quasar energy group

Noller Herbert
National CIG Program Manager
1400 Independence Ave., SW
Room 6175 South Building
Washington, D.C. 20250

August 11, 2015

RE: CIG Award # 69-3A75-11-208 Request to Release Equipment

Mr. Herbert,

Please allow this letter to serve as our formal request to NRCS to release the Phosphorus Recovery Equipment (PRS) from the demonstration project now that the grant period has closed.

As you will see in our final report due on August 31, 2015, the PRS system was a huge success. On August 25, 2015 we have been invited to present the technology to the Board of the Ohio Dairy Producer's Association along with Lou Brown, the farmer who hosted the demonstration. We have also received inquiries from Dairy Management Inc. (DMI) and Dairy Farmers of America. We have plans to continue marketing the equipment at the 2015 BioCycle Conference in Boston and, potentially, at the Ohio Farm Science Review in September. While all of these initiatives fall outside the scope of the CIG grant period they illustrate the success of the initiative and quasar's dedication to moving this technology forward as a solution to addressing phosphorus issues in impaired watersheds across the country.

Our engineers have already identified various improvements they would like to make to the process and equipment to reduce the overall system cost, making it more affordable for farmers. We plan to initiate these improvements immediately. Our long term goal is to contract with a major component manufacturer (like Parker Hannifin, who joined us for the demonstration) to produce a compact, streamlined version of the system for sale in the marketplace.

Please do not hesitate to contact me should you have any questions regarding our request or require additional information.

Regards,

Caroline Henry
Vice President, Marketing

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National CIG Program Manager
1400 Independence Ave., SW
Room 6175 South Building
Washington, D.C. 20250

August 31, 2015

Conservation Innovation Grant Final Report

quasar energy group

PROJECT OVERVIEW	
Awardee:	quasar energy group
CIG Award #:	69-3A75-11-208
Project Description:	Accelerating the adoption rate of innovative nutrient removal/recovery technology for manure management and load reduction in the Grand Lake St. Marys watershed.
Grant Period:	September 15, 2011 – July 31, 2015
Total Project Costs:	**Federal:** $1,000,000
	Matching Funds: $1,007,008
	Total Project Cost: $2,007,008
Project Deliverables:	**OBJECTIVE A:** Field Demonstration of Innovative Technology
	OBJECTIVE B: Verify environmental effectiveness of the technology
	OBJECTIVE C: Offset Minimal State Funding for Agricultural Pollution Problems
	OBJECTIVE D: Market technology to the region and encourage adoption

Executive Summary:

Grand Lake St. Marys (GLSM) is the drinking water supply for the City of Celina, Ohio and a popular recreational destination for tourists. Over the past decade, this vital community resource has experienced severe environmental problems. The progressive decline in the lake's water quality has primarily been attributed to excessive nutrient runoff from land application of manure by the region's more than 450 farms [i].

Recreation and business activity brings in an estimated 750,000 visitors annually and accounts for about $150 million of revenue to the local economy [ii]. Recreational activity alone supports about 2,500 local jobs [iii]. OEPA closed the lake to all recreational activity during the summer of 2010 because of high levels of microcystin and other toxins including cylindrospermopsin, a liver toxin and anatoxin and saxitoxin, nerve toxins. Microcystin levels were greater than 2,000 ppb in July, 2010 [iv] - much higher than the 20 ppm guideline for recreational contact established by the World Health Organization.

Toxic algae blooms and associated loss of recreation access to the lake correlates to a reduction in local economic activity. Recreational revenues have decreased by as much as 40% over the past two years representing an economic loss to the community of about $50 million [v]. Property values have fallen during this period by an estimated 15% [vi].

Studies have shown that excess phosphorus loading of the lake has been the primary reason for toxic algae blooms [1]. Agricultural runoff is of particular concern because field application of livestock manure is considered by the State of Ohio to be the largest contributor to the excess loading of phosphorous in GLSM [1]. It is estimated that dairy cows in Mercer and Auglaize Counties produce about 110,000 ton/year of manure solids containing about 250 ton/year phosphorous (P_2O_5) [vii].

Proper nutrient management has been identified as the solution to the watershed's deterioration. In 2011 **quasar energy group** (quasar) was awarded a Conservation Innovation Grant (CIG) to demonstrate an innovative approach to phosphorus management that would result in a concentrated nutrient solution that can be removed from the watershed and sold as an alternative to synthetic fertilizers. Dr. Yebo Li, of The Ohio State University College of Food, Agricultural and Biological Engineering (FABE) was responsible for validating the effectiveness of the equipment at removing phosphorus from manure. Dennis Hall and his team from The Ohio State University's Ohio BioProducts Innovation Center (OBIC) and OSU Extension Services were responsible for disseminating information throughout GLSM to educate and encourage adoption of this adaptive management practice.

In 2015, the Ohio Legislature passed S.B. 1, an unprecedented effort to limit phosphorus runoff from agriculture and municipal treatment plants to fight algae blooms in Lake Erie. Many farm fields in the Western Lake Erie Basin already have significant P volumes in the soil that will take decades of normal cropping and nutrient removal to draw down to an environmentally safe level. Land application of manure is not an option for these farms.

By demonstrating and verifying the environmental effectiveness of the Phosphorus Recovery System (**PRS)** quasar can encourage adoption of an innovative phosphorus management solution and replicate this activity across the region to significantly impact the watershed by; reducing downstream nutrient loads while maintaining agricultural productivity, and enhancing wildlife and ecosystem services.

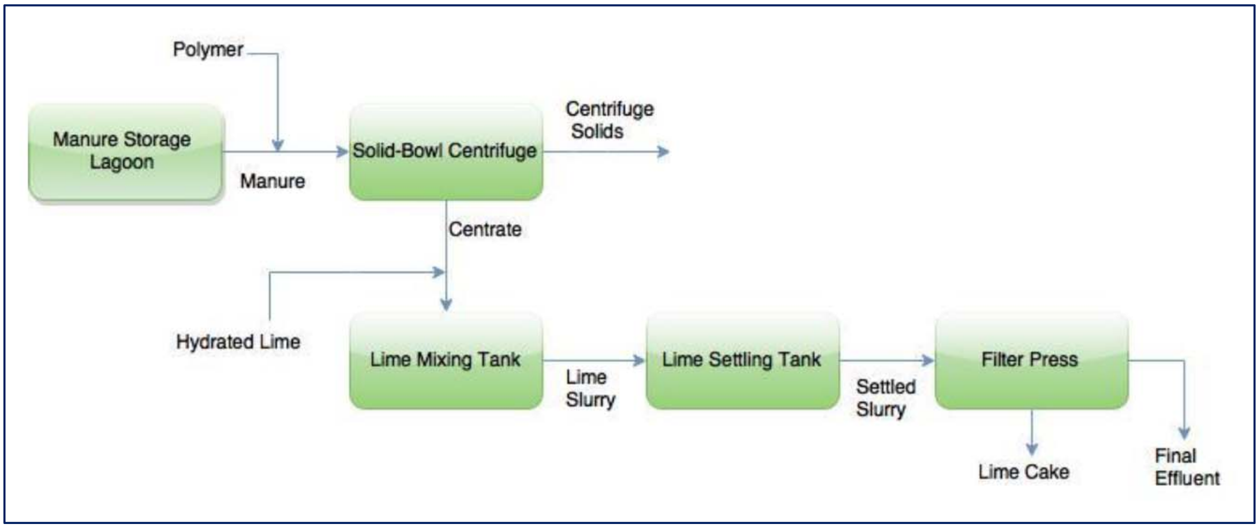
The Phosphorus Recovery System: quasar's Phosphorus Recovery System (PRS) was designed specifically to capture phosphorus from manure, resulting in a liquid with < 1 mg/L of phosphorus (P). The material retains nitrogen (N) and potassium (K) values with agronomic benefit to area farms.

