APPLICATION FOR COMPONENT ADDITION TO NRCS

NRCS Practice Standard 632

For Acceptance of Decanter Centrifuge Technology

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Decanter Centrifuge Technology

REQUEST

NRCS Practice Standard 632 Waste Separation Facility (CPS 632) serves as a comprehensive framework for evaluating various manure separation technologies. Newtrient has developed a testing and reporting protocol for manure separation technologies based on CPS 632, which has been successfully implemented at multiple sites. In light of this, we propose the inclusion of a supplement to CPS 632 specifically for the technology "*Decanter Centrifuge*." Decanter centrifuge technology offers a highly efficient and effective solution for dewatering and separating solids from liquid in dairy manure, thereby aiding in waste management and resource recovery. By adding this supplement to CPS 632, we aim to provide farmers and industry stakeholders with standardized guidelines and a proven approach to implementing centrifuge systems for waste separation. This will expand the range of options available under NRCS Practice Standard 632, enabling greater flexibility and promoting sustainable practices in waste management within the agricultural sector.

BRIEF DESCRIPTION OF COMPONENT CLASS

Centrifuge technology is a widely used method for solid-liquid separation. It utilizes centrifugal force to separate components based on their density and size. By rapidly rotating a bowl, the centrifuge induces the movement of heavier solids towards the outer edges while collecting lighter liquids in the center. This process enables efficient separation of solids and liquids in various industries and applications.

Centrifuges are commonly used in wastewater treatment, industrial processes, and agricultural settings. They offer advantages such as high separation efficiency, compact design, and versatility in handling different types of materials such as livestock waste, municipal wastewater, and waste oil. For livestock operations, centrifuge technology has the ability to separate solids from liquid waste streams, allowing for the recovery of valuable resources, specifically nutrient partitioning. It can improve the quality of liquid effluent, reduce environmental impacts, and provide cost-effective solutions for waste management.

Overall, centrifuge technology plays a crucial role in the efficient separation of solids and liquids, offering numerous benefits in terms of waste management, resource recovery, and environmental sustainability.

DETAILED DESCRIPTION

A decanter centrifuge is an advanced mechanical separation technology used for dewatering applications in various industries, including wastewater treatment, food processing, and agriculture. These centrifuges utilize the principle of sedimentation and centrifugal force in separating solids from liquids, nutrient partitioning, and providing efficient and effective dewatering solutions.

Main Components of a Centrifuge [**Figure 1**]:

- *Rotating Bowl*: The primary component of the centrifuge where the separation process takes place. It rotates at a high speed, generating centrifugal force to separate the different phases.
- *Screw Conveyor*: Located inside the rotating bowl, the screw conveyor transports the separated solid phase, also known as the cake, towards the discharge outlet.
- *Drive System*: Provides the power and control for the rotation of the bowl and the screw conveyor, allowing for the continuous operation of the centrifuge.

The centrifuge operates in a continuous mode, allowing for continuous feed and discharge of the separated phases.

The feed slurry, which contains a mixture of solid particles and liquid, is introduced into the rotating bowl through a feed inlet. As the bowl rotates at a high speed, typically ranging from 2,000 to 4,000 revolutions per minute (RPM), centrifugal force is generated, causing the denser solid particles to migrate towards the bowl's outer edge.

Separation occurs between the solid phase and the liquid phase. The screw conveyor transports the separated solid phase, or cake, towards the discharge outlet. The cake is discharged through a solids outlet, while the liquid phase, referred to as the centrate or effluent, overflows from a weir and is collected separately.

The decanter centrifuge offers efficient dewatering capabilities due to its continuous operation and high separation efficiency. It is equipped with various features to optimize performance, such as adjustable bowl speed, variable conveyor speed, and adjustable pool depth, allowing for fine-tuning of the separation process based on the specific characteristics of the feed slurry.

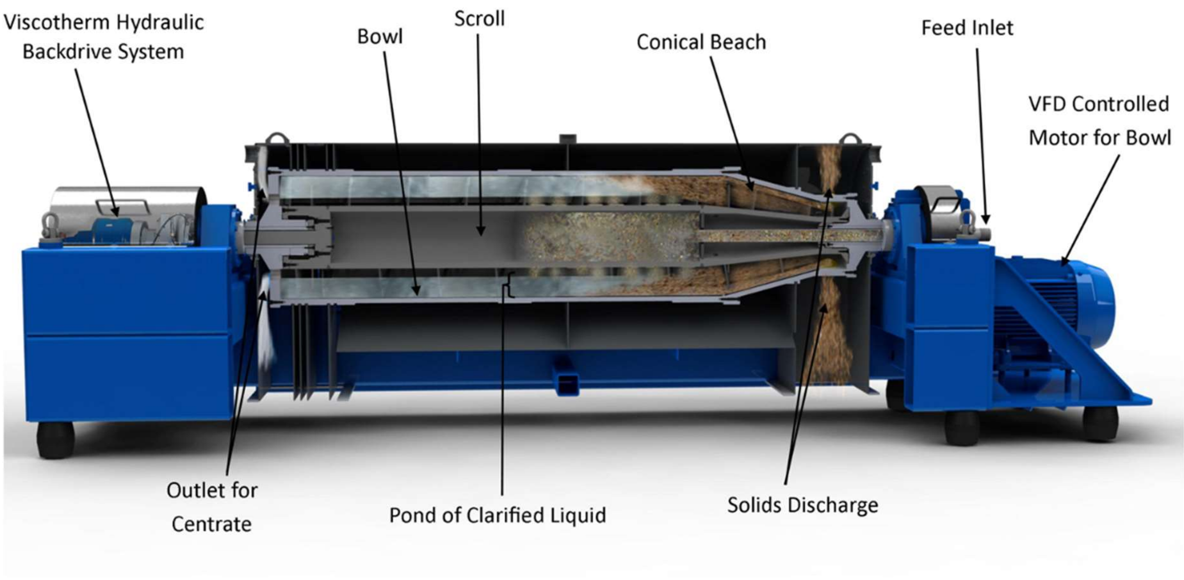


Figure 1. 2-Phase Decanter Centrisys Centrifuge System.

HOW PROPOSED SYSTEM ACCOMPLISHES PURPOSES OF THE STANDARD

The proposed centrifuge system effectively accomplishes the purposes outlined in the NRCS Practice Standard 632 Waste Separation Facility (CPS 632). This system addresses the key objectives of waste separation by providing efficient solid-liquid separation and dewatering capabilities, which are essential for managing organic waste materials in agriculture and other applications.

The centrifuge system achieves the following purposes of the standard:

1. *Solid-Liquid Separation*: The centrifuge utilizes centrifugal force to separate the solid and liquid phases of waste materials effectively. By rapidly rotating the waste stream, the system efficiently separates the denser solid particles from the liquid phase, facilitating the removal of suspended solids and reducing the organic content in the liquid fraction.

2. *Dewatering of Solids*: The centrifuge enables the dewatering of the separated solid fraction, reducing its moisture content and producing a drier and more manageable solid cake. This dewatering process significantly reduces the volume of the solid fraction, making it easier to handle, store, and transport.

3. *Compliance with Environmental Regulations*: The centrifuge system ensures compliance with environmental regulations by facilitating the responsible

management and treatment of waste materials. By effectively separating and dewatering the waste stream, the system helps reduce the environmental impact of organic waste by minimizing the potential for nutrient runoff, leaching, and contamination of water sources.

4. *Resource Recovery*: The centrifuge system allows for the recovery of valuable resources from the waste stream. The separated liquid fraction can undergo further treatment or be discharged responsibly, while the drier solid fraction can be utilized for nutrient recovery, composting, or other beneficial applications in agriculture or other industries.

The proposed centrifuge system aligns with the objectives of the NRCS Practice Standard 632 Waste Separation Facility (CPS 632) by providing an efficient and sustainable solution for managing organic waste. It offers a reliable means of achieving solid-liquid separation, dewatering of solids, and compliance with environmental regulations while enabling resource recovery.

Newtrient (www.newtrient.com), a company sponsored by the dairy industry with a focus on value-added and environmentally sustainable manure management, has conducted a comprehensive evaluation of technology classes in manure management and their effects on critical environmental indicators. As part of this evaluation, a thorough review of centrifuge technology has been conducted, including quantitative analysis, a summary discussion, and references to peer-reviewed literature. The detailed findings of this review are presented in Appendix A of this application.

Building upon the information provided in Appendix A, this section offers a brief discussion on the significant impact of centrifuge technology on key environmental indicators related to water quality, air emissions, and other relevant factors aligned with the objectives of Standard 632. In support of this discussion, Appendix B presents data from a specific commercial installation, offering visual representations and nutrient profiles that demonstrate the positive influence of integrating a Centrifuge system within a comprehensive manure management approach. Additionally, Appendix C contains the final report of the study conducted by Morgan Community College, focusing on the commercial installation and further insights into the effectiveness and benefits of centrifuge technology.

