Report of Pilot Program
Mercer County Short-term Dewatering Pilot
Document Number A010.20180405.01.005
Summary

Submitted to
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Dates of Program
March 5, 2018 – March 23, 2018

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Document Log

The following table summarizes relevant documents in support of the conducted pilot:

Table 1: Relevant Documents

Document Number	Description	Date of Issue
A010.20180107.01.002	Mercer County Short-term Dewatering Pilot	February 14, 2018
A010.20180314.01.002	Lime Jar Testing Procedure	March 14, 2018
A010.20180405.01.005	Summary Report of Pilot Program	April 14, 2018

Overview

Background

In spring/summer 2017, considerable investigation into potential dewatering technologies as potential components to the Quick Wash® Phosphorus Recovery Solution for the recovery of phosphorus from heavily loaded streams, such as manure, had been conducted with a focus on performance and cost. A total of 5 different vendor/technologies were investigated including:

- Fournier
- Prime Solutions
- Viroment
- Nexom
- First Wave
- Alfa Laval

Following an initial assessment, samples were sent to Fournier, Prime Solutions and Alfa Laval for testing. In addition, detailed cost estimates were requested for a target design criteria of 75gpm flow, 4% solids, 250 days/year operation at 10 hours per day. Additionally, an estimated pilot cost was requested for a 4 day pilot. After reviewing all of the data submitted, it was decided that a pilot would be conducted using Fournier as the technology to evaluate. Unfortunately, after mobilizing multiple technologies for a broader technology demonstration, the Fournier Technology was not able to create a floc capable of being dewatered at the target farm location. Samples from a second farm with deep pit manure storage also failed to floc, but a third farm with a shallow pit was successful. It was decided to suspend the broader pilot until the subject of why the Fournier technology was unable to create a floc in the field (despite multiple samples submitted prior to the pilot) could be investigated. It was determined that the problem with the initial attempt in the field was related to inappropriate polymer support that would have allowed Fournier to complete their portion of the overall pilot.

Subsequent to this determination, Prime Solutions recommended their polymer support company, Chemtron, who expressed interest in helping to find a solution. Two separate trips were made to the original host pilot site by Chemtron for this effort. On the first trip, an initial successful polymer was identified in a deep pit manure location and also confirmed as successful in the shallow pit operation. A second trip a month later confirmed the initial results plus a dairy manure sample obtained from a dairy lagoon.

While investigating alternative dewatering technologies to Fournier, a technology from KDS Separator (KDS Multi-disc Roller Separator) was found. This technology has an installed base of over 500 installations in Asia (primarily Japan), with considerable experience in dewatering of both swine and dairy manure (Appendix A). Figure 1 is a rendering of the overall KDS operation. Figure 2 is a picture of the pilot unit available. Presented separately was a summary of swine dewatering operation at 3 different operations in Japan with a solids content ranging from 0.1% up to 5%.

Figure 1: KDS Multi-disc Roller Separator

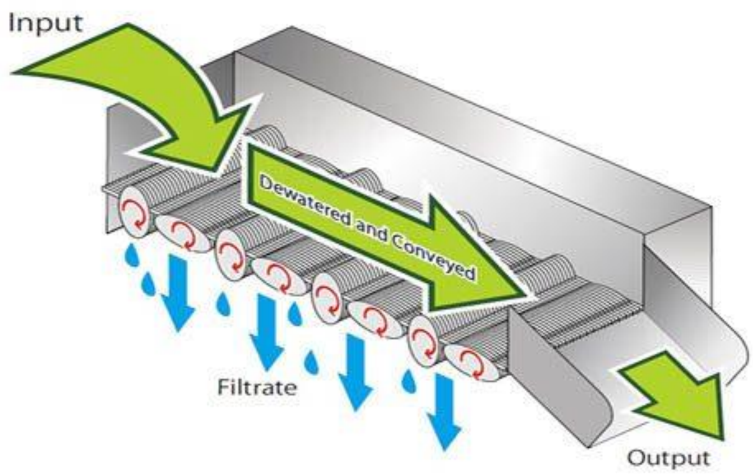


Figure 2: KDS Pilot Unit (SS-311D)

Partners

Based on the data presented, it was agreed to pursue a small scale demonstration of the KDS Dewatering Solution. Table 2 summarizes the various technology partners who participated in the pilot, while Table 3 summarizes those entities who offered support (financial and contributed services) to the program undertaken.

Table 2: Technology Partners

Organization	Principal individual	Role
Mercer County Ag Solutions	Theresa Dirksen	Program Sponsor
KDS Separator	Martin Witmer	Dewatering Technology
Chemtron	Chris Putt	Polymer Solutions
InNow LLC	Rick Johnson	Program Manager

Table 3: Program Sponsors

Organization	Support
Host Farm	Manure (swine and dairy)
VanTilburg Farms Inc.	Generator and Manure collection support
Lake Improvement Association	Funding
Mideast Dairy Producers Association	Funding
Mercer County Commissioners	Funding

Technology Description

The dewatering technology we evaluated is KDS Multi-disc Roller Separator produced by Kendensha Co, Ltd. A picture of the actual pilot unit used is shown in Figure 2. A waste stream to be dewatered enters the dewatering platform where lobed plates rotate allowing the entrained water to drain. The solids remaining are conveyed down the body to the discharge chute. Filtrate that comes out of the solution is collected under the platform for disposal or reuse. Because of its unique design, the unit is self-cleaning and no backflushing is required. The end result is an efficient compact design with very low energy requirements.

