NEWTRIENT

MARKETPLACE REPORT:

Survey of Products, Markets and Opportunities for Phosphorus Derived from Dairy Manure

MARCH 2018

EXECUTIVE SUMMARY

OVERVIEW

Newtrient was awarded a Vermont Clean Water Fund Grant and initiated work in May of 2017. The grant was divided into three distinct elements and this report focuses on two subcategories of Element 2 (Identification of Recovered P Products/Markets):

1. **Conduct survey of phosphorus-cake (P-cake) recovery products that are currently in the marketplace. Identify market opportunities as well as price sensitivities.**

2. **Identify relevant properties of P-cake in order to better define market opportunities that include product specifics and what manipulations would be needed to create various products for potential market uses.**

Through a comprehensive review of the current marketplace opportunities and gaps, Newtrient has demonstrated that commercial prospects for P-cake hold promise but our analysis suggests they are largely "emerging markets" with few success stories and even less hard data. There is one large-scale, dairy manure-based fertilizer production facility located in NW Indiana (Midwestern BioAg's subsidiary, Terra NU); however, little is known about the proprietary economics and the products are marketed as traditional fertilizer. There is an appealing, higher value organic fertilizer market that incorporates animal manure (primarily poultry litter); however, the market size is limited and will likely be a niche market for dairy.

RELEVANT PROPERTIES OF P-CAKE

As shown in Newtrient's Technology Catalog, new and innovative nutrient recovery technologies are permeating the dairy space. Several of these technologies focus on removing the phosphorus and organic nitrogen nutrients by partitioning the fine solids from the liquid fraction of the manure.

The quantity of phosphorus and organic nitrogen contained in the fine solids fraction of dairy manure is significant. Though the potential supply is substantial, dairy manure as excreted is approximately 90% water and the

resulting nutrient concentration is quite dilute. Historically, only the coarse fiber fraction of dairy manure was separated and the balance of the fine solids, where most of the nutrients reside, were managed with the liquid stream. Existing markets for the coarse fiber fraction are well known and include animal bedding, compost and a growing number of soil amendments and dairy-based soils. Several relatively new technologies being deployed on dairies target the fine solids fraction and produce a P-cake consisting of about 25% dry matter and 75% moisture content. Though this is a significant improvement over past technologies, this moisture level continues to make the P-cake difficult to store and transport and, in most cases, offers little product value without further processing.

MARKET GAPS AND OPPORTUNITIES

A dry product offers the potential to offset commercial fertilizer imports and opens the door to creating new fertilizer markets that could result in exporting phosphorus outside of the Lake Champlain Watershed. Beyond its implication to solving the challenge of storage/transportation, drying will achieve greater pathogen reduction and augment product use and marketability. Product stability and odor will also be improved (though consideration for the impact on air quality must also be considered).

One treatment approach prominently discussed throughout this report is polymer flocculation followed by dissolved air flotation and dewatering because this technology has been successfully implemented on several US dairies in recent years. The use of polymer precludes the resulting product from being marketed as an organic fertilizer and could also present other marketing challenges due to the complications of polymer chemistry and nutrient bioavailability. A second manure treatment approach highlighted in this report uses centrifugation (a type of mechanical separation) and is also commonly used on dairy farms The products generated from centrifugation and other mechanical separation techniques will likely meet organic fertilizer standards (provided they are used independent of polymer flocculation).

Considering manure treatment as a financial, processing and economic continuum, there could be a series of potential opportunities depending on one's goals and market drivers. A dry manure product that could be used on-farm according to the 4Rs (right source, right rate, right time and right place) represents one end of the continuum while a packaged organic fertilizer product, though the market volume is limited, could represent the other end.

CONCLUSIONS AND OBSERVATIONS ABOUT FUTURE WORK

The P-cake market is an emerging market with very few success stories to date. Concentrating phosphorus and organic nitrogen into a P-cake creates new and exciting opportunities for shifting the manure management paradigm from a disposal mindset dictated by manure storage capacity to one where nutrients are placed where and when they are needed. Further, this opens the door to manure-based fertilizer products with the potential to off-set commercial phosphorus imports. However, there is clearly a need to further process the P-cake to create a dry product and, in some cases, a granulated or pelletized product to facilitate storage, transport and market creation.

The cost of producing a manure-derived fertilizer product will always outpace the cost of commercial fertilizer. Though the price differential is a real obstacle, in most cases, the farmer's primary driver for adopting technology focuses on other factors such as on-farm operational constraints associated with nutrients. There are numerous benefits associated with adopting nutrient recovery technology. The supporting business case, however, can be challenging. Core to Newtrient's mission is to help the dairy sector identify additional benefits that improve the business case to the farmer. Because dairy products do not consider the cost of production or such things as societal benefits that come from adopting nutrient recovery technology, we often find it necessary to incorporate additional financial mechanisms such as environmental service markets and the manufacturing and marketing of manure-based products such as fertilizer.

KEY TAKEAWAYS

1. A dairy P-cake market appears to be emerging but is currently in its infancy and lacks a clear, compelling, widespread business case.
2. P-cake derived from dairy manure has limited market value unless it can be further processed and dried (and in some cases granulated or pelletized).
3. Further research/analysis is required to identify the economics and processing costs of producing a marketable product. Newtrient's dryer pilot work is scheduled for summer of 2018 and will provide additional insight.
4. There is one large-scale, dairy manure-based business (Midwestern BioAg's subsidiary, TerraNU) producing a commercial-grade product for widespread distribution. It's marketed as a fertilizer product with enhanced soil building properties due to the organic carbon content and micronutrients contained in the manure. However, we do not have insight into the economic standing of this venture.
5. Certified organic fertilizers enjoy a significant price premium over conventional commercial fertilizers (approximately 2-3x) and could offer a niche opportunity for Vermont dairy operations; however, this market has volume limitations.
6. Multiple benefits are needed to create a viable path to the adoption of phosphorus control technologies for Vermont dairy farms. Development of a P-cake market offers one mechanism to help fill the benefits gap.

MARKETPLACE REPORT

BACKGROUND

In the recent past, dairy manure has been applied on farmland consistent with the agronomic requirements of growing crops. Due to a growing population and increased dairy demand, herd density has drastically risen over the last 40 years. This presents farmers with considerably more manure challenges: management, storage and environmental issues. Newtrient, a private company that was formed in 2015 by 12 leading dairy cooperatives (including Agri-Mark and DFA) as well as Dairy Management, Inc. and the National Milk Producers Federation, was created to address some of the most challenging environmental issues facing the industry with the overarching goal of reducing dairy's environmental footprint. The following provides a comprehensive look at phosphorus products derived from dairy manure to serve as a guide toexploring new market opportunities in this area.

Vermont was one of the first states where Newtrient placed resources and effort due to the water quality challenges in the Lake Champlain Basin coupled with the environmental impact of dairy. Newtrient's approach has been centered around the development of a market-based mechanism (as one tool) to drive water quality improvement in the Lake Champlain Basin called an Environmental Services Marketplace ("ESM"). The goal of the ESM is to enable low cost pollution prevention activities to offset higher cost regulatory and societal obligations through the creation of verifiable environmental credits.

There is a direct connection between the concept of an ESM and a market for the physical product (e.g. P-cake). Further, the environmental benefits associated with more efficiently managing nutrients extend to improved soil health and reduced greenhouse gas (GHG) production. For example, when a dairy farm adopts technology for phosphorus removal (by targeting fine solids from the manure stream), not only is phosphorus captured as a solid product that can be transported to remote fields or shipped outside of sensitive watersheds, but soil health is improved, further reducing soil and nutrient losses to surface water, while sequestering carbon through purposeful application of the solid product.

New technologies are being adopted on US dairy farms to separate and concentrate nutrients; however, higher value outlets for the captured nutrients are not well understood and markets are largely undeveloped.

INDUSTRY OUTLOOK

Dairy farm sustainable management emphasizes the capture and reuse of valuable constitutes found in the manure. Even when best practices and manure management plans are followed, unusual rain events can impact manure storage capacities and result in less than optimum conditions for land application.

Development of new and innovative methods for the separation and concentration of valuable nutrients creates new opportunities for producing cleaner water, improving soil health and reducing dairy's GHG footprint. Due to the structured pricing formula for milk products, farmers do not have the ability to raise prices to offset the cost of adopting new and innovative nutrient recovery technologies. Farm management benefits are generated through the adoption of technology and practices (e.g. reduced manure management costs or increased crop yield); however, the benefits are typically less than the cost of adoption, creating a "benefits gap".

On behalf of American's dairy farmers, Newtrient is working to close the "benefits gap" and reach triple-bottom line sustainability through a marketplace approach that rewards and incentivizes farmers. Sustainable agricultural production practices and technologies can create positive environmental results through the development of a market-based platform, resulting in improved water quality, healthy soils, controlled run-off and reduce water demand, all of which contribute to a cleaner environment.

CLEAN WATER GRANT DELIVERABLES

This document was created to address Element 2 of Newtrient's Clean Water Grant consisting of two major headings and outlined in our Grant Application per the following stated deliverables:

A. Conduct survey of phosphorus-cake (p-cake) recovery products that are currently in the marketplace. Identify market opportunities as well as price sensitivities.

B. Identify relevant properties of P-cake in order to better define market opportunities that include product specifics and what manipulations would be needed to create various products for potential market uses.