<u>Reducing the nutrient content and organic strength of the liquid stream</u>

One of the primary benefits of centrifuge technology is its ability to effectively separate solid and liquid fractions of manure to reduce nutrient content and organic strength. By subjecting the manure to high centrifugal forces, the centrifuge system facilitates the separation of solids, which are rich in nutrients and organic matter, from the liquid fraction. This separation process significantly reduces the nutrient content of the liquid portion, making it less concentrated in nutrients such as nitrogen and phosphorus. The reduced nutrient content in the liquid fraction has positive implications for water quality management, as it minimizes the potential for nutrient runoff and leaching, helping prevent water pollution.

Furthermore, the solid fraction obtained through centrifuge technology undergoes dewatering, resulting in a significant reduction in organic strength. The dewatered solids have a lower moisture content, which contributes to their improved handling and storage characteristics. The reduced organic strength of the solid fraction enhances its suitability for various beneficial uses, such as nutrient-rich soil amendments or potential feedstock for anaerobic digestion systems.

Reducing odor and gaseous emissions

By separating the solid and liquid fractions of manure, the centrifuge technology can help remove solid particles that are often associated with odor generation. Solid materials, such as manure solids, bedding, and organic matter, are often significant contributors to odor formation. By effectively separating and removing these solids, the centrifuge technology may indirectly contribute to odor reduction.

Additionally, the separation of solid and liquid fractions can also help reduce the overall organic strength of the manure. Organic matter and high levels of nutrients in liquid manure can contribute to the release of gaseous emissions, including ammonia, hydrogen sulfide, volatile organic compounds, and greenhouse gases contribute to air quality related issues. By reducing the nutrient content and organic strength of the liquid fraction through centrifuge separation, the potential for gaseous emissions and associated air quality related issues may be minimized.

Facilitating desirable waste handling and storage

Centrifuge technology facilitates desirable waste handling and storage by dewatering the solid fraction of manure, reducing its moisture content, and improving manageability. The process also separates and concentrates nutrient-rich solids, making them easier to store and transport. Additionally, the reduction in organic strength achieved through centrifugation enhances overall manageability and storage conditions.

The Deer Valley Dairy study demonstrated that the dewatered solids obtained through centrifugation had a reduced moisture content, with an average of 72% moisture compared to the initial manure's average of 96% moisture. This significant reduction in moisture content enhances the handling and storage properties of the dewatered solids, making them more suitable for various applications.

Producing value added byproducts that facilitate manure and waste utilization

Centrifuge technology plays a critical role in producing value-added byproducts that facilitate the utilization of manure and waste. By effectively separating the solid and liquid fractions, the centrifuge system generates dewatered solids with reduced moisture content, making them ideal for various applications such as nutrient-rich soil amendments, bedding, or feedstock for anaerobic digestion. These dewatered solids offer improved handling and storage properties, providing a valuable resource for agricultural and energy production purposes. Simultaneously, the liquid fraction, with its reduced nutrient content, can be utilized for irrigation or undergo further treatment. This integrated approach not only promotes sustainable waste management but also maximizes the utilization of manure and waste resources, creating additional value and contributing to environmental and economic sustainability.

RANGE OF VOLUMETRIC AND MASS FLOW CAPACITIES AS WELL AS HYDRAULIC RETENTION TIME

The following section provides an overview of key parameters related to the performance of centrifuge systems in manure management:

- *Volumetric Flow*: The specific volumetric flow capacity of a centrifuge system can vary depending on the model and configuration. It is important to consider factors such as the size of the centrifuge, the desired throughput, and the characteristics of the waste stream to determine the appropriate volumetric flow capacity. Based on industry averages, centrifuge systems used for processing dairy manure generally have volumetric flow capacities ranging from 5 to 700 gallons per minute (gpm) or more.

- *Mass Flow*: The mass flow capacity of a centrifuge is influenced by factors such as the design of the centrifuge, the feed rate, and the properties of the waste material. Different centrifuge models offer varying mass flow capacities to accommodate different waste management requirements. The mass flow capacity of a centrifuge system for dairy manure can range from several hundred pounds per hour to several tons per hour.

- *Hydraulic Retention Times (HRT):* The hydraulic retention time in centrifuges processing dairy manure typically ranges from less than a minute to several minutes. The specific HRT will depend on the volumetric flow rate, the volume of the centrifuge, and the desired level of separation and processing. Optimizing the HRT allows for effective separation of solids from the liquid fraction while achieving the desired quality of both fractions.

DESIRED FEEDSTOCK CHARACTERISTICS

Feedstock are the materials fed into centrifuge systems for intended means of separation. In the context of centrifuge systems for waste management, there are certain desired feedstock characteristics that contribute to optimal performance and efficient operation. These characteristics include:

1. *Solid-Liquid Separation:* Centrifuge systems are designed to effectively separate solid particles from the liquid fraction of the waste material. Therefore, a desired feedstock characteristic is a sufficient concentration of solid particles that can be effectively separated by the centrifuge. The feedstock should have a balance between solid content and fluidity to ensure efficient separation and minimize clogging or blockages.

2. *Particle Size Distribution*: The particle size distribution of the feedstock is another important consideration. The ideal feedstock for centrifuge systems has a particle size distribution that allows for effective separation without excessive wear on the centrifuge components. It is desirable to have a range of particle sizes, including both smaller particles that can be efficiently separated and larger particles that are easily dewatered.

3. *Moisture Content*: The moisture content of the feedstock is a critical parameter that influences the efficiency of the centrifuge system. Ideally, the feedstock should have a moisture content that allows for efficient dewatering of the separated solids. Too high of a moisture content can result in reduced dewatering efficiency and increased energy consumption, while too low of a moisture content can lead to excessive dryness and difficulty in handling the separated solids. In general, a moisture content of around 70-80% is often considered optimal for centrifuge systems, as it allows for efficient dewatering while maintaining the physical integrity of the solids.

4. *Nutrient Content*: Depending on the intended application of the separated fractions, the nutrient content of the feedstock may be a desired characteristic. For example, in agricultural settings, a lowered nutrient content in the liquid fraction can make it more suitable for irrigation purposes, while the solid fraction with enhanced nutrient content can be used as nutrient-rich soil amendments.

Generally, the input should be sand-free raw or processed manure. It's important to note that the capabilities and specifications of the centrifuge system itself will also influence the desired feedstock characteristics.

EXPECTED SYSTEM PERFORMANCE

Centrifuge technology offers efficient solid-liquid separation and dewatering capabilities, providing the potential for significant improvements in waste management and resource utilization. The system's performance can be evaluated based on criteria such as separation efficiency, solids dryness, nutrient concentration, and overall operational reliability. By understanding the expected system performance, stakeholders can make informed decisions regarding the implementation and optimization of centrifuge technology in their waste management processes.

- *Changes in form or handling characteristics*
    - By effectively separating the solid and liquid fractions, centrifuges transform the consistency and properties of the waste stream. The solid fraction obtained through centrifugation undergoes dewatering, resulting in reduced moisture content and improved handling characteristics. The dewatered solids exhibit a higher degree of dryness, making them easier to store, transport, and utilize in various applications. The reduced moisture content also contributes to odor reduction and mitigates the potential for leachate formation during storage. Simultaneously, the liquid fraction undergoes a transformative process, becoming virtually free of non-colloidal and suspended solids after centrifugation. This refinement significantly minimizes sedimentation in downstream tanks and lagoons, particularly benefiting dairies utilizing the manure water for irrigation/fertigation. The reduction in solids content not only facilitates smoother irrigation nozzle operation but also lessens the need for maintenance due to plugging.
- *Nutrient fate or end use projections*
    - The nutrient fate projections following the separation process illustrate distinct destinies for the solid and liquid portions. In the stackable solid fraction, a significant portion of phosphorus (P) is concentrated, making it a valuable source for land application as nutrient-rich soil amendments. Additionally, a substantial amount of organic nitrogen (N) and carbon (C) becomes part of the solids, contributing to their nutrient content. On the other hand, the liquid fraction retains nearly all soluble nitrogen (ammonium and nitrates, nitrites), potassium (K), and experiences minimal loss in nitrogen content. This preservation of soluble nutrients in the liquid fraction proves beneficial for water quality management, minimizing the risk of nutrient runoff, leaching, and potential water pollution. The refined liquid fraction, with its nutrient concentration, offers opportunities for

further treatment or controlled irrigation, facilitating targeted nutrient application to crops while mitigating environmental impacts.