To improve the overall dewatering capability of the Separator, it is common to use a polymer in the input stream to maximize dewaterability. Numerous case studies have been completed where polymers were not required to achieve dewatered solids content of 20%+. With an installed base of over 528 units (primarily in Japan and Asia), the KDS Separator has demonstrated its ability to meet the demanding requirements of a wide range of industries. A summary of the installed base (references are available upon request) is given in Appendix A.

Pilot Program

Design

The pilot design was originally setup for a short-term duration (1 week) evaluation to confirm the ability of the KDS Multi-disc Roller Separator to separate both swine and dairy manure. For purposes of this evaluation, swine manure tested was taken from a deep pit configuration (that had been agitated) and dairy manure from a holding pond. Both sources were from farms owned and operated by the host farm. Both manure streams were to be tested with no chemical addition (polymer or coagulant), polymer only, and polymer + coagulant in order to develop a cost/performance profile. The use of chemicals was not optimized and was focused more on maximizing the impact of their use. Shortly after initiating the pilot, it was decided to extend it in order to complete additional swine manure testing.

During the course of each evaluation, samples of the raw manure, filtrate and dewatered solids were collected and analyzed by a third party lab (Brookside Labs). Samples were tested for the following:

Table 4: Analytical Tests per Manure Sample

Characteristic	Raw Manure	Filtrate	Dewatered solids*
Moisture, (%)	X	X	X
Total N, (lb/1000 gal)	X	X	X
Ammonia N, (lb/1000 gal)	X	X	X
Organic N, (lb/1000 gal)	X	X	X
P, (lb/1000 gal)	X	X	X
P2O5, (lb/1000 gal)	X	X	X
K, (lb/1000 gal)	X	X	X
K2O, (lb/1000 gal)	X	X	X
Ortho P (ppm)	X	X	

*: All units, except % Moisture, are in lb/ton

<u>Testing Plan</u>
The overall program involved the following:

<u>Equipment</u>
Use of the KDS SS-311D pilot unit. While limited to approximately 10 gpm and operational in a continuous mode, this unit provided adequate capacity for the pilot. The pilot skid consisted of 2 tanks (approximately 500L capacity each) with stirrers with a baffled plate between the 2 tanks. All manure entered the first tank and flowed to the rotating disks from the top of the second tank. A chemical dosing pump located on the pilot skid could introduce any chemicals desired into the first tank where they were continuously mixed through both tanks. All controls on the pilot skid were variable speed controlled so that flows could be adjusted as needed or desired.

As the manure flows across the rotating discs, filtrate flows into a collection tank and solids eventually exit the pilot unit on an inclined chute into a collection barrel. Pressure could be applied to material progressing across the rotating discs via a pneumatically actuated cylinder. For the dairy manure and initial swine manure tests, the pneumatic cylinder was not operational so a mechanical approach was used (2 cinder blocks located on the pressure plate).

A representative of KDS was on-site for week 1 for the evaluation and operation of the unit.

Polymer
The polymer used in the piloting was the same polymer that was tested prior to deployment of equipment. Additionally, prior to use, confirmation jar testing was conducted on-site. The polymer used for both manure studies was a high charge cationic emulsion that was fed at a rate of approximately 800-1000ppm.

Two separate coagulants were tested. For the dairy manure, an all organic cationic coagulant was used at a dosage of 500 ppm. This coagulant did not provide a positive response for the swine manure in jar testing, however, ferric chloride proved effective. Testing was conducted using 50ppm ferrous chloride obtained from a local wastewater treatment plant for the swine manure evaluation.

The polymer was mixed in a separate tank and pumped into the test unit via the on-board chemical dosing pump. Coagulants used were dosed neat – meaning they were introduced directly into the first tank on the KDS pilot skid.

A representative from Chemtron was present for the dairy and first swine manure evaluation.

Manure samples
As noted earlier, all manure evaluated was obtained from the host farm. Approximately 1000 gallons of each type of manure was obtained and transported to the test site using a water wagon provided by VanTilburg Farms. The wagon had provisions for continuous stirring of the transported manure so that a homogeneous sample was evaluated. Between dairy and swine manure, the wagon was flushed out using water to ensure minimum cross over contamination. The dairy manure was obtained from a holding pond while the swine manure was obtained from a deep pit manure system. The swine manure was "aged" (approximately 3-4 months) and was agitated prior to collection.

Prior to introduction into the KDS Separator, manure tested was circulated in the wagon approximately 5 minutes to ensure a homogeneous sample was obtained. Further, if a delay in the introduction of manure into the KDS Separator occurred, it was circulated to ensure minimal settling had occurred.

Figure 3 is an image of the pilot site showing the KDS Separator, manure wagon and solids collection barrels.

Figure 3: Pilot site layout

Protocol

Prior to the introduction of manure into the KDS Separator, manure to be tested was circulated in the manure wagon for approximately 5 minutes. Once ready, manure was introduced into the KDS Separator using the suction pump located on the pilot skid. The pilot unit was then run and samples collected for analysis. The raw feed sample was collected at the location where manure entered the first tank of the pilot skid. Filtrate samples were collected as filtrate entered the collection tank by collecting a beaker of material and then filling sample containers. The solids material was collected as it came off of the discharge chute.

A total of 3 manure evaluations were conducted as summarized in Table 5.

Table 5: Manure Evaluations Conducted

	Manure Stream		
	Dairy	**Swine #1**	**Swine #2**
No chemical	X	X	X
Polymer only	X	X	X
Polymer and coagulant	X		X

Swine #1 and Swine #2 samples were separate manure samples collected from the same deep pit configuration as described above.