The above deliverables are outlined under four general headings:

1. Relevant Properties of P-cake to Better Inform Market Opportunities
2. P-cake Products in the Marketplace
3. Identification of Market Opportunities and Price Sensitivities
4. Conclusions and Observations about Future Work

SECTION 1:
Relevant Properties of P-cake to Better Inform Market Opportunities

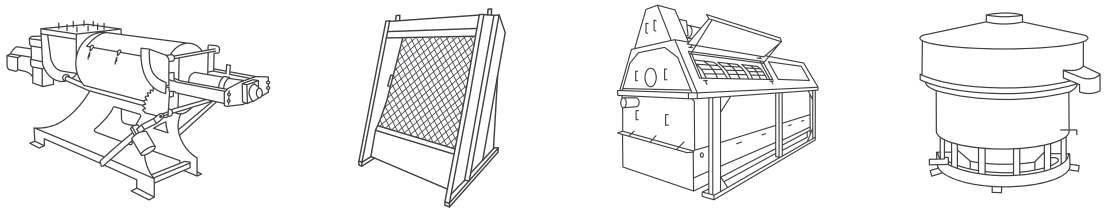
BACKGROUND

The term "P-cake" is often used by dairy operations to describe the resulting solid fraction, typically following coarse fiber separation, wherein fine solids are captured and dewatered to produce a stackable solid. The resulting P-cake contains a large fraction of the manure's initial phosphorus and organic nitrogen content. Throughout this document, P-cake is used interchangeably with dairy manure-based fertilizer. A dairy cow produces approximately 150 lb of liquid manure a day, comprised of about 130 lb of water and 20 lb of solids. Most dairy operations manage their manure as a semiliquid mixture, or slurry. Collectively, this slurry contains 1 lb of nitrogen, 0.2 lb of phosphorus and 0.2 lb of potassium.

Dairy manure solids fit under two basic categories:

Coarse Solids (or fiber) – Marketed under the category of "growing media" and represents most manure products in the marketplace. Growing media includes potting soils and soil amendments (compost).

The coarse solids, or fiber, are often separated from the fine solids and liquid fraction using various types of solid-liquid separation equipment such as screw presses, slope screens (only applicable to dilute manure streams as opposed to "as excreted") or rotary drums. Examples of course fiber separation technologies are schematically represented below in Figure 1. This process leaves most of the



Screw Press *Slope Screen* *Rotary Drum* *Vibratory Screen*

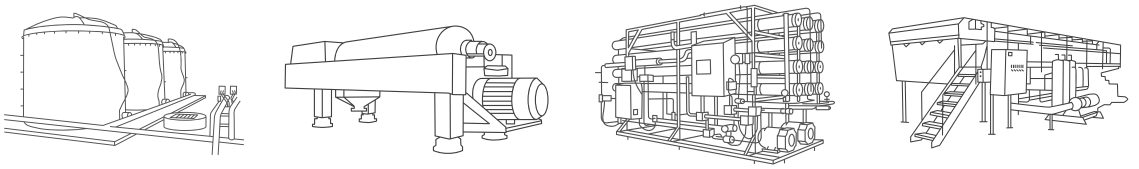
FIGURE 1: Course Solids Separation Technology

nutrients in the liquid and fine solids portion of the manure (N 65-95%; P, 70-95%, source: *Newtrient Literature Review and Practical Determination of the Relative Impacts of Selected Dairy Manure Treatment Methods on Critical Environmental and Operational Indicators,* pending publication). The market for coarse fiber is relatively well known within the dairy sector and includes reuse of the fiber for cow bedding, or with further processing, the production of soil amendment products.

Fine solids – represent a pathway to dairy manure-based fertilizer products. However, fine solids have traditionally been managed in the liquid form, stored in manure structures and land applied at agronomic rates. Historically, there has not been an incentive to target and capture these fine solids. As the dairy industry seeks to more effectively manage both water and nutrients, technology is being developed and adapted to more efficiently target and capture the nutrient fraction with an eye toward the creation of dairy manure-based fertilizer products.

P-CAKE PROCESSING AND VALUE

Typical P-cake production processes involve primary coarse fiber separation using traditional liquid solid separation technologies followed by advanced liquid solid separation processes such as polymer flocculation followed by dewatering or a mechanical separation technique such as centrifugation (with or without polymer flocculation). Unlike coarse fiber, markets for the captured fine solids are ill-defined. Examples of fine solids separation technologies are schematically represented below as Figure 2.



Polymer/Coagulant Treatment *Centrifugation* *Membrane Filtration* *Dissolved Air Flotation (DAF)*

FIGURE 2: Fine Solids Separation Technology

The nutrient composition of dairy manure depends on several factors including climate, ration, dairy management systems and operational philosophies; however, as a general benchmark, Table 1 below shows published values from American Society of Agricultural and Biological Engineers (ASABE) and Midwest Plan Services. The values are shown based on dry weight (DW) on a per cow basis.

Table 1 TYPICAL MANURE COMPOSITION AS COLLECTED

SOURCE	N (% DW)	P_2O_5 (% DW)	K_2O (% DW)
ASABE	5.0	2.0	1.4
Midwest Plan Services	5.0	2.6	2.9

The DW nutrient composition is calculated by dividing the nutrient mass by the total solids (TS) mass (as produced by the cow). The actual NPK composition for dairy derived products will vary depending on treatment methodology. For example, anaerobic digestion prior to nutrient separation will act to reduce the TS content of the manure stream (due to conversion of a fraction of TS to biogas) and this will be reflected in a higher nutrient concentration.

Despite a DW nutrient content that compares favorably to poultry litter-based fertilizer products in the marketplace, the biggest hurdle facing the creation of a viable dairy manure-based fertilizer product is one of moisture content. Dairy manure as excreted is 90%+ water and after fine solid separation and dewatering, is typically in the range of 25% dry matter (DM) and 75% moisture content. There are several examples of technologies being deployed by dairy farms to partition phosphorus and organic nitrogen as a high phosphorus cake like material (P-cake) with a DM content in the range of 25%. Though a huge improvement over raw manure, storage and logistical challenges remain that limit the ability to create durable off-take markets and largely restrict P-cake use to seasonal opportunities within a limited radius of the production facility.

SECTION 2:
P-cake Products in the Marketplace

COARSE SOLIDS – DAIRY MANURE-BASED GROWING MEDIA PRODUCTS

Dairy manure derived products in the marketplace are primarily soil amendment products built from the coarse solid fraction of manure. Examples include Magic Dirt (a line of bagged, retail soil products created from DVO digested solids), Vermont Natural Ag Product's Moo Doo® or Jolly Gardener Dehydrated Cow Manure. Though the market value of these products is quite high on a per ton basis, it is important to note that these products are very low in fertilizer content (why they are called soil amendments and not fertilizer) and the overall market size is modest at 1.6MM Tons or $180MM in packaged soil amendment sales. Over 85% of this market is sourced from compost (leaves, bark, grass clippings, etc.), peat or perlite (Fredonia Report). As a measure of the limits of retail package goods as an outlet for dairy manure solids, consider that the entire line of Magic Dirt products is sourced from only ten dairies.

Sampling of Dairy Manure-Based Growing Media Products (derived from the coarse fiber)

- Magic Dirt: Created from DVO digestate solids
  https://www.walmart.com/ip/Magic-Dirt-2-Cubic-Foot-Soil/139445557
- Moo Doo 0.5-0.3-0.5: Composted Cow Manure
  http://www.vermontnaturalagproducts.com/products/moo/moo-doo/
- Jolly Gardner Dehydrated Cow Manure 0.5-0.5-0.5
  https://www.hardwarestore.com/275552/jolly-gardener-products-composted-cow-manure-40lb-50055025#

FINE SOLIDS – DAIRY MANURE-BASED FERTILIZER PRODUCTS

Most of the commercially available animal manure-based fertilizer products are poultry litter derived with the notable exception of Midwestern BioAg's subsidiary TerraNU (described in detail following pages). Poultry litter is appealing as a fertilizer because it is generally collected in a much dryer form than dairy manure

and is easily manipulated via value-add processing such as composting and/or augmentation with other nutrients to achieve a desired product specification. When considered on a dry basis (excluding water), dairy manure has a similar nutrient composition as poultry litter. Unlike poultry litter, however, accessing the nutrients in dairy manure necessitates the application of advanced solids separation techniques such as centrifugation or polymer flocculation followed by dewatering to target the fine solids. Following dewatering, captured dairy manure fine solids are still in the range of 70-80% moisture with a density of about 1200 lb/cubic yard, thus creating logistical challenges for deploying as a resource without further processing (such as drying).

Below are three examples of poultry-based fertilizers in the market place (the Perdue MicroStart 60 product recently left the market but provides some insight into the value of this product (discussed later in Section 3, Identification of Market Opportunities and Price Sensitivities).

- Perdue MicroStart 60: Organic Chicken Manure
  http://ws680.nist.gov/bees/ProductListFiles/Perdue%20MicroStart%2060%20Fertilizer.pdf
- Pro-Gro 5-3-4: Organic Fertilizer
  http://norganics.com/index-12/index-11/fertilizers/progro/
- Sup'r Green 3-2-2: Organic Chicken Manure
  https://www.groworganic.com/sup-r-green-chicken-manure-partially-composted-25-lb.html?

CURRENT MARKETPLACE EXAMPLES

MidWestern BioAg's subsidiary TerraNU is the best available commercial example of using dairy manure as the base ingredient for production of a fertilizer product. Prairies Edge Dairy, a leading innovator in the dairy world, uses vacuum tankers to collect and deliver sand-laden dairy manure from their 14,500 sand bedded cows to a central treatment facility. A McLanahan sand separation system recycles the sand for cow bedding followed by a DVO digester for volatile solids conversion to biogas. The coarse fiber in the digestate is then removed using Vincent

Corporation screw presses. Finally, a Trident Nutrient Recovery System (polymer flocculation, dissolved air flotation and dewatering) is used to target the fine solids in the manure and produce a P-cake with a dry matter content of approximately 25%. The TerraNU facility, located adjacent to the Prairies Edge Dairy, purchases the P-cake from the dairy, blends in other ingredients and produces a dry, pelletized commercial-grade fertilizer. Figures 3 and 4 illustrate a basic process flow from manure production to fertilizer product and show a photo of the final pelletized product.

