first this sounds strange since potassium has always been thought to be plentiful, but plentiful K does not mean potassium is mobile in the soil or available to the crop. Research indicates potassium, like phosphorous, can become tied up in the soil and unavailable for the crop.

- ❖ Potassium Solubilizing Bacteria (KSB's) are known to release potassium for plant uptake. Like PSB's, KSB's are found in significant quantities in aerobic lagoons. Microbial Matrix Analysis of Aerobic demonstration ponds also reported KSB's in the 2 million to 10 billion cfu/g range. There are a number of other reasons why K may be more available in fields treated with "oxygen controlled" aerobic lagoon nutrients: better soil moisture, less compaction, more aeration and more KSB's are some of the reasons. Of course, reducing oxygen depletion, soil desiccation and moisture stress supports the growth of fungi to provide nutrient transport and increased root exposure to nutrients in the soil.

<u>Microbial Matrix Restoration for Degraded Farm Soils</u>: It is well understood that for soils to function productively, they must support an extended aerobic microbial matrix. Soil bacteria and fungi work in community. Where key microbial groups are deficient, others also function poorly. It is well documented that high BOD material, like raw manure or sewage sludge injected into the soil can have debilitating effects on the soil's aerobic microbial activity by depleting oxygen from the soil. Experience shows the soil's microbial matrix may not recover for an extended time, perhaps years after application. The EPA estimates over 50% of American farmlands are severely degraded.

- ❖ Results from aerobic demonstrations indicate the presence of aerobic microbial matrices forming in the lagoon that offer tremendous support for improving degraded soil fertility. It appears that applications of aerobic nutrients offer the promise to restore degraded soils by restoring the eco-system services of the soil's depleted microbial and fungal communities. Quantifying the results of this benefit will require microbial testing and monitoring of soils to identify which amendments from aerobic lagoons restore degraded soils to more productive capacity.

<u>Manure Distribution</u>: Manure distribution from raw manure storage lagoons with no circulation or oxygenation typically requires intense lagoon agitation to remix settled solids back into slurry form before pumping to the field. Agitation releases large amounts of gas, odors and pathogens into the atmosphere. Heavy equipment is needed for agitation as well as for knifing, injection and tanker application. The fossil fuel consumed for this type of field application is another source of GHG air pollution.

- ❖ Aerobic demonstration lagoons, except undersized sites with less than optimum minimum treatment volume, were able to be pumped without agitation. Agitation typically requires half the cost of manure application. By eliminating the need for agitation, this savings returns nearly double the annual cost of circulators and the power they require. Because aerobic nutrients are in plant available true liquid form, they can be applied by pivot or travelling gun whenever crops need nutrients most. Immediately incorporated into the soil with the ¼ - ½ inch of water, aerobic nutrient distribution using center pivots saves the farmer $50-$75 per acre each year in reduced field distribution costs, more than repaying the cost of pivots and at the same time further reducing fossil fuel consumption and GHG emissions. Agitation and application cost savings are already a tremendous payback for crop producers.

Soil Compaction: Greatly increased crop productivity is achieved by no-till farmers, partly because no-till avoids soil compaction. Studies show as much as 30% yield reduction from soil compaction, such as hauling manure onto alfalfa fields with heavy tankers.

- ❖ At aerobic lagoon demonstration sites, pivots were sometimes used by farmers to distribute manure nutrients directly onto crops during the growing season. Heavy equipment traffic across the field was avoided. Studies have shown yields of 20 - 30 bu more corn per acre. At $6.50/bu corn prices this adds $130-$195 more income per acre from reduced compaction because the nutrients were in true liquid form and could be distributed by center pivots without plugging nozzles.

Fertigation for "As-Needed" Field Application: Where crop available nutrients, especially crop ready nitrogen in ammonium form, can be applied as needed during the growing season, significant yield increases have been observed, most recently from research trials on Croplan Answer Plots in South Dakota. With manure, this can only be accomplished when aerobic crop-ready, true liquid nutrients at appropriate EC levels can be sprinkled directly onto growing crops without stressing or yellowing the plants. Manure usually cannot be applied on growing crops without burning or yellowing. Nutrients with EC levels below 12mhos are suitable for application to mature plants. Below 6mhos, applications are suitable for tender crops.

- ❖ In this project, aerobic demonstration lagoons typically achieved EC levels below 12mhos and some below 6mhos within a few months after startup. With EC levels in this range, nutrients can be applied directly on growing crops. A 10% -20% yield increase is available when the same amount of nutrient is applied at times when crops need nutrients most. This can mean 20-40 more bushels of corn in Iowa – a return of $130 - $260 more profit per acre at $6.50/bu corn with no additional input costs.

No-Till: Applying manure nutrients on no-till fields has always presented a challenge because raw manure needs to be incorporated, injected or knifed into the soil to avoid nitrogen losses and run-off. Incorporation, knifing and injection disturb the no-till soil bed, compact the soil and reduce the effectiveness of no-till. Raw manure, applied on top of no-till fields in the spring or fall, means manure would be likely to run off into waterways and nitrogen would volatize.

- ❖ Sprinkling non-volatilizing, plant available NH_4+ with other crop ready aerobic manure nutrients along with ¼ - ½ inch of water ensures nutrients will penetrate the no-till cover and become available to crop roots. No- till farmers can now make effective use of animal nutrients on their fields and save $90 - $140/acre of commercial fertilizer cost without disrupting or compacting the no-till soil bed.

Rescue Irrigation: In dry land farming where irrigation wells are not available, the farmer is at the mercy of the weather. Recent drought has driven home the need for rescue irrigation. Where lagoon water can be stored in good condition, free of odor and pathogens, this resource can provide tremendous value to agriculture and reduce the demand for fresh water.

- ❖ One demonstration site utilizes recycled lagoon water, stored in large basins in the fields, to provide rescue irrigation for crops in drought prone Southern Brown County, South Dakota. During the drought of the past summer, this farm maintained excellent corn yields and applied to soybeans, yield reached 67bu/acre – a record for this area.

A summary list of issues, errors and problems observed during the demonstration include:

- Several sites needed to raise their berm to achieve required treatment capacity, but farmers dragged their feet on taking this step. This becomes a chicken-or-the-egg problem. Farmers don't want to change until they see the system is working, but the system won't perform to expectations without the required treatment capacity.
- Two sites had to wait for water to add minimum treatment volume. Drought made spring run-off water scarce. Rural water is expensive to use in the millions of gallons to achieve initial minimum treatment volume and to replace evaporation losses.
- Lagoons pumped too easy. At least three sites pumped lagoons down too far before realizing they had no water left and were unable to circulate the incoming manure – or in the case of one dairy, they could not flush their barn.
- When adding water, the flush dairy added too much anoxic well water back into the lagoon too fast. This inactivated the aerobic biomass, created odor again and made the barn floor slippery. Dry microbes were added to the flush alleys to more quickly reduce slipperiness on the floor and the lagoon returned to odor-free status in a few weeks.
- When applying nutrients, one crop consultant failed to adjust for high (95%) crop available ammonium and overloaded the fields with nitrogen. The result was corn silage that wouldn't stop growing and ended the season with five to ten times the normal for what is considered excess nitrogen in stalk tissue.
- Not applying nutrients at optimum times: In full operation, aerobic lagoons nutrients have been transformed into odor-free, pathogen-free crop-ready fertilizer. When applied to alfalfa immediately after cutting, the tender crop did not yellow and produced extra tonnage per acre from one additional cutting that year. Some farmers are not used to applying nutrients on alfalfa in early spring or between cuttings. They were pleasantly surprised that aerobic manure didn't burn the crop. And they were ecstatic to achieve additional cuttings each year and to discover that subsequent cuttings were as good or better than the first cutting.

Summary of Data Outcomes showing improved lagoon health from pathogen reduction, improved air quality from reduction of odor, gas, severe GHG and PM precursors as well as improved manure handling and nutrient value indicators are reported below:

1. **Pathogen Reduction:** Pathogen reduction was measured from laboratory samples by counting CFU levels of E, coli. E. coli pathogen counts were typically reported at <100 cfu/g and frequently reported at less than 10 cfu/g.
2. **Volatile Fatty Acids (VFA's), Odor and Methane:** Volatile fatty acids provide a reliable measure of odor potential from manure lagoons and a reliable surrogate for the likelihood of methane production from these lagoons. VFS's quickly disappear from organic nutrient waste in the presence of oxygen – as does methane production. From 5,000-10,000 ppm of VFA's and higher are typical in untreated lagoons. Aerobic demonstration lagoons most often measured below 100ppm of VFA. The presumption is that methane would be reduced to similar low levels. To verify this assumption, direct counts of methanogens were taken and found to be low.
3. **Electrical Conductivity (EC):** EC levels in manure lagoons typically range from 0.1 to 70 mhos. EC levels can be tolerated up to 20mhos with some yellowing and leaf burning. For best fertigation results, EC levels are best below 12 mhos for mature crops and below 6 mhos when applied on young or tender plants to avoid yellowing or burning.

Demonstration aerobic lagoon samples were typically measured at or below 12 mhos averaging 9.7 mhos with a good number of lagoons at or below 6 mhos, indicating those lagoons were safe to apply even onto tender young crops.

4. **Odor and pH:** Anaerobic lagoons with pH above 8 are very prone to produce intense odors. The average pH in the aerobic demonstration lagoons was calculated at 7.7, ranging from 6.6 to 8.5. But even the higher pH lagoons did not produce odor. It appears adequate oxygen will prevent odor production even though pH levels might otherwise favor greater odor production.
5. **Ammonium ($NH4^+$):** The primary factor affecting non-volatilization of lagoon-N and its immediate availability to crops is the level of ammonium (NH4+), not ammonia (NH3) in the lagoon. Ammonium (not ammonia) levels in anaerobic lagoons might typically range from 15%-30% of N, mostly in the top water. Ammonium ($NH4^+$) averaged 60% and often reached 85%-95% of N in totally mixed aerobic demonstration lagoons, not just in the top water.
6. **Dry Matter (DM) Content** of manure affects the handling characteristics of manure and the amount of agitation required to re-mix settled solids into pumpable slurry. Typical manure in storage ranges from 3% - 9% DM or above. Aerobic demonstration lagoons typically reported DM at less than 1%, making them pumpable at any time without further mixing or agitation, even through pivots with precision drop nozzles.
7. **Microbial Matrix Analysis:** Total bacterial counts are often used to evaluate overall soil fertility likely to be achieved from nutrients applied to farm soils. A range of 100-300 ug/gdw or higher is considered a desirable amendment for mineralization and solubilization of plant nutrients. Total Bacteria Biomass from aerobic demonstration lagoons was found to average 257.9 ug/gdw – near the top of the desirable range. The lowest bacterial biomass found was 184.6 ug/gdw and several lagoons exceeded the 300 range. This would imply that aerobic lagoon liquids offer a valuable fertility amendment when applied to farm soils. Microbial data is reported for each Functional Group described below. Groups with cfu's reported below 1.00+5 are considered low. The single microbial group consistently found in this low range was methanogens.
    a. **Nitrifying Bacteria** convert Ammonium (NH4+) into Nitrate under aerobic conditions. Conversion to nitrate is intentionally restricted by oxygen supply in these aerobic demonstration lagoons to conserve energy and to prevent nitrous oxide formation in the lagoon. But conversion to nitrate can be accomplished rapidly in damp aerobic soils when nitrifying bacteria are present. All aerobic demonstration lagoons reported very high levels of nitrifying bacteria, some greater than 1 billion cfu/g, indicating that soil conversion to nitrate will be accomplished rapidly upon application of aerobic fertigation liquid.
    b. **Phosphorous Solubilizing Bacteria (PSB's)** releases phosphorous (P) that has become tied up in the soil and unavailable for plant uptake. Some heavily manured fields are very high in soil-bound phosphorous, at or above the 200ppm phosphorous limit. Aerobic demonstration lagoons reported high levels of PSB's, in the 1 million to 1 billion cfu/g range making them an excellent source for PSB soil amendments.
    c. **Potassium Solubilizing Bacteria (KSB's)** release potassium (K) that has become tied up in the soil and unavailable for plant uptake. The majority of US soils do not supply adequate plant available potassium to meet yield goals if the soil-K has become tied

up. KSB's from aerobic lagoons applied as soil amendments help to release potassium for plant uptake, ensuring that crops receive the potassium they need. Aerobic demonstration lagoons report high levels of KSB's, in the 10 million to 1 billion cfu/g range making them an excellent source for KSB soil amendments.

d. **Fluorescent Pseudomonads** trigger plant production of Indole Acetic Acid which is a precursor to plant hormones responsible for root growth. Increased root growth is paramount for high yielding hybrids to keep up with their own nutrient demand. Fluorescent Pseudomonads register some of the highest microbial counts, reaching 10- 100 billion cfu/g in a number of demonstration lagoons, thereby providing a highly valued microbial soil amendment for overall increased crop production with today's high yielding genetics.

e. **Methanogens** produce methane as a by-product of their metabolism. Methane is a severe green house gas and the project hoped to reduce methane production from manure lagoons. All known methanogens are obligate anaerobes, that is, they do not thrive in the presence of oxygen. Therefore, even in a restricted oxygen lagoon with a controlled balance between oxygen supply and demand, one would hope to find only low levels of methanogens. After extensive efforts in the laboratory to cultivate methanogens from lagoon water, all demonstration lagoons reported very low methanogen cfu response, never higher than 300,000 cfu/g compared to the millions and billions found for other functional groups. This level of methanogen population would equate to negligible, if any, production of methane from aerobic demonstration lagoons.

CONCLUSIONS AND RECOMMENDATIONS

Project outcomes clearly indicate Oxygenation-Circulator Platform (OCP) technology for aerobic treatment of animal waste lagoons is beneficial and ready to be widely recommended for common use. A recommended practice standard under which this technology might be implemented is provided in the Appendix to this report. NRCS is strongly encouraged to consider publication of this practice standard as one way to encourage adoption of superior manure management. It should also be recognized that while this practice offers tremendous opportunity for environmental and agricultural improvement, it is innovative and unfamiliar to farmers as well as technical consultants and advisors. Educational efforts will be needed to support the introduction of this practice. So Far, South Dakota State University has indicated interest to participate in continuing demonstration of aerobic technology. Arrangements are being made to set up a demonstration site at their dairy location.

The benefits of aerobic manure treatment through total pond circulation are clear. These benefits include: odor elimination, noxious gas reduction, mitigation of severe GHG emissions, pathogen inactivation and antibiotic residue degradation, superior soil and water protection by avoidance of fall, winter and spring manure applications, regeneration of degraded soil health and fertility, retention and conversion of more manure-N to non-volatilizing plant available ammonium (NH_4^+), EC levels that allow fertigation directly onto growing crops without stressing or burning plants, more rapid and complete degradation of manure solids to increase pumpability for distribution through center pivots, reduction or elimination of fossil fuel consumption and costs associated with lagoon agitation and manure spreading, use of manure nutrients on no-till fields and, of course, increased crop response and yields from timely application of crop ready nutrients when plants need fertilizer most. These benefits are among the significant outcomes available with aerobic manure management and are not obtainable from traditional manure practices. Such a list of benefits has never before been available from other manure management systems.