Objectives

This pilot had 3 specific objectives:

1. Demonstrate the ability to successfully dewater 2 different manure streams: Dairy and Swine;
2. Demonstrate the ability to achieve a significant phosphorus reduction in the resulting filtrate from each manure sample dewatered, and
3. Develop performance/cost ratios to determine optimum polymer/coagulant usage

Results

Laboratory Analytical Methods

All analytical testing conducted were completed at Brookside Labs. A summary of the specific test methods run is summarized in Appendix B.

Test results

Tables 6-8 summarize analytical results for the 3 manure streams evaluated. Also shown in Figure 4 are representative images of dairy and swine manure.

Table 6: Dairy Manure Results

Raw Dairy		
Moisture	95.74	%
Total N	16.7	lb/1000 gal
Ammonia N	11.87	lb/1000 gal
Organic N	4.83	lb/1000 gal
P	1.78	lb/1000 gal
P2O5	4.07	lb/1000 gal
K	12.54	lb/1000 gal
K2O	15.09	lb/1000 gal
Ortho P	122	ppm

Dairy Effluent #1 (no polymer)			% Removal	Dairy Effluent #2 (polymer)			% Removal	Dairy Effluent #3 (polymer + coagulent)			% Removal
Moisture	96.67	%	21.83%	Moisture	97.15	%	33.10%	Moisture	98.35	%	61.27%
Total N	15.26	lb/1000 gal	8.62%	Total N	13.45	lb/1000 gal	19.46%	Total N	10.79	lb/1000 gal	35.39%
Ammonia N	12.65	lb/1000 gal	-6.57%	Ammonia N	12.01	lb/1000 gal	-1.18%	Ammonia N	10.2	lb/1000 gal	14.07%
Organic N	2.61	lb/1000 gal	45.96%	Organic N	1.44	lb/1000 gal	70.19%	Organic N	0.59	lb/1000 gal	87.78%
P	1.6	lb/1000 gal	10.11%	P	1.35	lb/1000 gal	24.16%	P	0.51	lb/1000 gal	71.35%
P2O5	3.71	lb/1000 gal	8.85%	P2O5	3.13	lb/1000 gal	23.10%	P2O5	1.18	lb/1000 gal	71.01%
K	11.89	lb/1000 gal	5.18%	K	12.09	lb/1000 gal	3.59%	K	9.78	lb/1000 gal	22.01%
K2O	14.34	lb/1000 gal	4.97%	K2O	14.54	lb/1000 gal	3.64%	K2O	11.81	lb/1000 gal	21.74%
Ortho P	172	ppm	-40.98%	Ortho P	126	ppm	-3.28%	Ortho P	48	ppm	60.66%

Dairy Solids #1 (no polymer)				Dairy Solids #2 (polymer)			% increase	Dairy Solids #3 (polymer + coagulent)			% Increase
Moisture	86.69	%		Moisture	84.64	%		Moisture	83.06	%	
Total N	4.84	lb/ton		Total N	7.8	lb/ton	61.16%	Total N	10.28	lb/ton	112.40%
Ammonia N	2.6	lb/ton		Ammonia N	2.28	lb/ton	-12.31%	Ammonia N	2.32	lb/ton	-10.77%
Organic N	2.24	lb/ton		Organic N	5.52	lb/ton	146.43%	Organic N	7.96	lb/ton	255.36%
P	0.48	lb/ton		P	1.22	lb/ton	154.17%	P	1.62	lb/ton	237.50%
P2O5	1.1	lb/ton		P2O5	2.82	lb/ton	156.36%	P2O5	3.72	lb/ton	238.18%
K	3.04	lb/ton		K	3.68	lb/ton	21.05%	K	3.46	lb/ton	13.82%
K2O	3.64	lb/ton		K2O	4.46	lb/ton	22.53%	K2O	4.16	lb/ton	14.29%

Table 7: Swine 1 Manure Results

Raw Swine			Swine Effluent #1 (no polymer)			% Removal	Swine Effluent #2 (polymer)			% Removal
Moisture	95.22	%	Moisture	95.86	%	13.39%	Moisture	98.06	%	59.41%
Total N	41.61	lb/1000 gal	Total N	39.6	lb/1000 gal	4.83%	Total N	33.8	lb/1000 gal	18.77%
Ammonia N	40.09	lb/1000 gal	Ammonia N	37.67	lb/1000 gal	6.04%	Ammonia N	31.78	lb/1000 gal	20.73%
Organic N	1.52	lb/1000 gal	Organic N	1.93	lb/1000 gal	-26.97%	Organic N	2.02	lb/1000 gal	-32.89%
P	7.09	lb/1000 gal	P	4.87	lb/1000 gal	31.31%	P	0.92	lb/1000 gal	87.02%
P2O5	16.21	lb/1000 gal	P2O5	11.16	lb/1000 gal	31.15%	P2O5	2.1	lb/1000 gal	87.05%
K	21.94	lb/1000 gal	K	20.72	lb/1000 gal	5.56%	K	18.67	lb/1000 gal	14.90%
K2O	26.42	lb/1000 gal	K2O	25	lb/1000 gal	5.37%	K2O	22.45	lb/1000 gal	15.03%
Ortho P	467	ppm	Ortho P	133	ppm	71.52%	Ortho P	69	ppm	85.22%
			Swine Solids #1 (no polymer)			% increase	Swine Solids #2 (polymer)			% increase
			Moisture	81.18	%		Moisture	79.53	%	
			Total N	12.98	lb/ton		Total N	20.34	lb/ton	56.70%
			Ammonia N	8.42	lb/ton		Ammonia N	8.66	lb/ton	2.85%
			Organic N	4.56	lb/ton		Organic N	11.68	lb/ton	156.14%
			P	2.94	lb/ton		P	9.42	lb/ton	220.41%
			P2O5	6.74	lb/ton		P2O5	21.58	lb/ton	220.18%
			K	5	lb/ton		K	5.2	lb/ton	4.00%
			K2O	6.02	lb/ton		K2O	6.26	lb/ton	3.99%