Photo 1: OSU Dr. Li, Adam Kalaf and quasar's Adam Dellinger coordinate during OSU-OARDC demonstration
Photo credit OSU - OARDC

As part of his role in the project, Dr. Yebo Li of The Ohio State University and his research team were responsible for reviewing the design and performance of the PRS during an initial demonstration of the equipment on the OSU – Ohio Agricultural Research and

Development Center campus in Wooster, Ohio. An excerpt from Dr. Li's paper describing the process flow of the equipment is provided below (description of Phases I – III) and is illustrated in Figure 1 below. A full copy of Dr. Li's report can be found at the end of this document.

Figure 1: *PRS Process Flow Diagram*



Phase 1. Initial solid-liquid separation with polymer flocculation

Manure slurry from the lagoon is fed into a solid-bowl centrifuge using a sludge pump for an initial solid-liquid separation. To enhance flocculation of solids, polymer flocculants are incorporated by the Siemens Polyblend unit attached to the centrifuge, which flash-mixes water and polymer to a 1% solution, which is then added to the sludge line. Polymer addition is suggested if there are large amount of small particles in the sludge; otherwise, no polymer addition is needed. The solid products (centrifuge solids) captured by centrifugation are conveyed off of the trailer and into a container or trailer to transport off-site. This initial separation is expected to remove around 70% of solids and most of the large particles.

Photo 3: OSU Adam Khalaf collects samples of solids as they are conveyed to the trailer
Photo credit OSU - OARDC

Photo 2: High P dewatered solids
Photo credit OSU - OARDC

Phase 2. P removal by lime precipitation and settling

*The liquid obtained from step 1 (**centrate**) will go through the centrifuge drain to a rectangular stainless steel open-top **centrate collection tank** located directly beneath the centrifuge bowl. Liquid hydrated lime ($Ca(OH)_2$), stored in a HDPE tote on the trailer, is pumped directly into the centrate collection tank. In wastewater treatment, lime is a commonly-used additive to promote precipitation of phosphorus as various calcium-phosphorus compounds. Near the inlet of the hydrated lime dosing line, a small agitator mixes the hydrated lime with the centrate. The hydrated lime flow rate can be adjusted as needed in order to achieve a target pH of at least 10.5 to efficiently coagulate and precipitate fine solid particles not captured by the centrifuge such as colloidal magnesium (Mg) and P. If Phase 1 is conducted without the aid of polymer, higher hydrated lime dosage might be needed.*

*A sump pump located at the other end of the centrate collection tank will pump the mixture to a 350-gallon **lime mixing tank** located at the back of the trailer. The lime mixing tank consists of an inlet at the bottom, a mixer, and a gravity overflow outlet at the top. In this tank, the lime and centrate will be further mixed for 8-10 minutes to improve the efficiency of the P precipitation reactions. pH will be monitored in this tank.*

*From the mixing tank, the hydrated lime-centrate mixture will overflow out of the top of the lime mixing tank into the **lime settling tank**. The lime settling tank is a 500-gallon rectangular cone-bottom tank with a top inlet and top outlet on opposite sides separated by a baffle, and an outlet located at the bottom of the cone. In this tank the precipitated solids will settle to the bottom. The baffle prevents any solids from short-circuiting to the top outlet and contaminating the clarified liquid. Clarified liquid exits from the top outlet either back to the lagoon, or to a holding tanker, depending on the needs of the farm.*

Phase 3. Filter press separation

*Settled solids are pumped from the bottom of the lime settling tank by the lime sludge pump, which pumps the mixture into a **filter press** for a secondary dewatering process. The precipitated solids are captured by a series of filter plates lined with cloths which allow liquid to pass through while retaining the solids. The pressure produced by a pump will continuously squeeze the remaining liquid out of the press once the plates are full of solids. Filtered liquid can be either transferred back to the lagoon or to a holding tanker, depending on the needs of the farm. Once the filter plates are full of lime solids (**lime cake**), the lime sludge pump will be shut down and the solids will be fall off by gravity to rolling bins dumped with the aid of a forklift. Fig. 1 depicts an overview of this process.*

Photo 4: Filter press dispensing lime cake (Photo by OSU – OARDC Ken Chamberlain)

Review of the Project Deliverables:

Deliverable 1: quasar's team of engineers and scientists were responsible for completing parts 1 – 4 identified under this portion of the project.

DELIVERABLE 1	
OBJECTIVE A: Field Demonstrate of Innovative Technology	**Measures: (1)** Laboratory analysis of manure to optimize performance **(2)** Order equipment, **(3)** Installation of equipment to manage flow rate of 20 gmp - 50 gpm of manure, **(4)** Operation of facility.

1) Extensive testing was performed by quasar's process engineers and laboratory technicians using quasar's in-house laboratory to confirm the optimal conditions for operating the system to achieve the desired phosphorus recovery results and manage between 20 and 50 gpm of manure.

2) PRS was designed and engineering by quasar's team using a combination of off-the-shelf and custom fabricated components.

3) The integration of PRS components was performed in Wooster, Ohio on the OSU-OARDC campus. Equipment was tested using manure trucked in from an area farmer to confirm ability to manage 20 – 50 gpm of manure.

4) The CIG project team ran various tests on the complete system immediately following integration to confirm performance of the centrifuge, type and quantity of polymer additive, and impact and quantity of lime.

DELIVERABLE 2	
OBJECTIVE B: Verify environmental effectiveness of the technology	**Measures: (1)** Laboratory evaluation of phosphorous product to confirm concentration of >5,000 mg/L. **(2)** Laboratory evaluation of remaining liquid to confirm that typical processed water phosphorous concentration requirements for discharge to land can be met (<1 mg/L). **(3)** Based on this information, confirm the quantity of nutrients annually diverted by the facility and the impact on participating EQIP producers, **(4)** Evaluate the opportunity to sell concentrated product outside of the region and obtain letters of interest from distributors.

Deliverable 2: Dr. Yebo Li, professor in the Department of Food, Agricultural and Biological Engineering at OSU and his team of researchers were responsible for performing laboratory tests to confirm the project's compliance with #1 and #2 of the second set of deliverables.

1) Laboratory analysis of manure for P content pre-treatment ranges between 205 ppm (Wooster area L&R Dairy Farm) and 211 ppm (New Bremen Brownhaven Farms). After processing, P concentrations in the post-centrifuge solids ranged from 952 ppm (L&R Dairy Farm) to 5668 ppm (Brownhaven). The difference in results is mostly explained by the apparent improvement in centrifuge performance. In the first demonstration, the incoming manure was 5% TS and the post-centrifuge solids were 16% TS. In the second demonstration, the manure was much thinner (1.4% TS) but the centrifuge solids still had higher TS (22.5%) than the first demonstration. The centrifuge was better at separating solids and thus concentrating the P during the second demonstration. Polymer dosage was also higher at the second demonstration because the manure was so thin.