The stage is set for tremendous breakthroughs in superior agricultural manure management for the environment. For the first time, solutions for many of agriculture's most severe, unresolved environmental concerns are at hand. Equipment to accomplish these goals has proven reliable. Performance is effective and affordable. Aerobic management offers manure management improvements across a broad range of agricultural practices – and at the same time provides significant additional farm income to pay for changes! (See table below.)

But nothing is free or likely to happen without effort and purpose.

Yes, there is motivation in the desire of many farmers to eliminate the multiple negative side-effects of traditional animal waste management – especially noxious gas and odors on the farm.

Yes, enhanced farm income can provide resources to pay for the changes required to effectively utilize aerobic manure management practices.

Yes, aerobic paybacks appear to significantly exceed cost, spelling increased profits for farmers and reduced food prices for consumers.

Yes, odor free manure management now appears to be within reach.

Unfortunately, conservation culture may have eroded among farmers. The rich culture of resource conservation inherited from our grandfathers has waned - especially as regards manure. Without appropriate technologies to do the job, manure management has become a thankless, costly and difficult chore. Raw, untreated manure poses high risks and offers small payback. Sometimes manure is over applied, simply to dispose of it at lowest cost. Such practices degrade farm productivity. High BOD manure applications stress and inactivate aerobic microbial and fungal activity, reducing fertility in the soil. Raw manure is offensive to neighbors. It easily leaches out or runs-off fields. Fertility is lost. The list of problems goes on.

From an air quality perspective, traditional manure management is an unmitigated nightmare. Storage and distribution of raw manure has uncontrollable side effects. Continuing to store and spread raw manure is beginning to haunt livestock producers. Repeatedly, producers are denied permits for livestock operations due to fierce opposition from vocal neighbors and rural residents who strongly oppose further degradation of the environment and rural quality of life.

In truth, many livestock producers themselves are sick of working in barns filled with noxious gas and odors. They want different manure management tools and a better quality of life for themselves, their families and their neighbors. And in the final analysis, animals themselves are impacted by in-barn air quality. Swine in particular, also turkeys and even dairy underperform in barns filled with gas and require more feed to achieve the same yield. Aerobic manure management provides profitability and sustainability for livestock and crop operations.

Farm advisors, partners and influencers can have a tremendous effect on agricultural innovation. Thus far, most are completely unaware that aerobic manure management might be any different from traditional manure practices. And in fact, some influential professionals may have motivation to discourage the use of aerobic manure management techniques.

Technical Service Providers, including engineers who design manure management systems thus far have no exposure to the benefits of aerobic manure management, nor do they have experience of its practice. As a result, some engineers may prefer to focus on increasingly complex systems, such as anaerobic digesters, which net higher fees for more costly designs. Or they may simply prefer to provide the same manure system offered in the past. This presents tremendous opportunity and challenge for professional development efforts today.

Anaerobic Digester industry promoters may have the most reason to encourage aerobic treatment as a cure for the intense odor and gas emitted from digester effluents. Lack of information, however, can lead to the perception that aerobic treatment is a competitor.

Bankers need aerobic education because they influence and often participate in EQIP lending. Thus far, they have no idea that farmers might make more money with less risk by adopting somewhat higher cost manure management practices. Without knowledge of risk reduction, paybacks and revenue streams from aerobic manure management, bankers may be disinclined to approve money for something they might perceive to simply reduce odors on the farm.

Veterinarians can be very influential on livestock farms. They will need to understand the human and animal health benefits of gas and odor-free barns. Research completed at land grant colleges in the '70's showed 12%-15% reduction in feed conversion for swine raised in the gas and odor of pit barns. But veterinarians might be reluctant to condone the use of recycled pond liquid for continuous barn cleaning. They will need to see manure reports which show that pathogens have been eliminated from aerobic treated "safe water."

County Commissioners, state permitting agencies and legislative authorities have already begun to restrict the use of open-air ponds. Tired of hearing odor complaints, many agencies simply deny open-air ponds, especially for swine manure. The belief is that out of sight is out of mind. Minnesota, for example, has a law on the books that does not allow open-air swine lagoons. The benefits of aerobic manure management are not available from pits or covered ponds, and there is no need to cover an odor-free, pathogen-free open-air pond.

NRCS will face a challenge to help educate this array of industry influencers regarding the air quality, water quality and soil improvement goals available from aerobic manure management.

What can NRCS do to enhance the acceptance of aerobic manure benefits?

NRCS can use this breakthrough project in conferences, media and press releases as an example for why their work is important, and why funding for such projects is important.

NRCS can review the recommended Practice Standards in this document to ensure that appropriate options are in place to encourage and support the costs implied by aerobic treatment, such as larger lagoons, mechanical circulation and energy costs.

NRCS should consider establishment of aerobic demonstration/test-bed locations in partnership with land grant colleges, technical schools and other sustainability agriculture education providers to utilize these as demonstration sites where aerobic outcomes and results can be measured, verified and expanded into new areas of research. One such site is already proposed for SDSU's dairy facility in Brookings, South Dakota.

NRCS should consider establishment of a central source, contact point and taxonomy center for aerobic manure management information to pull together the partial pieces, different approaches and varied research efforts about aerobic manure treatment and to overcome the lack of organized and readily available knowledge in this discipline.

NRCS might arrange, present or encourage conferences and seminars to explore the range of opportunity for environmental and economic improvement from aerobic manure management.

NRCS might encourage travel for NRCS staff and others to visit aerobic sites, and let these staff experience firsthand the "no odor" and other benefits at any of these sites.

NRCS might contact/interact with Chesapeake Bas regulators to expose them to the significant improvements provided by mechanical pond circulation for aerobic treatment. The process allows animal waste to be quickly decomposed and safely stored until it can be applied directly to plants, and NOT stored in the soil, where it can run off or leach into groundwater.

NRCS might further interact with the EPA to document low-cost tools to eliminate odor and reduce greenhouse gas emissions, and to ask that EPA help provide a pathway to funding assistance at high impact sites and provide local examples throughout the nation.

NRCS might consider a renewal of efforts to reinstate some process for carbon credits that might apply to aerobic manure management systems.

NRCS might run tests on circulator performance and reliability as well as require reporting that avoids neglect and management error. The demonstration provided assurance of circulator equipment reliability. The equipment did not fail or show signs of wear during the life of the project. However, aerobic performance is troubled by inattentive management, unstable power supply, unreliable Internet services and uncontained trash entering lagoons.

Farm income enhancement available when farmers adopt odor-free, pathogen-free aerobic manure management is conservatively estimated at the following levels:

AEROBIC ROI: Added income/savings estimated for	Swine/1000lbAU	Dairy/1000lbAU
increased nitrogen recovery in crop available form, providing 50%-75% more ammonium to the crop	$42.58	$41.18
significantly lower field application costs saving $50-$75 per acre	$24.21	$16.80
enhanced crop response with 10%-20% increased yields, 20bu/acre more yield @ $5 corn	$59.46	$60.00
less odor and pathogen stress on livestock & humans, 40% reduced vet med costs @ $33/AU	$13.20	$13.20
avoided environmental risk and penalties from GHG's, leaching and run-off	NA	NA
lower risk of nuisance lawsuits from neighbors, estimated at $10,000/year/1000AU	$10.00	$10.00
TOTAL ADDED "AEROBIC" INCOME/SAVINGS	**$149.45**	**$141.18**

Expectations of improved farm profits from aerobic manure management are significant for livestock producers. When translated to crop farmers who adopt aerobic manure practices, preliminary projections appear to justify profits/savings in the range of $150-$250 per acre.

Circulators proved very reliable. Placed on the first lagoon in December of 2009 in the teeth of what turned out to be a severe winter in Wisconsin, the installation ran reliably throughout the winter with no service outages except for one lightning strike in the spring. The equipment was not affected by adverse weather and has not presented maintenance or repair issues the way prior equipment from other manufacturers did. The equipment on this site is now nearly through its fourth winter without incident. This is encouraging evidence that oxygenation circulator platforms (OCP's) can perform reliably, even under harsh conditions.

Odor reduction was immediate and dramatic. This dairy scrapes manure into a flush flume. Recycled pond liquid is pumped back to flush manure from the flume into the lagoon. In the past, when pumps came on, the odor was sickening and the operator typically moved to the other end of the barn to escape the smell. Even during the first winter, operators and visitors stood comfortably beside the flume to watch the flush and reported no severe odor. Air quality and odor control continued uninterrupted through spring thaw and summer heat.

Recovered sand bedding was cleaner. This dairy recovers sand from a sand lane and returns it for use in bedding the barn. With better quality water through the flush flume, more sand and less manure are recovered, providing lighter colored, cleaner and dryer, odor free bedding.

Odor complaints ceased. This farmer regularly received complaints from neighbors for over ten years regarding odor during field application, especially with summer spreading on alfalfa fields. One elderly neighbor, whose backyard abuts the alfalfa field, typically sat on her porch with a phone in her lap to immediately call County Commissioners with odor complaints when spreading began. The first application after aerobic installation, with wind blowing across the field directly toward where she sat, she did not place the call. In addition, crop consultants who walked the field the day after application, were surprised to find no odor from residual manure slurry on the ground. Treated manure nutrients had already soaked into the ground, which was dry and clean. There was no indication of yellowing or damage of tender alfalfa sprouts. The farmer reported he harvested the alfalfa crop in 21 days, instead of the usual 28 days to cutting. This produced five cuttings per year instead of four and increased tonnage by more than 25% with each cutting as good as, or better, than the previous one.

Manure pumpers noted that no agitation was required to pump the entire lagoon and that material sprayed on top the field was immediately absorbed into the soil with no slurry residue left on the ground. Three lab samples were submitted to the labs during the first nine months of testing at this site. Samples showed a steady increase in total nitrogen and an increase in ammonium (NH_4+) as a percent of Total-N. This means more manure nitrogen entering the lagoon is continuously converted to ammonium. Ammonium is not readily susceptible to denitrification or off-gassing from the lagoon and can be applied directly onto crops during the growing season when it is less likely to leach out of the soil.

Circulator equipment is capable of handling significant challenges. One farmer had his lagoon pumped shortly before circulator installation. Because manure applicators did not successfully agitate the solid side of this two-stage lagoon, circulator equipment had to be installed directly into the solids. Nevertheless, the equipment started up and ran without problem. Observers noted continuous digestion of measurable amount of solids in only a few months. By the end of the first year, solids were gone.

As settled solids digest, they become notably lighter and rise to the surface of the lagoon in a process known as bulking. When large chunks come up directly below the circulators, they can disrupt machine operation and, in a few instances, the additional amp drain triggered breakers to shut off the current. The owner simply pushed the reset button and the machines started running again. Automatic restart has been installed to cope with this condition.

Owners noted the potential for change in manure management. One farmer said he wished he had known about this technology sooner. Work and family life near the livestock facility are much more pleasant. This farmer and his neighbor plan to acquire a large travelling gun for distribution of nutrient foliar feeding on top the growing crop. This will be done to gain the promise of additional crop yields from timely fertilizer applications during the growing season, not otherwise possible with manure. This practice will help avoid leaching and run-off from manure applications on wet or frozen ground, but can be desirable only when odor, pathogens and GHG's have been eliminated, nutrients are in crop-ready condition and EC's are low enough to prevent crop yellowing that can occur when applying untreated liquid manure on growing crops.

APPENDIX A: TECHNOLOGY DOCUMENTS

Oxygenation Circulator Platform (OCP) technology is recommended for common usage in the aerobic treatment of manure lagoons. A recommended practice standard under which this technology would be implemented is provided below. It is strongly recommended that NRCS consider publication of this practice standard as one way to implement economical aerobic manure management. And also it needs to be recognized that this Practice, while it offers tremendous opportunity for environmental and agricultural improvement, is innovative and will be unfamiliar to farmers as well as technical consultants and advisors. Significant educational efforts will be needed to support the introduction of this practice.

NATURAL RESOURCES CONSERVATION SERVICE
CONSERVATION PRACTICE STANDARD

AEROBIC MANURE TREATMENT THROUGH TOTAL LAGOON CIRCULATION

(no.)
CODE XXX

DEFINITION

An animal waste treatment system consisting of a Minimum Treatment lagoon and a Treated Nutrient Storage lagoon or a combination of both in an uncovered structure that has a surface exposed to sunlight and atmosphere. Mechanical upflow circulation equipment is properly designed and installed per manufacturer's recommendation. The system will provide continuous vertical lagoon circulation sufficient to expose the entire contents several times each hour to atmospheric oxygen and UV sunlight for re-oxygenation, pathogen inactivation and antibiotic residue degradation, leaving no uncirculated zones that might provide refuge for anaerobic bacteria, pathogens or residues.

PURPOSE

To establish a manure treatment and storage system conducive to aerobic bacterial activity and unfavorable for anaerobic activity, pathogens and antibiotic residues. By supporting aerobic bacterial activity in manure lagoons, air quality risks such as odors, noxious gas, pathogens and severe greenhouse gasses including Methane and Nitrous Oxide are reduced or eliminated while more nitrogen is retained and converted to plant available ammonium. Less time is required for manure to decompose and to be transformed into odor-free, plant available nutrients. In particular, dry matter decomposes more rapidly and completely to improve pumpability and allow for fertigation without plugging spray nozzles. EC levels are brought into crop ready ranges so that nutrient material can be applied directly onto growing plants. This means animal waste nutrients can be applied onto farm fields, including no-till fields during the growing season. Applying plant nutrients onto crops during the growing season reduces the risks of leaching and runoff as well as severe air quality risks from Nitrous Oxide which is often associated with long term storage of unstabilized animal waste in lagoons or in the soil.

When adequate circulation equipment is installed and operational, aerobic manure treatment proceeds without odor. Lagoons with little or no anaerobic activity are effectively incapable of producing odors, noxious gas or greenhouse gases such as ammonia, hydrogen sulfide, methane, nitrous oxide, etc. which always result from anaerobic activity.

Aerobic treatment through Total Lagoon Circulation is an effective process to eliminate severe greenhouse gas formation from manure systems and provides another method for claiming future carbon credits in a quest for improved environmental husbandry.