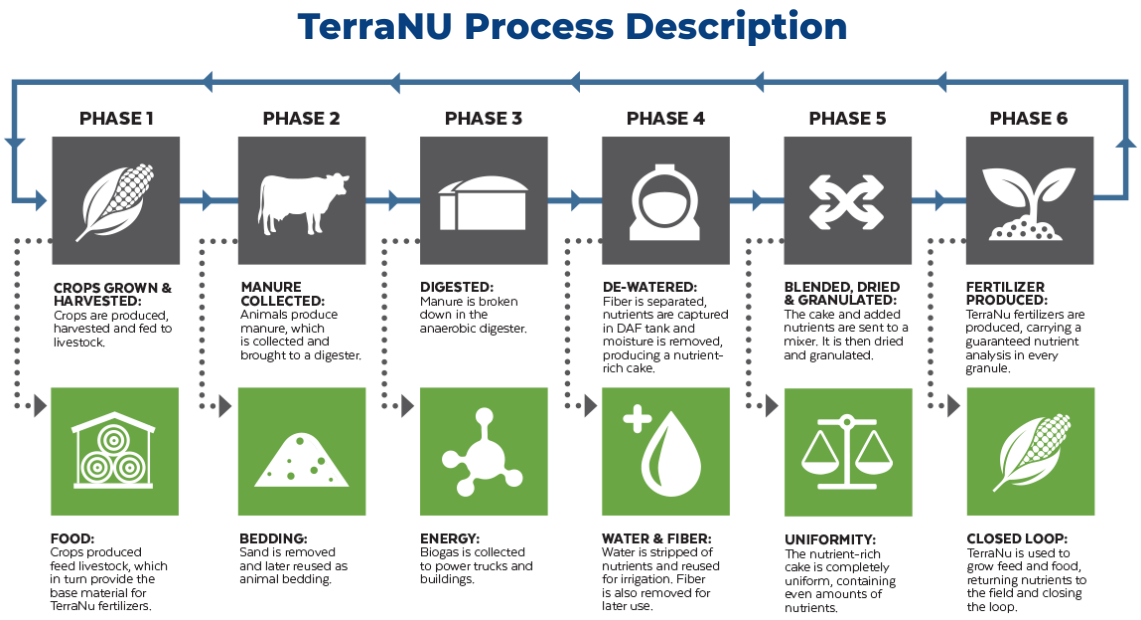


FIGURE 3: TerraNU Process Description **Source:** www.midwesternbioag.com/terranu/

FIGURE 4: View of Pelletized Manure-Based Product produced by TerraNU

The TerraNU operation has access to the P-cake from a single dairy with 14,500 cows and offers an economy of scale not readily duplicated. The plant economics are proprietary, but the plant is part of a commercial business and therefore believed to be cost effective and replicable. Though Vermont does not offer single dairies of this scale, with aggregation of manure from multiple farms, a regional plant based on this design may be suited for Addison or Franklin counties where there exists sufficient density of dairy farms to potentially support this type of centralized fertilizer production facility.

The product produced from the TerraNU process does not (currently) meet the standards to be considered an organic fertilizer product. This is presumably driven by the fact that the polymers used in the process are not considered organic. An organic fertilizer product commands a significantly greater value in the marketplace as compared to a non-organic product and is further discussed in Section 3.

SECTION 3:
Identification of P-cake Market Opportunities and Price Sensitivities

BACKGROUND

There are several technology options available to the dairy sector for partitioning the fine solid fraction of liquid manure into a stackable product or P-cake. In general, available technologies use some variation of polymer flocculation followed by one or more dewatering steps or mechanical separation such as centrifugation or a combination of polymer flocculation and mechanical separation. Newtrient is also aware of an evaporative technology being designed to produce a dry product (88%+ TS). This technology is currently in the development phase with the first full-scale installation scheduled for late 2018. Newtrient remains close to the development of this technology and will be monitoring the results of this initial full-scale installation.

EXAMPLES: APPLICATION OF DAIRY-SCALE TECHNOLOGY AND CURRENT EXPERIENCES TO DATE

Example #1:

In Vermont, Machia & Sons Dairy, located in Sheldon, VT is one of the larger dairy operations in the state with a milk cow herd of 725 cows. Machia & Sons, in collaboration with Native Energy, installed a centrifuge system (without polymer addition) to capture fine solids following coarse fiber separation in 2016. A screw press is used to remove the coarse fiber which is used for cow bedding.

Outside of Vermont, polymer flocculation followed by mechanical dewatering has proven to be a reasonable method of processing manure into a product of potential value. As discussed above in Section 2, this was done at Prairie's Edge Dairy in Indiana. Another system using this approach is Edaleen Dairy in Lyndon, WA. Newtrient recently completed a case study for this dairy and details pertaining to the system equipment, configuration, analytical results, operating costs and capital cost structures and the dairy's experiences with its P-cake are presented on the following page.

Example #2:

Edaleen Dairy is located west of the Cascade Mountains in western Washington in the community of Lynden. Edaleen Dairy has one of the more advanced manure management systems in the country. The collected dairy manure is first processed through a DVO mesophilic mixed plug-flow anaerobic digester. The digester effluent is then passed over a GEA slope screen producing a high quality fibrous product used for bedding and sold off-farm as a soil amendment ingredient (into a commercial retail-packaged product). The liquid effluent from the screen is sent to a DVO phosphorus recovery system (polymer flocculation, dissolved air flotation and dewatering). The system was installed in phases beginning in 2012 and the DVO phosphorus recovery system was added in 2017 with the goal of partitioning suspended solids and associated phosphorus and nitrogen into a stackable solid (this project was led by Craig Frear, a member of our Newtrient Technical Team and the Case Study is presented as Attachment 1).

System monitoring was performed by Washington State University and early results are presented in Table 2 showing system solids and nutrient partitioning performance. Preliminary data indicated nearly 90% phosphorus partitioning with the solids.

Table 2 SOLIDS AND NUTRIENT PARTITIONING PERFORMANCE

	TS (%)	VS (% OF TS)	TSS (G/L)	N (G/L)	P (MG/L)	K (G/L)	FLOW RATE (GPM)
Post AD/Sep Liquid **DVO FSS Effluent**	2.82 ± 0.29 1.17 ± 0.26	71.3 ± 2.7 59.5 ± 8.8	20.98 ± 3.4 1.85 ± 0.32	1.98 ± 0.21 1.30 ± 0.25	270 ± 19 36 ± 6	1.51 ± 0.12 1.41 ± 0.09	46.13 41.75
Reduction by Conc. (%)	58.5	16.6	91.2	34.3	86.7	6.6	9.5
Reduction by Mass (%)	62.5	16.6	92.0	40.6	87.96	15.5	

Table 3 outlines the solids characteristics and illustrates a total solids (TS) concentration of approximately 24% dry matter and highlights a major challenge with this type of technology as a stand-alone proposition – excellent phosphorus removal capability; however, conventional dewatering technology (e.g. moving disc press) still produces a product that is about 75% water. The logistics of storing and transporting this wet, heavy material, though significantly improved over raw manure, still present a host of challenges.

Table 3 DAF SOLIDS CHARACTERISTICS AND PARAMETERS

	TS (%)	VS (% OF TS)	EC (MMHOS/CM)	N (% DW)	P2O5 (% DW)	K2O (% DW)	FLOW RATE (YD^3/DAY)
DVO FSS Solids	24.4 ± 4.1	79.9 ± 2.9	2.31 ± 0.48	4.5 ± 1.1	3.8 ± 0.8	0.9 ± 0.2	40 ± 7
	C: 39.3 ± 5.1 Ca: 4.1 ± 0.6 Mg: 1.2 ± 0.1 Fe: 0.2 ± 0.04 S: 0.7 ± 0.1 % DW						
	Mo: 0.95 Ni: 0.77 Se: 0.30 As: 0.09 Cd: 0.04 Cr: 0.76 Co: 0.62 Cu: 25.6 Pb: 0.12 Hg: 0.01 Zn: 83.7 ppm						

Table 4 provides insight as it relates to the capital and operating costs associated with the adoption of a chemical treatment system with dissolved air flotation and dewatering for targeting fine solids removal.

Table 4 ECONOMIC SUMMARY

DVO FSS Capital Installed	$607,465	$21.20 per 1,000 gallons throughput	$339 per cow	
DVO FSS O&M	80-140 ppm polymer dosing	40 kWh/h electrical	40 minutes/day labor	3% capital parts
	$89,866-122,189 per year	$3.10-4.30 per 1,000 gallons throughput	$50-68 per cow per year	
DVO FSS Solids	103 lbs. N per cow per year	87 lbs. P2O5 per cow per year	21 lbs. K2O per cow per year	

DVO Phosphorus Recovery System Side View.

Daily volume of stackable solids produced by DVO Phosphorus Recovery System.

FIGURE 5: Edaleen Dairy DAF System and Separated Fine Solids

Example #3:

As described in Section 2, there is only one dairy manure-derived fertilizer product currently available in the marketplace (Midwestern BioAg's TerraNU operation in Fair Oaks, IN). The TerraNU facility currently purchases P-cake produced from Prairies Edge Dairy which employs a Trident Nutrient Recovery System (from a technology standpoint, it is very similar to the Edaleen Dairy process) and augments the P-cake with other ingredients followed by drying and pelletizing. Newtrient does not have insight relative to the economics of the TerraNU process; however, considering it is a private enterprise, we believe the economics that drove the initial investment were sound. Whether the business model stands the test of time remains to be determined.