2) Laboratory analysis of post-treatment liquid of both L&R Dairy Farm manure and Brownhaven Dairy manure achieved a phosphorus level of <1 ppm (or mg/L) achieving the project's primary objective. Further explanation of laboratory testing performed by Dr. Li and his team is provided below (an excerpt found on page 4 of Dr. Li's project report)

Samples were collected and analyzed by researchers from the lab of Dr. Yebo Li, OSU-FABE. The OSU team collected samples of the raw manure slurry, centrifuge solids and centrate from Phase 1 and the filter press lime cake and the lime-treated final effluent from Phase 3. For each product produced by the system, samples were taken at two different time periods during the demonstration. The OSU team evaluated total solids (TS), volatile solids (VS), nitrogen content (N), phosphorus content (P), potassium content (K) and carbon-nitrogen ratio (C:N). Results are shown in Tables 1 and 2.

The analytical tools/methods utilized by OSU included: inductively-coupled plasma mass spectrometry for P and K determination, elemental analysis via varioMax Elementar for C:N, total Kjeldahl nitrogen analysis for N, and gravimetric analysis for TS, VS determination. All analyses were done in triplicate unless otherwise noted. Values reflect averages across two sampling periods.

Table 1. System Performance at July 22nd Demonstration at OARDC

Sampling Point	TS (%)	VS (%)	N (ppm)	P (ppm)	C:N
Inflow Manure	5.3	83.2	1,510	205	10.8
Post-Centrifuge Solids	16.0	86.4	5,490	952	14.1
Post-Centrifuge Liquid	1.5	51.6	1,220	34	-
Post-Filter Press Solids	42.0	4.2	2,600	606	12.2
Final Effluent	1.0	36.3	684	<0.50	-

Table 2. System Performance at July 28th Demonstration at Brownhaven Farm

Sampling Point	TS (%)	VS (%)	N (ppm)	P (ppm)	K (ppm)	C:N
Inflow Manure	1.4	59.6	1,444	211	1,461	5.48
Post-Centrifuge Solids	22.6	71.7	8,019	5,668	2,620	10.16
Post-Centrifuge Liquid	0.6	42.4	1,352	51	168	-
Post-Filter Press Solids	41.4	3.5	1,851	736	726	14.02
Final Effluent	0.5	24.4	1,105	<0.50	66	-

3) Analysis of the quantity of P annually diverted from the Grand Lake St. Marys watershed was focused on results from the demonstration performed at Brownhaven Dairy, as L&R Dairy Farm was used for convenience of initial testing and is not located in the impacted watershed. Based on the OSU Manure Management Guide, an average dairy cow produces 0.168 lbs of P_20_5 per day, 365 days per year. Brownhaven Farm's herd is 265 dairy cows which therefore produce an

Photo 5: Material samples from left to right: slurry enters lagoon, solids after dewatering, liquids after dewatering, final low P product

estimated 16,249 lbs of P_20_5 per year (or 8.1 tons of P_20_5). This results in the removal of 3.5 tons of P each year from the watershed using PRS (P_20_5 /2.29 = P).

Brownhaven Farms (projections based on laboratory analysis from demonstration)	
Type	**Tons Diverted Per Year**
P_20_5	8.1 tons
P	3.5 tons

It is estimated that dairy cows in Mercer and Auglaize Counties produce about 110,000 ton/year of manure solids containing about 250 ton/year phosphorous (P_2O_5) [viii]. Lou Brown and Brownhaven Farms is an EQIP eligible agricultural producer. PRS was designed as a mobile system that could be shared by multiple farms (or through an agricultural co-operative) to keep costs low. One PRS could be used by 5 farms the approximate size of Brownhaven to manage their stored manure, resulting in the diversion of a total of 40 tons of P_2O_5 (or 17.5 tons of P) each year - a material impact to the cause of GLSM watershed algae blooms.

4) With laboratory tests complete, we are in the process of considering various options for marketing the solids product. While we have not secured letters of intent from end users, we have identified two potential options for the solids and held multiple conversations with entities that may be interested in the marketing solids. 1) to use as animal bedding, peat alternative or land apply the concentrated solid material at agronomic rates on farms outside of the watershed, where phosphorus is a valued nutrient, or 2) to incorporate an additional technology into the process that results in a highly concentrated (up to 90% reduction in volume) biochar material.

Deliverable 3: Following the demonstration at Brownhaven Farms, quasar's engineering team considered the operational requirements and up-front costs of the PRS system.

DELIVERABLE 3	
OBJECTIVE C: Offset Minimal State Funding for Agricultural Pollution Problems	**Measures: (1)** quasar will perform a complete economic assessment of the facility based on actual operating results. **(2)** Based on this assessment, a financial model will be developed that includes: a**)** annual operating costs, and **b)** payback.

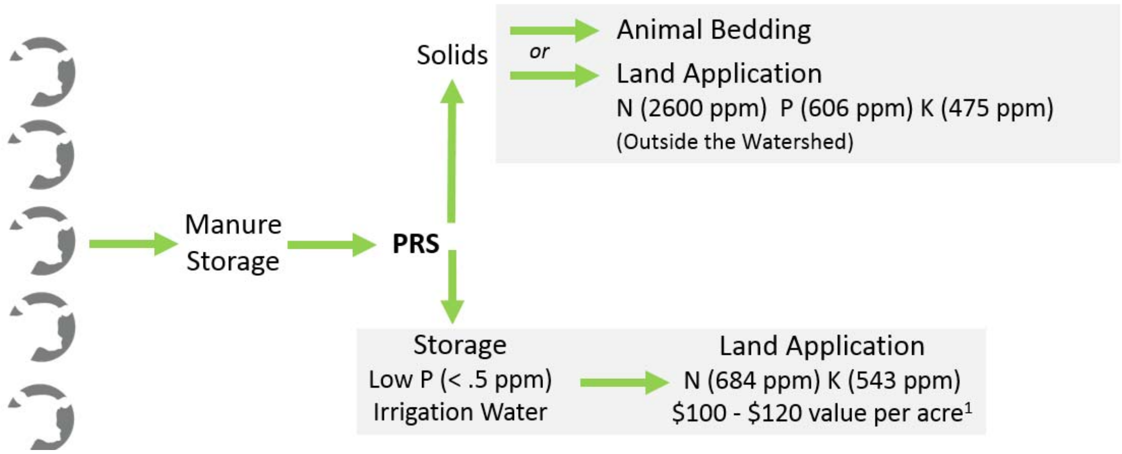
1) While the actual cost of a system is difficult to determine due to the design, testing, integration and adjustment costs associated with building the system prototype for the demonstration, we estimate a replica could be constructed for under $1,000,000. Upon completion of Phase II (discussed later in the document) we anticipate reducing the cost of a PRS to $500,000. Preliminary operating costs are estimated at between $0.03 and $0.04 per gallon, including polymer addition, lime, acid, electricity usage, lagoon mixing, and labor.