CONDITIONS WHERE THIS PRACTICE APPLIES

Where manure can be stored and treated in an open lagoon
Where mechanical circulation/aeration is allowed as a component of agricultural waste management
Where pathogen reduction and degradation of anti-biotic residue in animal wastes are desirable
Where minimization of greenhouse gas production from farm animal manure is a priority
Where elimination of manure odor is a priority
Where pumpability of lagoon contents is desired for field application during the growing season
Where intentions are to retain as much nitrogen as possible from animal manure for field application
Where immediate uptake of plant nutrients upon distribution to growing crops is desired
Where leaching or runoff of spread or injected manure is a pollution concern
Where odor-free "safe water" is desired for continuous barn cleaning to reduce in-barn gas and odor
For lagoons utilizing embankments with a vertical depth of 35 feet or less
Where carbon-credit programs offer premiums for greenhouse gas reduction

CRITERIA

Aerobic Manure Treatment through Total Lagoon Circulation utilizes mechanical circulation equipment to keep the entire lagoon in continuous vertical upflow and provide complete mixing. To be effective for odor control and pathogen reduction with maximum nitrogen conversion to plant available ammonium, Mechanical Circulation equipment must remain in continuous, 24 hour operation. Failure to keep the lagoon in vertical upflow allows facilitative anaerobic activity to gain a foot-hold within the lagoon. Intermittent or reduced operation, or inadequate equipment, such that suspended solids are no longer brought continuously to the surface, allows residues and pathogens to survive and anaerobic bacteria to thrive at lower lagoon levels. Anaerobic activity releases noxious gas and odors as well as severe Greenhouse Gasses such as nitrous oxide and methane. Furthermore, inadequate circulation allows reversal of liquid ammonium to ammonia gas which volatilizes off the lagoon as ammonia or as dinitrogen gas through the well known process of de-nitrification. All this begins to happen subtly, often without notice in only a short time after equipment stops functioning. Mechanical Upflow Circulation Equipment MUST be running at all times to maintain effective Aerobic Manure Treatment through Total Lagoon Circulation.

Laws and Regulations

All federal, state, and local laws, rules, and regulations governing the construction and use of waste treatment lagoons must be followed.

Laws and regulations of particular concern include those involving county zoning, water and drainage rights, land use, land disturbance by construction, pollution control, property easements, wetlands, preservation of cultural resources, and endangered species apply.

Where State Regulators approval is to be obtained, such State Regulation requirements must be met.
State and Federal Dam safety requirements shall be met for construction of facilities with embankments.

The owner or operator shall be responsible for securing all required permits or approvals related to waste treatment, and for operating and maintaining any components in accordance with applicable laws and regulations.

Location

Treatment lagoons shall not be located within the 100-year frequency flood plain unless the structure is protected from inundation and damage that may occur during the 100-year frequency flood event.

Treatment Lagoons, and wastewater disposal sites cannot be located closer than 1,000 feet from an existing public water well or drinking water source nor 250 feet from a well or drinking water source not owned by the producer.

Treatment Lagoons and wastewater disposal sites shall not be located closer than 150 feet from water well or drinking water source that is owned by the producer.

Treatment Lagoons shall be located so the potential impacts from breach of embankment, accidental release, and liner failure are minimized; and separation distances are such that prevailing winds and landscape elements such as building arrangement, landforms, and vegetation minimize odors and protect aesthetic values.

Treatment Lagoons should be located so they have as little drainage area into the lagoon as possible. If a lagoon has any drainage area, the volume of normal runoff during the treatment period and 25year, 24-hour storm event runoff shall be included in the required volume of the lagoon.

Mechanical Equipment

Continuous and relentless full-time operation of Mechanical Upflow Equipment and its proper installation design is paramount to the success of the system. The equipment to be installed shall be designed by the manufacturer to provide complete lagoon circulation, bringing liquids and solids from the bottom of the lagoon to the top of the lagoon, in a continuous non-turbulent flow. Equipment advertized as providing a facilitative zone and/or anaerobic zone within lagoons are NOT acceptable to meet this Standard. Goals can NOT be met without complete lagoon circulation. (see reference documentation for effective operational function and goals). Multiple units shall be installed in a pattern which assures no areas of the lagoon are left undisturbed. Equipment is to operate continuously without interruption and repairs are serviced in a timely manner.

Equipment Monitoring

Research has proven time after time that repair or restarting mechanical equipment after power interruption or failure is not often a priority in the complex and many duties at a farm operation. Research indicates that a 3rd party monitoring system providing the required inspection via remote observation to inform owners of needed attention in a required timeframe needed to prevent greenhouse gas releases, odors, and invisible nitrogen gassing, through an undesirable de-nitrification process. 3rd Party remote monitoring, control, and repair mobilization systems are much preferred to expecting a farm operator to responsively tend to that work.

Continuous Equipment Operation

Experience shows that field trash, barn trash, afterbirth, bale netting and twine, pieces of silage bags or even grocery bags blown in or entering from the barn will rag up impellers and caused reduced or interrupted circulation. Aerobic system design must give consideration to facilities or mechanisms to prevent of this kind of material from entering the system. Trash lanes or sand recovery lanes built into the waste systems are recommended to prevent barn trash from entering the lagoon. Farm field fence of adequate height is needed to be placed appropriately for the locality and wind strength. Monitoring guidelines for equipment operations must include requirements for de-ragging impellers on an as needed basis whenever observation indicates reduced circulation or service interruption.

Soils and Foundation

Treatment Lagoons shall be located in soils with limited permeability which meet all applicable regulations, or the lagoon shall be lined. Information and guidance on controlling seepage from waste impoundments can be found in the Agricultural Waste Management Field Handbook (AWMFH), Appendix 10D.

The treatment lagoon shall have a bottom elevation that is a minimum of two feet above the seasonal high water table unless special design features are incorporated that address buoyant forces, lagoon seepage rates, and non-encroachment of the water table by contaminants. The water table may be lowered by use of perimeter drains to meet this requirement.

Earthen lagoon structures

Unless supported by a soil investigation, excavated side slopes shall be no steeper than 3 horizontal to 1 vertical.

Wind and Wave Protection

Erosion protection shall be provided for earthen waste treatment lagoons having a five-acre or larger liquid surface at maximum operating level or as required bu state regulations.

Embankments

The minimum elevation of the top of the settled embankment shall be one foot above the lagoon's required volume. Minimum freeboard for facilities permitted by the State must meet state regulations. This height shall be increased by the amount needed to ensure that the top elevation will be maintained after settlement. Where required compaction is less than 95 percent of ASTM D698 standard maximum dry unit weight (standard proctor density,) the fill height increase for settlement shall not be less than 5 percent. Earth embankment slopes must be designed to be stable, and must be 3 horizontal to 1 vertical or flatter. Minimum top widths are shown in Table 1 below.

Table 1 – Minimum Top Widths Total Embankment

Height at Centerline, feet	Top Width, feet
9.9 or less	8
10.0 to 19.9	10
20 to 24.9	12
25 to 29.9	14
30 to 35	15

Note – State Regulation may require other widths.

Clay Liners

Clay liners must be at least 18 inches thick and compacted to at least 95 percent of standard maximum dry unit weight (standard proctor density), and at water content within 2 percent of optimum as determined by ASTM D698. Where State approval will be obtained, the compacted clay liner must meet State regulatory requirements.

Flexible Membranes

Flexible membrane liners shall meet or exceed the requirements of flexible membrane linings specified in Lagoon Sealing or Lining, Flexible Membrane (521A).

Inlet

Inlets shall enter the lagoon at or above the full level. Inlets shall be of any permanent type designed to resist corrosion, plugging, freeze damage, and ultraviolet ray deterioration, while incorporating erosion protection as necessary.

For inlets carrying solids, the inlet should be designed to direct waste away from the sides or ends of the lagoon. Minimum pipe diameter shall be 12 inches. The preferred pipe slope for gravity flow is one percent. Flatter slopes may be used where provision is made to clear blockages.

Outlet

No outlet shall automatically reduce the required Minimum Treatment Volume of the lagoon. Outlets from the required volume shall be designed to resist corrosion, freezing and plugging.

Facility for Drawdown

Access areas and ramps that facilitate safe drawdown of the liquid level in the lagoon shall be provided and shall have slopes that facilitate a safe operating environment. Docks, wells, pumping platforms, retaining walls, etc., shall permit drawdown without causing erosion or damage to liners..

Sludge Removal

A properly operating aerobic circulation system will be bringing solids up from the bottom on a relentless and continuous basis, and provides no opportunity for settled sludge to form. No Provision shall be required for periodic removal of accumulated sludge to preserve lagoon treatment capacity. Where lagoon overloading has occurred and at least 20% settled sludge is apparent, the farm operator will be required to remove the settled solids and reduce the overloading to the lagoon or increase the lagoon size or build additional capacity for the new loadings.

Groundwater Monitoring

Where treatment lagoons are located over shallow aquifers or where discharge to groundwater may occur, regularly sampled groundwater monitoring wells or a Groundwater Discharge Permit may be required. For each affected site, these requirements will be as specified by State Regulators.

Erosion Protection

Embankments and disturbed areas surrounding the lagoon shall be treated to control erosion. This includes the inside slopes of the lagoon as needed to protect the integrity of the liner.

Safety

Designs shall include appropriate safety features to minimize the hazards of the facility. Warning signs, fences, and other devices shall be provided to keep flotsam and debris from blowing into the lagoon area, and to ensure the safety of humans and livestock.

Waste Loading

Daily waste loading shall be based on the maximum daily loading considering all waste sources that will be treated by the lagoon. Reliable local information or laboratory test data should be used if available. If local information is not available Chapter 4 of the AWMFH may be used for estimating waste loading. Mechanical treatment function shall be designed on the basis of daily BOD5 or Volatile Solids loading and aeration equipment manufacturer's performance data for oxygen transfer and mixing. Aeration equipment shall provide a minimum of one pound of oxygen per pound of daily BOD5.

Treatment Period

Because the minimum treatment volume is substantial compared to the relatively small continuous daily inflows, after the initial installation is functioning, the majority of lagoon water is always already treated, and there is NO required detention time between drawdown events. Instead, because of the significant amount of minimum treatment volume required, a process of “pump down and refilling with fresh water” is best implemented to withdraw as much of the nutrients from the past year's production, always leaving the minimum treatment volume with water for treatment and/or recycled flushing of barn gutters, alleys and pits where desired. BMP for refilling MTV is to direct fresh water into a secondary (if available in the system) storage pond where it can be conditioned before adding into the MTV lagoon. If no treated nutrient storage lagoon is available, refill must be accomplished at an inflow rate that does not disrupt the aerobic activity in the MTV lagoon, based on equipment manufacturer recommendations.

Required Lagoon Design Considerations:

The lagoon system shall have the capability of containing the following quantities:

Minimum Treatment Volume (MTV) per manufacturer’s recommendations;

Nutrient Storage Volume accumulated during the treatment period;

Minimum /maximum circulation depth per equipment manufacturer specifications;

For exposed lagoon systems, depth of mean annual precipitation less evaporation on the surface area;

Mean annual runoff (if the structure receives runoff from an open lot or other drainage area);

The lagoon system shall include the capacity to contain the 100year frequency, 24-hour duration storm precipitation.

Additional treated nutrient storage lagoons as may be required to meet management goals or regulatory requirements.

Operating Levels

The operating level shall provide the required volume plus the included storm event precipitation on the surface of the lagoon. Maximum drawdown level shall be the lagoon level that maintains the required minimum treatment volume. Permanent markers shall be installed at these elevations, and referenced and described in the operation and maintenance plan. Proper operating range of the lagoon is above maximum drawdown level and below operating level.

Other Design Considerations

The formation of Struvite (salt crystals) in pumped systems can be inherent in certain geographical areas, depending on water quality. Wherever pumped systems are considered for inclusion in the waste management process, including recycling for barn cleaning or pumping through pivots for field application, review should be performed by the designer to recognize where local water quality may be conducive to Struvite formation in any pumping system, and if so, plan for sufficient circulators to provide additional circulation to assure extensive aerobic activity to generate carbon-dioxide in the water to lower pH to levels normally known to prevent struvite formation at that location. Reduced pH also helps to avoid ammonia formation and assure Nitrogen remains in ammonium form.

Depth Requirements

The minimum depth at maximum drawdown shall be set to equipment manufacturer standards.

CONSIDERATIONS

Lagoons should be located as close to the source of waste as possible.

Except for cases of very high dry matter loading, such as high amounts of straw bedding, there exists no need for Solid/liquid separation since aerobic activity will be designed to meet decomposition needs.

The configuration of the lagoon should give consideration for use of the lagoon water for recirculation through barn alleys , gutters and pits to help reduce odors and pathogens within the barn systems, as well as consideration for effective nutrient distribution to growing crops.

Consideration should be given to the conservation of water. In times of drought especially in dry land farming, wastewater lagoons can be recycled for use as rescue irrigation. Consideration should be given to reducing the surface to volume ratio of treated lagoons by increasing the depth to help minimize evaporation and conserve water. Less evaporation also means greater nitrogen retention and reduced N-loss to the atmosphere

Due consideration should be given to economics, the overall waste management plan, and safety and health factors.

CONSIDERATIONS FOR MINIMIZING THE POTENTIAL FOR AND IMPACTS OF SUDDEN BREACH OF EMBANKMENT OR ACCIDENTAL RELEASE FROM THE REQUIRED VOLUME

Features, safeguards, and/or management measures to minimize/mitigate embankment failure or accidental release risks/impacts should be considered when any of the categories listed in Table 2 may be significantly affected. Consider including:

An auxiliary storage or treatment lagoon to help assure containment and encourage distribution onto growing crops;

Reinforced embankment - such as, additional top width, flattened and/or armored downstream side slopes;

Secondary containment;

Water level indicators or recorders;

Locked fence gate and locked equipment housing;

Alarm system;

Another means of emptying the volume.

Table 2 – Potential Impact Categories from Breach of Embankment or Accidental Release
Surface water bodies - perennial streams, lakes, wetlands, and estuaries.
Critical habitat for threatened and endangered species.
Riparian areas.
Farmstead or other areas of habitation.
Off-farm property.
Historical and/or archaeological sites or structures that meet the eligibility criteria for listing in the National Register of Historical Places.

CONSIDERATIONS FOR MINIMIZING THE POTENTIAL OF LAGOON LINER SEEPAGE

Consider providing additional safety from lagoon seepage when conditions listed in Table 3 exist. Consider including:

A clay Liner

A flexible membrane liner;

Concrete liners would not be considered reliable.

Table 3 – Potential Impact Categories for Liner Seepage
Any underlying aquifer is at a shallow depth and not confined;
The vadose zone is a rock;
The aquifer is a domestic water supply or ecologically vital water supply;
The site is located in an area of carbonate rock (limestone or dolomite).

SUGGESTED MODIFICATIONS TO OTHER STANDARDS:

Reference to this xxx proposed practice should be given in Practice 359, in the "CONSIDERATIONS FOR IMPROVING AIR QUALITY" paragraph found towards the end of the document.

Reference to this xxx proposed practice should be given in Practice 633 Waste Utilization documentation.

PLANS AND SPECIFICATIONS

Plans and specifications shall meet this standard and shall include requirements needed to achieve its purpose.

OPERATION AND MAINTENANCE

An O&M Plan must be developed for use by the owner/operator. The plan shall contain the criteria for maintaining all required treatment volumes, all mechanical equipment in full time operation, operational requirements for drawdown, restriction from and removal of non-biodegradable items within the lagoon, and the role of permanent markers.

The Plan shall include the requirement that treated nutrients be removed from the lagoon and utilized at locations, times, rates, and volume in accordance with the overall aerobic nutrient management system plan.

In addition, the plan shall include a strategy for removal and disposition of nutrient waste with least environmental damage during the normal seasonal period to the extent necessary to insure the lagoon's safe operation.