It should be kept in mind that Midwestern BioAg's overall business model is to work with farmers to manage their soil health to improve crop yields. Midwestern BioAg does sell physical products, but its true intent is to put acreage under its management approach. Selling soil amendments and fertilizers may be an outgrowth of that relationship but not the primary goal.

The product produced from the TerraNU process does not (currently) meet the standards to be considered an organic fertilizer product. This is presumably driven by the fact that the polymers and other ingredients used in the process are not considered organic. Though Newtrient is not familiar with the economics of the TerraNU products, they currently market the product to help grow yields, increase profits and improve soil health. Nevertheless, an organic fertilizer product commands a significantly greater value in the marketplace as compared to a non-organic product.

DAIRY P-CAKE PRODUCT EXPERIENCE

Based on verbal communication with Machia & Sons dairy, the centrifuge has performed as anticipated; however, the dairy has not had success finding an outlet for the captured P-cake and only operates the centrifuge on a periodic basis as dictated by the internal needs of the farm's operations. The most significant obstacle to selling the P-cake as a commercial product appear to be the logistical challenges driven by a high water content.

Edaleen Dairy has been storing the captured solids off-site during the winter (at a rate of 40 yards per day) and has expressed concern regarding storage capacity. Last fall, the dairy was able to market the product to local fields that were in need of organic matter and nutrients. Based on the nutrient value (retail NPK value) and a 1.2x adder to account for secondary/micronutrients, the estimated value of the product is $20/wet ton. Unfortunately, the market is underdeveloped at this time and the farmer is "selling" the product for the price of transportation.

Lastly, and as described above, Prairies Edge Dairy sells its P-cake to Midwestern BioAg's subsidiary, TerraNU, where it is combined with other ingredients, dried and pelletized to create a manure-based fertilizer product.

The major takeaway is that, though technologies such as polymer flocculation followed by dissolved air flotation and dewatering (e.g. the process used by Edaleen Dairy and Prairies Edge Dairy) or centrifugation (e.g. process used by Machia & Sons Dairy) are effective at partitioning suspended solids and associated phosphorous and organic nitrogen, there is simply too much water to logistically manage the final product, whether for onsite storage and use or off-site transport. However, if drying can be incorporated, a business case may exist.

POTENTIAL FOR MANURE-BASED ORGANIC FERTILIZER PRODUCTS

Manure-based organic fertilizers and composts are far more expensive, based on NPK content, than synthetic fertilizers, and therefore are purchased for added perceived value to the end user. Organic fertilizer/compost/soil amendment proponents point out the soil building benefits of these organic products and often refer to the need to "feed the soil" and then the plants through that process. Certified organic dairies, cattle and vegetable farms turn to these products for these benefits and to comply with their certification requirements. Progressive agricultural businesses and gardeners view organic fertilizer and compost as environmentally preferable, with lower impacts than fossil-fuel derived fertilizers. This may or may not be the case when analyzed through the lens of a disciplined environmental life cycle analysis, but the consumer perception is certainly currently fixed in that belief.

NEWTRIENT REPORT: NORTH AMERICAN ORGANIC FERTILIZER MARKET

The highest economic value outlet for P-cake is the organic fertilizer market. There is readily available pricing data for specialty packaged organic fertilizer; however, the relative quantity of organic product that is packaged and sold at "big box stores" is a fraction of the total organic fertilizer product sold in the marketplace. To evaluate the potential value of dairy manure derived organic fertilizer, it is necessary to benchmark against other products in the marketplace sold in bulk quantities. Pricing data for bulk organic fertilizer is surprisingly difficult to access. The best example we were able to identify is a product manufactured from poultry litter at Perdue AgriRecycle's facility in Seaford, Delaware. The facility is permitted for 80,000 tons of poultry litter per year; however, according to a December 12, 2016, presentation made by Perdue Farm's Vice President of Sustainability, Steve Levitsky, the facility typically processes about 40,000 tons annually. Perdue invested more than $60 million in the construction and operation of the facility which processed approximately 66 million pounds of nitrogen and 44 million pounds of phosphorus since the operation was started up in July 2001. In 2015, 72% of the recovered nutrients were shipped outside of the Chesapeake Basin. The facility dries and pelletizes poultry litter and produces two organic fertilizer products. The product that most closely resembles the NPK potential of dairy manure is MicroStart 60, 3-2-3 NPK (presented as Attachment II). Mr. Levitsky's presentation states that the operation has never been profitable. Recent press releases suggest Perdue Agribusiness has made additional investment in a composting facility at this location and it is not clear if the drying and pelletizing equipment is still operational (presentation titled, "Water Quality Trading Advisory Committee, Perdue Farms", presented as Attachment III).

Newtrient was able to verify 2017 pricing for the MicroStart60 product at $140 per ton, FOB the Perdue Facility in Seaford, DE. Considering only the nitrogen and phosphorus components and assuming nitrogen and phosphorus carry approximately the same market value, on a per pound basis, nitrogen and phosphorus are valued at $140/ton ÷ [2000 lbs/ton x 5% (3% N and 2% P)] = $1.40/lb as nitrogen or phosphorus. When accounting for the cost of transportation to the end user (MicroStart60 pricing is FOB Seaford, Delaware), the product value is something on the order of 2-3 times that of conventional fertilizer (current market value for phosphorus and nitrogen is in the $0.30-0.40/lb range).

Newtrient commissioned MARKETSANDMARKETS to produce a report titled, "North American Fertilizers Market". This effort was separate and apart from our VT Clean Water Fund Grant; however, it has provided valuable insight to the probable manure derived US organic fertilizer market size. Table 5 provides the estimated 2017 North American organic fertilizer market derived from animal manure, estimated at 232 kilotons or approximately 255,200 tons per year. Figure 6 illustrates that the US market represents 68.5% of the North American organic market, therefore, the estimated US market for manure derived organic fertilizer is approximately 175,000 tons per year.

Table 5 NORTH AMERICA: ANNIMAL BASED ORGANIC FERTILIZERS MARKET, BY SOURCE, 2015 TO 2022 (KT)

SOURCE	2015	2016	2017 -E	2022 -P	CAGR (2017–2022)
Manure	191.7	210.1	231.8	417.5	12.49%
Blood meal	TBD	TBD	TBD	TBD	TBD
Bone meal	TBD	TBD	TBD	TBD	TBD
Feather meal	TBD	TBD	TBD	TBD	TBD
Fishmeal & other by-products	TBD	TBD	TBD	TBD	TBD
TOTAL	**624.6**	**693.5**	**774.9**	**1,485.2**	**100.0%**

-E = Estimated **-P** = Projected

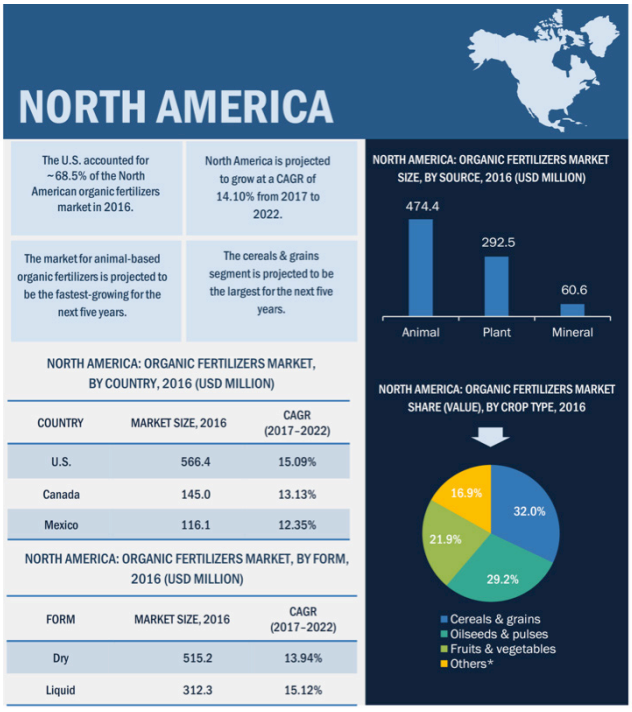


FIGURE 6: North America: Organic Fertilizers Market Snapshot

*Others include corn gluten meal and soybean meal.

Source: Press Releases, Investor Presentations, Expert Interviews, and MarketsandMarkets Analysis

As a frame of reference, if we assume the fine solids are captured from 100% of Vermont's dairy herd, the total contribution to the manure derived organic fertilizer marketplace becomes 135,000 cows x 7.5 lb/cow/day fine solids (ASABE and Midwest Plan Services estimate 20 lbs TS/cow/day and assuming 7.5 lb/cow/day is captured as fine solids) x 365 days/year ÷ 2000 lb/ton = 185,000 tons per year. The key takeaway of this example is to illustrate that the higher value organic fertilizer market offers limited capacity as an outlet. This in no way should preclude the pursuit of the higher value organic market as it could provide an outlet for a portion of VT manure (Figure 7 illustrates that New York ranks third in terms of organic production); however, the potential of the non-organic market will offer greater volume opportunity, though at a lower price.