Table 8: Swine 2 Manure Results

Raw Swine			Swine Effluent #1 (no polymer)			% Removal	Swine Effluent #2 (polymer)			% Removal	Swine Effluent #3 (polymer+coagulent)			% Removal
Moisture	95.22	%	Moisture	95.64	%	8.79%	Moisture	98.51	%	68.83%	Moisture	98.12	%	56.88%
Total N	41.61	lb/1000 gal	Total N	42.02	lb/1000 gal	-0.99%	Total N	29.65	lb/1000 gal	28.74%	Total N	28.47	lb/1000 gal	31.58%
Ammonia N	40.09	lb/1000 gal	Ammonia N	39.48	lb/1000 gal	1.52%	Ammonia N	27.2	lb/1000 gal	32.15%	Ammonia N	26.04	lb/1000 gal	35.05%
Organic N	1.52	lb/1000 gal	Organic N	2.53	lb/1000 gal	-66.45%	Organic N	2.46	lb/1000 gal	-61.84%	Organic N	2.43	lb/1000 gal	-59.87%
P	7.09	lb/1000 gal	P	8.94	lb/1000 gal	-26.09%	P	1.19	lb/1000 gal	83.22%	P	2.01	lb/1000 gal	71.65%
P2O5	16.21	lb/1000 gal	P2O5	20.5	lb/1000 gal	-26.47%	P2O5	2.71	lb/1000 gal	83.28%	P2O5	4.6	lb/1000 gal	71.62%
K	21.94	lb/1000 gal	K	20.67	lb/1000 gal	5.79%	K	19.06	lb/1000 gal	13.13%	K	18.75	lb/1000 gal	14.54%
K2O	26.42	lb/1000 gal	K2O	24.89	lb/1000 gal	5.79%	K2O	22.96	lb/1000 gal	13.10%	K2O	22.61	lb/1000 gal	14.42%
Ortho P	467	ppm	Ortho P	7.2	ppm	98.46%	Ortho P	30.2	ppm	93.53%	Ortho P	21.65	ppm	95.36%

Swine Solids #3 (polymer+coagulent)			% increase*
Moisture	82.39	%	
Total N	23.5	lb/ton	81.05%
Ammonia N	7.34	lb/ton	-12.83%
Organic N	16.16	lb/ton	254.39%
P	8.62	lb/ton	193.20%
P2O5	19.76	lb/ton	193.18%
K	4.82	lb/ton	-3.60%
K2O	5.82	lb/ton	-3.32%

* Increase relative to Swine 1 no polymer

Figure 4: Representative Photos

Dairy Manure, no polymer

Swine Manure 1 - with polymer

Moisture content

Figure 5 shows the data collected for the moisture content of both the filtrate and solids for each manure evaluated. As expected, solids capture rate increased and more water was squeezed from the solids as chemical treatment (polymer and polymer/coagulant) were used – meaning that more of the solids were captured and retained in the cake produced. This increase in solids content is shown in Figure 6.

Figure 5: Moisture content of filtrate samples

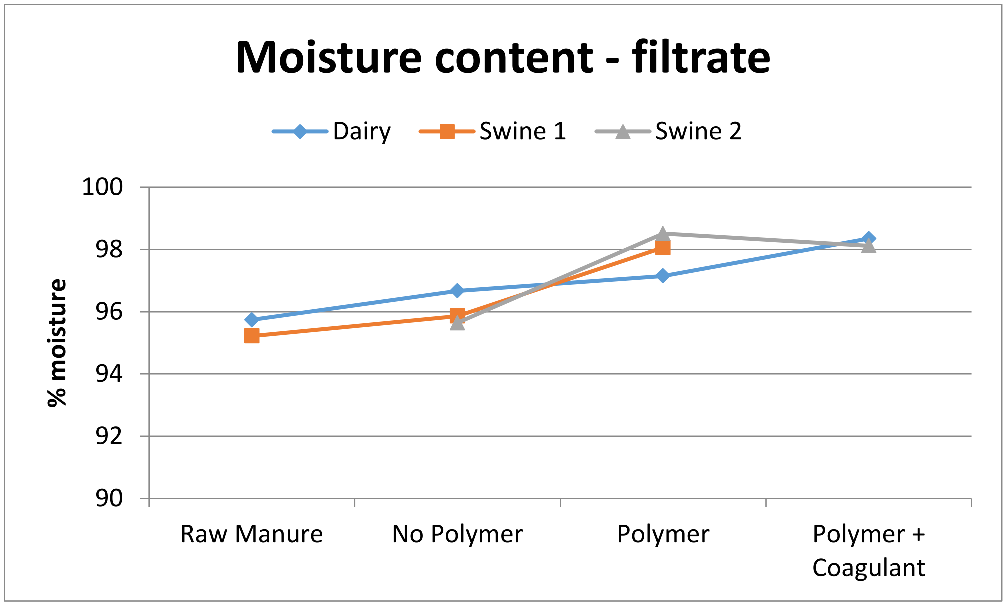
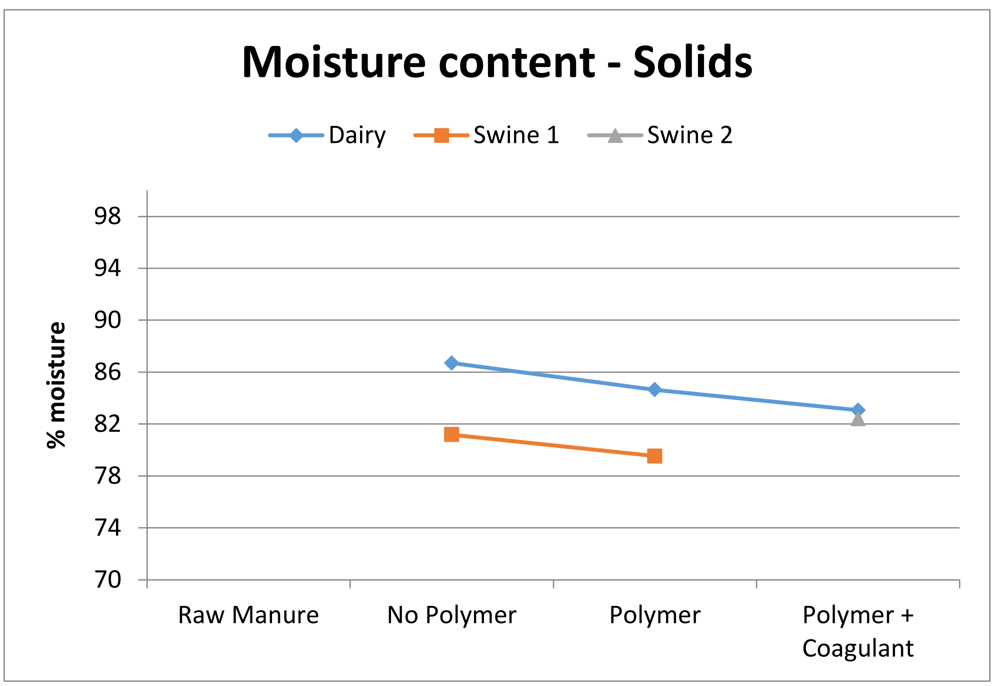