Development of an emergency action plan should be considered for lagoons where there is a potential for significant impact from breach or accidental release. The plan shall include site-specific provisions for emergency actions that will minimize these impacts.

REFERENCES

Animal Waste Management to Protect Water Livestock Waste Facilities Handbook
Quality (EC 895) – South Dakota (MPWS-18) Midwest Plan Service.
Cooperative Extension Service.

Concrete Manure Storages Handbook
(MWPS-36) Midwest Plan Service.

Fact Sheet – Technical Note

Summary and Analysis/Report

AEROBIC TREATMENT THROUGH CONTINUOUS LAGOON CIRCULATION
CODE XXX PROPOSED

Landowner/Operator ____

Job Location____ GPS _________________________________

Prepared by ____ Date _______________________

Operation and Maintenance Items

A properly operated and maintained aerobic nutrient management treatment lagoon system is an asset to your farm in many ways. Crop ready plant available nutrients, manure odor elimination and conversion of manure into pump able true liquid are only a few of the benefits. This system is designed and installed to provide full conversion of manure into crop ready plant nutrients that can be stored for an extended time and can be applied onto growing crops during the growing season without significant loss of nutrient value. Several things are required for effective operation:

1. Minimum Treatment depth and volume must be maintained for the circulation equipment to function properly.
2. Circulation Equipment must be able to operate without being encumbered by flotsam or debris that can wrap up on the impeller system.
3. Circulators must be in continuous operation to assure lagoon is always and fully conducive to harboring aerobic bacteria and simultaneously provides a harsh environment to anaerobic bacteria, to limit their presence, eliminating traditional manure odor.

Tempting to many operators is the ability to fully dewater a properly operating lagoon because it pumps so easily. Pumping below Minimum Operating Level must be avoided. Pumping below the minimum treatment volume causes problems with the treatment system and also disrupts the ability to recirculate treated water through any barn cleaning system that may be in use.

The estimated life span of this installation is at least 20 years. The effective operation of this installation can be assured and life expectancy increased by developing and carrying out an effective operation and maintenance program. **Inspection** r**equirements for effective operation and maintenance include:**

Lagoon Structure:

1. Inspect the lagoon weekly and after any significant rainfall, documenting each inspection in permanent records.
2. Fences, screens, or other devices to prohibit plants/weeds and trash from blowing into the lagoon must be maintained.
3. Screens and/or rodent guards must be maintained and in place. Repair any rodent, burrowing animal, vandalism, vehicle, or livestock damage to the lagoon.
4. Inspect concrete for accelerated weathering, spalling, settlement, misalignment, or cracks. Repair defects.
5. Inspect rock riprap for accelerated weathering and displacement. Repair to original grades if necessary.
6. Excessive erosion, settlement, and/or cracks in earthen sections must be investigated (to determine the cause) and repaired.
7. Maintain vigorous growth of specified vegetative coverings. This includes reseeding, fertilization, and application of herbicides when necessary. Periodic mowing or short-term grazing may also be needed.
8. Remove all large weeds, shrubs and woody vegetation. This includes shrubs and trees that are growing close enough to the structure to impact earth embankments with root growth.
9. Check for unusual seepage on the backside of the lagoon dike.

10. Clean lagoon inflow screening system or trash collection lanes to assure major contaminants such as plastic netting, rags, bags, twine, animal placenta, and other difficult-to-decompose items are not entering the lagoon.
11. Note that the lagoon effluent level must be at or above minimum treatment elevation and below maximum operating limits.

Circulation/Aeration Equipment:

1. Visually note each circulator is in operation, and is not exhibiting any signs of deficiency, such as wobbling or bobbing. If issues exist, immediately implement repair process so circulators quickly get back into effective service.
2. Inspect power supply system for the circulators, noting any conditions which indicate needed repair or replacement.
3. Inspect anchoring and positioning system to assure circulators cannot stray from their intended area of influence.
4. Inspect monitoring and control system for each unit to assure operations control.

Lagoon Recirculation or Dewatering Equipment:

1. Inspect Wetwell and Inlet Pipe structure for any signs of irregularities.
2. Inspect power supply system and controllers for wetwell pump(s).
3. Inspect wetwell pump operation, assuring no wobbling or other indication of unsoundness. Assure sufficient water supply is coming through the Inlet Pipe from the Lagoon, such that the pump is submerged.
4. Lagoon Effluent should be tested regularly for pH, keeping in mind that Struvite formation is possible within recirculation piping and equipment if pH levels rise much above 7.0. If local water used for the animal operation has high mineral content possibly conducive to Struvite formations, an acid flush return line should be installed along the wetwell force main line so the acid flush process can effectively address the Struvite formations at a lower cost, limiting the acid used, recycling it through only the wetwell and force main lines, not across the barn floor or manure pits under the barn..

Lagoon Dewatering - Fertigation Operation:

1. Because of the high decomposition rates provided by total circulation within the lagoon, all of the manure nutrients become available to plant growth at distribution time, usually without burning or yellowing when directly applied to growing crops. ***Prior to distribution, lagoon effluent should be tested for nutrients and for electrical conductivity rating, to assure safety for the particular crop it will be applied to.***
2. Assure circulator cable anchoring systems flex sufficiently to not damage circulators or tether cables when the lagoon effluent level recedes.
3. The high decomposition rates provided by aerobic treatment using total lagoon circulation also assure conversion/ decomposition/ elimination of dry matter within the lagoon effluent. For those who are used to pumping manure through irrigation equipment, a pleasant surprise is that irrigation equipment nozzles no longer plug up, and the dewatering system proceeds without the difficulty associated with raw manure. **IT IS IMPORTANT TO STOP PUMPING when the lagoon reaches the minimum treatment level so as to retain minimum treatment volume so the aerobic equipment can continue to work.**
4. Alternate systems for dewatering the lagoon are available to farmers, even if irrigation equipment is not in place at all farm fields. Because traditional manure pumping equipment normally is used prior to planting or after harvest, such equipment is usually idle during much of the crop growing season. Using such pumping equipment and hoses for transporting lagoon effluent to portable pivots or guns allows a cost effective way to fertigate sites previously thought inaccessible.
5. Because of the required minimum treatment volume inherent with a total lagoon circulation system, a substantial amount of nutrients are left within the lagoon system's treatment volume. After pumping down to the minimum treatment volume, pumping must cease. Several dilution processes can be implemented as additional water is available. Care should be taken to not add too much water too quickly such that it would disrupt the biological activity. Well water is often cold and without oxygen, needing to be slowly added to the system so as not to shock or inhibit the existing aerobic microbial biomass.
6. A final pumping from the lagoon should be performed late in the growing season to help assure adequate storage volume is provided in the lagoon throughout the non-crop season until the next crop season arrives.

Other ____

AEROBIC MANURE TREATMENT THROUGH TOTAL LAGOON CIRCULATION

These deliverables apply to this individual practice. For other planned practice deliverables, please refer to those specific SOW's.

DESIGN

Deliverables

1. Pre-design conference with client and Natural Resources Conservation Service (NRCS) representative.
2. Design documentation that will demonstrate that the criteria in NRCS practice standard have been met and are compatible with other planned and applied practices:
    a. Practice purpose(s) as identified in the conservation plan.
    b. List of required permits to be obtained by the client.
    c. Compliance with NRCS national and state utility safety policy NEM, Part 503 -Safety, Subpart A, Engineering Activities Affecting Utilities, 503.00 through 503.06).
    d. List of facilitating practices.
    e. Practice standard criteria related computations and analysis to develop plans and specifications including but not limited to:
        i. Geology and Soil Mechanics (NEM, Subpart 531a).
        ii. Storage and Treatment Volume.
        iii. Maximum and Minimum Operating Levels.
        iv. Structural, Mechanical, and Appurtenances.
        v. Maximize Clean Water Diversion.
        vi. Environmental Considerations (e.g., liner failure, location, breaching, air quality).
        vii. Safety Considerations (NEM, Part 503-Safety, Subpart A, 503.06 through 503.12).
3. Sufficient copies of written plans and specifications including sketches and drawings shall be provided to the client that adequately describes the requirements to install the practice and obtain necessary permits.
4. Specific detailed requirements for Waste Treatment Lagoon design and the development of construction plans and specifications are outlined in the South Dakota Engineering and Spot Checking Manual (SDEDSCM), under the Waste Management Structure Practice Requirements. Where specific forms or job sheets are mentioned in the SDEDSCM, an equivalent may be substituted. The guidance contained in this manual shall be considered as the minimum acceptable for this practice.
5. Design Report and Inspection Plan as appropriate (NEM, Part 511, Subpart B, Documentation, 511.11, and Part 512, Subpart D, Quality Assurance Activities, 512.30 through 512.32).
6. Operation and Maintenance Plan.
7. Certifications that the design meets practice standard criteria and comply with applicable laws and regulations (NEM, Subpart A, 505.03(b)(2)).
8. Develop and sign an engineer's cost estimate based on project quantities. Provide revised cost estimates in the event of changes to project quantities or completion of final design.
9. Develop a list of practices for the project that includes the practice unit and extent. Provide a revised list of practices, practice units, and extents in the event of changes to these values or completion of the final design.
10. Provide an anticipated installation schedule.
11. Design modifications during installation as required.

INSTALLATION

Deliverables

1. Pre-installation conference with client, contractor, and NRCS representatives
2. Verification that client has obtained required permits.
3. Staking and layout according to plans and specifications including applicable layout notes.
4. Installation inspection (according to inspection plan as appropriate):
    a. Actual materials used (NEM, Part 512, Subpart D, Quality Assurance Reviews, 512.33).
    b. Inspection records.
5. Specific detailed requirements for AEROBIC TREATMENT THROUGH CONTINUOUS LAGOON CIRCULATION installation are outlined in national references, under the Waste Management Structure Practice Requirements. Where specific forms or job sheets are mentioned, an equivalent may be substituted. The guidance contained in this manual shall be considered as the minimum acceptable for this practice.
6. Facilitate and implement required design modifications with client and original designer.
7. Advise client/NRCS on compliance issues with all federal, state, Tribal, and local laws, regulations, and NRCS policies during installation.
8. Certification that the installation process and materials meet design and permit requirements.

CHECK OUT

Deliverables

1. As-Built documentation:
    1. Extent of practice units applied.
    2. Drawings.
    3. Final quantities.
2. Specific detailed requirements for AEROBIC TREATMENT THROUGH CONTINUOUS LAGOON CIRCULATION checkout design and the development on construction plans and specifications are outlined in the national documentation, under the Waste Management Structure Practice Requirements. Where specific forms or job sheets are mentioned, an equivalent may be substituted. The guidance contained in this manual shall be considered as the minimum acceptable for this practice.
3. Certification that the installation meets NRCS standards and specifications and is in compliance with permits (NEM, Subpart A, 505.03(c)(1)).
4. Progress reporting.

REFERENCES

- NRCS National Technical Guide (eFOTG), Section IV, Conservation Practice Standard - Waste Treatment Lagoon (359)
- NRCS Agricultural Waste Management Field Handbook
- NRCS NEM
- NRCS National Environmental Compliance Handbook
- NRCS Cultural Resources Handbook NRCS AEROBIC TREATMENT THROUGH CONTINUOUS LAGOON CIRCULATION (Proposed)

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AEROBIC MANURE TREATMENT THROUGH TOTAL LAGOON CIRCULATION

Decomposition of nutrient wastes, plant, animal or human, normally occurs through bacterial activity. Bacterial activity is either aerobic (use oxygen to thrive) or anaerobic (oxygen is hostile to them). Since the 1970's, attention has been given to developing anaerobic digesters and harvesting methane gas for energy production. Offering an excellent alternative, this fact sheet discusses the benefits and paybacks of Aerobic Treatment for animal wastes – which, it must be remembered, will still be necessary to stabilize waste and reduce the odors and GHG's given off by anaerobic digester effluent.

Understanding Aerobic Treatment is simplified by examining "compost" systems. Compost piles need to be turned or stirred regularly to assure oxygen throughout, allowing aerobic bacteria to thrive and consume wastes, decomposing them into basic plant nutrients without the odors and GHG's given off by anaerobic activities. In nature, mountain streams tumbling over rocks provide tremendous oxygenation and cleansing to the water. In shallow lagoons, wave action does the same, re-oxygenating and mixing dissolved oxygen throughout the lagoon.

Decades ago, to augment wastewater treatment, engineers devised procedures that inject air into waste water treatment lagoons by blowing bubbles. The concept of "blower horsepower" became popular as the basis for design decisions because it was easy to derive the necessary power consumption. Thus, wastewater treatment through air-water surface interface was neglected and largely forgotten.

Recently, air-water surface interface has been reexamined due to lower energy costs and other important benefits. To achieve this goal, equipment used to enhance re-oxygenation and mixing creates specific and continuous upward flows of water within the lagoon, providing an ever changing surface for re-oxygenation as well as providing mixing within the lagoon.

Much like composting activities, lagoon circulation distributes oxygen throughout the lagoon to establish an environment to supports aerobic bacteria and is hostile for anaerobic bacteria. Inhibiting anaerobic activity is important for reduction of severe greenhouse gas such as methane and nitrous oxide.

Equally importantly for some, inhibiting anaerobic activities restricts the formation of odors and noxious gasses that negatively impact quality of life and may be harmful to human and animal health.

Furthermore, although not often discussed in air quality circles, the reduction of pathogens from animal waste nutrients before distribution onto farm fields can be very important in reducing the risk of human exposure to disease causing agents that may be present in the animal environment.

DISCUSSION: Potential benefits, requirements, likely problems, solutions to problems, and falseness/misconceptions surrounding Aeration through Circulation are discussed below:

Potential Benefits to be Derived from Aerobic Manure Management Systems:

1. **Rapid nutrient stabilization.** Aerobic treatment for manure transformation is designed to supply adequate oxygen for production of ammonium but not to oversupply oxygen for the production of nitrate. This ensures animal waste nitrogen is converted into ammonium. Ammonium does not easily evaporate and is retained in the confines of the lagoon. And unlike nitrate, ammonium does not denitrify into dinitrogen gas which can quickly exit the lagoon.