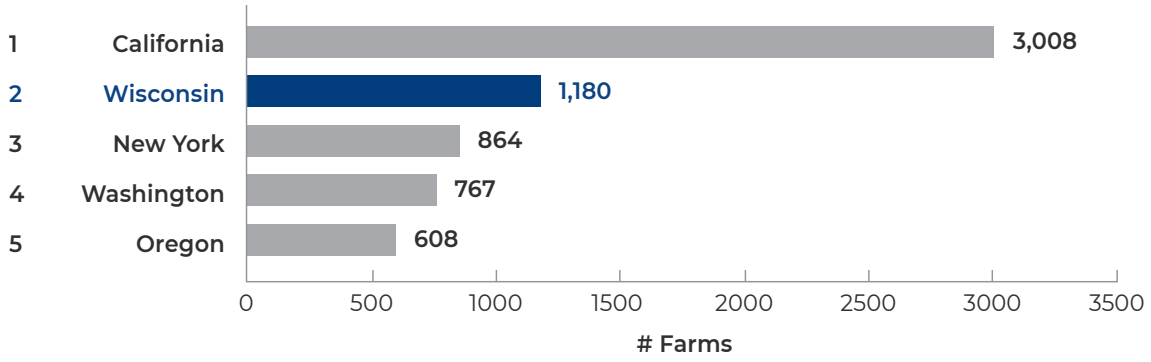


FIGURE 7: Top Five States in Number of Organic Farms, 2012

Source: USDA. 2012. *Census of Agriculture, Special Organic Tabulation.*

SECTION 4:
Conclusions and Observations about Future Work

The P-cake market is an emerging market with very few success stories to date. Concentrating phosphorus and organic nitrogen into a P-cake creates new and exciting opportunities for shifting the manure management paradigm from a disposal mindset dictated by manure storage capacity to one where nutrients are placed where and when they are needed. Further, this opens the door to manure-based fertilizer products with the potential to off-set commercial phosphorus imports. There is clearly a need to further process the P-cake to create a dry product and, in some cases, a granulated or pelletized product to facilitate storage, transport and buyer acceptance.

The cost of producing a manure-derived fertilizer product will always outpace the cost of commercial fertilizer. Though the price differential is a real obstacle, in most cases, the farmer's primary driver for adopting technology focuses on other factors such as on-farm operational constraints associated with nutrients. There are numerous benefits linked to adopting nutrient recovery technology; however, in aggregate, the business case is negative without external support. Core to Newtrient's mission is to help the dairy sector identify additional benefits through mechanisms like environmental markets that generate value for improving air and water quality, enhancing soil health as well as the creation of value-add manure-based products such as fertilizer and soil amendments.

Typical P-cake is 20–30% total solids or, put another way, 70-80% water with a density of about 1200 lbs/yd3. The water content is a significant detractor from a storage standpoint (both volume and potential for product degradation) and the weight limits the transport range for off-farm use.

In most cases, farms are hauling the P-cake to remote fields that can utilize the concentrated nutrients. Some farms have been successful in creating seasonal and limited sales; however, apart from Midwestern BioAg's TerraNU facility, none of the P-cake projects we have encountered in the dairy industry have been able to create a durable market for their P-cake.

KEY TAKEAWAYS

1. A dairy P-cake market appears to be emerging but is currently in its infancy and lacks a clear, compelling, widespread business case.
2. P-cake derived from dairy manure has limited market value unless it can be further processed and dried (and in some cases granulated or pelletized).
3. Further research/analysis is required to identify the economics and processing costs of producing a marketable product. Newtrient's dryer pilot work is scheduled for summer of 2018 and will provide additional insight.
4. There is one large-scale, dairy manure-based business (Midwestern BioAg's subsidiary, TerraNU) producing a commercial-grade product for widespread distribution. It's marketed as a fertilizer product with enhanced soil building properties due to the organic carbon content and micronutrients contained in the manure. However, we do not have insight into the economic standing of this venture.
5. Certified organic fertilizers enjoy a significant price premium over conventional commercial fertilizers (approximately 2-3x) and could offer a niche opportunity for Vermont dairy operations; however, this market has volume limitations.
6. Multiple benefits are needed to create a viable path to the adoption of phosphorus control technologies for Vermont dairy farms. Development of a P-cake market offers one mechanism to help fill the benefits gap.

PENDING STEPS UNDER NEWTRIENT'S CLEAN WATER FUND GRANT

1. Conduct on farm testing at Machia & Sons Dairy (P-cake from their centrifuge Process) to develop background data necessary to evaluate potential product outlets.
2. Perform product formulation and testing driven by pilot work and interface with regional fertilizer blenders regarding product development and economic opportunities.
3. Delineate market mechanisms and drivers for organic and non-organic fertilizer products.
4. Establish parameters for grow test requirements.
5. Develop an economic model built around the phosphorus opportunity hierarchy. The intent of the phosphorus hierarchy is to depict the continuum of manure treatment. Figure 8 illustrates that the most direct method of phosphorus management is localized application (following the 4Rs) followed by increasing levels of treatment to produce a product with an enhanced selling price and improved transportability (although it does not speak to the overall return on investment nor the market opportunity).

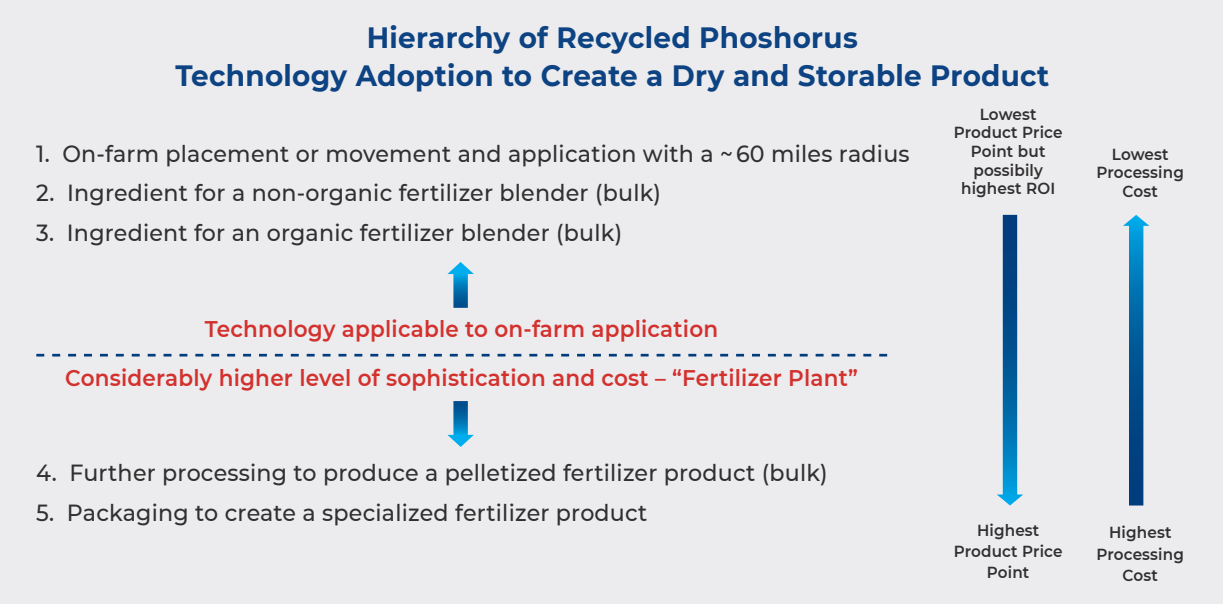


FIGURE 8: Phosphorus Hierarchy

RECOMMENDED NEXT STEPS (OUTSIDE SCOPE OF EXISTING CLEAN WATER FUND GRANT)

1. Work with other Vermont stakeholders to create an agreed upon mass balance framework for determining opportunities for localized placement of phosphorus and identification of areas requiring phosphorus export from the Lake Champlain Watershed.

2. Refine market opportunities for product creation to more clearly define the potential for export markets as organic and traditional fertilizer products.

3. Develop a comprehensive and optimized approach that identifies critical source areas in the Lake Champlain basin and systematically applies combinations of practices, on-farm technologies and centralized treatment facilities to create quantified and durable water quality improvement (Figure 9).

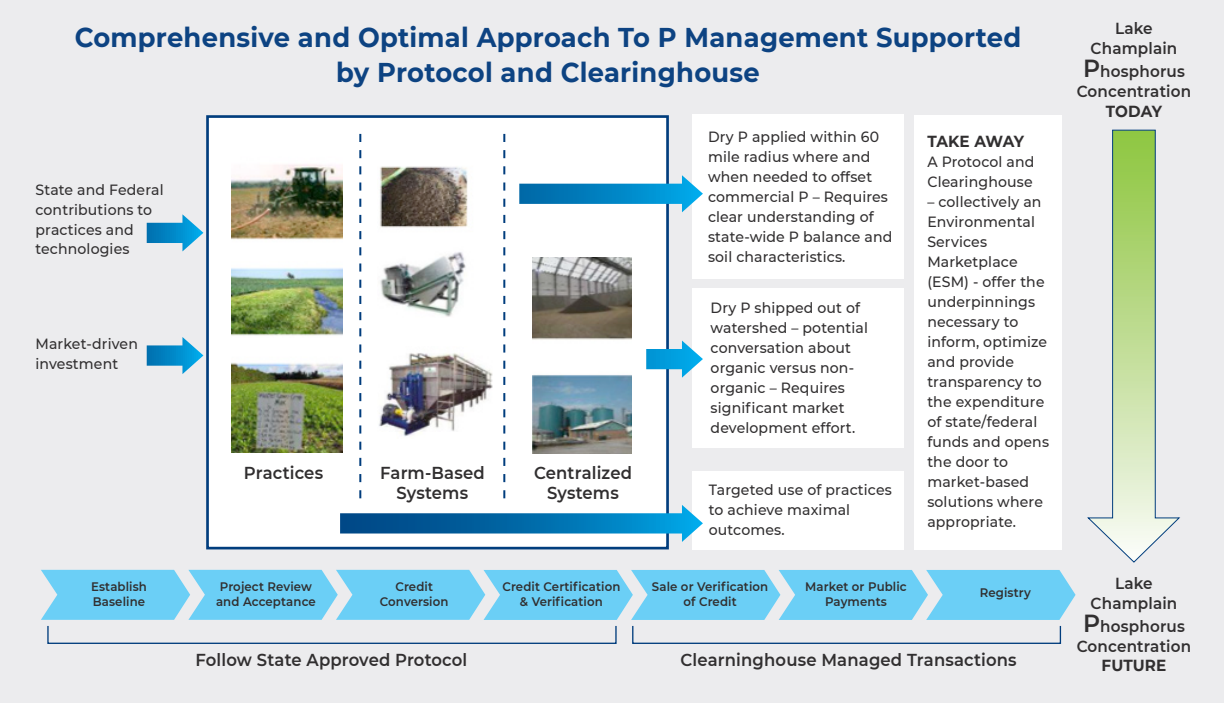


FIGURE 9: ESM Underpinning Resource Use and Optimization

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Vendor:
DVO Incorporated
820 W. Main St.
Chilton, WI 53014 USA
1-920-849-9797
info@dvoinc.com
www.dvoinc.com/phosphorus-recovery.php