- *Macro-nutrient reductions or transformations*
    - See 'Nutrient fate or end use projections' above.
- *Pathogen reductions or eliminations*
    - A study by Zong Liu et al. (2017) investigated the impact of centrifuge separation on pathogen reduction in dairy manure. The research found that centrifugation at high "g"-forces achieved significant reductions in bacterial indicator levels in the liquid stream of the manure, demonstrating potential for pathogen elimination. However, the study also highlighted the need for further research and equipment optimization to enhance pathogen reduction and address emerging concerns related to zoonotic pathogen control.
    - Centrisys makes no pathogen reduction benefit claims with their equipment.
- *Air emissions*
    - By effectively separating solids from the liquid fraction, the centrifuge helps to minimize the release of volatile organic compounds (VOCs) and other odorous compounds into the air. The removal of solids can significantly reduce the overall organic load and potential for anaerobic decomposition, which is a major source of odors and gaseous emissions. Additionally, the dewatering process in centrifuges can result in a reduction in moisture content, further decreasing the potential for anaerobic conditions and the production of odorous gases.
- *Water emissions*
    - Centrifugation can help reduce the volume and concentration of nutrients and other contaminants in the liquid effluent. This process aids in minimizing the potential for nutrient runoff, leaching, and pollution into water bodies. Additionally, the dewatering of solids through centrifugation reduces the moisture content, resulting in a more concentrated and manageable solid product. This facilitates the storage, handling, and transport of the solids, reducing the risk of water contamination during these processes. Overall, centrifuge technology offers effective control over fugitive emissions, ensuring the responsible management of manure and minimizing the impact on water resources and ecosystems.

PROCESS MONITORING AND CONTROL SYSTEM REQUIRMENTS

Process monitoring and control systems are crucial for optimizing the performance of centrifuge technology in manure management. These systems enable real-time monitoring and control of key parameters specific to centrifuge operations, ensuring efficient and effective separation of solids and liquids.

- *Required monitoring*— A comprehensive process monitoring system for centrifuge technology in manure management should include monitoring of key parameters such as centrifuge speed, feed rates, discharge rates, solids content, and moisture content. Additionally, monitoring of pressure differentials, temperature, and vibration can provide valuable insights into the operational performance of the centrifuge system. Real-time monitoring of these parameters allows operators to identify any deviations from desired operating conditions and take corrective actions promptly.
- *Required control*— To ensure optimal performance and efficiency, a robust control system is necessary for centrifuge-based manure management. This includes control over centrifuge speed, feed rates, discharge rates, and cake thickness. The control system should enable precise adjustments and automation of these parameters to maintain optimal separation efficiency and maximize the quality of the separated fractions. Additionally, automated controls for equipment such as polymer dosing systems, pumps, and valves can enhance the overall efficiency and reliability of the centrifuge system when these are used.
- *Equipment included for monitoring*— A comprehensive process monitoring system for centrifuge technology may include various equipment, such as sensors, probes, and meters, to measure and monitor key parameters. This can include flow meters, pressure transducers, moisture sensors, temperature sensors, and vibration sensors. Data acquisition systems and software are also essential for collecting and analyzing the monitoring data in real-time.
- *Equipment included for controlling*— The control system for centrifuge-based manure management may involve equipment such as variable frequency drives (VFDs) to control the speed of the centrifuge motor. Additionally, automated valves, pumps, and dosing systems may be included to regulate feed rates, discharge rates, and polymer dosing. Programmable logic controllers (PLCs) or other control devices are utilized to integrate and manage the control functions, providing precise control over the centrifuge operation.

TYPICAL OPERATIONS/MAINTENANCE PLAN WITH MONITORING REQUIREMENTS AND REPLACEMENT SCHEDULE

A typical operations and maintenance plan for centrifuge technology in manure management includes regular monitoring requirements and a replacement schedule to ensure reliable and efficient operation of the system.

Monitoring Requirements:

1. *Daily Monitoring*: Perform daily checks of key parameters such as centrifuge speed, feed rates, discharge rates, and cake thickness. Monitor the solids content and moisture content of the separated fractions. Inspect pressure differentials, temperature, and vibration levels.

2. *Regular Sampling*: Conduct regular sampling of the influent, effluent, and separated fractions to assess the nutrient content, particle size distribution, and pathogen levels. Analyze the samples in a laboratory to evaluate the performance of the centrifuge system.

3. *Data Logging*: Utilize a data acquisition system to continuously log and store monitoring data for analysis and trend identification. Monitor trends in performance indicators over time to identify any deviations or potential issues.

Replacement Schedule:

1. *Wear Parts*: Identify and maintain a schedule for the replacement of worn parts, such as centrifuge screens, seals, and bearings. Replace these components based on manufacturer recommendations or when signs of wear and deterioration are observed.

2. *Maintenance Intervals*: Schedule regular maintenance intervals for cleaning, lubrication, and inspection of critical components. Follow the manufacturer's guidelines for maintenance tasks and frequency.

3. *Sensor Calibration*: Calibrate monitoring sensors, probes, and meters periodically to ensure accurate measurement and reliable data.

The operations and maintenance plan should be tailored to the specific centrifuge model and manufacturer recommendations. Adherence to the plan, along with regular monitoring and timely replacement of worn components, will help maximize the longevity, efficiency, and performance of the centrifuge system. Regular maintenance and monitoring allow for early detection of potential issues, reducing downtime and improving overall operational reliability.

CHEMICAL INFORMATION

Centrifuge technology in manure management may involve the use of chemicals for various purposes, such as in coagulation and flocculation processes. The specific chemicals used, and their quantities will depend on the specific centrifuge system and the desired treatment objectives. It is essential to consider the following aspects:

1. *Coagulation*: Coagulation is a chemical process that utilizes alum (aluminum sulfate), ferric chloride, or other chemicals to neutralize the charge of suspended particles, forming small flocs. The selection and dosage of coagulant chemicals will depend on the specific requirements of the centrifuge system.
2. *Flocculation*: Flocculation is a physical process that allows for the binding of the smaller flocs together, making them larger and easier to separate from a liquid stream. Polyacrylamides, a type of polymer, are a commonly used chemical to enhance the formation and size of flocs. To optimally perform flocculation, coagulation is a necessary preceding step. The selection and dosage of polymers will depend on the specific requirements of the centrifuge.
3. *Compatibility and Environmental Considerations*: When using chemicals in centrifuge systems, it is crucial to consider their compatibility with the manure and the potential environmental impacts. Ensure that the selected chemicals are suitable for the intended application and will not negatively affect the quality of the separated fractions or pose risks to the environment.
4. *Safety and Handling*: Follow proper safety protocols and guidelines when handling and storing chemicals. Ensure that operators are trained in the safe use and handling of chemicals, including wearing appropriate personal protective equipment (PPE) and following applicable regulations and guidelines.

ESTIMATED INSTALLATION AND OPERATION COST

Industry averages provide a general estimate of the expenses involved in acquiring and installing centrifuge technology. It is important to note that these costs are subject to variation based on specific project requirements and market conditions.

<u>Equipment and Installation Capital Costs</u>

The equipment costs include the purchase of the centrifuge system, which comprises the main centrifuge unit, associated controls, and any necessary ancillary equipment. As of 2023, industry averages suggest that the capital cost of a centrifuge system can range from $400,000 to $750,000 or more, depending on factors such as capacity, design specifications, and additional features.

Operation and Maintenance Costs (O&M)

- ***Electrical—*** Electrical consumption is a significant component of the operational costs for a centrifuge system. The power requirements of the centrifuge unit, auxiliary equipment, and control systems contribute to the electrical expenses. The exact electrical costs will depend on factors such as the size and efficiency of the equipment, operating hours, local electricity rates, and any energy-saving measures implemented. On average, electrical costs can range from several hundred to several thousand dollars per month.
- ***Labor—*** Labor costs are another important aspect of operating a centrifuge system. These costs include the wages of the personnel responsible for operating and monitoring the system, conducting routine maintenance tasks, and troubleshooting any operational issues. Generally, the time commitment for system management can range from a few hours per week to several hours, depending on the complexity of the equipment and the volume of waste being processed. The specific labor costs will depend on factors such as the system's complexity, the required level of staffing, and the prevailing labor rates in the area.
- ***Maintenance Replacement—*** Maintenance costs may include the periodic replacement of components, such as gaskets, seals, bearings, and filters. The frequency and extent of maintenance requirements will depend on the manufacturer's recommendations, the operating conditions, and the system's utilization. It is important to budget for ongoing maintenance costs to keep the centrifuge system operating efficiently and minimize any potential downtime or performance issues.

EXAMPLE WARRANTY

The warranty for a centrifuge system can vary depending on the manufacturer and the specific terms and conditions of the warranty agreement. Typically, centrifuge manufacturers provide warranties to cover defects in materials and workmanship for a specified period. As an example, a typical warranty for a centrifuge system may include:

1. *Equipment Warranty*: The centrifuge equipment is warranted against defects in materials and workmanship for a specific period, typically ranging from one to three years. During this period, the manufacturer will repair or replace any components or parts that are found to be defective due to manufacturing issues.
2. *Performance Warranty*: Some manufacturers may offer a performance warranty that guarantees the system's performance and functionality. This warranty ensures that the centrifuge system will meet or exceed certain performance

specifications, such as separation efficiency or capacity, as specified in the warranty agreement.