2) A farm the size of Brownhaven will typically manage 8 million gallons of manure (including accumulated rainwater) each year via lagoon storage and land application. OSU Extension Services estimates the cost of handling manure at between $0.0075 and $0.017 per gallon[ix], depending on the system used. Brownhaven manages their manure for $0.015 per gallon, or $120,000 per year. PRS does not eliminate the need to land apply material but provides an option

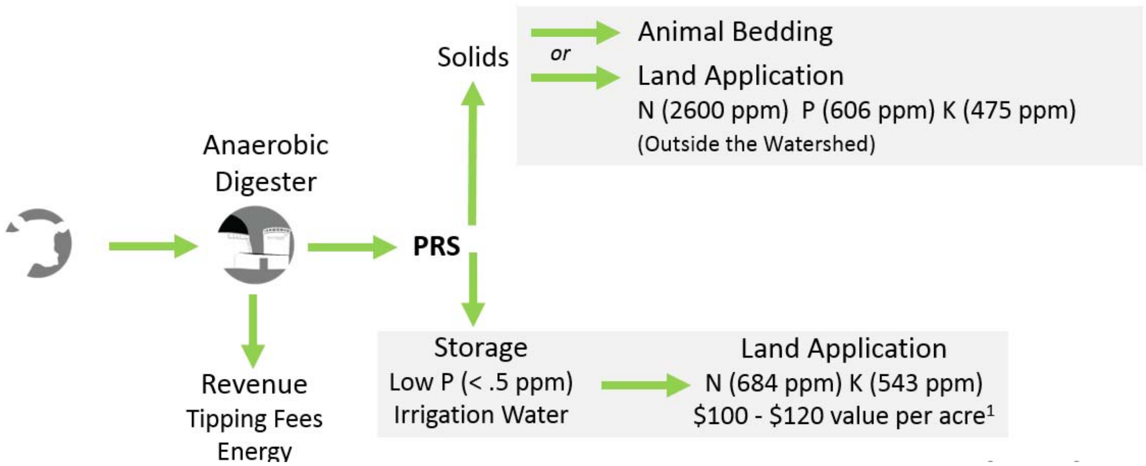
for farmers whose fields may have already exceeded P limits. With PRS, instead of directly applying manure to fields, farmers would apply the liquid end product of the PRS system that is low in P (< .5 mg/L) but retains N and K value.

Nutrient trading programs present a potential revenue stream for farmers or co-ops deploying PRS technology. In the Great Miami River Watershed, phosphorus (P) is trading for an average of $1.48 per pound. A similar program could be instituted in the GLSM to encourage technology adoption and reduce costs for farmers.

We anticipate two routes for the deployment of PRS at farms in the watershed;
Option 1: A group of farmers or a farm co-operative purchases and shares the equipment and related capital expenses.



Option 2: PRS technology can be scaled to manage unlimited amounts of manure and be dedicated to a single farm. An anaerobic digester can generate revenue to offset the cost of purchasing equipment.



1. *Based on application rate of 8,000 – 10,000 gallons per acre. Value may vary based on soil composition and crop yield expectation*.

Deliverable 4: A fundamental goal of the Conservation Innovation Grant program is *to stimulate the development and adoption of innovative conservation approaches and technologies.* Deliverables 1 and 2 focused on the development of an innovative conservation technology (PRS), while Deliverables 3 and 4 were designed to encourage the adoption of the technology both within the Grand Lake St. Marys watershed an in distressed watersheds across the state and country.

DELIVERABLE 4	
OBJECTIVE D: Market technology to the region and encourage adoption	**Measures: (1)** In collaboration with OSU Extension Services, host project tours and seminars to educate regional farmers about the technology and promote adoption across the region. **(2)** Collaborate with regional economic development organizations, including government entities, to market the opportunity the technology presents for the regional environment and economy. **(3)** Evaluate the national opportunity for transferring the technology.

1) As with any innovative technology, a key challenge to adoption involves building credibility and reducing risk in order to gain market acceptance of the technology. To accomplish this deliverable, quasar collaborated with Ohio BioProducts Innovation Center (OBIC) and OSU Extension services to inform farmers in the watershed about PRS as a phosphorus management solution.

   Two demonstrations of quasar's phosphorus removal system took place in late July (7/22 and 7/28). The first demonstration was held at the quasar digester facility on the Wooster, Ohio campus of the Ohio Agricultural Research and Development Center (OARDC). This demonstration was closed to the public and was intended primarily to give Dr. Yebo Li an opportunity to evaluate the completed system in operation and collect samples of material as well as to give NRCS representatives a chance to review the finished system. Unfortunately, scheduling conflicts prevented Ohio NRCS representatives from participating. They will be provided with Dr. Li's report.

Photo 6: OSU Adam Khalaf and Dr. Yebo Li collect samples of PRS material at various stages (Photo by OSU – OARDC Ken Chamberlain)

   A second, public demonstration took place at Brownhaven Dairy Farm in the Grand Lake St. Mary's watershed on July 28th. quasar and OSU representatives were on-hand to answer questions about the system's operating parameters and capabilities. During the demonstration Dr. Li's team took additional material samples for evaluation (the results are available on page 6, Table 2 of this report). More than fifty local farmers and representatives of Ohio's agricultural community attended the event including representatives from:

Dairy Management, Inc.
Newtrients

U.S. Senator Sherrod Brown's Office
Ohio Senate President Keith Faber's Office
Ohio Farm Bureau
Ohio Department of Natural Resources
Wright State University
Auglaize County Soil and Water Conservation District
Mercer County Soil and Water Conservation District
Nature Conservancy
OSU Extension Service
GLSM Restoration
Ohio Department of Agriculture
Ohio NRCS

2) The following inquiries and initiatives have been undertaken to disseminate information regarding PRS to the agricultural community.

- The Daily Standard and the Ohio Country Journal attended the demonstration and published an article about the system. A copy of the article is attached at the end of this section.

- quasar representatives were invited to present information regarding PRS to the Board of the Ohio Dairy Producers Association.

- The PRS system will be at Ohio's Farm Science Review in Columbus, OH from September 22 – 24. Farm Science Review is the largest agricultural trade show in the state.

3) The opportunity to transfer PRS technology from Ohio's distressed Grand Lake St. Marys watershed across the country is significant – **stopping phosphorus run-off at its source is the best long term option for conquering algae blooms.** The following initiatives have been undertaken to promote adoption of PRS across the country:

- BioCycle Magazine is writing a feature article on PRS for their BioCycle REFOR15 conference issue and quasar's President Mel Kurtz has been asked to give a presentation on PRS at the conference.

- quasar sent over 2,000 e-blasts (pictured on the right) to area farmers, state and federal legislators, and regulatory agencies announcing the successful event and providing information regarding the technology. A full copy of the blast is provided at the end of this report. From the blast we have received multiple inquiries from agricultural producers and co-operatives regarding the system.

quasar

quasar Provides A SOLUTION TO ALGAE BLOOMS

quasar Demonstrates its Phosphorus Recovery System (PRS) in New Bremen, OH

CONGRATULATIONS to quasar's Conservation Innovation Grant (CIG) team for completing the equipment demonstration at Lou Brown's Brownhaven Farm on July 28th. The equipment demonstration was a huge success. Please join us in congratulating the following employees for their significant efforts to complete this project:

Adam Dellinger, Mark Bender, Mike Ammon, Bobby Luciano, Jim Green, Les Mann, Monte King, Brandon Ammon, Chad King, Christy Schaad, Sergio Mendoza, Laura Lemon and Karl LeFever.