Industry:
Fine Solids and Phosphorus Separation

Project type:
Post Anaerobic Digestion Fine Solids and Phosphorous Separation

Project goal:
Partition remaining suspended solids and associated phosphorus and nitrogen into stackable solid

Study Prepared by:
Craig Frear

Date of Case Study:
September 27, 2017

DVO Phosphorus Recovery System

Edaleen Dairy, Lynden, WA

OVERVIEW

Edaleen dairy is a 1,800 wet-cow dairy in Northwest Washington State producing an approximate 7% total solids manure wastewater from a combination of alley-scrapers, maternity barn flush and parlour/wash water. This manure wastewater is then pumped to a DVO mesophilic mixed plug-flow anaerobic digester that practices limited co-digestion with off-farm organics (<5% volume). Effluent from the digester is then sent to a GEA/Houle two-stage, slope-screen solids separator for separation of fibrous, coarse solids. The resulting liquid, still containing large amounts of suspended solids and associated nutrients, is sent through a DVO Phosphorus Recovery System, which is a modified dissolved air flotation (DAF) system. Separated solids are a wet but stackable product rich in nutrients, particularly phosphorus. Final liquid wastewater is then sent to lagoon for storage and subsequent land application.

BACKGROUND

The DVO Phosphorus Recovery System adds important nutrient partitioning capabilities to the Edaleen dairy manure management system.

Edaleen dairy is a family-owned producer/processor located in Lynden Washington, presently milking approximately 1,800 Holstein wet cow equivalents. Edaleen dairy has one of the more complete, modern manure management systems in the US, which they have phased into place since 2012. The system starts with alley cable-scrapers as well as a flush system within their maternity barn. The combined scrape and flush manure are mixed with farm wash water to manure pits. The manure wastewater from these pits is sent to a DVO mesophilic mixed plug-flow anaerobic digester for treatment and production of renewable electricity and carbon credits in a Dresser-Rand Guascor SFGLD 560 engine/generator combined heat and power system packaged by Martin Energy Group. Effluent from the digester is passed across a GEA/Houle two-stage, slope-screen separator, producing a high-quality fibrous solid used as both an internal animal bedding and sold off-farm as a soil amendment ingredient to a commercial retail product. Liquid effluent from the screen is sent to an equalization pit for control of flows and timing,

FIGURE 1. MANURE MANAGEMENT SYSTEM FLOWCHART — DVO PHOSPHORUS RECOVERY SYSTEM (SOLID PRODUCT CIRCLED).

"We invested in the advanced solids/nutrient system because the future of the dairy industry is evolving, and the needle is moving towards nutrient management systems as a key element in creating a closed loop, sustainable farm where nothing goes to waste, and we steward the land with utmost care so it can feed future generations."

***Mitch Moorlag,** General Manager Edaleen Dairy*

with dispersal to a DVO Phosphorus Recovery, modified dissolved air flotation (DAF) system for recovery of fine solids and associated nutrients. Collected solids are hauled and stored to an off-site location, with local agricultural producers with fields in transition using the solids as carbon/nutrient soil amendment. Final liquid effluent is stored in lagoons until ultimate use as fertilizer for nearby fields/forage crops.

KEY LEARNINGS

The DVO Phosphorus Recovery system provides a unique ability to produce both low solids/nutrient irrigation water and a stackable nutrient-rich solid.

The DVO Phosphorus Recovery System is a modified DAF system comprising several key components: a polymer mixing and dosing system, a micro-air compression and injection system, a proprietary manure/polymer/air mixing tube for optimal treatment, the DAF vessel itself for separation, rise and skimming of solids, and lastly dewatering moving disc presses for production of a stackable solid under continuous flow conditions. The system is placed at an elevation that allows for gravity feed of manure to an equalization pit, mixing/pumping from the pit to the system, and gravity feed of both produced solids to a concrete pad and treated tea-water liquid to a storage lagoon. The system is placed within a dedicated processing building. Solids are presently trucked daily to a long-term storage building with sales to nearby crop producers with transition fields in need of carbon and nutrient supplementation.

The entire system is automated for continuous operation, only turning off when float valves on the equalization pit determines low flow and temporary stop/restart of operations. Regular operations/maintenance is a daily 20-minute walk-through and completion of monitoring checklist with a morning filling of solid polymer to a feed hopper.

KEY BENEFITS

Production of a low-solids, low nutrient irrigation tea water — The system is effective in removing nearly all suspended solids and a large fraction of total solids, producing an irrigation water more suitable for use in a variety of irrigation systems. Importantly, during lagoon storage, prior to irrigation of fields, there exists reduced need for costly agitation and/or dredging due to the removal of these solids. Removal of solids from the anaerobic lagoon to a more primarily aerobic storage and processing also reduces the greenhouse gas footprint of the dairy, beyond what is already accomplished.

Production of a nice, stackable pile of nutrient-rich solids — The system partitions these solids and associated nutrients to a dewatered, stackable pile. With approximately 90% of phosphorus and 35% of nitrogen and appreciable amounts of secondary and micro-nutrients from the influent within the solids, the solids can be either sold off-farm or more optimally applied to dairy fields as an organic-matter fertilizer.

Savings in both energy and manure management costs — While hard to quantify from a true accounting of farm manure management and application costs, the partitioning as noted above can clearly lead to important savings in both energy and manure management costs. Specifically, reduced energy to mix, dredge, pump and haul liquid manure; greater flexibility in targeting specific fractions and types of nutrients to individual fields/crops; and with potential export off the farm, reduced acreage, haul and/or application costs to meet dairy nutrient management plans.

Potential sales/export of solids and nutrients off-farm — Presently, the dairy has negotiated contracts for the solids whereby neighboring crop producers with transition fields in need of organic matter and nutrients will pick up the solids. This is in-part due to the new product, lack of mature markets and the raw, wet nature of the product. There is potential with either time or down-stream drying/processing to achieve higher sales and revenues. Even without, significant benefit exists for the dairy to remove this nutrient load from their nutrient management plan accounting.

RESULTS

Washington State University (WSU) recently monitored the Edaleen DVO Phosphorus Recovery system for a combination of solids/nutrient partitioning performance, solids product characteristics and project techno-economics (2-week period, morning and afternoon duplicate grab samples mixed into single sample for approximately n =12 samples with replicates for reporting of mean and standard deviations). While the study report is not complete and is finalizing additional data and flow refinements, the following is a summary of the early results.

Key Benefits & Results Summary:

- Production of nearly 4.7 wet tons of solids per cow per year at 25% total solids
- 62% and 92% reduction of total solids and total suspended solids in liquid wastewater
- 40%, 88%, and 15% N, P, K reduction in liquid wastewater
- Third party purchase/installation capital costs of $219 and $339 per cow, respectively for equipment and total installed system
- Third party O/M costs average of $50-68 per cow per year

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Highlights of the following tables are:

- Strong partitioning of key nutrients out of the liquid fraction and into the solids product, notably approximately 62%, 92%, 40%, 88%, and 15% total solids, total suspended solids, total nitrogen, total phosphorus, and potassium. Total liquid fraction reduced in volumetric flow rate by approximately 10%.
- Solids were produced as a relatively dry stackable pile, with a yield of 4.7 tons per cow per year (1.14 dry tons per cow per year), having a density of 1,149 lbs. per cubic yard. Fertilizer value as reported in typical dry units are 4.5%, 3.8%, 0.9% NPK with significant amounts of carbon (39%), calcium (4.1%), and magnesium (1.2%), with no concerns regarding heavy metals. Salts as a measurement of electro-conductivity (EC) were on the moderate end while pathogen as measured by faecal coliform indicators were well below Class A bio-solids standards at a mean of 145 MPN/g DW.
- Economics highlight equipment and total installed costs of $219 and $339, respectively with installed including design, permitting, engineering, groundwork, pads, pumps/mixers, equalization tank, and building. The data collected was performed while dosing polymer at 136.5 parts per million, although the dairy has subsequently lowered the dosing significantly and is seeing no negative effects on performance (WSU data still to be completed). At both the lower and higher ranges of polymer dosing, the estimated operating costs including electrical, chemical, labour and maintenance are $50-68 per cow per year.