Figure 6: Moisture content of cake produced



Phosphorus impact

Figure 7 shows the reduction of phosphorus in filtrate of each sample as a function of chemical addition. While a reduction in phosphorus contained in the various filtrate streams decreased as a result of dewatering, the most significant impact was noticed when polymer and polymer plus coagulant dosing was incorporated.

Figure 7: Filtrate P reduction

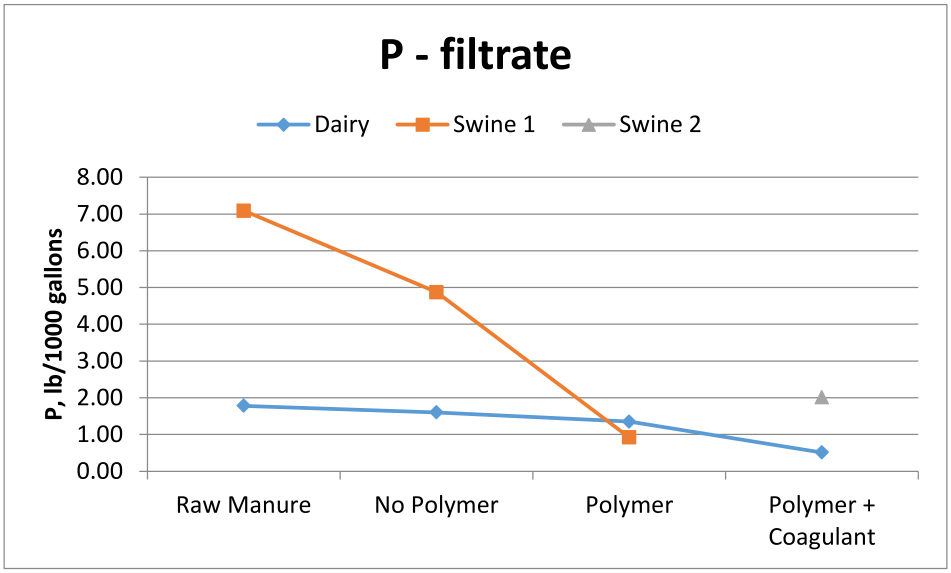
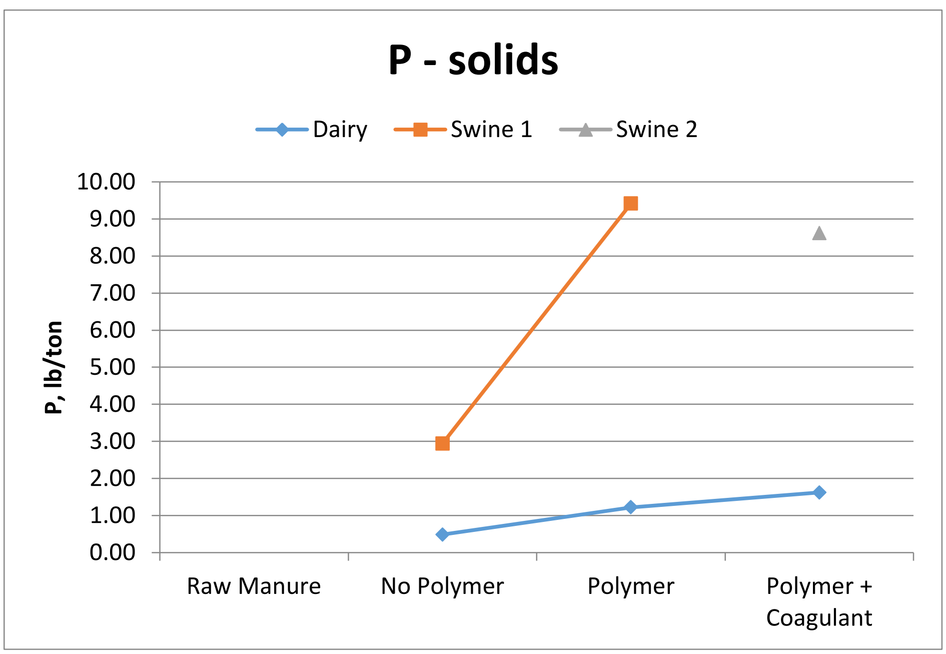


Figure 8 summarizes the phosphorus content in solids resulting from chemical addition.