About the Demonstration: On Tuesday July 28, 2015 representatives from quasar energy group along with The Ohio State University and the Ohio BioProducts Innovation Center unveiled a new technology designed specifically to address phosphorus overloading in Ohio's Grand Lake St. Marys watershed. The Phosphorus Recovery System (PRS) is able to recover phosphorus from manure and other organic residuals at an efficiency rate of approximately 99.5% (or **< .5 mg/L phosphorus**) as validated by The Ohio State University.

Nearly 75 people turned out to watch quasar's PRS demonstration at Brownhaven Farms in New Bremen, Ohio. The demonstration illustrated how technology can prevent phosphorus from entering a distressed watershed without impeding agricultural operations.

Read more about quasar's event here and see a copy of the OSU laboratory results.

The PRS demonstration by quasar was funded in part through a USDA NRCS Conservation Innovation Grant (CIG) and is a collaboration with The Ohio State University and Ohio BioProducts Innovation Center.

Sustainable Technology Solutions . . .

INTERESTED IN LEARNING MORE?
Contact a member of the quasar team:
(216) 986 - 9999 x 120
or cressen@quasareg.com

quasar energy group
5755 Granger Road
Cleveland, Ohio 44131
(216) 986 - 9999 or info@quasareg.com

Photo 7: PRS e-blast

Phase II PRS Updates: PRS as demonstrated at Brownhaven Dairy will most likely not be the final system configuration. As we continue to evaluate the economics of the system we are acutely aware that affordability must go hand-in-hand with accelerated deployment. With quasar's obligations under our Conservation Innovation Grant complete, we are ready to move forward with Phase II of PRS development which include;

PRS Phase II:

Improvement: Reduce high pH in solids due to lime.
Solution: Substitute other coagulants for lime to mitigate pH and improve ease of operation.

Improvement: Reduce the cost of capital equipment.
Solution: Substitute the centrifuge with a screw press.

Improvement: Identify alternatives to improve logistics outside the watershed.
Solution: Drying to remove excess water or biochar production.

Phase II of PRS development will focus not only on deployment of the technology in agricultural applications, but also at municipal treatment plants. The impact of algae blooms from phosphorus overloading spreads beyond GLSM and threatens multiple major waterbodies across the county, including Ohio's Lake Erie. According to the U.S. Geological Survey's most recent data[x] , the origins of phosphorus in Lake Erie are as follows:

- Sewage: 46.1%
- Urban Land: 12.9%
- Agriculture: 36.6% (breakdown below)
    - Farm Fertilizer: 22.0%
    - Manure (Confined Animals): 12.9%
    - Manure (Unconfined Animals): 1.7%
- Forest/Wetland: 4.1%

With statistics illustrating that sewage contributes 46.1% of the phosphorus to Lake Erie it is clear that a collaborative initiative between agriculture and wastewater must ensue to resolve the problem.

Conclusion: The CIG project demonstrated to farmers across the GLSM watershed that phosphorus solutions are not limited to chemical treatment and dredging, which only address the symptoms of the problem, not the cause. PRS manages the phosphorus before it enters the watershed and diverts it to where it is needed while allowing farmers to continue operating. Phase II PRS improvements will further refine the technology to reduce costs and improve overall performance to facilitate broad adoption in distressed watersheds.

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[i] OEPA Report: Grand Lake St. Marys & Its Watershed: Water Quality Improvement Initiatives

[ii] Economic Impact of Tourism in Auglaize and Mercer County. Report prepared by Tourism Economics, Wayne, PA, published September 2009.

[iii] Grand Lake St, Marys/Wabash River Watershed Action Plan, December 31, 2009.

[iv] OEPA Press Release, Public Interest Center, State Issues Stronger Advisory for Grand Lake St. Marys; Advises Against Boating and Fishing, July 16, 2010

[v] Disaster Declaration Survey (commissioned by Gov. Strickland)

[vi] WRIST, Inc. Housing Statistics, 2009, 2010

[vii] Dairy Manure Production and Nutrient Content, John P. Chastain, and James J. Camberato,

[viii] Dairy Manure Production and Nutrient Content, John P. Chastain, and James J. Camberato,

[ix] OSU Extension Services: An Economic Comparison of Three Manure Handling Systems
[x] USGS more information available here *Notes: a) the data for point sources is from 2002, it will be updated with 2012 numbers within the next 1.5 years, and b) only reports data for what enters Lake Erie from the United States*

ATTACHMENTS:

1. OSU Report on Testing of the quasar Phosphorus Removal System by Dr. Yebo Li
2. OSU Lab Report
3. Phosphorus Recovery System Flyer
4. The Daily Standard: Company Demonstrates Process of Making Manure's Phosphorus Easier to Manager
5. Ohio Country Journal: Phosphorus Recovery System Addresses Water Quality Challenges with Manure

THE OHIO STATE UNIVERSITY

College of Food, Agriculture and Environmental Sciences
Ohio Agricultural Research and Development Center

Department of Food, Agricultural, and
Biological Engineering

1680 Madison Avenue
Wooster, OH 44691

oardc.osu.edu/bioenergy

August 19, 2015

Dear Ms. Henry,

I supervised the compositional analysis of the phosphorus in the final effluent from *quasar energy group's* Phosphorus Recovery System. The analyses were conducted in my Bioproducts and Bioenergy Research Laboratory located at the Ohio Agricultural Research and Development Center/Ohio State University in Wooster, Ohio.

The samples of the effluent were collected and analyzed after each test (July 22 and July 28). The phosphorus level in the final effluent was less than 1.0 ppm.

Sincerely,

Yebo Li

Yebo Li, Professor
Department of Food, Agricultural and Biological Engineering
Department of Chemical and Biomolecular Engineering

Report on the testing of the quasar phosphorous removal system

Yebo Li, Adam Khalaf, Fuqing Xu

The Ohio State University

Introduction

Application of animal manure to agricultural fields is common practice in Ohio agriculture. However, this practice contributes to severe phosphorus (P) overloading in Northwest Ohio soils, which in turn contributes to the nutrient runoff that causes eutrophication of waterways and leads to harmful algal blooms. In the Grand Lake St. Mary's and Lake Erie watersheds, blooms of the toxin-producing blue-green algae known as *Microcystis* adversely impact ecosystems, human health and business alike. These issues have drawn national attention as in the summer of 2014, when half a million residents of Toledo, Ohio suffered from a drinking water shortage due to a harmful algal bloom in Lake Erie. This summer at Grand Lake St. Mary's, the EPA has advised residents to avoid any contact whatsoever with lake water due to high levels of algal toxins. Phosphorus removal and recovery methods are now urgently needed in Ohio watersheds as well as many regions of the country.

The P removal system developed by *quasar energy group* aims to cost-effectively remove P from animal manure and other high strength wastewaters before land application. The system is mounted on a mobile trailer that can be transported to different locations for manure and wastewater treatment. Target performance for this system includes producing a liquid stream with P concentration below 1 ppm for land application, and producing a solid stream with P concentration greater than 5000 ppm. The P-rich solids can be stored and transported out of the P-overloaded watershed. The detailed process description and an evaluation of the system performance from two public demonstrations are included below.