2. **Low energy requirements**. Surface re-oxygenation combined with total lagoon mixing, in place of blower horsepower, provides a vast improvement on oxygenation costs. The movement of the water not only achieves the most efficient form of re-oxygenation, but also keeps larger/heavier decomposable particles in suspension where they are aerobically decomposed.
3. **No odor.** Much of the offensive odor from manure lagoons comes from ammonia. A properly designed aerobic system quickly stabilizes ammonia and converts it to ammonium. All other manure related odors are the result of anaerobic bacterial decomposition. A properly operating circulated lagoon creates a hostile environment for anaerobic bacteria, eliminating the potential for odor production from anaerobic decomposition.
4. **Manure decomposition.** With sufficient oxygen provided to continuously offset incoming BOD_5, after approximately 28 days of aerobic exposure, manure is fully decomposed, with all nutrients readily available for fertilizer application. Fresh daily supplies of animal waste buffered within the lagoon's substantial minimum treatment volume, along with continuous mixing and surface re-oxygenation ensures that the lagoon is rich with bacteria ready to consume the relatively small waste stream entering the lagoon on a daily basis.
5. **Pathogen Elimination.** The lagoon surface is continuously renewing itself. Oxygen depleted bottom water is brought to the surface and exposed to atmospheric oxygen and UV sunlight (during daylight hours). After adequate exposure, the ultraviolet spectrum of natural sunlight provides effective sterilization and inactivation of pathogens. Reports of samples from aerobic circulation systems, prior to fertigation, show E. Coli at almost non-existent levels.
6. **Recycling Safe Water for Barn Cleaning**. Properly designed circulation systems are rich with aerobic bacteria, pathogen free, and are able to be recirculated through barns to provide “safe water” for flush systems designed for cleaning animal confinement floors. As opposed to fresh well water, which leaves a slimy residue because of its lack of bacteria and oxygen, recirculated treated lagoon water effectively erodes and dilutes manure within gutters and carries it away with the flush water, leaving barn floors clean and non-slippery.
7. **Fertigation**. Treated odor free lagoon water is stored until needed for application by fertigation directly onto growing crops through traditional irrigation equipment. Animal waste has been converted to plant ready nutrients, and the nitrogen is in ammonium form, readily able to be adsorbed directly through crop leaves and root systems already in place. Ammonium reaching the ground Bonds to most soils and does not run off, since ammonium as a positive ion and most soil is negatively charged. Because of ionic interaction, risk of Nitrogen runoff into the environment is greatly reduced.
8. **P and K Uptake**. Independent Research has shown that crop Nitrogen provided in Ammonium form encourages uptake of Phosphorus and Potash. Some researchers speculate the uptake is due to Ammonium's positive ion freeing up ionic activity normally tied up by the other Nitrogen negative ionic fertilizer sources. Others explain the P & K uptake to be a result of solubilizing bacteria developed in the lagoon and carried to the fields as an aerobic soil amendment. If in fact, nutrients provided by aerated lagoon systems help utilize Phosphorus and Potash in the field, the process can help Phosphorus rich soils reduce their high level of phosphorous burden.

Requirements for Performing Aeration by Circulation:

1. **An Open Lagoon**, with surface exposed to the atmospheric oxygen and sunlight.
2. **Sufficient Treatment Volume** in addition to required storage and freeboard.
3. **Mechanical circulation/aeration equipment** installed in a well designed manner and maintained in continuous operation.

4. **Fencing** around the lagoon to keep plastic bags, field trash, tumbleweeds, etc., out of the lagoon. This will rag up impellers and reduce circulation performance.
5. **Manure stream intercepts or trash lanes** to keep afterbirth, plastic bale netting, hoof wrap or other non-decomposable material or large amounts of bedding material out of lagoons.
6. **Stop pumping or dewatering** to avoid reducing minimum treatment volume in the lagoon. Minimum treatment provides working volume and bacteria to treat incoming nutrient flows.
7. **Monitoring systems** must be in place to assure continuous mechanical circulator operations are not disrupted. Disruption of circulation quickly leads to a return of anaerobic conditions within the lagoon, loss of N-value by volitilization of ammonia and the production of severe GHG methane and nitrous oxide as well as hydrogen sulfide and other PM precursors.
8. **Adequate Storage Volume** is encourage to assure flexibility for the operator to apply nutrients onto growing crops at the optimum stage of plant development for enhanced nutrient value. It will also be advantageous for the farmer to be able to apply more nutrients in one year and hold back the next due to changing weather, rainfall, temperature or crop rotation.
9. **Connection to center pivots**, *where possible*, to provide effective means of fertigating crop nutrients onto farm fields during the growing seasons when plants need nutrients most – thus avoiding application of animal waste onto wet or frozen ground when there is no growing crop present to assure nutrient uptake and avoid leaching or run off from farm fields.

Potential Problems:

1. **Poor aerobic design, inadequate power supply, poor equipment choice and mechanical failures.** The decomposition process has a natural balance. As long as sufficient oxygen is provided, almost all manure nitrogen is converted to ammonium and retained in the lagoon. If more oxygen is provided than is needed for conversion to ammonium, the ammonium will be converted to nitrate, a form that is difficult to control in the environment and can further decompose through denitrification – even without producing odor. Denitrification occurs when aeration within a treated lagoon stops. This denitrification process is well known in the wastewater treatment industry where it is used by design to rid domestic wastewater lagoons of their nitrogen before discharging into a stream or river. Domestic treatment plants want to get rid of nitrogen. Farmers usually want just the opposite, to retain as much nitrogen as possible for growing their crops, lest they have to buy and apply additional synthetic fertilizer.
2. **Failure to monitor/respond to equipment service needs**. History has shown that when a circulator has quit working, the operator can be slow to put it back into service. In some instances, all of the equipment stops, yet the operator has more important things to do than get them up and running again. The mechanical failure seems insignificant, but the “un-smelled” and unseen loss of nitrogen can be a major loss to the farming operation. Nitrogen gas has no odor, nor is it visible, so the farmer cannot know he has waited too long to put his equipment back in service. The only indication the system is failing is when odor becomes obvious, and by that time significant denitrification has already occurred.
3. **Failure to maintain minimum treatment volume.** History also shows that operators tend to want, if possible, to apply all of the lagoon nutrients to their crops, failing to retain enough treatment volume of lagoon water to keep the aerobic process functioning or in cases of flush barns, to provide flush system water for the equipment to function. This is especially true at locations that previously were designed for insufficient days of storage. Such locations were always to be emptied as much as possible to make room for the next cycle's manure production. It can be frustrating to stop pulling water from a lagoon that pumps so easily when in the past it was absolutely required to pump it down as far as possible – and that was difficult to do. Unless a fail-safe is put in place, pumping often continues past the stop mark.

4. **Trash entering the lagoon.** Weeds, netting and twine from bales, plastic bags from feed and silage, or afterbirth and placenta from pigs and cows will cause disruption in equipment operations. An investment in a farm field fence surrounding the lagoon, as well as proper management decisions to prevent non-decomposable material from entering the lagoon will help assure minimum downtime and service calls for aerobic circulator equipment.
5. **Electric energy costs**. Cumulative energy costs can seem large at converted lagoon sites. Where it might previously have been "ok" without motors running, in some cases, the added monthly bill will tempt the operator to shut off the system periodically. Without understanding the process of denitrification, by shutting the system down operators can lose nitrogen from the lagoon. Lost nitrogen obviously needs to be replaced by purchased nitrogen, usually at a higher cost. So no net gain is made by shutting down the manure stabilization process. The higher cost is simply sent to a different supplier.
6. **Struvite formation**. Where operators choose to eliminate gas and odor from their barns, they sometimes adopt a flush system or continuous pit recharge. By increasing ammonium fertilizer retention in aerobic lagoons, the conditions for struvite formation are enhanced. Adequate circulation to maintain pH in the neutral or acidic range will help prevent struvite formation.

Solutions to Potential Problems:

1. Lagoon design MUST include sufficient minimum treatment volume with clear marker indicating the stop pumping level and even better a lagoon level alert system to inform the owner/operator of pumping when the lagoon level goes below the minimum treatment level.

2. Lagoon design MUST include sufficient treated storage to help assure that operators can chose when to apply nutrients or delay their application without risk of overflowing the lagoon. Understanding nutrients no longer need to be knifed into the ground, but they can instead be applied to standing/growing crops without threat of "burning" such crops is paramount. Extensive yield increases are possible by timely application of nitrogen rich lagoon water to crops compared to field application on bare farm ground before the crop is planted or after harvest.

Falseness/Misconceptions:

1. **Research and reporting of the nitrogen retention** of Aerobic treatment systems have in the past sometimes incorrectly reported low nitrogen retention. This misinformation is likely based on systems using blower horsepower without adequate lagoon circulation, especially with systems that provide intensive treatment at the front end, but failed to provide sufficient continuous circulation to retain stabilized ammonium in the lagoon. Such reporting was likely established at treatment plants which purposely denitrify wastewater in effort to clean it for release into streams instead of applying it to crops.

2. **"More oxygen" is not better than "just enough oxygen"** Research has shown that some arbitrary level of excess "dissolved oxygen" within the lagoon is not only unnecessary for ammonium retention, but is actually detrimental to the success of stabilizing as much nitrogen as possible at the lowest energy cost. The goal of oxygenation circulation is to simply assure that the aerobic bacteria are given an environment that provides sufficient oxygen levels for them to survive and thrive. In other words, supply meets demand. Establishing requirements where surplus residual oxygen must be maintained is beyond need and requires 2x -3x more energy. In addition, N is then converted to nitrate which can become problematic in the field environment.

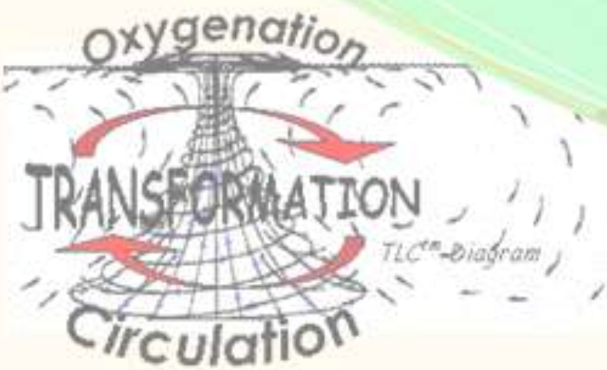
3. **Not every operator will be dedicated to keeping the equipment running**. Decades of operations review show that even with the best and most dedicated farm operators, equipment can go offline for weeks at a time before even being noticed. Farm manure lagoons, no matter what design, are usually away from buildings and are often not visited unless they have obvious leaks and/or are to be emptied. If/when equipment is finally found to be out of service, it may take

quite a while for owner/operators to find time to deal with the problem. During equipment downtime, denitrification can more easily occur, with loss of nutrients. In the worst case, surface aeration activity is slowed and anaerobic bacteria can start to take over, allowing odors and greenhouse gasses to be re-generated.

4. **It is a misconception that manure can simply be stored without losing nutrients**. Nature is relentless and quick: If manure is not given sufficient aerobic treatment, anaerobic bacteria begin their activity and proceed without delay. Denitrification and methane production is a large part of anaerobic decomposition. Denitrification means the loss of nitrogen from the manure, never to be recaptured.

5. **Manure transformation cannot be accomplished by Anaerobic Digesters.** The misconception is that processes which go on inside a digester will produce a more stable effluent emerging from the digester. The opposite is true. Anaerobic digester effluent is in a highly excited microbial state that actually produces more odor, noxious gas and severe GHG's than before it was digested. Further nitrogen losses will proceed quickly, unless the effluent is treated aerobically. This is because the digester is not able to consume the entire nutrient in the manure. Energy gained from the methane may be less valuable than the nitrogen lost from manure. In fact, with a digester system, the energy produced is often sold at wholesale. Yet, additional Nitrogen is needed by the crop to uptake the Phosphorus still left in the digester effluent. The additional Nitrogen must be purchased at "retail," likely establishing a losing balance sheet. By circulating an effluent lagoon, the nitrogen is saved, the phosphorus is saved, the lagoon has no odor, the lagoon nutrients can be applied by fertigation equipment, and the manure nutrients can offer the largest increase in value by being applied to standing crops.

6. **Many believe raw manure to be equal to treated manure.** This is a misconception. Untreated Manure is a strong corrosive. Raw un-decomposed manure has a high EC value, and is corrosive to metal and plants alike. It is true that pumping raw manure through irrigation equipment is corrosive to equipment and likely to burn or yellow the crop. A well designed aerobic treatment lagoon is not a manure lagoon. It is a falseness that well circulated aerobic lagoon water will be detrimental to crops or irrigation equipment. A properly operating aerobic treatment lagoon has a very low electrical conductivity (EC) value, which indicates several things: It is non-corrosive, and it is safe for application to standing crops.



The eXpert Company

April 2010

EQUIPMENT INFORMATION SHEET

Floating Oxygenation Circulator

RIBC 9000 Series Circul-O²-Rater™ (*Patent No.: US 8,191,868 B2*)

Manufacturer:	*THE EXPERT COMPANY INC.*, Circul-O²-Rater™ *Division*
Model:	*RIBC 9000 Series*
Horsepower:	Fractional, operating up to 1 hp/unit
Pumping:	6,266 gallons per minute to the surface
Circulation:	Toroidal Vortex, Min: $9 m^3/S = 318 ft^3/S$ or 8.5 million gallons/hour

Oxygen Transfer, Mixing and Dispersion:

Standard Oxygen Transfer = 25lbs/hr of Dissolved + Microbial Oxygen

Oxygen Dispersion:	600'R in lake water	100'R in waste water
Mixing Zone :	600'R in lake water	100'R in waste water
Effective Depth	Min 6'	Max 33'+

BOD reduction @ 77°F water temp at sea level:

Est: 15 lbs from DO + 5lbs from Microbial/hr x 24 = 480lbs/unit/day

Additional Benefits:

Energy Savings: up to 90% compared with blower/aspirator/venturi systems
More Manure-N recovery in crop available ammonium form
Pathogen reduction and large molecule degradation
Provide "safe water" to be recycled for beneficial reuse

***** *<u>Rotating Inverse Biological Contactor</u> (RIBC™) labeled "inverse" because the liquid rotates and tumbles its microbial contents into direct biological contact with atmospheric oxygen and UV sunlight. By contrast, ordinary Rotating Biological Contactors (RBC's) utilize solid disks to establish contact with the atmosphere. The RIBC™ contact surface is calculated as the "area of influence" x "frequency of surface renewal." RIBC™ delivers more BOD reduction than available from disk based RBC devices without bearing wear-out and maintenance required when using large rotating machines.***

*RIBC™ = Rotating Inverse Biological Contactor

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The eXpert Company

April 2010

MODE OF ACTION

How it works

RIBC 9000 - Circul–O²–Rater™

Floating Oxygenation Circulator

The floating ***Circul–O²-Rater***™ induces ***Toroidal Liquid Circulation***™ (***TLC***™) to deliver benefits from Oxygenation, Circulation and UV Exposure.

- A toroidal vortex gently sweeps across the bottom collecting available nutrients.
- Enzymatic nutrients travel up the vortex, mixing with aerobic microbes.
- At the surface, nutrients, microbes and water are enriched with oxygen.
- The biomass travels outward in direct contact with the atmospheric and into quiescent waters where microbial digestion readily occurs.
- On the surface, pathogens are deactivated and large molecules degraded by repeated exposure to UV radiation from sunlight.
- Down-flows move colonizing algae off the surface to prevent algal bloom.
- Cross-flows carry dissolved oxygen and aerobic microbes back across the bottom of the pond to digest sludge and avoid costly mechanical removal.
- ***Toroidal Liquid Circulation***™ ***(TLC***™***)*** combines microbes into bio-flocs and bio-films where complex microbial transformations and further large molecule degradation occur.