Figure 8: Solids P increase



The preceding data summaries for P reduction are tabulated in Table 9 (Filtrate Streams) and Table 10 (Solids produced).

Table 9: P reduction as function of chemical usage - Filtrate

Manure Stream	Percent reduction from raw manure		
	No polymer	Polymer	Polymer + coagulant
Dairy	10.11	24.16	71.35
Swine 1	31.31	87.02	
Swine 2	-26.09	83.22	71.65

Note: Swine 2 comparisons made to raw Swine 1. No raw Swine 2 evaluated

Table 10: P increase as function of chemical usage - Solids

Manure Stream	Percent increase from no polymer baseline		
	No polymer	Polymer	Polymer + coagulant
Dairy	Baseline	154.17	237.50
Swine 1	Baseline	220.41	
Swine 2			193.20

These data support that some minimal reduction in phosphorus in dewatered filtrate is achievable. A significantly greater reduction in filtrate phosphorus can occur with the use of a polymer and polymer + coagulant. The pilot did not evaluate the effectiveness of a coagulant only, nor did it evaluate optimum dosing levels or optimization of polymer type as a function of the manure stream.

These data further support that when dewatered with chemical usage, a significant increase in the phosphorus content of dewatered cake results – as would be expected.

Liming Jar Testing

One potential option to further reduce filtrate phosphorus levels without the use of chemical additions is to treat the filtrate resulting from no polymer dewatering with the Quick Wash process from Renewable Nutrients. The Quick Wash process involves a 2 step process as summarized below:

Step 1 Solubilization: In this step, phosphorus contained in the stream to be treated is solubilized by lowering pH. This results in the water soluble phosphorus (orthophosphate) moving from the solids to the liquid stream. The degree of solubilization has ranged from 50-95% in bench testing at USDA depending on the particular stream and pH achieved. Following solubilization, the remaining solids contain very low total phosphorus (TP) and have the potential to be land-applied given the lower phosphorus.

Step 2 Precipitation: In this step, the water soluble orthophosphate is precipitated through the addition of lime, producing a calcium phosphate material. The resulting liquid now contains a negligible amount of phosphorus, and the calcium phosphate produced represents a usable secondary product with commercial value.

A series of jar tests were conducted using the filtrate stream produced from the Swine 1 no polymer test to visually assess the potential to precipitate out the soluble phosphorus through the addition of lime. Appendix D summarizes the test method used, and the photos in Figure 9 show that a noticeable precipitate was formed as a function of the amount of lime added. Due to the relatively low volume of supernate present, no analytical tests were conducted on these to determine the impact on phosphorus reduction, but the visual results do warrant further consideration.

Figure 9: Lime jar testing visual results as a function of lime addition

Initial Operating Cost Estimates

The KDS Separation Technology offers several advantages over conventional dewatering options – most importantly very low energy consumption and low maintenance costs. A thorough cost analysis is in progress considering a 10 year present worth total cost of ownership, to include capital, maintenance and consumable costs. Based on the performance observed, it would be estimated that operating costs would consist of 2 primary components: power and polymer costs. Power consumption on a per gallon basis is estimated at \$0.00003/gallon treated, with chemical costs estimated at \$0.010 - \$0.015/gallon treated at the rates dosed during the pilot. It should be noted that further optimization is possible to minimize both chemical costs and type. It is believed that total operating costs could be ~\$0.0075 per gallon treated once optimized.

Conclusions

1. The KDS Separator was able to successfully dewater both dairy and swine manure. Performance with polymer and polymer + coagulant dosing increased solids capture rate and provided exceptional reduction of phosphorus in the resulting filtrate of approximately 75-80%.
2. The operating costs associated with use of the KDS Separator are estimated to be close to $0.0075/gallon if optimized chemical dosing is employed. Other means of reducing filtrate phosphorus levels (such as use of lime) were not evaluated, but could offer a considerably cheaper alternative than use of polymers and coagulants.
3. The KDS Separator offers a simple, easy to operate and lower cost option for the dewatering of manure streams than conventional dewatering technologies.