3. *Extended Warranty Options*: Manufacturers may provide the option to purchase extended warranties for additional coverage beyond the standard warranty period. These extended warranties can offer continued protection and peace of mind for an extended duration, typically for an additional cost.

It is important to carefully review the warranty terms and conditions provided by the manufacturer to understand the coverage, exclusions, and any specific requirements or limitations. It is also advisable to maintain proper documentation, such as records of maintenance and service performed, to comply with the warranty requirements.

It is worth noting that warranty coverage may differ between different components or parts of the centrifuge system, such as the centrifuge unit, control panel, motors, or other accessories. Therefore, it is essential to review the warranty details for each specific component included in the centrifuge system.

Overall, the warranty provides assurance that the centrifuge system is free from defects and will perform as intended within the specified warranty period. It is recommended to consult with the manufacturer or authorized dealers for the specific warranty information pertaining to the centrifuge system being considered.

RECOMMENDED RECORD KEEPING

Proper record-keeping is essential for the effective management and maintenance of a centrifuge system. It allows for accurate monitoring, troubleshooting, and evaluation of system performance. The following are recommended record-keeping practices for a centrifuge system:

1. *Operating Logs*: Maintain detailed operating logs that document the operation of the centrifuge system. These logs should include information such as operating hours, flow rates, process parameters, maintenance activities, lengths and frequencies of downtimes, and any observations or issues encountered during operation. These records help track system performance, identify trends, and provide valuable information for troubleshooting and optimizing the system.

2. *Maintenance Records*: Keep records of all maintenance activities performed on the centrifuge system. This includes routine maintenance tasks such as lubrication, inspection, cleaning, and calibration. Record the date, nature of the maintenance task, parts replaced or repaired, and any notes or observations related to the maintenance activity. These records ensure that maintenance is

performed regularly and in accordance with manufacturer recommendations, promoting the longevity and reliability of the centrifuge system.

3. *Service and Repair History*: Maintain a comprehensive history of any service or repair performed on the centrifuge system. This includes records of any professional servicing, repairs, or component replacements conducted by authorized technicians or service providers. These records help track the overall performance and reliability of the system, as well as provide valuable information for warranty claims or future maintenance needs.
4. *Performance Data*: Collect and record performance data related to the centrifuge system, such as separation efficiency, solids content in the effluent, nutrient concentration, or any other relevant parameters. This data can be used for system evaluation, comparison, and optimization over time. It also aids in meeting regulatory compliance requirements and demonstrating the system's effectiveness in achieving desired outcomes.
5. *Training and Certification Records*: Keep records of training and certification for operators and maintenance personnel involved in the operation and maintenance of the centrifuge system. Document the dates of training, topics covered, and certifications obtained. These records demonstrate the qualifications and competence of the personnel responsible for the system's operation and maintenance.

Maintaining organized and up-to-date records allows for effective system management, troubleshooting, and compliance with regulatory requirements. These records provide valuable historical information, support system optimization, and contribute to the overall efficient and reliable operation of the centrifuge system.

ALTERNATIVES FOR THE USE OF BYPRODUCTS

The byproducts generated from the centrifuge system offer various alternatives for their utilization, promoting sustainable waste management and resource recovery. Some potential alternatives for the use of these byproducts include:

1. *Soil Amendments*: The dewatered solids from the centrifuge, which are rich in nutrients and organic matter, can be utilized as soil amendments. They can be applied to agricultural fields, pastures, or gardens to improve soil fertility, enhance nutrient availability, and promote plant growth. The nutrient content of the dewatered solids can be tailored to meet specific crop or soil requirements through appropriate blending or nutrient management strategies.

2. *Anaerobic Digestion*: The dewatered solids can serve as a potential feedstock for anaerobic digestion systems. Anaerobic digestion is a biological process that converts organic matter into biogas, a renewable energy source, and produces digestate as a byproduct. By introducing the dewatered solids into anaerobic digesters, biogas production can be enhanced, contributing to renewable energy generation while further reducing the organic strength of the byproducts.

3. *Composting*: The dewatered solids can be composted to produce high-quality organic compost. Composting is a natural process that converts organic materials into a stable, nutrient-rich soil amendment. The dewatered solids, when combined with other organic materials such as yard waste or agricultural residues, can undergo controlled decomposition, resulting in the production of compost that can be used for landscaping, horticulture, or soil improvement purposes.

4. *Biomass Conversion*: The dewatered solids can be used as a potential feedstock for biomass conversion technologies. These technologies include thermal processes such as pyrolysis or gasification, which convert biomass into biochar, syngas, or bio-oil. These products can be utilized for energy production, soil amendment, or as precursor materials for bio-based products.

5. *Nutrient Recovery*: The liquid fraction obtained from the centrifuge, which has reduced nutrient content, can undergo further treatment for nutrient recovery. Technologies such as struvite precipitation or nutrient stripping can be employed to extract valuable nutrients such as phosphorus and nitrogen from the liquid fraction. These recovered nutrients can be used as fertilizers or sold as nutrient-rich products.

6. *Bedding*: The dewatered solids obtained from the centrifuge can have reduced moisture content and improved handling characteristics, making them suitable for use as comfortable and absorbent bedding for animals.

7. *Other Applications*: Depending on the specific characteristics and composition of the byproducts, there may be other potential applications. For example, if the dewatered solids have unique properties such as high fiber content, they can be explored for use in the production of bio-based materials or specialty products.

Exploring and implementing alternative uses for the byproducts generated from the centrifuge system not only helps in reducing waste and environmental impact but also presents opportunities for resource recovery, energy generation, and value-added product development. The choice of the most suitable alternative will depend on factors such as local market demand, regulatory requirements, and the specific characteristics of the byproducts.

INDEPENDENT VERIFIABLE DATA DEMONSTRATING RESULTS/CREDENTIALS

Appendix A is a summary of the independent review of peer-reviewed and technical data available for this class of technology and is available through Newtrient. The Newtrient work involves an internal peer-review, comprised of ten national experts in the field of manure management, with the final output presently being prepared for external peer-review and publication. While the reference list is not a complete listing of all related peer-reviewed literature it does highlight key references specific to this class of technology and how it relates to key performance indicators within this NRCS Standard 632.

Appendix B is a summary of data obtained during a Newtrient-managed third-party review of a Centrisys Decanter Centrifuge system at Deer Valley Dairy in Fort Morgan, CO. The information was from a 15-week analysis of the system and its performance by the Morgan Community College—the work has not been peer-reviewed.

Appendix C is the complete Morgan Community College report detailing the third-party review at Deer Valley Dairy in Fort Morgan, CO.

CONTACT INFORMATION—VENDOR

While not an absolutely conclusive list, the list below identifies vendors that are active in the application of this class of technology on manure projects within the US.

1. ***DariTech, Inc. – Decanting Centrifuge***
   Address: 8540 Benson Rd. Lynden, WA
   Phone: 360-354-6900
   Website: https://daritech.com/
   Contact: steve@dt-environmental.com
   Company Information: DariTech, Inc., as a leading provider of innovative dairy manure handling systems throughout North America, has joined up with Vision Machine, Inc., to bring you the most cost efficient, durable decanter centrifuge on the market. U.S. built, with field serviceable wear parts, DT centrifuges provide modern dairy operations with the ability to manage their manure as best fits the operation. From closed loop flush dairies that use little water, to center pivot irrigation without clogging nozzles, to compact and simple nutrient recovery, DT centrifuge systems are customized for dairy goals.

2. ***GEA Houle – Decanting Centrifuge***
   Address: 1880 Country Farm Dr. Naperville, IL
   Phone: 630-453-8867
   Website: https://www.gea.com/en/index.jsp
   Contact: jeramy.sanford@gea.com

Company Information: The WaterMaster decanter from GEA is a continuously operating centrifuge with a horizontal solid-wall bowl developed specifically for the requirements of dewatering industrial and municipal sewage sludge. The frame is of open design with gravity discharge of the clarified phase.

3. ***Centrisys/CNP – Decanter Centrifuge***
   Address: 9586 58th Place Kenosha, WI
   Phone: 262-747-2384
   Website: https://www.centrisys.com/
   Contact: info@centrisys-cnp.com
   Company Information: The Centrisys decanter centrifuge is a technology which utilizes centrifugal force to separate solids away from the liquid in the manure slurry. The slurry is spun at high speeds within the centrifuge and the separated solids are extracted with a concentrically mounted scroll conveyor. Because the technology applies centrifugal force to the slurry, higher levels of solids and nutrient removal are achievable as compared with conventional (screen-based) manure separation methods.