The RIBC™* process combines continuous surface renewal and re-oxygenation with gentle, *Toroidal Liquid Circulation*™ *(TLC*™*)* to maintain a fully aerobic water column and avoid dead spots where muck and sludge can accumulate to release offensive gasses and odors. With good design each unit circulates 9+ million gallons of water and supplies 20lbs of Dissolved Oxygen (DO) per hour, plus an estimated 5lbs of microbial oxygen from direct atmospheric contact. One *Circul-O²-Rater*™ supports reduction of about 20lbs of BOD per hour. UV exposure from sunlight assists pathogen inactivation and large molecule degradation.

*RIBC™ = Rotating Inverse Biological Contactor

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Sample Date	Name	Type	Dry matter	Nitrogen	NH4 Nit	NO3 N	P	K	pH	Ec	S	Ca	Mg
			%	%	%	%	%	%	VALUE	MMHOS	%	%	%
07/23/2012	ARENS	Swine	0.10	0.02	0.01	0.0010	1.11	9.17	7.5	1.98	0.44	3.67	2.00
10/20/2012	ARENS	Swine	0.30	0.03	0.02	0.0003	1.45	10.36	7.9	1.60	1.27	4.64	2.54
04/07/2011	BABCOCK NORTH	Swine	0.40	0.11	0.07	0.0009	1.21	16.44	7.7	7.33	0.65	2.71	0.91
04/07/2011	BABCOCK SOUTH	Swine	0.06	0.05	0.02	0.0008	1.75	18.63	7.8	2.47	1.13	5.63	2.63
02/02/2010	CR FARMS	Swine	8.00	0.04	0.02	n/a	0.50	23.55	8.1	10.50	2.21	1.27	0.58
06/15/2012	CR FARMS	Swine	1.20	0.09	0.07	0.0017	0.62	19.76	7.9	14.35	0.62	1.58	0.47
03/28/2013	CR FARMS	Swine	1.40	0.13	0.09	0.0024	0.35	22.25	8.2	19.68	0.97	0.83	0.32
10/04/2012	HUTTERVILLE N	Swine	0.20	0.05	0.04	0.0006	1.47	10.94	7.9	0.00	1.56	3.03	2.38
06/21/2012	HUTTERVILLE S	Dairy	0.30	0.05	0.05	0.0012	1.53	10.35	7.7	5.63	1.13	3.52	2.13
07/03/2012	NAGEL	Dairy	2.50	0.19	0.08	0.0022	0.90	7.93	7.2	13.83	0.57	2.74	1.17
03/11/2010	NOBLE	Dairy	0.90	0.08	0.05	0.0010	0.76	6.84	8.0	7.80	0.86	3.72	2.24
04/28/2010	NOBLE	Dairy	1.60	0.13	0.07	0.0010	1.11	6.92	7.3	11.17	0.66	3.53	1.99
06/16/2010	NOBLE	Dairy	1.60	0.13	0.08	0.0008	1.15	6.07	7.5	10.21	0.69	3.47	2.02
04/29/2011	NOBLE	Dairy	1.20	0.13	0.07	0.0013	0.69	8.93	7.9	10.92	0.63	2.52	1.77
07/11/2012	NOBLE	Dairy	1.70	0.12	0.06	0.0016	0.88	9.10	7.7	12.02	0.62	3.92	2.14
02/02/2010	OAKLANE	Dairy	0.60	0.10	0.04	n/a	0.57	11.70	7.9	7.63	0.90	3.36	3.35
03/28/2012	OAKLANE	Dairy	0.50	0.07	0.03	0.0013	0.60	1.16	8.2	6.51	1.52	3.90	2.98
06/05/2012	OAKLANE	Dairy	0.60	0.07	0.03	0.0008	0.82	9.18	8.5	6.07	0.46	4.23	2.51
04/07/2011	OSTROWSKI PLR	Dairy	1.00	0.13	0.07	0.0009	0.86	8.93	7.7	9.60	0.89	2.83	1.51
07/05/2012	OSTROWSKI PLR	Dairy	0.50	0.05	0.04	0.0009	1.56	10.66	7.5	5.39	0.58	3.22	2.22
04/07/2011	OSTROWSKI MAIN	Dairy	0.90	0.12	0.07	0.0008	0.67	10.53	8.2	9.26	1.18	1.61	1.70
07/06/2011	OSTROWSKI MAIN	Dairy	1.20	0.11	0.09	0.0009	0.68	7.73	7.4	9.56	0.48	2.87	1.49
08/16/2011	OSTROWSKI MAIN	Dairy	0.80	0.08	0.07	0.0010	1.20	9.47	8.1	6.87	0.58	3.71	2.00
07/05/2012	OSTROWSKI MAIN	Dairy	1.30	0.13	0.04	0.0014	1.08	10.68	7.9	10.41	0.62	3.18	1.96
07/25/2012	PLATTE E	Swine	1.20	0.17	0.13	0.0020	0.69	15.76	8.0	16.39	0.83	1.39	0.54
10/04/2012	PLATTE E	Swine	1.70	0.17	0.09	0.0020	0.82	14.06	8.2	8.22	0.82	2.18	0.80
06/16/2010	TAUSCHER	Dairy	3.30	0.19	0.10	0.0013	0.98	5.67	7.0	12.91	0.73	3.07	1.33
04/08/2011	TAUSCHER	Dairy	1.10	0.11	0.07	0.0013	0.78	9.36	7.4	11.47	0.77	3.95	1.34
06/20/2011	TAUSCHER	Dairy	4.30	0.21	0.11	0.0018	0.88	4.04	6.6	13.97	0.51	5.01	1.06
10/12/2011	TAUSCHER	Dairy	4.90	0.20	0.09	0.0011	0.81	4.45	7.4	12.21	0.54	5.40	0.92
07/05/2012	TAUSCHER	Dairy	5.80	0.22	0.09	0.0027	0.60	3.50	7.3	13.68	0.39	5.90	0.76
07/21/2011	VANDERGEEST LG	Dairy	3.20	0.20	0.08	0.0012	2.02	5.93	7.1	13.38	0.64	2.74	1.71
09/01/2011	VANDERGEEST LG	Dairy	2.00	0.17	0.08	0.0013	1.52	8.61	7.5	12.45	0.70	3.08	1.43
10/07/2011	VANDERGEEST LG	Dairy	1.60	0.11	0.09	0.0013	1.46	10.89	7.7	12.00	0.72	3.27	1.36
07/07/2012	VANDERGEEST LG	Dairy	3.70	0.19	0.11	0.0015	1.98	5.33	7.7	11.72	0.56	2.56	1.45
07/07/2012	VANDERGEEST PIT	Dairy	3.30	0.20	0.11	0.0015	1.98	5.36	7.6	11.46	0.56	2.62	1.45

Name	Type	Cu	Fe	Mn	Zn	Na	Total Coliform Count	Escherichia coli	Aerobic Plate Count	Anaerobic Plate Count	Volatile Fatty Acids
		PPM	PPM	PPM	PPM	%	CFU/g	CFU/g	CFU/g	CFU/g	mg/L
ARENS	Swine	17	422	217	50	3.22	600,000	600,000	10,000,000	300,000	<100
ARENS	Swine	55	836	259	182	3.14	260,000	170,000	10,000,000	400,000	<0.01
BABCOCK NORTH	Swine	115	676	100	491	3.82					
BABCOCK SOUTH	Swine	225	1438	263	388	4.63					
CR FARMS	Swine	170	941	102	671	6.38	<10	<10	6,000	2,000	980
CR FARMS	Swine	326	1240	117	693	4.93	40	40	2,000	4,000	<0.01%
CR FARMS	Swine	264	720	75	478	5.02					
HUTTERVILLE N	Swine	45	203	97	78	13.47	100	90	70,000	8,000	<0.01
HUTTERVILLE S	Dairy	92	428	165	247	9.95					
NAGEL	Dairy	1184	1070	254	237	1.48	<1000	<1000	1,300,000	1,000	25.22%
NOBLE	Dairy	430	2155	286	277	3.54	10	<10	60,000	460,000	1068
NOBLE	Dairy	525	2317	318	444	3.65					
NOBLE	Dairy	510	2616	314	463	3.40					
NOBLE	Dairy	215	1660	231	506	4.21					
NOBLE	Dairy	192	1786	278	428	4.02	<1000	<1000	3,000,000	26,000	<0.01%
OAKLANE	Dairy	65	446	437	197	4.70	<10	<10	60,000	12,000	540
OAKLANE	Dairy	80	486	288	238	4.86					
OAKLANE	Dairy	164	503	284	243	3.59	<10,000	<10,000	4,200	40,000	<0.01%
OSTROWSKI PLR	Dairy	132	530	287	257	2.49					
OSTROWSKI PLR	Dairy	224	786	338	344	4.18	<1000	<1000	30,000	3,000	<0.01%
OSTROWSKI MAIN	Dairy	104	770	255	263	2.74					
OSTROWSKI MAIN	Dairy	90	1684	415	263	2.13					
OSTROWSKI MAIN	Dairy	135	660	379	368	2.74	12,000	<10	61,000,000	10,000,000	<0.01%
OSTROWSKI MAIN	Dairy	96	812	310	354	3.22	<1000	<1000	30,000	100,000	<0.01%
PLATTE E	Swine	556	1481	189	1548	5.11	<10,000	<10,000	200,000	10,000	<100
PLATTE E	Swine	542	1624	272	1724	4.54	40	<10	8,600,000	390,000	<0.01
TAUSCHER	Dairy	679	835	204	269	1.31					
TAUSCHER	Dairy	369	593	151	243	4.34					
TAUSCHER	Dairy	390	965	200	254	1.08					
TAUSCHER	Dairy	410	1096	180	541	1.27					
TAUSCHER	Dairy	399	874	140	189	1.31	<1000	<1000	400,000	100,000	1.29%
VANDERGEEST LG	Dairy	1250	950	358	403	1.75					
VANDERGEEST LG	Dairy	1291	902	347	444	2.62	10,000	4,000	36,000	14,000,000	<100
VANDERGEEST LG	Dairy	1365	880	340	413	2.58					
VANDERGEEST LG	Dairy	1105	780	312	346	1.29	<1000	<1000	100,000	26,000	<0.01%
VANDERGEEST PIT	Dairy	1130	788	321	343	1.27	<1000	<1000	380,000	1,000	1.40%

Microbial Matrix Systems Inc.
2300 Ferry St #5 Albany, OR 97322 P.O. Box 209 Tangent, OR 97389
Lab: 541-967-0550 Cell: 541-990-0439 lrogers@microbialmatrix.com

Colony Forming Units per milliliter (cfu/mL) is written in Scientific Notation.
Move decimal point to right as indicated by exponential,
e.g. 8.00E+08 is 800,000,000 or eight hundred million colony forming units per ml.
See Interpretive guide for functional group role.

MMSI Sample #	Sample ID	Farm Type	Methanogens	Phosphorus Solublizers	Potassium Solublizers	Fluorescent Psuedomonads	Cellulose Degraders	Chitin Utilizers	Nitrifying Bacteria	Sporeformers
			CFU/ml(gm)	CFU/ml(gm)	CFU/ml(gm)	CFU/ml(gm)	CFU/ml(gm)	CFU/ml(gm)	CFU/ml(gm)	CFU/ml(gm)
5069	Arens	Swine	3.00E+05	1.00E+10	1.00E+10	2.00E+07	1.00E+06	0.00E+00	1.00E+10	3.00E+06
5061	CR Farms	Swine	2.00E+05	1.00E+05	1.00E+07	1.00E+06	1.00E+09	0.00E+00	1.00E+04	4.30E+05
5060	Hutterville	Swine	1.00E+05	3.00E+08	1.00E+07	9.00E+07	1.00E+07	1.00E+04	1.10E+08	3.00E+07
5062	Nagel	Dairy	2.30E+05	3.20E+10	1.00E+10	1.00E+10	1.00E+06	1.00E+04	1.00E+10	4.30E+06
5068	Noble	Dairy	2.00E+04	1.30E+07	1.00E+05	1.00E+05	1.00E+06	2.00E+04	1.10E+06	3.00E+07
5059	Oaklane	Dairy	1.00E+05	1.00E+05	1.00E+06	2.00E+07	1.00E+05	1.00E+04	2.60E+07	6.80E+07
5064	Ostrowski Pit	Dairy	1.10E+05	2.10E+06	1.00E+07	7.00E+08	1.00E+10	1.00E+03	2.50E+08	1.00E+07
5065	Ostrowski Main	Dairy	1.30E+05	1.00E+06	1.00E+07	1.00E+10	1.00E+07	1.00E+03	6.00E+05	1.90E+07
5070	Platte	Swine	2.10E+05	1.00E+10	1.00E+10	1.00E+11	1.00E+04	0.00E+00	1.00E+10	4.00E+06
5066	Tauscher	Dairy	2.10E+05	1.40E+07	1.00E+07	1.00E+05	1.00E+06	4.00E+03	1.00E+06	4.80E+06
5063	Vandergeest Plr	Dairy	1.00E+05	1.30E+08	1.40E+07	1.50E+11	1.00E+07	2.00E+03	2.10E+08	1.00E+06
5067	Vandergeest Main	Dairy	2.00E+05	2.50E+09	1.00E+09	3.10E+10	1.00E+07	1.00E+04	8.00E+09	3.50E+07

Methanogens: Bacteria that exist in low levels of oxygen and produce methane as a by-product of their metabolism.

Sporeforming Bacteria are used in agricultural products since they can withstand desication, have high storageability, & can exist in extreme conditions like fluctutions in soil temp.

Cellulose Degrading Bacteria metabolize lignocellulytic material and can be beneficial in the breakdown of plant residue.

Chtin Utilizing Bacteria are used in ag products to help control insect and fungal pathogen pressures. The bodies of insects and some fungi are comprised of chitinaceous material.

Phosphorus Solublizing Bacteria are highly beneficial in alkaline soils with high levels of Calcium and help to solublize or break the bond between Calcium and Phosphorus in soil.

Potassium Solublizing Bacteria are highly beneficial in alkaline soils with high levels of Calcium and help to solublize or break the bond between Calcium and Potassium in soil.

Fluorescent Pseudomonads trigger the plant production of Indole Acetic Acid which is a precursor to plant growth hormones responsible for root growth.

Nitrifying Bacteria convert Ammonium Nitrogen into Nitrate Nitrogen.

Microbial Matrix Systems Inc.