Process description

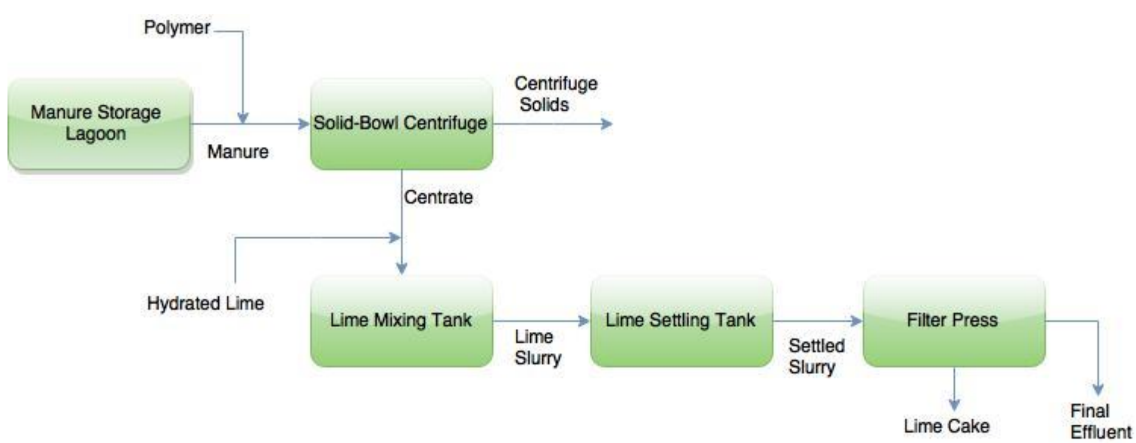

Fig. 1 Process diagram

Phase 1. Initial solid-liquid separation with polymer flocculation

Manure slurry from the lagoon is fed into a **solid-bowl centrifuge** using a **sludge pump** for an initial solid-liquid separation. To enhance flocculation of solids, polymer flocculants are incorporated by the Siemens Polyblend unit attached to the centrifuge, which flash-mixes water and polymer to a 1% solution, which is then added to the sludge line. Polymer addition is suggested if there are large amount of small particles in the sludge; otherwise, no polymer addition is needed. The solid products (**centrifuge solids**) captured by centrifugation are conveyed off of the trailer and into a container or trailer to transport off-site. This initial separation is expected to remove around 70% of solids and most of the large particles.

Phase 2. P removal by lime precipitation and settling

The liquid obtained from step 1 (**centrate**) will go through the centrifuge drain to a rectangular stainless steel open-top **centrate collection tank** located directly beneath the centrifuge bowl. Liquid hydrated lime ($Ca(OH)_2$), stored in a HDPE tote on the trailer, is pumped directly into the centrate collection tank. In wastewater treatment, lime is a commonly-used additive to promote precipitation of phosphorus as various calcium-phosphorus compounds. Near the inlet of the hydrated lime dosing line, a small agitator mixes the hydrated lime with the centrate. The hydrated lime flow rate can be adjusted as needed in order to achieve a target pH of at least 10.5 to efficiently coagulate and precipitate fine solid particles not captured by the centrifuge such as colloidal magnesium (Mg) and P. If Phase 1 is conducted without the aid of polymer, higher hydrated lime dosage might be needed.

A sump pump located at the other end of the centrate collection tank will pump the mixture to a 350-gallon **lime mixing tank** located at the back of the trailer. The lime mixing tank consists of an inlet at the bottom, a mixer, and a gravity overflow outlet at the top. In this tank, the lime and centrate will be further mixed for 8-10 minutes to improve the efficiency of the P precipitation reactions. pH will be monitored in this tank.

From the mixing tank, the hydrated lime-centrate mixture will overflow out of the top of the lime mixing tank into the **lime settling tank**. The lime settling tank is a 500-gallon rectangular cone-bottom tank with a top inlet and top outlet on opposite sides separated by a baffle, and an outlet located at the bottom of the cone. In this tank the precipitated solids will settle to the bottom. The baffle prevents any solids from short-circuiting to the top outlet and contaminating the clarified liquid. Clarified liquid exits from the top outlet either back to the lagoon, or to a holding tanker, depending on the needs of the farm.

Phase 3. Filter press separation

Settled solids are pumped from the bottom of the lime settling tank by the lime sludge pump, which pumps the mixture into a **filter press** for a secondary dewatering process. The precipitated solids are captured by a series of filter plates lined with cloths which allow liquid to pass through while retaining the solids. The pressure produced by a pump will continuously squeeze the remaining liquid out of the press once the plates are full of solids. Filtered liquid can be either transferred back to the lagoon or to a holding tanker, depending on the needs of the farm. Once the filter plates are full of lime solids (**lime cake**), the lime sludge pump will be shut down and the solids will be fall off by gravity to rolling bins dumped with the aid of a forklift. Fig. 1 depicts an overview of this process.

Centrifuge Solids

Lime cake

Lime-treated centrate

Testing Results and conclusions

Two public demonstrations of quasar's phosphorus removal system took place in late July (7/22 and 7/28). The first demonstration was held at the quasar digester facility on the campus of the Ohio Agricultural Research and Development Center (OARDC) in Wooster, Ohio. The second demonstration took place at Brownhaven Farm, a dairy farm in the Grand Lake St. Mary's area owned by Lou Brown. To evaluate system performance, at both demonstrations samples were collected and analyzed by researchers from the lab of Dr. Yebo Li, professor in the Department of Food, Agricultural and Biological Engineering at OSU.

The OSU team collected samples of the raw manure slurry, centrifuge solids and centrate from Phase 1 and the filter press lime cake and the lime-treated final effluent from Phase 3. For each product produced by the system, samples were taken at two different time periods during the demonstration. The OSU team evaluated total solids (TS), volatile solids (VS), nitrogen content (N), phosphorus content (P), potassium content (K) and carbon-nitrogen ratio (C:N). Results are shown in Tables 1 and 2.

The analytical tools/methods utilized by OSU included: inductively-coupled plasma mass spectrometry for P and K determination, elemental analysis via varioMax Elementar for C:N, total Kjeldahl nitrogen analysis for N, and gravimetric analysis for TS, VS determination. All analyses were done in triplicate unless otherwise noted. Values reflect averages across two sampling periods.

Table 1. System Performance at July 22nd Demonstration at OARDC

Sampling Point	TS (%)	VS (%)	N (ppm)	P (ppm)	C:N
Inflow Manure	5.3	83.2	1510	205	10.8
Post-Centrifuge Solids	16.0	86.4	5490	952	14.1
Post-Centrifuge Liquid	1.5	51.6	1220	34	-
Post-Filter Press Solids	42.0	4.2	2600	606	12.2
Final Effluent	1.0	36.3	684	<0.50	-

Table 2. System Performance at July 28th Demonstration at Brownhaven Farm						
Sampling Point	**TS (%)**	**VS (%)**	**N (ppm)**	**P (ppm)**	**K (ppm)**	**C:N**
Inflow Manure	1.4	59.6	1444	211	1461	5.48
Post-Centrifuge Solids	22.6	71.7	8019	5668	2620	10.16
Post-Centrifuge Liquid	0.6	42.4	1352	51	168	-
Post-Filter Press Solids	41.4	3.5	1851	736	726	14.02
Final Effluent	0.5	24.4	1105	<0.50	66	-

Notes:

C:N ratio reported for solid components only
Each sample tested in triplicate for P, K, N, in duplicate for C:N

Conclusions:

At both demonstrations of the P removal system, quasar was able to achieve P concentrations below 1 ppm in the final liquid effluent. At Brownhaven Farm, the system also achieved the goal of 5000 ppm in the post-centrifuge solids. Based on the OSU analysis, quasar's process was capable of meeting target P levels in the solid and liquid portions.