TABLE 1. SOLIDS AND NUTRIENT PORTIONING PERFORMANCE

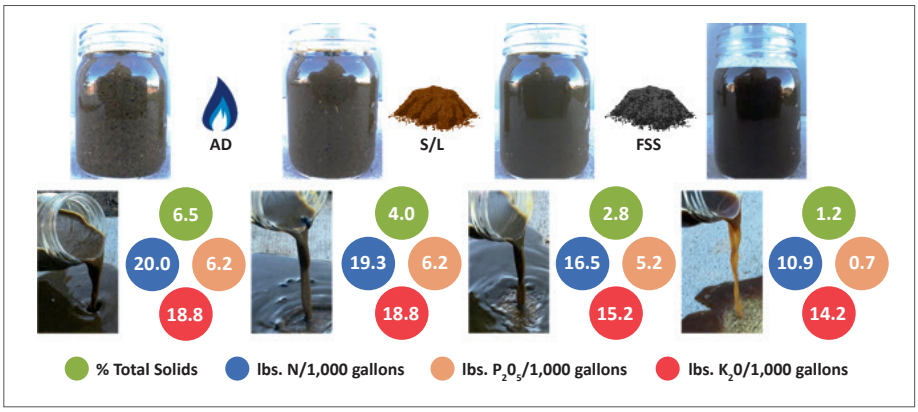
	TS (%)	VS (% of TS)	TSS (g/L)	N (g/L)	P (mg/L)	K (g/L)	Flow Rate (GPM)
Post AD/Sep Liquid	2.82 ± 0.29	71.3 ± 2.7	20.98 ± 3.4	1.98 ± 0.21	270 ± 19	1.51 ± 0.12	46.13
DVO FSS Effluent	1.17 ± 0.26	59.5 ± 8.8	1.85 ± 0.32	1.30 ± 0.25	36 ± 6	1.41 ± 0.09	41.75
Reduction by Conc. (%)	58.5	16.6	91.2	34.3	86.7	6.6	9.5
Reduction by Mass (%)	62.5	16.6	92.0	40.6	87.96	15.5	

TABLE 2. DAF SOLIDS CHARACTERISTICS AND PARAMETERS

	TS (%)	VS (% of TS)	EC (mmhos/cm)	N (% DW)	P2O5 (% DW)	K2O (% DW)	Flow Rate (yd³/day)
DVO FSS Solids	24.4 ± 4.1	79.9 ± 2.9	2.31 ± 0.48	4.5 ± 1.1	3.8 ± 0.8	0.9 ± 0.2	40 ± 7
	C: 39.3 ± 5.1 Ca: 4.1 ± 0.6 Mg: 1.2 ± 0.1 Fe: 0.2 ± 0.04 S: 0.7 ± 0.1 % DW						
	Mo: 0.95 Ni: 0.77 Se: 0.30 As: 0.09 Cd: 0.04 Cr: 0.76 Co: 0.62 Cu: 25.6 Pb: 0.12 Hg: 0.01 Zn: 83.7 ppm						

TABLE 3. ECONOMIC SUMMARY

DVO FSS Capital Installed	$607,465	$21.20 per 1,000 gallons throughput	$339 per cow
DVO FSS O&M	80-140 ppm polymer dosing	40 kWh/h electrical	40 minutes/day labor	3% capital parts
	$89,866-122,189 per year	$3.10-4.30 per 1,000 gallons throughput	$50-68 per cow per year
DVO FSS Solids	103 lbs. N per cow per year	87 lbs. P_2O_5 per cow per year	21 lbs. K_2O per cow per year



Pictogram of full-Edaleen system including DVO Phosphorus Recovery System **(a)** liquid samples at various stages of process; **(b)** liquid-poured samples at various stages of process; **(c)** NPK fertilizer values along various stages of process.

Organizations Involved:

Farm or facility
Edaleen Dairy

Electrical Utility
Puget Sound Energy

Engineers
DVO Inc.

Contractor
Regenis

Developers
Edaleen Dairy

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CONCLUSION

The DVO Phosphorus Recovery System is an integral part of the Edaleen Dairy manure management system, positioned after anaerobic digestion and fibrous solids separation. Produced solids partition a significant fraction of phosphorus and nitrogen into stackable, solid form while producing a low-nutrient, tea-water significantly reduced in suspended solids. While a more-costly unit operation than simple fibrous solids separation, the gains in nutrient partitioning, wastewater volume reduction, and tea-water irrigation water can be of importance to some dairies. Early evaluation shows a constant and steady operation producing a dry, stackable product with quite consistent performance. Further observation will be required to better ascertain long-term maintenance costs as well as development of markets, uses and price points for the solids.

DVO AT EDALEEN DAIRY PROJECT BY THE NUMBERS

Location type	Dairy
Number of animals	Approximately 1,800 wet cow equivalents
Type of bedding	Digested, separated fibrous solids
Manure collection	Alley cable scraper with one maternity barn flush
Daily flow	85,000 gallons per day
System designed by	• DVO Two Stage Mixed Plug-Flow Anaerobic Digester • Dresser-Rand Guascor Engine with Martin Machinery Package • GEA Houle Two stage slope screen manure separator • DVO Phosphorus Recovery system
Date operational	Fall 2017
Energy produced/required	• DVO Anaerobic digester approximately 40-45 KW parasitic load • GEA/Houle Separator approximately 2 KW parasitic load • DVO Phosphorus Recovery system approximately 40 KW parasitic load
Installed energy production capacity	Averaging 544 KW of electrical generation to the grid from the anaerobic digester
Products produced	Electrical Power, Green Tags, Carbon Credits, Tipping Fees, Fibrous Solids Bedding Offset, Fibrous Solids Soil Amendment Ingredient, Fine Solids Soil Amendment
Residual materials	• Digested, separated liquid manure wastewater • Fine Solids Soil Amendment
Residual storage	• Lagoon storage for digested, separated liquid manure wastewater • On-site storage for fibrous solids prior to use/sales • On-site storage for fine solids prior to use/sales
Residual use	• Wastewater residual fate as fertilizer for local fields/forage crops • Fibrous solids recycled internally as bedding and sold as ingredient to retail soil amendment • Fine solids as fertilizer to local fields/forage crops or sold as fertilizer/soil amendment to fields undergoing crop rotation
Electrical utility	Electrical power purchase agreement with Puget Sound Electric
Ownership structure	Family owned dairy

DVO Phosphorus Recovery System Side View.

Daily volume of stackable solids produced by DVO Phosphorus Recovery System.

For more information about DVO Phosphorus Recovery System, or to join our mailing list, email info@newtrientllc.com.

Newtrient's mission is to help all dairy farmers reduce the environmental footprint of manure while enhancing their economic opportunities and their social license to operate. The information contained in this case study was developed with the cooperation of the organizations involved and Newtrient has endeavoured to make sure it is accurate and complete as possible.

Equipment and Technology:

Manure collection
GEA/Houle Alley Scrapers, GEA/Houle mixers/pumps

Primary treatment
DVO Two-Stage Mixed Plug-Flow Mesophilic Anaerobic Digester

Secondary treatment
GEA/Houle Two-Stage Slope Screen Solids Separator

Tertiary treatment
DVO Phosphorus Recovery Modified Dissolved Air Flotation (DAF) System

Energy systems
Dresser-Rand Guascor SFGLD 560 engine/generator set, heat recovery and interconnect packaged by Martin Energy Group

Other
Regenis construction, installation and operation/ maintenance

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Perdue MicroStart 60 Fertilizer

Product Selection and Description

Perdue AgriRecycle's MicroStart 60™ is a slow-release nitrogen fertilizer consisting almost entirely of chicken litter, a byproduct of the poultry industry. Its Nitrogen-Phosphorus-Potassium (NPK) ratio is 4-2-3.

For the BEES system, the functional unit for fertilizers is applying 10 kg (22 lb) nitrogen per acre for a period of ten years. A typical application of MicroStart 60™ is 318 kg (700 lb) per acre. As the nitrogen in one application is released over a period of three years, fertilizer use per acre, per year, is 106 kg (233 lb). To achieve a 10 kg (22 lb) nitrogen per acre requirement, however, this amount is scaled up to 245 kg (540 lb) of fertilizer per acre per year.[1]

Flow Diagram

The flow diagram below shows the major elements of the production of this product, as it is currently modeled for BEES.

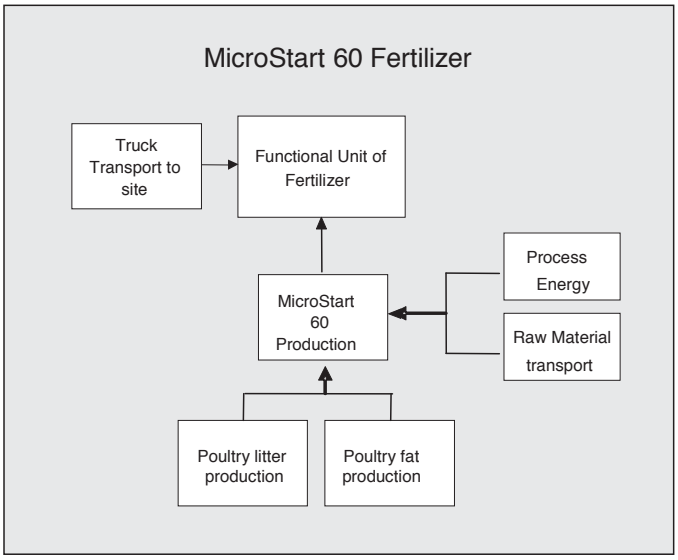


Figure 1: MicroStart 60™ Fertilizer System Boundaries

Raw Materials

Microstart 60 is composed of raw poultry litter and poultry fat, in the proportions shown in the Table below.

Table 1: Microstart 60 Constituents

Constituent	*Mass Fraction (%)*
Raw poultry litter	99.9
Poultry fat	0.1

The raw poultry litter is a byproduct of the poultry industry and would otherwise be a waste product. Therefore, any impacts associated with its production, such as chicken farming and poultry production, are allocated to the production of the poultry, not the litter. Wastewater generation from poultry production processes is accounted

[1] While this may not be the manufacturer's suggested rate of use for this product, an adjustment was made to enable comparison of BEES fertilizers on a functionally equivalent performance basis.

for in the context of poultry fat production; poultry fat accounts for 0.1 % of the inputs to these processes.[2]

Manufacturing

Energy Requirements and Emissions. Electricity and #2 diesel oil for a generator are among the energy requirements for manufacturing. Steam is generated from a 74.6 kW (100 hp) boiler, for palletizing and heating the finished product, for use of a scrubber, and for dust control. Approximately 472 MJ (131 kWh) and 0.04 m^3 (10 gal) of diesel are required to produce one ton (2 000 lb) of fertilizer. Electricity is modeled using the U.S. average electric grid from the U.S. LCI Database. Diesel fuel production data comes from the U.S. LCI Database, as does a portion of the data used to represent its combustion in a boiler. Data for some of the diesel emissions is provided directly by Perdue AgriRecycle, and is included in the BEES model as follows.