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MMSI Sample #	Sample ID	Farm Type	Dry Weight of 1g Sample	Active Fungi	Active Bacteria	Total Fungi	Fungal Dia.	Total Bacteria	Interpretation
	Desired Range		(g)	2-10µg/gdw	10-60µg/gdw	050-200 µg/gdw	(µm)	100-300 µg/gdw	*All populations are within or above desired range. This is a good indication of good potential for mineralization of plant needed nutrients.*
5069	Arens	Swine	0.00	0.0	13.3	14.9	NR	184.6	
5061	CR Farms	Swine	1.00	0.3	21.5	11.5	2.5	353.4	
5060	Hutterville	Swine	1.00	0.6	17.9	1.2	2.5	384.8	
5062	Nagel	Dairy	1.00	0.0	27.6	8.6	NR	341.6	
5068	Noble	Dairy	0.00	0.0	23.6	5.7	NR	216.0	
5059	Oaklane	Dairy	1.00	0.0	18.9	0.0	NR	184.6	
5064	Ostrowski Pit	Dairy	1.00	0.0	9.7	6.9	NR	235.6	
5065	Ostrowski Main	Dairy	0.00	0.0	27.1	6.9	NR	294.5	
5070	Platte	Swine	0.00	0.0	15.4	2.3	NR	200.3	
5066	Tauscher	Dairy	0.00	0.0	20.1	20.1	NR	216.0	
5063	Vandergeest Plr	Dairy	1.00	3.4	34.0	1.4	2.5	274.9	
5067	Vandergeest Main	Dairy	0.00	0.0	32.3	4.6	NR	208.1	

APPENDIX C: EQIP ELIGIBLE PRODUCERS IN THE PROJECT

Name	Required forms
Jay H. Noble, et al Noble View Dairy, LLC 21747 Plank Rd., Kansasville WI 53139	Current FSA Documents on file FSA Office, Kenosha WI
Alan J. Tauscher, et al Tauscher Farms, Inc 4866 Meadow Drive, Green Bay WI 54313	Current FSA Documents on file FSA Office, Brown County WI
Jason Nagle, et al Nagel Dairy Farms, LLC N6841 County Road V, Deerbrook, WI 54242	Current FSA Documents on file FSA Office, Lincoln-Langlade WI
George Waldner, et al Hutterville Hutterian Brethren Inc 14625 401st Ave, Stratford SD 57474	Current FSA Documents on file FSA Office, Brown County SD
Richard Ostrowski, et al., Ostrowski Farms Inc. 2021 Cherry Drive, Eland WI 54427	Current FSA Documents on file FSA Office, Marathon County WI
Jacob Wipf, et al. Oaklane Hutterian Brethren, Inc 26730 423rd Ave, Alexandria SD 57311	Current FSA Documents on file FSA Office, Hanson County SD
Dr. Chad Bierman ` Babcock Genomics N6647 CTH XX; Box 577, Holmen, WI 54636-0577	Current FSA documents on file FSA Office, Onalaska WI
Randy and Connie Heitzman Members, CR Farms LLC 41911 277th St, Parkston, SD 57366-5828	Current FSA Documents on file FSA Office, Hanson County SD
Dale Stahl, Secretary Platte Hutterian Brethren Inc 35271 - 270th St., Platte, SD 57369-6007	Current FSA Documents on file FSA Office, Charles Mix County SD
Jason & Jayne Arens 88763 554th Ave. Crofton, NE 68730-4013	Current FSA Documents on file FSA Office, Cedar County NE
Lee VanderGeest et al. VanderGeest Dairy Cattle Inc 5555 Hwy A, Merrill WI 54452-7939	Current FSA Documents on file FSA Office, Marathon Co WI

APPENDIX D: MAPS OF PARTICIPANT LOCATIONS

Demonstration Site Locations: Wisconsin (Numbers are confirmed sites. Letters are back-up sites.)

1. Jay Noble – 700 cow sand bed
21747 Plank RD, Kansasville WI 53139-9736
2. Babcock Genetics – 1100 Sow F-F Site
PO Box 577. Holmen, WI 54636
3. Tauscher Farms, – 250 cow straw bed
4866 Meadow Dr., Green Bay WI, 54313
4. Ostrowski Farms – 1400 cow sand bed
2021 Cherry Dr., Eland WI 54427
5. Van Der Geest Dairy – 3,000 cow straw
5555 Cnty Hwy A, Merrill, WI 54452
6. Nagel Dairy – 500 cow sand bed
N6841 County Rd V, Deerbrook WI 54424

a. Dennis Stilling – 1700 sow F-W site
7960 Wood Rd, Watertown WI 53549

b. Peterson Dairy – 100 cow straw bed
1751 Cherry Dr, Eland, WI 54427

Demonstration Site Locations: South Dakota

1. Hutterville Colony Farms – 850 Sow F-F
14625-401st Ave, Stratford SD 57474-7204
2. Platte Colony Farm – 900 Sow F-F Site
35271 - 270th St., Platte, SD 57369-6007
3. Oak Lane Dairy – 450 cow shavings bedding
26730-423rd Ave, Alexandria, SD 57311-7110
4. CR Farms – 600 head finisher barn
41911 277th St., Parkston, SD 57366-5828

a. Arens Farm – 450 sow F-W
88763 554 Ave., Crofton, NE 68730-4013

APPENDIX E: SUMMARY DESCRIPTION OF PARTICIPATING SITES

Summary	Vander Geest - WI	Ostrowski-WI	Noble - WI	Nagel-WI	Tauscher - WI	Babcock-WI
Type of Operation	Dairy: milk cows, raises forage crops , corn silage alfalfa haylage	Dairy: milk cows, raises forage crops , corn silage alfalfa haylage	Dairy: milk cows & dry cows only raises alfalfa	Dairy; Milk cows and Heifers, raises forage crops corn silage and alfalfa haylage	dairy farm; raises forage crop , corn silage & alfalfa haylage	Swine:1,000 sows, 225 boars for semen, selling guilts, semen and 11,000 finishers
Size of Operation	3500 cows 2800 milking 700 dry; sends heifers out to custom raiser.	1400 milk cows 720 in new flush barn 680 in old scraper barn heifer & dry cows house elsewhere	350 cows milking & dry	950 animals; 550 milking balance dry cows and heifers	500 animals w 250 milking	7200 plus animal inventory on site --4000 finishers; 950 sows; 200 boars; 2000 prewean & nursery
Size of Lagoon(s)	2 lagoons 4 mil & 40 mil gal	7500 gal sand settling basin & 5 mil gal; both new	4 mil gal	10 mil	3.5 mil gal	1st lagoon 22,840,000 gal; 2nd lagoon 15,270,000
Lagoon Capacity	treatment + 12 mos storage	storage treatment for 12 mos	storage treatment for 10 mos	large open lagoon storage for 14 mos	6 mos storage	storage treatment 12 plus months
Lagoon Construction	earthen basin, clay lined	concrete lined	earthen basin w clay liner	concrete liner	earthen basin w clay liner	earthen basin clay liner
Type of Manure	separated	separated	unseparated	unseparated	unseparated	unseparated
Type of Floor	solid	solid	solid	solid grooved	solid	slatted shallow pit
Type of Bedding	separated solids	sand	sand bedding; has sand lane & reclaims sand for bedding	sand bedding w sand lane for reclaiming sand for bedding	1/3 shaving plus 2/3 pulp mill sludge	no bedding (slatted floors)

Summary	Vander Geest - WI	Ostrowski-WI	Noble - WI	Nagel-WI	Tauscher - WI	Babcock-WI
Type of Cleaning	floors flushed every 30 min and scraped once daily	floors flushed every 30 min and scraped once daily	scrape 3 times daily to central flume, gravity flow to lagoon	scrape for now--future flush	scrape 3 times daily; pump to lagoon	slatted floor, pull plug from shallow pit
How Manure is Used	Aerobic treated manure is used as fertilizer, spring and fall	Aerobic treated fertigated directly on crops as fertilizer	Aerobic nutrients self applied after each cutting; for one extra cutting	Aerobic nutrients on silage corn and soybeans, spring and fall	Aerobic treated manure applied as fertilizer, spring and fall	neighbor uses all nutrients on corn fields
How Manure is Applied	self applied tanker inject plus traveling gun	self applied tanker inject plus center pivot	surface applied by spray from tanker truck on alfalfa fields	self applied spring & fall; before plant or after harvest	custom applied by injection	center pivot during summer plus injection in spring
When, Where Manure Applied	spring & fall injection some traveling gun application on crops	spring & fall injection seasonal use of center pivot	applied on alfalfa after each cutting to start the next crop	spring & fall injection . Before planting & after harvest on corn silage & soybeans	spring & fall injection; before planting and after harvest	Neighbor fields contiguous with the swine operation
Crop Response	not collected as fact	not collected as fact	alfalfa responded with growth time reduced from 28 to 21 days; 1 extra cutting	not collected as fact	No change, appear same as before	not collected as fact
Circulators Installed	21 units base on 1 per 150 animal units	10 units base 1 on sand lagoon 6 on main lagoon 3 on joint heard parlor/holding area lagoon	6 units 1 per 100 animal units	10 units-1 per animal unit	4 units; only 250 cows; 1 unit per 60 cows	8 units on 1st lagoon; 2 units on 2nd lagoon
Perceived Changes in Lagoon	less odor, less viscosity, more pump ability	less odor, more pump ability	neighbors no longer call sheriff when owner starts to pump lagoon	reduced odor; more pump ability; less odor to bother neighbors	lagoon required less agitation so resulted in less cost for owner	odor has become a non factor ; manure is much easier to pump

Summary	Vander Geest - WI	Ostrowski-WI	Noble - WI	Nagel-WI	Tauscher - WI	Babcock-WI
Perceived Changes Overall	less odor, floors not slippery, better working conditions, better animal health	less odor, better working conditions, better herd health	reduction in odor; increase in crop; better conditions fro workers & animals	less odor; good flush water; better health	greatly reduced odor on farm site and during agitation and pumping	no odor from lagoon
Initial Reasons for Participation	wanted to solve odor problem for neighbors; wanted better flush water	wanted to increase herd using a year round flush with less odor	problem with neighbors because of odor	to solve odor problems & provide a better product to use as flush water	make manure easier to pump to field and inject	wanted to reduce odor drifting over hwy to apartment housing complex
Summary of Outcomes	Owner stated this was the 3rd attempt to obtain good flush water and now has accomplished that goal. He had complaints near and far about odor. But no longer has odor complaint problems.	Owner wanted to increase his heard by 720 cows to 1400 total. Wanted to flush year round; didn't want slippery alleys; wanted reduced odor or no odor. Owner accomplished all of these goals and a lagoon that is pump able.	Owners greatest problem, odor! Caused concern that it would put him out of business. Installing circulators has solved the odor problem. He started making cheese to increase income.	Constructing 1st segment of 2000 cow free stall. When done, it will provide a better income at less cost. This will be accomplished by flushing the barn automatically every 1/2 hour without slippery alleys plus no odor.	Owner wanted to reduce costs of agitation and pumping; was not concerned about odor. The first thing he noticed was lack of odor (nice surprise). The custom pumper said it took very little agitation.	After solids were removed, landscape netting began to surface and rag up impellers. Had been used in building the lagoon 15 years earlier. No way to remove it. Had to discontinue circulators

Summary	Hutterville - SD	Oak Lane - SD	CR Farms - SD	Platte Colony - SD	Arens - NE
Type of Operation	Swine FF, dairy free stall with alley scraper and beef feedlot. Water storage ponds in the fields	New Jersey Dairy. Automatic Flush recycles safe water from lagoon	small stand alone finisher barn on mixed crop and beef operation	large FF swine operation with beef, turkey and crops	New built family farrowing barn and cropping. Sells baby pigs.
Size of Operation	850 sows FF, about 18,000 finishers year. 200 dairy and 500 beef. Dairy expansion plan	450 head, 350 milking. Still building herd.	500 finishers	850 sow20,000 finishers	450 sows
Size of Lagoon(s)	swine lagoon 3 acre, 24' deep. Dairy/beef 300'x850'x24'	Oversized lagoon built for expansion	lagoon too small need to raise berm	two large side by side lagoons with equalizer pipe	about 2-3 million gallons
Lagoon Capacity	Swine lagoon 15 mil gals Dairy-beef 30 mil gals	9 million gallons. About twice as much as needed.	about 500K gallons	12 million +10 million gallons in both lagoons	about 2-3 million gallons
Lagoon Construction	Earthen clay lined	Clay lined	earthen clay	Earthen Berm with clay and rip-rap	earthen dug into hillside w clay liner
Type of Manure	no longer separated	unseparated	unseparated	unseparated	
Type of Floor	Swine shallow slats Dairy solid scraped Beef dry lot runoff	solid concrete flushed. Added rubber mats after the barn was in operation.	full slats on shallow pit	fully slatted floors	fully slatted on shallow pits
Type of Bedding	wheat straw	Shavings	none	no bedding	none

Summary	Hutterville - SD	Oak Lane - SD	CR Farms - SD	Platte Colony - SD	Arens - NE
Type of Cleaning	Swine Tip tank in shallow pits. Dairy Automatic Scraper	every alley flushed once each hour	Flo-thru gutters recently added	pull plug with partial recharge	Continuous flo-thru pits recycled from lagoon
How Manure is Used	diluted manure provides fertilizer and rescue irrigation	Applied to corn or wheat after harvest.	spread on corn fields	Before circulators installed pivot distribution killed radish cover crop	on corn and soybean fields
How Manure is Applied	Crop applied by pivot	Knifed or injected in the soil. Considering pivot distribution.	surface applied with tillage for incorporation	Normally spread on corn fields	Wants to sprinkle on fields from pivots
When, Where Manure Applied	On growing crops when plants need nutrients and water	Fall application onto closest fields available	Fall application normally	Fall applied	not yet applied
Crop Response	Usually has the best crops in the county	not collected to compare manure outcomes	not measured	not measured except for radish crop	not yet measured
Circulators Installed	8 units on swine and 3 units on dairy/beef	9 units initially, followed by 2 more units	1 unit for the whole pond	8 units, four on each pond	4 units
Perceived Changes in Lagoon	Eliminated odor and reduced solids. Lagoon turned pink then blue.	Eliminated odor, reduced solids and no flies	eliminated odor	eliminated odor and reduced solids when fully operating	received lots of afterbirth and ragged up impellers

Summary	Hutterville - SD	Oak Lane - SD	CR Farms - SD	Platte Colony - SD	Arens - NE
Perceived Changes Overall	No odor from lagoon	reduced odor from the barn during flushing.	no odor from lagoon or barn	odor in the village was greatly reduced	Odor was eliminated but circulators underperformed
Initial Reasons for Participation	Needed another pivot but could not get permit because of odor.	Previously eliminated odor from swine lagoon but circulators failed.	to avoid odor complaints from neighbor across the road	wanted to reduce odor in the village	wanted to avoid odor in the barn where father and kids work
Summary of Outcomes	Village and county wanted relief from odor of pig lagoon. Farmer wanted some way to remove 9 feet of manure solids. Crops needed more nutrients. Everyone got their way!	Very happy with odor elimination and reliable equipment but barn trash in the lagoon ragged up impellers and caused poor performance.	Wife very happy to clean barn without tremendous odor. Neighbor no longer complains	Odor completely eliminated by circulators. solids had built up in the lagoon to nearly 6' of depth. Beginning to recover depth. Interrupted by Rip-Rap repairs.	Reduced circulation allowed Struvite formation in recycle pumps when afterbirth ragged up impellers. Farm struggling with struvite

APPENDIX F: SELECTED SITE-DESCRIPTION AND DETAILS

SITE 1: HUTTERVILLE COLONY SD--SWINE, DAIRY & BEEF

Photos of the install on an 800 sow, farrow to finish site at Hutterville Colony Farm in Southern Brown County, near Aberdeen SD illustrate scenes observed at installation and start up of aerobic *Circul-O^2-Raters™* on waste lagoons.

The grey pedestal seen directly in front of the telehandler delivers power and controls VFD drives to speed up, slow down, stop or reverse each unit independently via Internet.