Attachment for figures:

Above: quasar's phosphorus removal system at Brownhaven farm in New Bremen, OH

From left to right: influent manure, centrifuge solids, centrate, final effluent from July 28 demo

THE OHIO STATE UNIVERSITY

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July 27, 2015

Dear Ms. Henry,

I supervised the compositional analysis of the phosphorus in the final effluent from *quasar energy group's* Phosphorus Recovery System. The analyses were conducted in my Bioproducts and Bioenergy Research Laboratory located at the Ohio Agricultural Research and Development Center/Ohio State University in Wooster, Ohio.

The samples of the effluent were collected and analyzed in triplicate on July 22-July 27, 2015. The phosphorus level in the final effluent was 0.3 ppm. Summary of the results can be found in the table below.

Sampling Point	**TS (%)**	**VS (% of TS)**	**N (ppm*)**	**P (ppm*)**	**K (ppm*)**
Inflow Manure	5.3	83.2	1510	204	451
Post-Centrifuge Solids	16.1	86.4	5490	952	821
Post-Centrifuge Liquid	1.5	51.6	1220	33	707
Post-Filter Press Solids	42.0	4.2	2600	606	475
Final Effluent	1	36.3	684	0.3	523

*Based on wet weight

Sincerely,

Yebo Li

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quasar's Phosphorus Recovery System (PRS) is able to recover phosphorus from manure and other organic residuals at an efficiency rate of approximately 99.5% (or < 1 mg/L phosphorus) as validated by Ohio State University's Department of Food, Agricultural and Biological Engineering (FABE). The PRS was designed by quasar and funded in part through a USDA NRCS Conservation Innovation Grant.

HOW IT WORKS

1. Manure is pumped into the system.

2. Manure is then processed through solids separation technology (in this case a centrifuge) which segregates solids from liquids. The resultant solids have a total solids content of approximately 25% and contain 90% - 95% of the manure phosphorus. The solids are conveyed to a storage unit. Liquids from the system drain into a collection tank directly below the centrifuge.

3. Liquid hydrated lime ($Ca(OH)_2$) is pumped directly into the collection tank where it is mixed with the liquids coming off the solid separation equipment. This mixture is brought to a target pH of at least 10.5 to facilitate coagulation and precipitation of remaining solids not captured by the solid separation equipment. Another pump then sends this material to a lime mixing tank where it will be further mixed to ensure a uniform pH.

4. The material will overflow out of the top of the lime mixing tank into a lime settling tank. Here, precipitated solids will settle to the bottom of the tank and clarified liquids will exit the process through a top outlet.

5. Settled solids and liquids are pumped out of the bottom of the lime settling tank and into a filter press. The filter press is a secondary solids separation system that squeezes liquids out of the material. Filtered liquid from the press will have a **phosphorus content of < 1 mg/L** and can be used for irrigation. The separated lime solids (lime cake) are blended with collected solids from Step 2 and can be transported affordably out of the distressed watershed.

THE DAILY STANDARD

Thursday, July 30, 2015

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Company demonstrates process of making manure's phosphorous easier to manage

By NANCY ALLEN
nallen@dailystandard.com

NEW BREMEN — A portable unit that processes liquid dairy manure into a phosphorous-rich solid and mostly clean water was tested this week at an Auglaize County farm.

The unit separates manure solids from the liquid, keeping more than 90 percent of the phosphorous with the solids. The solid, now in a much more manageable form, can be shipped off the farm and the liquid can be used to irrigate crops or returned to the manure lagoon.

"In short, the goal is to manage the phosphorous," said Mel Kurtz, president of Cleveland-based Quasar Energy Group, the company that tested the unit. "Everyone in the neighborhood knows this and Toledo knows this."

Found in manure and man-made fertilizers, phosphorous is the main nutrient contributing to toxic blue-green algal blooms in Grand Lake, Lake Erie and other Ohio waters. Grand Lake in Mercer and Auglaize counties has had a water advisory placed on it by the state every year since 2009 due to unsafe levels of algae toxins. A Lake Erie algal bloom last summer prompted Toledo to issue a two-day drinking water ban for its 400,000 users.

About 50 people viewed the technology at Brownhaven Dairy owned by Lou and Alan Brown on state Route 364. Liquid manure from a lagoon on the farm in the Grand Lake Watershed was used in the test.

A centrifuge inside the unit separates the manure solids from the liquid, explained Bobby Luciano, a Quasar electrical engineer.

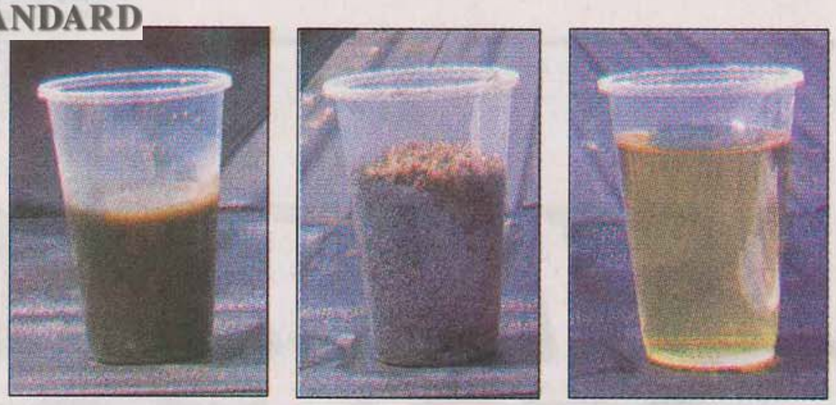
"The solids contain the majority of the phosphorous," he said. "Then you can truck the solid away at the end, so it's removed from the watershed."

The solid product coming out

See PROCESS, back page

Nancy Allen/The Daily Standard

About 50 people gather this week at Brownhaven Dairy in Auglaize County to watch a phosphorous recovery system used on liquid dairy manure. Developed by Cleveland-based Quasar Energy Group, the system separates manure solids from the liquid, keeping up to 98 percent of the phosphorous with the solids.



Nancy Allen photos/The Daily Standard

From left, are three cups containing untreated liquid dairy manure, manure solids after much of the liquid has been removed and the resulting clean water.

Process

(Continued from front page)

of the unit on Tuesday at first looked gloppy. After a while it turned to a fluffy potting soil-like substance. Lime and a polymer are used to bind the phosphorous to the solids.

The clean water left at the end of the process was pumped back into the dairy's manure lagoon. Previous tests done by Ohio State University show the solid contains up to 98 percent of the phosphorous, while the water has less than one milligram per liter of phosphorous. Since the water contains very little phosphorous, it could be land applied, Luciano said.