Recommended next steps

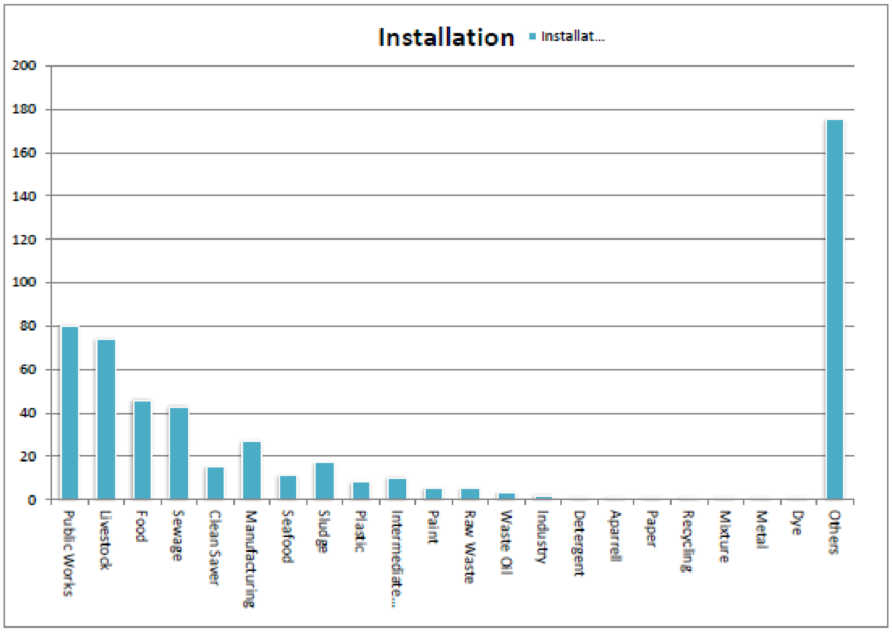
The following next steps are recommended based on the results of this pilot:

1. A detailed cost analysis be completed to identify a 10 year present worth analysis on a per gallon treated basis. This analysis to include estimated capital and maintenance costs.
2. This was a short-term evaluation under adverse (below freezing) conditions. Further optimization of polymer dosage and development of the liming option for treatment of the filtrate stream should be considered.
3. Efforts should be directed towards identifying a couple of installations where longer-term performance can be demonstrated.

Appendix A: KDS Installed Base

Updated 2016-08-25

Application	Installation
Public Works	80
Livestock	74
Food	46
Sewage	43
Clean Saver	15
Manufacturing	27
Seafood	11
Sludge	17
Plastic	8
Intermediate Treatment	10
Paint	5
Raw Waste	5
Waste Oil	3
Industry	2
Detergent	1
Aparrell	1
Paper	1
Recycling	1
Mixture	1
Metal	1
Dye	1
Others	175
Total	**528**



Livestock /Manure Related Applications

Installation Year	Area	Application	Model	Capacity
2005	Kagoshima	Livestock Manure	SS-26	
2006	Shimane	Dairy Cattle Manure	CSS-38-2T	1.5㎥/h
	Shimane	Dairy Cattle Manure	CSS-38D	1.5㎥/h
	Kagoshima	Livestock Manure	CSS-515-3T	
2007	Tottori	Milking Parlor Wastewater	SS-26	1㎥/h
2009	Tottori	Livestock Manure	SS300-0810D	
2011		Bird Manure	SS-26	16kg-DS/h
	Kumamoto	Livestock Manure	SS-511D	1.4m3/h (WAS) + 1.0m3/h (Raw Urine) = 2.4m3/h
	Aichi	Livestock Feed Related	SS-311D	20kg-DS/h
	Aichi	Livestock Feed Related	SS-26	16kg-DS/h
2012	Fukuoka	Rabbit Manure	SS-311D	1.5～2m3/h
	Ibaraki	Pig Manure	SS-311D	20kg-DS/h
	Tochigi	Livestock Manure	SS-311D	20kg-DS/h
	Aomori	Pig Manure	SS-311D	20kg-DS/h
	Shimane	Livestock Manure	SS-311D	20kg-DS/h
	Shimane	Pig Manure	SS-612	100kg-DS/h
	Shimane	Pig Manure	SS-711D	3㎥/h
	Iwate	Pig Manure	SS-311D	20kg-DS/h
2013	Shimane	Pig Manure	SS-618D	3㎥/h
	Kagawa	Livestock Manure	SS-311D	20～30kg-DS/h
	Iwate	Pig Manure	SS-611D	40～60kg-DS/h
	Iwate	Pig Manure	SS-611D	40～60kg-DS/h
	Kagawa	Cattle Manure	SS-311D	20～30kg-DS/h
	Tochigi	Cattle Manure	SS-311D	20～30kg-DS/h
2014	Shimane	Pig Manure	SS-618D	3㎥/h
	Aichi	Pig Manure	SS-611D	49kg-DS/h
	Saudi Arabia	Lamb Slaughterhouse Wastewater	SS-612	3㎥/h

Appendix B: Analytical Methods – Manure Analysis

Moisture/Dry Matter	110 degrees Celsius for 16 hours Method 2.0 from "Recommended Methods of Manure Analysis" Method 2.2
Total Nitrogen	Combustion by Elementar Vario Max CN Method 3.3 from "Recommended Methods of Manure Analysis" and TMECC method 4.02 (adapted from AOAC 990.03)
Ammonium-N	KCL Extraction determined on FIA Lab flow injection autoanalyzer. Method 4.3 from "Recommended Methods of Manure Analysis" (Adapted from USEPA 350.1)
Mineral Digestion	Nitric acid digestion inCEM Mars Microwave system. Method 5.3 from "Recommended Methods of Manure Analysis" and TMECC 4.12 (Adapted from EPA 3051)
Mineral Determination	The digested samples are analyzed on Thermal 6500 Dou ICP. Method 6.3 from "Recommended Methods of Manure Analysis" and TMECC 4.14
Water Extractable P	100:1 solution:solids ratio, sample is shaken for one hour at 150 rpm. Sample is then filtered and analyzed on ICP (Reference Wolf, Ann, Peter Kleinman, Andrew Sharpley et.al. Soil Sci.Soc.Am.J 66:2009-2015
Organic Matter/Ash	Samples muffled in an ashing oven at 550 degrees Celsius for 2 hours. Method 5.07 from the TMECC (EPA method 160.4)