PIC 1 - LOADING WORK BARGE TO SET UNITS IN PLACE ON LAGOON.

Steep sidewalls on this 15 year old lagoon did not allow direct access to the water level. Of note in the picture above, the surface of the water is relatively clear of floating scum or debris prior to start up of the machines. The lagoon has a solid separator on intake that removes much of the larger solid material in manure. Fines from undigested feed that remain in the liquid, settle to the bottom of the lagoon. About 4'-6' of undigested feed was found under 4'-5' of water in this three and one half acre lagoon. This build-up of nearly 500,000 bushels of undigested feed accumulated in less than 4 years since the lagoon was last cleaned out.

PIC 2 – UNITS SET IN PLACE. NOT YET POWERED UP.

A small amount of sediment was raised when the work barge powered up near shore. But the lagoon surface remains mostly clear of scum. This surface condition changes markedly when machines are power up and upflow circulation begins as seen in the next picture.

Fifteen minutes after start up, organic material raised by up-welling of the water under the influence of up-flow circulators nearly covers the surface of the lagoon. This material is the result of lighter organic solids being brought to the surface from below where they usually reside just above the heavier settled material at the bottom. In the presence of atmospheric oxygen and aerobic microbes this scum will disappear in just a few days. Heavier settled material at the bottom will take longer to digest. Of course, during installation on a new lagoon, this initial organic cover would not be observed.

The system does not risk an initial increase of odor when circulators are started up. Typically large amounts of odor production occur during high power agitation of anaerobic manure lagoons in preparation for pumping. This does not happen with circulator at start up because only a small amount of material is brought to the surface at any time. Heavy organic bottom sludge is not disturbed and large amounts of trapped gas bubbles are not released. The thin film of material brought to the surface is immediately oxygenated to stop the production of gas and odor that might otherwise occur.

PIC 3 – JUNE 11TH 2012, SCUM COVERS MOST OF THE LAGOON SURFACE 15 MINUTES AFTER START-UP

Immediately after start up, the surface of the lagoon will begin to be covered with light scum brought up from the sediment layer at the bottom of the lagoon. This provides evidence that circulation is reaching the bottom of the lagoon. A typical 40' diameter circle of open water is seen around the circulator in the center of the PIC 3. This open area allows oxygen depleted water drawn up from the bottom of the lagoon to be exposed to the atmosphere and re-oxygenated before it is again transported downward to support aerobic digestion of the heavier organic material on the bottom. The scum covering the lagoon dissipates in a few days as aerobic bacteria work rapidly to decompose floating solid materials.

Aerobic microbial activity (with oxygen) is found to be 10x's faster than anaerobic activity (without oxygen). Waste nutrients are quickly transformed into true liquid, crop available fertilizer. With the bonus that GHG's, especially methane and nitrous oxide, other noxious gasses, odors and pathogens are completely eliminated by this top-to-bottom aerobic circulation process. The entire contents of the lagoon are repeatedly exposed to atmospheric re-oxygenation as well as to Direct UV radiation, several times each hour. Cumulative UV exposure is estimated at 10-15 minutes each daylight hour.

BRIEF HISTORY OF THE HUTTERVILLE LAGOON SYSTEM

The Hutterville lagoon system has been in service for about 15 years. It consists of a large, primary settling basin with approximately three acres of surface, 24' deep followed by two even larger storage basins. Top water is pumped from the primary lagoon to storage lagoons and then to pivots for distribution onto crops. The system supplies both rescue irrigation and crop nutrients. The system is designed to support farming in a drought prone area of Southern Brown County SD with no underground aquifers available to supply high performance irrigation wells.

The barns that feed this lagoon system raise about 20,000 finished pigs each year from an 800+ farrow-to-finish operation. The fully slatted barns utilize tip-tanks to automatically flush the under-floor pits several times each day. A separator system intercepts manure coming from the barn and recycles undigested feed to beef lots on the premises. Of course not all undigested feed can be recovered by screening and a significant amount settles to the bottom of the first lagoon. Top water from this lagoon is then pumped to large storage basins located out in the fields from which the liquid is distributed as fertigation for growing crops.

Ten years after construction, the primary lagoon was found to be filling rapidly with solids. The primary lagoon held 9' of solids at the time, accumulating about 1' of settled solids per year in lost capacity. The depth of sludge in the lagoon contributed to an anoxic environment that was highly productive of odors, noxious gasses and GHG's including methane and nitrous oxide. In addition, the un-aerated top water produced additional gas and odors.

The consequences of lagoons in anaerobic condition include loss of nitrogen value for crop production, high EC levels that stress and yellow tender crops, intense odor from pivots, increasing complaints from neighbors, and a steady loss of lagoon capacity over the ten years the lagoon had been in service.

Beginning in July of 2006, 9 floating LRPM circulators with ¾ hp electric motors were installed on the primary lagoon. At that time the lagoon contained 9' of sediment under 10' of water. The circulators performed well. The first 4 feet of light sediment was digested and odor was reduced by an estimated 80% after only 45 days. The next 5 feet of compacted sludge required 4 months to reduce. With circulation in place, the lagoon remained odor and sediment free for nearly 3 years. During this time, failure of earlier generation equipment began to reduce circulation. By 2009, most of the earlier circulators had stopped running. Odor returned and the primary lagoon again began to fill with sediment. The owners jumped at the chance to participate in a demonstration of more reliable equipment. The new equipment has continued to run faultlessly and the manure lagoons have returned to their previous odor-free state.

SITE 2: OAK LANE SD--DAIRY

Nine *Circul-O_2-Rater™* units were installed on a 9 million gallon lagoon serving a 450 cow facility at Oak Lane Colony Dairy SD. Recycled water from this lagoon is used to flush the ultra-modern 8-row dairy facility. The dairy and its flushing action can be viewed on YouTube at "Oak Lane 8 Row."

When the dairy was built, the owners installed aerobic circulators that initially functioned well to oxygenate the flush water and eliminate flies and odor from the barn. Problems began to develop from trash entering the lagoon. Equipment failures and the need for frequent service calls led the owners to discontinue aerobic lagoon treatment.

Odor soon returned to the lagoon and the barn. When approached, the owners were eager to try a more reliable system that might provide them with the benefits of aerobic treatment, but without the problems. *Circul-O_2-Rater™* Equipment was installed and ran on these lagoons for 18 months.

Efforts to prevent trash in the lagoon were partially successful. Service calls continued. The equipment kept running despite being ragged up. However circulation was diminished.

Further efforts to eliminate field and barn trash from entering the lagoon were attempted. A chain link cage was installed at the splash pad to prevent barn trash and afterbirth from entering the lagoon. Success was minimal and rag-ups continued. Due to frequent high wind in South Dakota, farm field fencing will be needed around the lagoon to keep out field trash including cornstalks, fireweed and plastic bags that blow into the lagoon from surrounding fields. A better solution to prevent barn trash and afterbirth from entering the lagoon is still under discussion.

Wood shavings are slow to decompose and can build up in the lagoon. The suggestion to use ground corn cob bedding was tried. Corn cobs digest much better than straw or shavings and can be easily collected from the farmer's own corn fields, providing opportunity for the dairy to save money on bedding. In this case the herd was suffering a nutrition problem and the cows ate the bedding.

Although this incident led to recognition and correction of the nutrition deficiency and a significant increase in milk production, the dairy returned to using shavings for bedding. Shavings are not usually a problem when circulation is maintained at full capacity. But with the challenges from trash in the water, aerobic circulators were struggling to keep up.

After 18 months of aerobic demonstration, circulators were turned off and removed from the Oak Lane manure lagoon due to uncontrolled trash entering the system and ragging up the impellers causing them to underperform.

Trash containment was designed into the original barn construction to prevent barn trash from entering the lagoon. However trash controls in the barn were intentionally circumvented by the barn manager and herdsmen to allow afterbirth, bale netting, hoof wrap, plastic bags and hypodermic needles to bypass the screens and grates. This was justified based on the management philosophy that an automated flush barn should not require workers to dispose of trash inside the barn.

Owners are pondering steps to take in recovering the odor-free status they previously enjoyed. The manufacturer has been testing a more weed less impeller for challenging installations like this one. These impellers will be offered to the location so that the demonstration can be continued and the site can be odor free again.

SITE 3: CR FARMS SD--SWINE

One *Circul-O_2-Rater™* unit was installed on a small 500,000 gallon lagoon serving a 650 head finishing barn 10 miles east of Parkston South Dakota.

The owner has a neighbor living just 500 yards across the street from this barn. To reduce odor at the neighbors residence, CR farms had previously installed a wind driven circulator on the pig lagoon. This unit did a credible job reducing odor in the lagoon. But now the odor from the barn was much more noticeable and the neighbor continued to complain.

This slatted floor barn was converted by the owner to a "Flo-Thru" gutter and pit cleaning system using recycled liquid from the odor-free, pathogen-free nutrient waste lagoon. The benefits of using safe water from aerobic lagoons to continuously transport manure out of the barn and eliminate in-barn odor can be seen on YouTube at "CR Farms odor free pig barn."

Unfortunately, wind and solar units fail to retain nitrogen in manure due to intermittent aerobic-anaerobic cycling that naturally occurs with wind or solar power. When wind recedes or the sun goes down after a period of time oxygenating the lagoon, nitrogen is lost by denitrification and the value of the nutrients is reduced. This is an odorless process,

Initial reports indicate that the electric circulators maintained the odor reduction and are now retaining more manure-N in the lagoon and converting it to NH_4+, first year available ammonium in crop ready form.

Because this has been a dry year, evaporation has reduced the amount of liquid in the lagoon and it is currently functioning without the desired minimum treatment volume need for effective re-oxygenation and circulation in the lagoon. As a result of increasing concentrations of dry matter in the lagoon, EC readings are high and the lagoon is not currently suitable for application onto growing crops. The farmer has been made aware of this situation and understands the need for more water in the lagoon.

However no run-off water is currently available for the farmer to replenish his lagoon. Rural water to bring the lagoon back to minimum aerobic treatment volume would be expensive. At $2/1,000 gals, replenishing nearly 200,000 gallons would cost $400 per fill. During a dry season at this location, evaporation could remove this amount of water in a short time, perhaps only a month or two. The farmer is considering putting in irrigation for his crops and to manage his manure distribution. An irrigation well would allow him to control the water levels in his lagoon.

Currently the farmer, his wife who cleans the barn and the neighbor who lives across the road are content with their odor-free status and the farm will wait for rainfall before they refill the lagoon.

State	**WI**	**WI**	**WI**	**WI**	**WI**	**WI**	**SD**	**SD**	**SD**	**SD**	**SD**	**NE**
Name	**Noble**	**Taus cher**	**Nagle**	**Ostrow ski**	**Babcock**	**Vander Geest**	**Hutter ville**	**Hutter ville**	**Oak lane**	**Heitz man**	**Platte**	**Arens**
Type	**Dairy**	**Dairy**	**Dairy**	**Dairy**	**Swine**	**Dairy**	**Dairy**	**Swine**	**Dairy**	**Swine**	**Swine**	**Swine**
Lagoons	**1**	**1**	**1**	**3**	**2**	**1**	**1**	**1**	**1**	**1**	**2**	**1**
Install	12/15/09	06/17/10	07/30/12	11/16/10	10/20/10	06/27/11	07/05/12	07/05/12	06/27/11	06/27/11	06/17/11	07/05/12
Machine Equipment												
Circulator Model A	6	4	10	10	10	21	3	8	11	1	8	4
Control Module (per 3)			3	3	2	7	1	2	3			
Control Module (per 2)	3	4			2			1	1		4	2
Control Module (per 1)			1	1						1		
Control Stand	0	2	2	2	4	7	1	3	4	1	4	2
One time use equipment												
Cable (100 feet)				3		7			3	1	4	
Cable Float Kit			35	15	30	56	18	25	31	2	20	14
Shore posts/Anchors		1		6	8				6	2		4
Monitoring Equip												
Communications Cabinet	1	1	1	1	1	1		1	1	1	1	1
Camera			1	2		1		1	1	1	2	1
Wireless Antenna set	1	1	1	1	1	1		1	1	0	1	1

APPENDIX H: BUDGET INFORMATION

APPENDIX I: OUTREACH EFFORTS

Outreach efforts on this project have been conducted in a number of ways and all sites have received numerous visitors. A few have been more popular than others.

1. **Initial Statewide Classified Ads** to extend the invitation for project participation across the entire state of South Dakota. Ads appear in 128 newspapers with a paid circulation of 303,000 and more than 700,000 readers and on the statewide website.

2. **Oak Lane 450 Cow Dairy Open House** attracted over 500 visitors to an aerobic, odor-free dairy where the barn was cleaned every hour, 24 hours a day using odor-free, pathogen free recycled "safe water" from the aerobic treatment lagoon. Video tours of this facility have been placed on YouTube at "Oak Lane – Eight Row" and have been viewed over 10,000 times. In addition the dairy has received over 25 bus tours. The President and the head of the Ag Tech Department at nearby Mitchell Technical Institute spent time observing the aerobic installation. Indian and Chinese Graduate Students at SDSU toured the facility. Individuals and groups from farms in Wisconsin, Minnesota, Iowa, Nebraska, Kansas, North Dakota, Montana, Manitoba, Alberta and Saskatchewan as well as visitors from other countries including England, Denmark, Germany and Mexico have toured the facility.

3. **CR Farms Finisher Site** is a 600 pig operation that has received visitors from Minnesota, Wisconsin, Iowa, Nebraska and Kansas as well as visitors from England. The owners installed aerobic circulators on their lagoon to reduce the odor that affected their neighbor only 500 yards directly across the road. Then they discovered the pits under their barn were then producing much more odor than the lagoon. They remodeled their slatted floor barn to include Flo-Thru™ gutters to recycle odor-free, pathogen-free safe water for continuously cleaning their barn and eliminating odor from the pits. The barn is featured on YouTube at "CR Farms Odor Free" and has been viewed nearly 300 times.

4. **Vander Geest Dairy** *(www.vandergeestdairy.com)* is a 3,000 cow dairy in north central Wisconsin and regularly offers educational and farm tours of their state of the art facility. Thousands of visitors from all over the world tour this facility each year and it is a favorite spot for World Dairy Expo visitors.

5. **Noble View Dairy** is a 700 cow cheese dairy near Milwaukee Wisconsin. This dairy has been visited by state and national NRCS staff. Industry representatives from Watertronics Corporation a global leader in water harvesting and reuse are interested in the effectiveness of aerobic circulator technology for water recovery and reuse. Lindsay Irrigation has visited and are pursuing a demonstration site in Nebraska to evaluate the effectiveness of oxygenation-circulators for nutrient transformation and fertigation.

6. **Arens Farrowing Site** is a 450 sow in Nebraska came on stream late in the project due to construction delays at their new lagoon and barn. The site has been visited by Nebraska university personnel, as well as bankers and professionals interested in the site.

7. **South Dakota State University** has requested a demonstration of aerobic circulator technology to be established at the university dairy site. Plans are underway to install demonstration equipment at this site this spring.