Table 2: Microstart 60 Manufacturing Emissions

Air Emission	*g/kg (lb/ton)*
Nitrogen Oxides	1.24 (2.48)
Carbon Dioxide	1.61 (3.21)
Sulfur Dioxide	1.61 (3.21)
Particulates (unspecified)	1.23 (2.45)
Ammonia	0.48 (0.95)

Transportation. The raw litter is transported an average of 120 km (75 mi) and the poultry fat 161 km (100 mi) to Perdue AgriRecycle's facility.

Water Effluents. About 10 tanker loads of water effluents per week are generated from manufacturing Microstart 60™. However, this water is beneficially applied on land for irrigation, so is not modeled as a wastewater or as specific water effluents.

Transportation

Truck and rail are both used to ship Microstart 60™ to customers located across the United States. The transportation distance is modeled as a variable of the BEES system, with burdens shared equally by truck and rail.

Installation

Any burdens that may arise from on-site application of fertilizer are not accounted for in BEES.

Use

The nitrogen in the fertilier is released over a three-year period. Microstart 60™ is fully biodegradable.

End of Life

There are no end of life burdens for this product since it is fully consumed during use, eliminating the need for waste management.

References

Life Cycle Data

"U.S. Life Cycle Inventory Database." (2012). National Renewable Energy Laboratory, 2012. Accessed November 19, 2012: https://www.lcacommons.gov/nrel/search

World Bank Group, "Meat Processing and Rendering," Pollution Prevention and Abatement Handbook (World Bank, July 1998). Found at: http://documents.worldbank.org/curated/en/758631468314701365/pdf/multi0page.pdf

Industry Contacts

Joe Koch, Perdue AgriRecycle (2005)

[2] World Bank Group, "Meat Processing and Rendering," (World Bank, July 1998). Found at: http://lnweb18.worldbank.org/essd/essd.nsf/GlobalView/PPAH/$File/65_meat.pdf.

Water Quality Trading Advisory Committee Perdue Farms

December 12, 2016

Perdue AgriRecycle, Seaford AgriSoil and Nutrient Trading Potential

- Perdue AgriRecycle
- Seaford AgriSoil
- Nutrient Trading Potential

Source: Management information.

Perdue AgriRecycle, Seaford AgriSoil and Nutrient Trading Potential

- **Perdue AgriRecycle**
- **Seaford AgriSoil**
- **Nutrient Trading Potential**

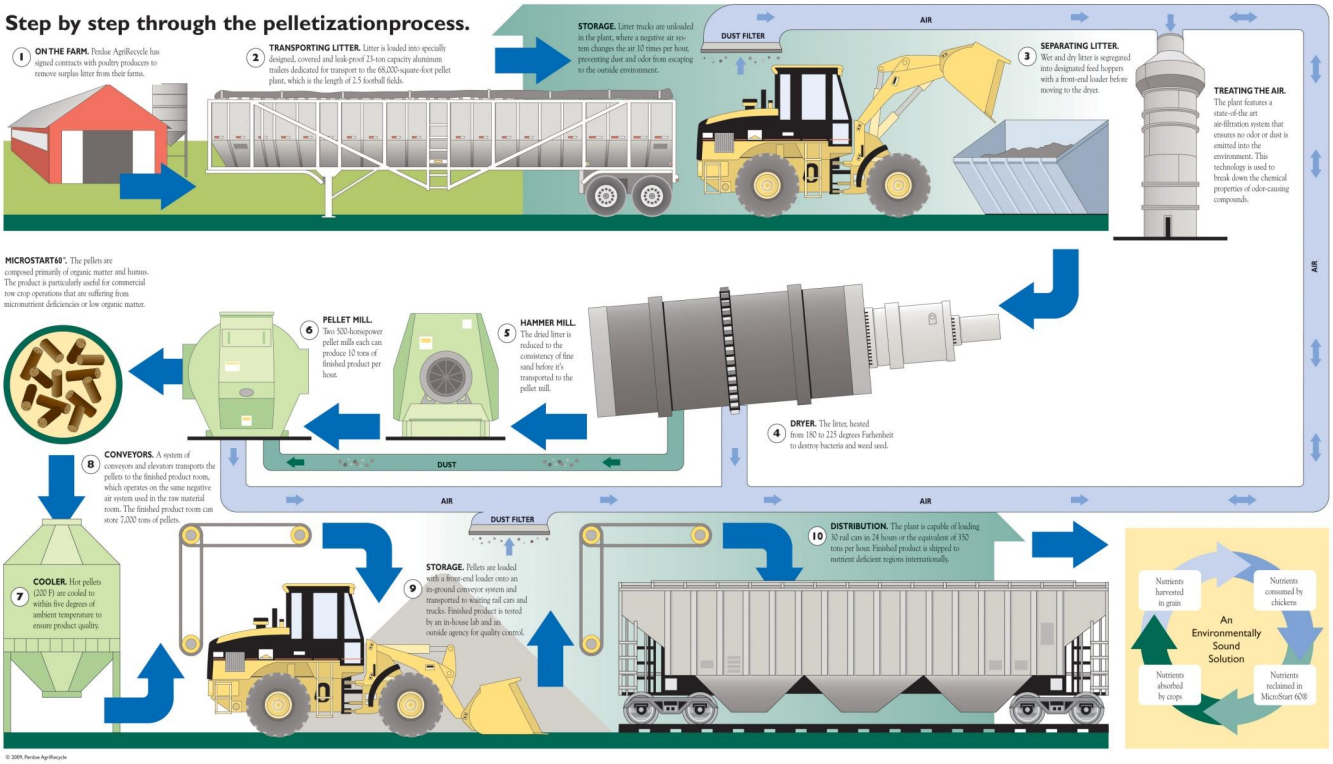
Source: Management information.

Perdue AgriRecycle Facility
Seaford, Delaware

Perdue AgriRecycle Facility
Seaford, Delaware

- Opened in July 2001
- Approximately 1 million tons processed to date
- Approximately 50% of the material shipped outside of Chesapeake Basin

Perdue AgriRecycle Facility
Seaford. Delaware



Perdue AgriRecycle Facility
Seaford, DE

- Perdue has spent over $60 million on constructing and operating the facility
- Facility has never been profitable
- Approximately 66 million pounds of Nitrogen and Potassium and 44 million pounds of Phosphorus have been moved through the facility

Source: Management information.

Perdue AgriRecycle Facility
Seaford, DE

- 72% of the material was shipped outside the Chesapeake Basin in 2015
- It is permitted for 80,000 tons of poultry litter
- Perdue typically runs approximately 40,000 tons through the facility annually

Source: Management information.

Perdue AgriRecycle Facility Seaford, DE

- MicroSTART60 organic fertilizer has a nutrient analysis of 3-2-3 NPK and MicroSTART60 Prilled Plus has a nutrient analysis of 7-1-1 NPK.

- Perdue AgriBusiness' products are compliant with USDA National Organic Program (NOP) for use in organic crop production.

- All of Perdue AgriBusiness' products are listed by the Organic Materials Review Institute (OMRI).

Perdue AgriRecycle, AgriSoil and Nutrient Trading Potential

- Perdue AgriRecycle
- **Seaford AgriSoil**
- Nutrient Trading Potential

Source: Management information.

Seaford AgriSoil Facility
Seaford, DE

Seaford AgriSoil Facility
Seaford, DE

- Opened December 5, 2016
- $12 million construction cost
- Large receiving/mixing building, windrow bunkers, covers for compost, and large curing area
- Constructed adjacent to Perdue AgriRecycle

Source: Management information.

Seaford AgriSoil Facility
Seaford, DE

- Diffuse Air Floatation (DAF) material from Georgetown and Milford Plants (16,000 tons 1st year) – Previously Land Applied
- Hatchery Waste from hatcheries on Delmarva
- Poultry litter from Delmarva (5,000 tons 1st year) – Previously Land Applied
- Perdue AgriRecycle Scrubber Water (24,000 tons 1st year) – Previously Land Applied

Source: Management information.

Perdue Farms

Seaford AgriSoil Facility
Seaford, DE

- Material is mixed and composted
- Placed under cover and negative air pressure pulled through the pile
- Biofilter on receiving/mixing building
- Final compost will be sold to landscaping companies, bagged and sold in retail, and used as soil amendment

Source: Management information.

Seaford AgriSoil Facility
Seaford, DE

- DNREC will expand permit based on successful operation and sale of compost
- Potential to add approximately 40,000 tons of poultry litter and DAF material in the future
- Can further reduce land application of nutrients

Source: Management information.

Perdue AgriRecycle, AgriSoil and Nutrient Trading Potential

- Perdue AgriRecycle
- Seaford AgriSoil
- **Nutrient Trading Potential**

Source: Management information.

Nutrient Trading Potential

- PAR - 40,000 tons of Poultry Litter
  - 1,200 tons of N and 800 tons of P
  - Over 50% moved out of Chesapeake
- Seaford AgriSoil currently will take 45,000 tons of land applied nutrients
  - N and P will be calculated once startup is complete
  - Will need to analyze relocation efforts

Source: Management information.

Nutrient Trading Potential

- Perdue will work with WQTAC, MDA, and MDE to identify best N and P avoidance calculations
- Perdue will continue to track nutrient data and location data for Seaford AgriSoil

Source: Management information.

Questions?

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Source: Management information.