   Although Centrisys decanter centrifuges are used across a wide-array of industries, anywhere it is necessary to separate solids from liquid, the DT series decanter is a Centrisys product made specifically with manure processing in mind – with special considerations given to the abrasive and potentially variable nature of manure and manure systems.

4. ***Hiller – Decanting Centrifuge***
   Address: 1010 Mclean St. Lampasas, TX
   Phone: 855-556-5707
   Website: http://www.hiller-us.com/
   Contact: info@hiller-us.com
   Company Information: DecaPress DP - Hiller Separation & Process US offers the complete range of DecaPress DP Model horizontal decanter centrifuges incorporating decades of mechanical knowledge and process experience to provide an effective, low-maintenance solution for continuous liquid-solid separation, liquid clarifying and/or solids dewatering with advanced mechanical features and superior processing performance.

5. ***Kyte Centrifuge, LLC – Decanting Centrifuge***
   Address: 59 W. Bradford Hill Rd. Mills River, NC
   Phone: 832-368-2667
   Website: https://www.kytecentrifuge.com/
   Contact: dave@kytecentrifuge.com

Company Information: Capable of solids separation down to 25 microns or less. No screens of filter media used. No polymer or coagulants needed. Up to 40% dry solids discharge. Separates 55-75% of volatile solids. 30-50% less costly than new centrifuges.

6. ***Flottweg Centrifuges – Decanter Centrifuge***
   Address: 10700 Toebben Dr. Independence, KY
   Phone: (859) 448-2300
   Website: https://www.flottweg.com/
   Contact: sales@flottweg.net
   Company Information: With over 60 years of centrifuge design experience, Flottweg's custom-made decanter series is designed to fit the needs of various industries. The Flottweg decanter centrifuge is continuously automated to separate suspended fine solids and deliver an optimally clarified liquid phase with minimal operator effort. With a wide range of protective measures, Flottweg decanter centrifuges provide a potential reduction in maintenance costs. Several controls and features offer safety and security measures to both operators and the environment through monitoring systems to control vibration and speed and sealing systems to seal separation spaces from the atmosphere.

CONTACT INFORMATION—USER

Commercial facilities presently operating in the U.S. with this class of technology are identified above. The list is a best effort but may not be completely inclusive of all installations. For Centrisys Centrifuge alone – 2,000+ installations worldwide.

Decanter Centrifuge Technology

We are not authorized to provide this information.

OTHER CONSIDERATIONS

The NRCS documentation specifies that a third-party review shall contain 15 specific items that comprise the report above, but as part of working with the farm(s) and the technology provider during the 15-week evaluation period there are often other important and valuable learnings that may be helpful for NRCS and others as they consider this technology. Below is a list of Other Considerations that should be included in the evaluation of this technology:

- There were no additional insights into the evaluation of centrifuge technology beyond the specific items outlined in the NRCS documentation, identified during this study.

CONCLUSION

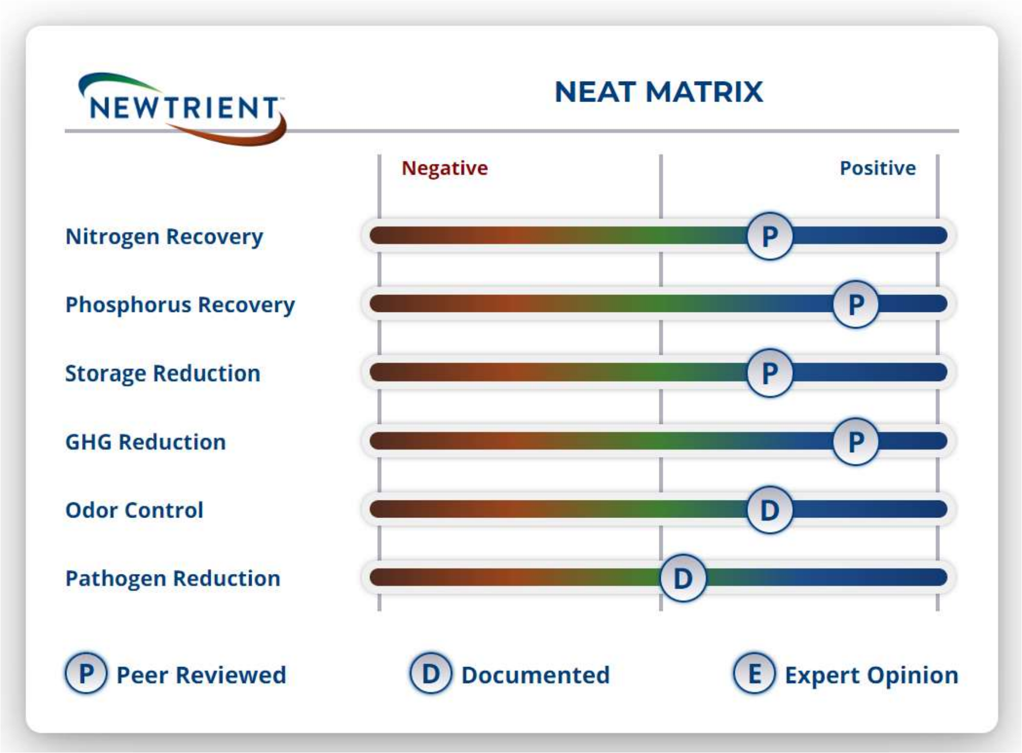
The incorporation of decanter centrifuges in dairy operations offers a range of benefits that contribute to enhanced reliability, performance, and efficiency. These centrifuges are designed to deliver optimal results based on the specific characteristics of each operation and the composition of the dairy feed. When compared to conventional equipment, decanter centrifuges stand out for their superior performance. They can separate out up to three times the total solids without the need for coagulants and polymers, and even greater results can be achieved with the use of additives. The phosphorus removal capabilities are remarkable, reaching 50 percent or more without chemical additions and up to 75 percent or more with chemical additions. Furthermore, decanter centrifuges offer cost savings due to simplified setup, reduced maintenance and cleaning time, and the ability to run autonomously.

The adoption of decanter centrifuges enables dairy farmers to manage manure effectively and efficiently, leading to economic and environmental advantages. By concentrating nutrients into manure solids, less hauling is required, helping producers meet nutrient removal permit requirements and reducing the frequency of storage lagoon dredging. Recycling manure liquid minimizes water use, while the recovered solids can be utilized as bedding material or soil amendments. Decanter centrifuges can also serve as a pretreatment step to enhance the efficiency, reliability, and throughput of advanced technologies such as ultrafiltration or vermifiltration. The superior phosphorus removal and reverse osmosis capabilities make decanter centrifuges a top choice in their class.

Overall, decanter centrifuges provide dairy operations with a cost-effective and efficient solution for managing manure, improving nutrient management, and promoting environmental sustainability. The advantages they offer in terms of solids and nutrient removal, cost savings, and the ability to meet regulatory requirements make them a valuable asset for dairy farmers seeking to optimize their operations and minimize their environmental footprint.

Appendix A

NEWTRIENT CRITICAL INDICATOR ANALYSIS—CENTRIFUGE



Overall Summary

Centrifuge technologies offer effective removal of non-dissolved particles from the waste stream, resulting in a lower solid-to-liquid ratio that can be used as stackable solids or high-quality "tea water" for irrigation. The technology shows significant variation in energy use, operational intensity, and cost depending on the specific site and the use of polymer. When used with polymer, the recovery rates and impact on critical indicators are improved.

Centrifuge technologies have a proven track record in various applications, including nitrogen and phosphorus recovery, reduction of storage needs, and odor control. The technology offers a reliable and efficient solution for managing waste, while also providing opportunities for nutrient recovery and environmental sustainability.

It is important to consider site-specific factors, such as the need for polymer use and the desired outcomes, to determine the most suitable Centrifuge technology and optimize its performance. By selecting the appropriate technology and operational parameters, dairy farmers can benefit from the positive impact on nutrient management, waste reduction, and overall environmental impact.

References

Liu Z., Carroll Z.S., Long S.C., Roa-Espinosa A., Runge T. Centrifuge separation effect on bacterial indicator reduction in dairy manure. J Environ Manage. 2017 Apr 15; 191:268-274. doi: 10.1016/j.jenvman.2017.01.022. Epub 2017 Jan 23. PMID: 28126613.

Appendix B

Third-Party Review of Centrisys Centrifuge System at Deer Valley Dairy – Fort Morgan, CO (Report Summary)

University Partner
William Miller
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JANUARY 2024

BACKGROUND

Phosphorus (P) accumulation in soils and water bodies poses a significant environmental challenge, largely fueled by the overuse of fertilizers and the subsequent increase in P content within crops and animal manure. This cyclical phenomenon disrupts the delicate balance of soil and water quality, necessitating a proactive approach to break the chain. Addressing the imbalanced P cycle becomes imperative, especially in situations where farms face challenges in managing surplus dairy manure. Farms often struggle with limited land availability, creating an imbalance between supply of manure and the land available to apply manure, and intensifying the need for innovative solutions to prevent excess P from entering the environment.