Appendix C: Jar Testing Procedure

Lime Jar Testing Procedure

Document Number A010.20180314.01.002

Equipment

- Sample jar: 16oz jar (0.4732L)
- Coffee measuring cup: 1 tablespoon (0.0147ml) – Figure 1
- Hi-Cal lime: 30lb/ft^3 – Figure 2
- Mixing container: Black and Decker juicer – Figure 3
- Filtrate: Dewatered swine manure filtrate
- Beaker to collect filtrate

Procedure

1. As swine manure is being dewatered, collect filtrate and wash out mixing container.
2. Collect filtrate sample and fill sample jar to approximately 16 ounce capacity. Collect one sample with no lime addition for comparison.
3. Pour sample jar material into mixer.
4. Add desired amount of lime.
5. Mix sample for approximately 5 seconds on high setting. To ensure sample is evenly mixed, gently rotate mixer off-axis while mixing.
6. Pour out sample after mixing into sample jar. Before completely emptying the mixer ensure that no residual lime remains in the mixer by re-adding approximately 25% of the volume back into the mixer and sloshing it around to capture any settled material.
7. Once sample container is filled, secure lid and note number of tablespoons added onto the label (Figure 4).
8. Mix clean filtrate into the mixing container to ensure no residual material is present.
9. Allow samples to sit undisturbed with lid off to allow material to settle. Note the presence of clear liquid after 10 minutes, 12 hours and 24 hours (Figure 5).

Calculated concentration of lime addition

Table 1 summarizes the estimated lime concentration for samples tested on March 14, 2018.

Table 1: Lime concentration calculations

Filtrate, jar	Tablespoons	ml lime	mg lime	Vol filtrate, L	Conc, mg/L
1	2	0.0294	14.13	0.4732	29.9
1	3	0.0441	21.19	0.4732	44.8
1	4	0.0588	28.26	0.4732	59.7
1	5	0.0735	35.32	0.4732	74.6
1	6	0.0882	42.38	0.4732	89.6
1	8	0.1176	56.51	0.4732	119.4
1	10	0.1470	70.64	0.4732	149.3

Appendix C: Figures

Appendix D

Opportunities for Improvement

Throughout any pilot, opportunities for improvement are usually identified that could aid future pilots in being more efficiently run. The following summarizes an initial list for consideration in future efforts.

Opportunity	Background
Shipping coordination	Better communications and coordination with the firm delivering and picking up the pilot unit should be made to ensure adequate equipment is available for loading and unloading a crated pilot unit.
Critical spare parts available	Several problems were encountered with the air actuator system and resulted in the actuator only being used for a short period due to spare parts needed. This was aggravated by the below freezing temperatures making the ability to work with equipment more difficult.
Pilot unit tank cleanout	While there were drain plugs in the KDS unit, a coned or sloped tank bottom would have facilitated clean out after the pilot.
Chemical dosing	The actual dosing of chemicals was somewhat approximated by field conditions. A more precise estimate of the delivery flow would also be desired. Further, due to low temperatures, some of the chemical dosing lines froze throughout the night making startup very time consuming.
Control sensitivity	All controls on the KDS pilot skid have variable speed capability but no calibration to delivery flows (for incoming manure to be dewatered or chemical dosing) was developed or available.
Check list	While simple to operate, a check list of startup and shutdown items would be helpful.
Pilot skid	While the pilot skid is generally well laid out, its ability to move from site to site for short term evaluations is not very convenient since the unit is crated and must be enclosed in order to move. This results in higher deployment costs due to shipping expenses.

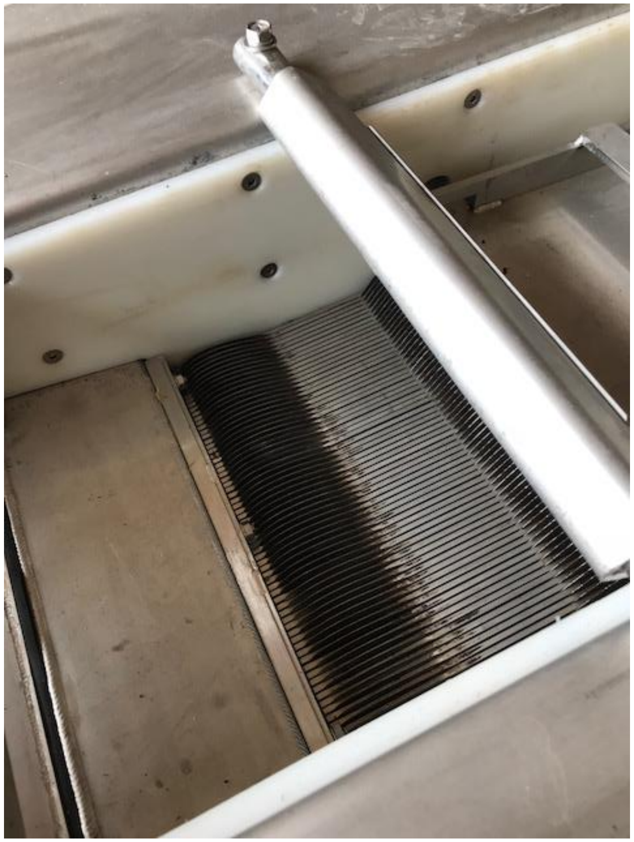
Appendix E: Pilot Photos

Pilot unit as received

Discharge chute

Loading plate with pneumatic actuator

Appendix F (continued)



Separator Plates

Variable Speed Controllers

Swine manure deep pit agitation