Kurtz estimates the unit would cost about $600,000 but expects the price to fall as the technology improves. Quasar's partner, Parker-Hannifin, is working to make the units less costly, he said.

"The plan is to make this more cost effective," Kurtz said.

State agriculture engineer Terry Mescher said the technology is a step in the right direction but the cost of purchasing and operating the equipment will determine its feasibility, he said.

"It improves the economic aspect of transporting manure," he said. "I think there is some potential here but the technology is under development."

Both dairy and swine manures contain a large amount of water, making it costly and difficult to transport.

Several hog operations and a few dairy operations transport manure out of the watershed to meet soil phosphorous limits in their nutrient management plans, said Frances Springer, a state nutrient management specialist who works with Grand Lake Watershed farmers.

The plans and other rules were mandated after the state in 2011 designated the watershed distressed because humans and animals were sickened by algal toxins in Grand Lake during summer 2010. A nutrient management plan is a formal document that tells farmers how to best manage their manure so it does not run off and pollute waterways. The algae's main food source is phosphorous found in manure, which runs off mostly farmland, the largest land use in the 58,000-acre watershed.

Lou Brown said he was happy with the number of people who turned out to see the test and ask questions. The dairy has received various conservation awards during the past few years.

Brown said he felt the technology holds promise as a means to reduce phosphorous coming off farms but stopped short of saying he might purchase one.

"If our lakes show improvements maybe farms won't need it or maybe wastewater treatment plants could use it."

Tuesday's test cost about $2.2 million to conduct, Luciano said. The test was funded through a $1 million Conservation Innovation grant Quasar received from the U.S. Department of Agricultures' Natural Resources Conservation Service and $1 million from Quasar.

Phosphorus Recovery System addresses water quality challenges with manure

August 27, 2015
By Alyssa Muhlenkamp, Ohio's Country Journal field reporter

The vexing problem of phosphorus in the water continues to make big headlines and haunt animal agriculture. This political hot button, however, has led to some positive developments in research regarding on-farm practices and technology. One of the most recently announced innovations addressing this problem is the Phosphorus Recovery System (PRS) from Quasar Energy that removes nearly all of the phosphorus from manure.


This is the process the manure goes through in the PRS.

The Brown family dairy farm near New Bremen, in the heart of one of Ohio's key livestock regions, hosted an event in conjunction with the Quasar Energy Group demonstrating the new Phosphorus Recovery System (PRS) in July.

"It's funny that we are doing this here because I'm probably the one that helped start this phosphorus problem in the first place," Alvin Brown said. "I used to want every inch of every field covered with manure, and now, we are working to reverse that idea and the growing problem."

Alvin started his farm with 10 dairy heifers in 1959, and his son, Lou, is now running the farm with about 275 milking cows along with 180 heifers at a near-by farm. Lou has put great effort into helping find new ways to reduce the phosphorus issues in his area. He is a member of the Auglaize County Soil and Water Board, Lake Loramie Advisory Board, Ag Solutions, Great Lakes Initiative, and Top of Ohio. On top of all those organizations, he is also currently serving as the Director of Ohio Dairy Producers.

"It was not just random luck that our farm was chosen for this demonstration with Quasar," Lou said. "Our whole family has put so much time and focus on this issue, that it only makes sense to have it here today."

Lou's son, Dan, obtained his master's degree in biodigesters at The Ohio State University in Wooster where he actually worked with Quasar on the research and other aspects of the project to develop the PRS. They started this project three years ago hoping to develop a digester to help lower the amount of phosphorus in the manure from their livestock.

On the Brown farm alone, their cows will produce up to eight tons of manure per day. In order to be able to move this large amount of manure off the farm, the Browns have a nutrient management plan in place with more than 1,000 acres of land where they are allowed to spread the manure. Everyone who raises livestock in a distressed watershed, such as theirs, must have one of these plans set up with their local Natural Resources Conservation Service in order to spread any manure on the land. This practice is progressively being recommended to other watersheds as well for prevention of phosphorus issues in the future.

According to the Quasar Energy Group, farmers are not solely responsible for the current phosphorus management issues. There are 1,200 wastewater treatment plants between Wapakoneta and Lake Erie that contribute to these problems, At peak flow, 710,000 gallons of water flow into Lake Erie just from the Maumee River every second with phosphorus from farms and water treatments facilities collected along the way.

Lou Brown hosted the Phosphorus Recovery System (PRS) demonstration from Quasar Energy on his farm near New Bremen.

This is where the Phosphorus Recovery System can be beneficial. As of right now, a farmer is not allowed to spread manure within 200 feet of surrounding waterways because of phosphorus run-off concerns. By removing the phosphorus from the manure, it opens up the possibility of removing those barriers. This can also add other opportunities for manure application including sidedressing corn, depending on the nitrates in the test results, or selling the phosphorus that was removed. This dried form of phosphorus removed from the manure through the process is easy to transport, and it has the possibility to be extremely valuable to the farmers, wastewater treatment plants, and cities who choose to remove the phosphorus from the manure and other wastes.

Quasar has not been able to completely remove the phosphorus, but the group has been able to reduce the levels from 204 parts per million to just .3 parts per million in their tests.

Quasar is able to accomplish this through a five-step system. First, the manure is pumped into the system from the holding pond. The manure is then processed through the centrifuge that separates the solids from the liquids. The solids from this separation have a total solid content of approximately 25% and contain 90% to 95% of the manure's phosphorus. Those solids get conveyed to a different storage unit where liquids from the segregates drain into the collection tank located below the centrifuge where it is mixed with liquid hydrated lime. The lime helps control the pH to at least 10.5 to enable thickening and precipitation of the remaining solids that were not captured in the first separation process.

A pump sends this material to a lime mixing tank where it gets further mixed to ensure a uniform pH. The material will overflow out of the top of the mixing tank into a lime settling tank. The solids settle to the bottom of the tank and the liquids leave through a top outlet during this phase. The settled solids and liquids then get pumped out of the tank into a filter press or plate frame press. It will squeeze the liquids out of the material, and this liquid material will have a phosphorus content less than 1 milligram per liter, which can be used for irrigation. The separated lime solids, or lime cake as the Quasar Energy Group likes to call it, can be blended with the solids that were collected from the centrifuge and transported out to another farm or away from the distressed watershed.

The work for the PRS was funded through a USDA-NRCS Conservation Innovation Grant of almost $1 million. Quasar Energy Group is now currently partnering with the Parker-Hannifin Corporation of Columbus that makes many of the fittings for the PRS to make it more affordable for the farmers. The two groups believe that they can achieve the same results with fewer costs and a smaller-scale system that farmers can have easier access to and could afford to purchase for themselves or at least with a group of neighboring farmers. Brown thinks farmers would only have to put in two to three hours a day into separating if they had the system directly on their farm each day. Depending on the value of the removed phosphorus, this could easily be worth the extra time put into this process.

The demonstration that took place at the Brown's farm was only the second public demonstration for the PRS.

"This is not a well-known John Deere tractor; it is the first of its kind," Lou said. "Some people are bit gun shy of the new technology while others are willing to lead this project. Regardless, the wide variety of people in attendance from neighboring farmers to the local NRCS, Farm Bureau, Extension, and even senators goes to show how important and beneficial this system could be for Lake Erie and other distressed areas."