In response to this challenge, technologies like the centrifuge have emerged as promising interventions, offering a potential remedy by extracting fine solids and surplus P from dairy manure. Previous studies, such as those by Massey and Payne in 2019, have demonstrated the technology's remarkable high removal rates, indicating its potential to enhance flush water performance, and drastically reduce the costs associated with liquid effluent land application. Additionally, the practical reusability of separated solids as bedding and the cost-effective transport of partitioned nutrients over extended distances have been substantiated through research by Risse et al. in 2001.

Within the framework of the USDA Conservation Innovation Grant (CIG) project, Newtrient initiated a centrifuge evaluation at Deer Valley Dairy in Fort Morgan, CO. The objective of this study was to explore the performance and water quality advantages of the Centrisys Decanter Centrifuge in separating solids and nutrients from the dairy waste stream.

INTRODUCTION

In dairy, the efficient management of waste streams is pivotal to environmental stewardship. Centrifuges, specifically tailored for dairy applications, have emerged as promising solutions, reshaping the way dairy farms handle their waste. Designed with precision, these centrifuges play a pivotal role in separating solids from liquid waste streams, ensuring both efficient waste management and recovery of valuable resources.

At its core, a centrifuge operates as a sophisticated mechanical separator, employing the principles of sedimentation and centrifugal force to achieve efficient dewatering. The process begins with the introduction of a feed slurry—a mixture of solid particles and liquid—into the rotating bowl through a feed inlet. As the bowl spins at high speeds, often ranging from 2,000 to 4,000 revolutions per minute (rpm), centrifugal force propels denser solid particles to the outer edges of the bowl, creating a clear distinction between the solid phase, known as the cake, and the liquid phase, which collects in the center of the bowl from an overflow weir, referred to as the centrate or effluent.

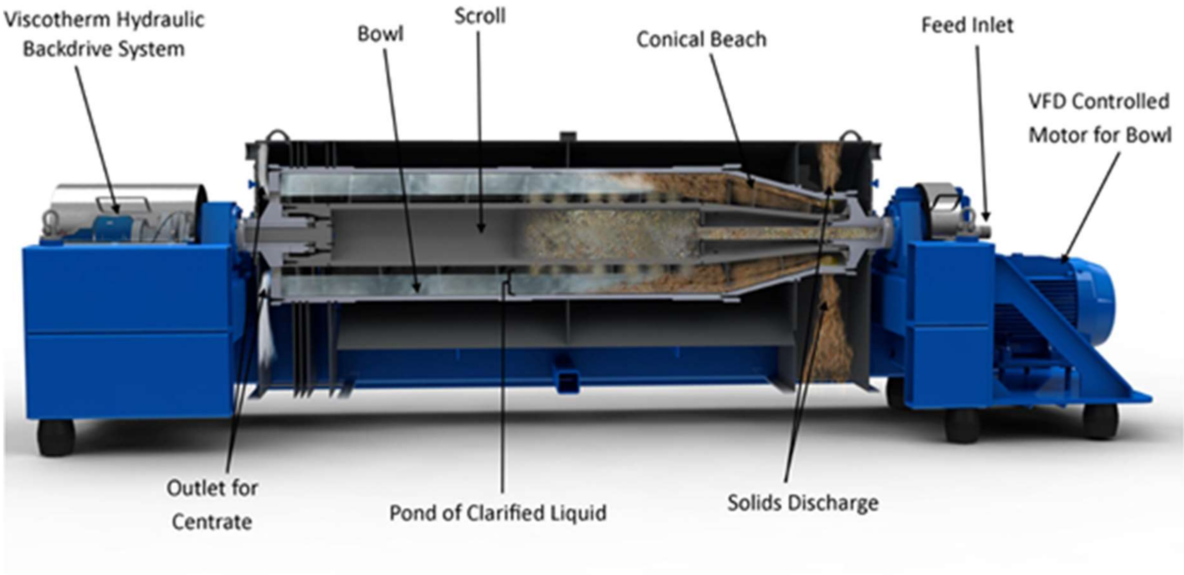

Figure 1. 2-Phase Decanter Centrisys Centrifuge System.

KEY COMPONENTS OF DECANTER CENTRIFUGES:

1. **Rotating Bowl:** The heart of the decanter centrifuge, the rotating bowl, initiates the separation process. Its rapid rotation generates centrifugal force, driving the separation of solids and liquids.

2. **Screw Conveyor:** Housed within the bowl, the screw conveyor swiftly transports the separated solid phase (cake) towards the discharge outlet, ensuring continuous and efficient processing.

3. **Drive System:** Providing the necessary power and control, the drive system facilitates the rotation of both the bowl and the screw conveyor, enabling seamless, uninterrupted operation.

METHODOLOGY

Throughout the study, a total of five different samples were collected three times a week for 15 weeks from Deer Valley Dairy, using a Centrisys CS30-4 centrifuge for separation. The sampling process involved determining liquid inflow and outflow rates through a static sloped screen separator and the centrifuge. Manure was passed over a static sloped screen at an average flow rate of 491 gallons per minute (gpm). The collected solids were categorized as coarse (from the screen) and fine (from the centrifuge). Three liquid samples were collected: "Liquid 1" from the sloped screen inflow, "Liquid 2" from the discharge pipe to storage ponds, and "Liquid 3" after passing through the centrifuge and destined for crop irrigation.

Each of the 45 samples were stored appropriately, and those sent to an external lab were packed in ice and shipped weekly to A&L Great Lakes Laboratories in Fort Wayne, IN.

DISCUSSION OF RESULTS

KEY BENEFITS OF A CENTRIFUGE

The study conducted at Deer Valley Dairy provides valuable insights into the composition of solid and liquid samples collected. The research aimed to understand the impact of centrifuge operations on various analytes (substances being analyzed), shedding light on the efficiency of the separation process. This comprehensive analysis evaluated both solid and liquid components, providing a holistic view of the dairy waste processing system.

Performance: The centrifuge exhibited outstanding performance in the separation of solids from liquid waste, as evidenced by the significant enrichment of key elements in the fine solid samples compared to coarse solids (Table 1). Elements such as aluminum, iron, manganese, phosphorus, and copper displayed remarkable enrichment factors, indicating the centrifuge's effectiveness in removing these components from the liquid waste stream. Additionally, the observed depletion of analytes in the liquid samples after centrifugation illustrated the technology's efficiency in eliminating solid particles and associated nutrients.

Table 1. Solid Measurements.

	Coarse Solids (n =39)			Fine Solids (n=39)		
	Mean	Median	Std. Dev.	Mean	Median	Std. Dev.
Moisture	83.83	84.87	2.49	71.79	72.13	2.28
Organic Matter (%)	14.31	13.68	1.95	19.89	19.66	1.96
Organic Carbon (%)	8.33	7.95	1.13	11.54	11.40	1.14
C:N	31.8	31.6	4.5	23.7	23.7	2.6
Kjeldahl Nitrogen (%)	0.264	0.261	0.036	0.489	0.490	0.034
Ammonium (%)	0.059	0.060	0.023	0.082	0.080	0.016
Organic Nitrogen (%)	0.205	0.208	0.043	0.407	0.406	0.033
Phosphorus (%)	0.043	0.044	0.008	0.154	0.150	0.019
Potassium (%)	0.108	0.107	0.019	0.140	0.141	0.015
Sulfur (%)	0.05	0.05	0.01	0.10	0.10	0.01
Magnesium (%)	0.06	0.06	0.01	0.18	0.18	0.02
Calcium (%)	0.21	0.19	0.06	0.76	0.74	0.09
Sodium (%)	0.07	0.07	0.01	0.07	0.07	0.01
Aluminum (ppm)	104.2	99.0	27.6	585.5	564.0	98.7
Copper (ppm)	6.6	6.4	2.8	18.9	19.0	5.1

Iron (ppm)	125.0	120.0	41.4	611.5	589.0	89.1
Manganese (ppm)	8.4	8.1	1.7	32.7	32.0	3.6
Zinc (ppm)	14.7	15.0	3.6	39.5	39.0	6.9

Enhanced Nutrient Concentration: The study revealed a substantial increase in essential nutrients, including phosphorus, organic carbon, and organic nitrogen, in the fine solid samples. This enrichment implies that the centrifuge technology effectively concentrates valuable nutrients present in dairy waste. Such enhancement is crucial for agricultural applications, as nutrient-rich organic matter is highly beneficial for soil fertility and plant growth. The concentrated organic material obtained through centrifugation can serve as a valuable organic fertilizer, promoting sustainable farming practices.

Visual analysis (Figure 2) provided tangible evidence of enrichment, with the fine solids appearing darker and nutrient-rich compared to coarse solids. This visual confirmation underlines the technology's effectiveness in enhancing organic matter and nutrient content in the separated material.

Figure 2. Fine and Coarse Solids Comparison.

Phosphorus enrichment, a critical element for plant growth, occurred nearly four-fold without the use of polymers. This efficient phosphorus concentration highlights the technology's potential to enhance soil fertility. The positive correlation observed between phosphorus enrichment and solid material (Figure 3) indicates the consistent performance of the centrifuge. Understanding such correlations can aid in optimizing the separation process, ensuring a more precise concentration of valuable nutrients.

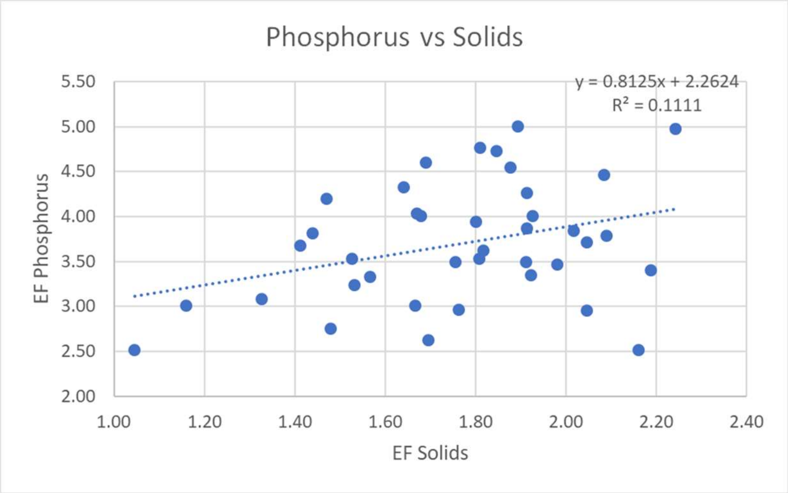

Figure 3. Linear Regression of Phosphorus vs. Solids.

Reduced Water Content and Efficient Land Application: The reduction in moisture content observed in fine solids indicates the efficient removal of excess water during the centrifugation process. This reduction not only makes the waste material more concentrated but also enhances its suitability for land application. Lower moisture content increases the cost efficiency of transportation, handling, and application, making the process more economically viable for farmers.

Potential for Crop Irrigation: Although diluted, the liquid effluent fraction still contains valuable nutrients (Table 2). The ability to use this nutrient-enriched effluent for crop irrigation is significant. It minimizes waste by recycling nutrients back into agricultural systems, thereby reducing the environmental impact of dairy operations. Additionally, the reduction of clogging issues in the irrigation system makes the technology more practical for real-world agricultural applications.

Table 2. Liquid Measurements.

	Liquid 1 (n = 39)		Liquid 2 (n = 31)		Liquid 3 (n =39)	
	Mean	Median	Mean	Median	Mean	Median
Moisture	95.80	95.79	96.62	96.72	97.85	97.85
Organic Matter (%)	3.18	3.05	2.39	2.36	1.32	1.28
Organic Carbon (%)	1.85	1.77	1.39	1.37	0.77	0.74
C: N	10.9	10.9	8.3	8.4	5.2	5.1
Kjeldahl Nitrogen (%)	0.168	0.169	0.166	0.165	0.145	0.148
Ammonium (%)	0.064	0.070	0.064	0.070	0.067	0.070
Organic Nitrogen (%)	0.104	0.106	0.102	0.104	0.078	0.077
Phosphorus (%)	0.031	0.034	0.032	0.033	0.024	0.023
Potassium (%)	0.099	0.105	0.104	0.106	0.101	0.102
Sulfur (%)	0.03	0.03	0.02	0.03	0.02	0.02
Magnesium (%)	0.04	0.04	0.04	0.04	0.03	0.03
Calcium (%)	0.11	0.11	0.11	0.11	0.07	0.07
Sodium (%)	0.07	0.07	0.07	0.07	0.07	0.07

Aluminum (ppm)	61.41	59.00	56.81	57.00	31.85	29.00
Copper (ppm)	3.88	4.00	3.89	4.00	2.88	2.80
Iron (ppm)	59.31	54.00	49.84	48.00	23.15	22.00
Manganese (ppm)	4.84	5.00	4.87	5.00	3.18	3.20
Zinc (ppm)	9.56	9.90	9.84	10.00	7.72	8.00

KEY ISSUES AND CHALLENGES

It is worth noting that the provided report focused more on presenting findings and results rather than explicitly highlighting key issues and challenges. Therefore, the identified challenges are inferred based on the information provided in the report.

Performance and Enrichment Factors: The study revealed that the enrichment factors of various analytes differed between the fine and coarse solid samples. While most analytes showed enhancement in the fine solids, sodium was an exception. Understanding and optimizing the performance and enrichment factors of the centrifuge posed a challenge to maximize the separation of solids and nutrients effectively. Research and refinement are necessary to address this challenge comprehensively.

Although not used during this study, one consideration to further enhance nutrient enrichment would be the use of chemicals in coagulation and flocculation processes. Coagulation is a chemical process that utilizes alum (aluminum sulfate), ferric chloride, or other chemicals to neutralize the charge of suspended particles, forming small flocs. Flocculation is a physical process that allows for the binding of the smaller flocs together, making them larger and easier to separate from a liquid stream. Polyacrylamides, a type of polymer, are a commonly used chemical to enhance the formation and size of flocs. The selection and dosage of chemicals depends on the amount of solids and nutrients one wants to remove from the waste stream. As much as 70% of the nitrogen and 95% percent of the phosphorus can be removed when both a coagulant and polymer are used.

Depletion in Liquid Samples: The analysis of the liquid samples indicated a depletion of analytes as they progressed from the sloped screen to the centrifuge and further to the irrigation system. The centrifuge was found to be a significant contributor to this depletion. Managing and mitigating the loss of nutrients during the centrifuge process presented a challenge for ensuring efficient nutrient recovery and utilization. Understanding the factors contributing to this discrepancy poses a challenge, requiring further investigation. Addressing this issue is vital to ensure a comprehensive understanding of nutrient dynamics during the separation process.

IMPLICATIONS

This evaluation emphasizes the importance of operational protocols and equipment functionality in ensuring the technology's optimal performance. While the Centrisys Decanter Centrifuge offers notable benefits in nutrient enrichment, challenges persist in achieving uniform depletion and optimizing enrichment factors. Addressing these issues through further research and development efforts is essential to harness the technology's full potential within the dairy context.

In conclusion, the study demonstrates that centrifuge technology holds significant promise for dairies. Its ability to concentrate valuable nutrients, reduce water content, remove additional solids, and offer potential applications in agriculture makes it a valuable tool for promoting environmental stewardship within the dairy industry. Addressing the identified challenges and conducting further research will pave the way for the widespread adoption of this technology, contributing to a more sustainable dairy industry. For additional information on the vendor, environmental impacts, financial implications, and Centrisys Decanter Centrifuge technology visit the Centrisys Vendor Snapshot on the Newtrient website.

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Risse, L.M., M.L Cabrera, A.J. Franzluebbers, J.W. Gaskin, J.E. Gilley, R. Killorn, D.E. Radcliffe, E.W. Tollner, and H. Zhang. 2001. Land Application of Manure for Beneficial Reuse. lpelc

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Appendix C

Third-Party Review of Centrisys Centrifuge System at Deer Valley Dairy in Fort Morgan, CO. (Full Report)

Deer Valley Dairy

prepared by William Miller and Steven Sjostedt

Introduction

As part of the USDA Conservation Innovation Grant (CIG) project Newtrient has four technologies that were selected for first year waste studies. Among them was the evaluation of performance and water quality advantages of utilizing a Centrisys Centrifuge in separating solids and nutrients from the dairy waste stream at the Deer Valley Dairy in Fort Morgan, CO. High removal rates can improve flush water performance and reduce land application costs of liquid effluent (Massey and Payne, 2019). Separated solids can be used as bedding and partitioned nutrients in solids can be hauled longer distances more economically (Risse et. al., 2001).

Methods

Sampling methods are as follows: Liquid inflow and outflow rates through the sloped screen and centrifuge will be determined. The composited samples were transferred to appropriate containers (bags for solids and bottles for liquids). The manure was passed over a gravity-inclined (sloped) screen at an average flow rate of 491 gallons per minute. The solids collected by the sloped screen were referred to as coarse and the solids that were removed from the centrifuge were listed as fine. The inflow to the sloped screen was also where the first liquid sample (Liquid #1) was collected. The second liquid sample (Liquid #2) was collected from a pipe carrying the discharge from the screen to a series of storage ponds outside the structure housing the centrifuge (Secondary Storage Pond, see Diagram 1). The final liquid sample (Liquid #3) was collected after passing through the centrifuge (Filtration Storage Pond), on its way to a center-pivot that would be used to irrigate crops with nutrient enhanced water.

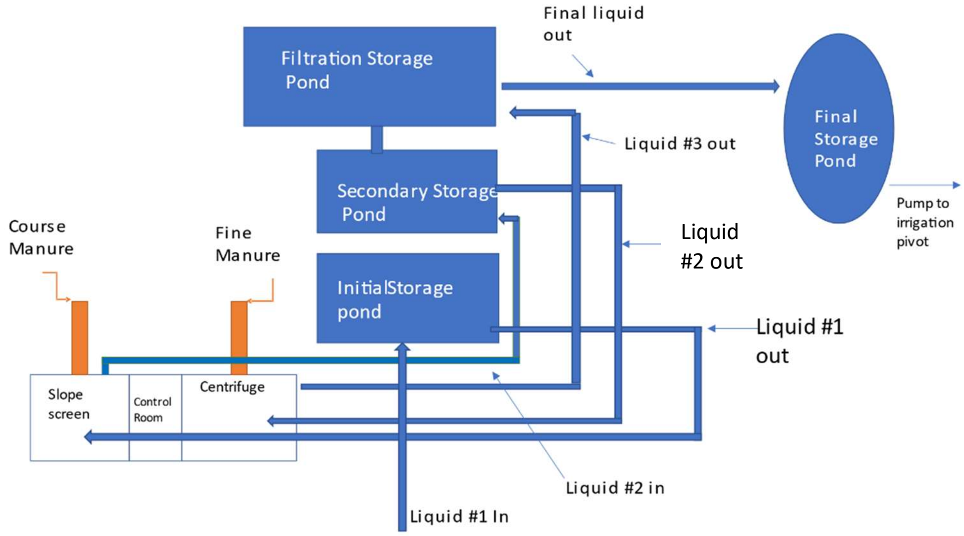
At the end of each sampling day five sample containers were filled. Samples were stored in a cooler during transport and subsamples (if required) were refrigerated or frozen (for sample going out to external lab) upon return to Morgan Community College. For samples being sent to an external lab: frozen samples were packed in ice in 2-mil poly box bag/liner and shipped to A&L Great Lakes Laboratories 3505 Conestoga Drive, Fort Wayne, IN 46808. Samples were sent to the testing lab on a weekly basis.

Starting on July 13th and a series of 45 measurements of solid and liquid manure samples were collected at Deer Valley Dairy in Fort Morgan, Colorado. A Centrisys CS30-4 centrifuge was used to separate the contents of the storage ponds into fine manure and liquid #3. The flowrate into the centrifuge had an average inflow rate of 300 gallons per minute. The centrifuge was operational except for the following dates (August 1st and 31st, September 15th, October 5th and 31st, and November 2nd). A sampling schematic is provided in diagram 1.


Figure 1 Liquid Storage Areas

It should be noted that there may have been some liquid cross-over between the various liquid holding areas. When liquid levels were high, liquid could cross between storage areas (figure 1). The amount of crossover was assumed small and should have minimal impact on the resulting values from the sampling effort.

Diagram 1 Sampling Sites



Results

Solid Samples

All samples collected at Deer Valley Dairy were sent for analysis to A & L Great Lakes Laboratories in Fort Wayne, IN. Samples were collected on 45 days over an 18-week period. The six days that the centrifuge was inoperable have been removed for this analysis. For comparison, the unfiltered data has been included in Appendix 1.

With the notable exception of sodium all the analytes were enhanced in the fine solid samples relative to the coarse samples. This enhancement is referred to as an Enrichment Factor. The median values for the enrichment factors are reported.

EQ. 1 $$EF = \frac{Fine\ Solid}{Coarse\ Solid}$$

The greatest enrichment factors were observed for aluminum (5.68) and iron (5.17), both of which were sampled in parts per million quantities. The next tier of enrichment factors observed were for manganese (3.91), phosphorus (3.67), and copper (3.02), again all the concentrations were low, with the notable exception of phosphorus. Magnesium (2.83), zinc (2.65) organic nitrogen compounds (2.01) and sulfur (2.00) experienced at least a doubling of the concentration in the fine manure. The lowest observed enhancements were for organic matter and organic carbon (1.45), ammonium (1.40) and potassium (1.30). The data is summarized in Table 1.

Table 1 (Solid Measurements)

	Coarse Solids (n =39)			Fine Solid (n=39)		
	Mean	Median	Std. Dev.	Mean	Median	Std. Dev.
Moisture	83.83	84.87	2.49	71.79	72.13	2.28
Organic Matter (%)	14.31	13.68	1.95	19.89	19.66	1.96
Organic Carbon (%)	8.33	7.95	1.13	11.54	11.40	1.14
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Kjeldahl Nitrogen (%)	0.264	0.261	0.036	0.489	0.490	0.034
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Phosphorus (%)	0.043	0.044	0.008	0.154	0.150	0.019
Potassium (%)	0.108	0.107	0.019	0.140	0.141	0.015
Sulfur (%)	0.05	0.05	0.01	0.10	0.10	0.01
Magnesium (%)	0.06	0.06	0.01	0.18	0.18	0.02
Calcium (%)	0.21	0.19	0.06	0.76	0.74	0.09
Sodium (%)	0.07	0.07	0.01	0.07	0.07	0.01
Aluminum (ppm)	104.2	99.0	27.6	585.5	564.0	98.7
Copper (ppm)	6.6	6.4	2.8	18.9	19.0	5.1
Iron (ppm)	125.0	120.0	41.4	611.5	589.0	89.1
Manganese (ppm)	8.4	8.1	1.7	32.7	32.0	3.6
Zinc (ppm)	14.7	15.0	3.6	39.5	39.0	6.9

Chart 1: Time Series of Organic Carbon

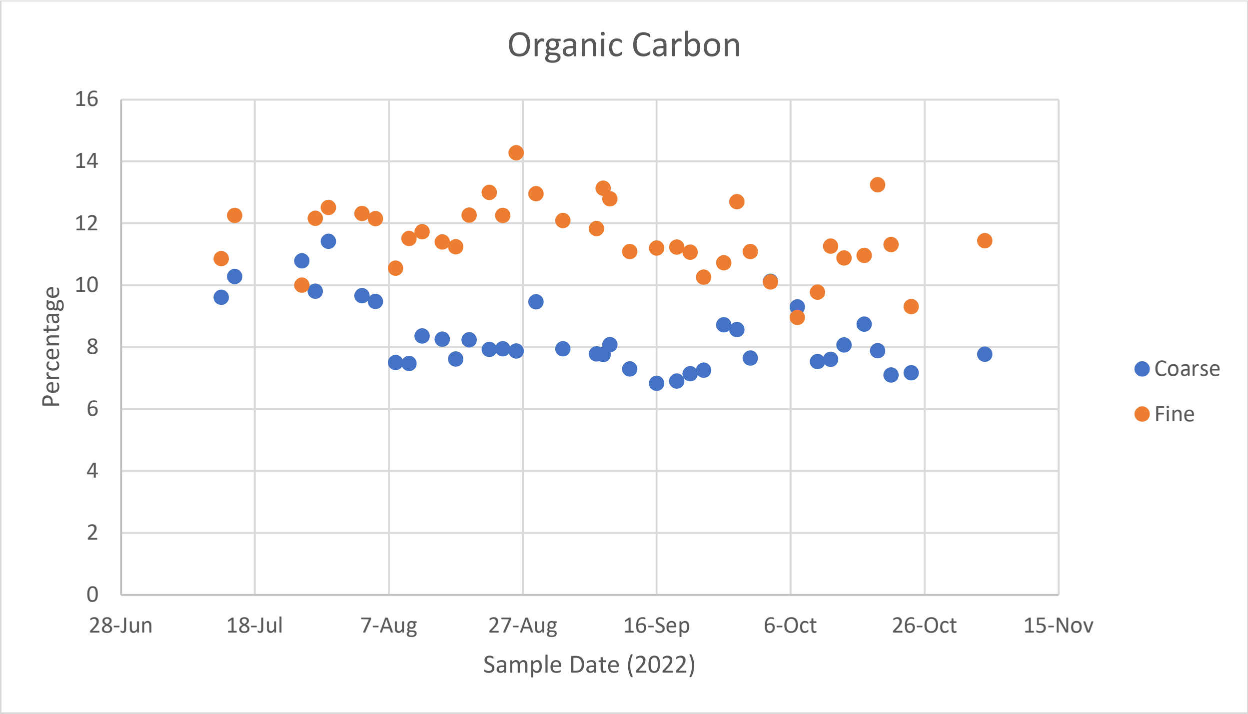


Chart 2: Time Series for Total Kjeldahl Nitrogen

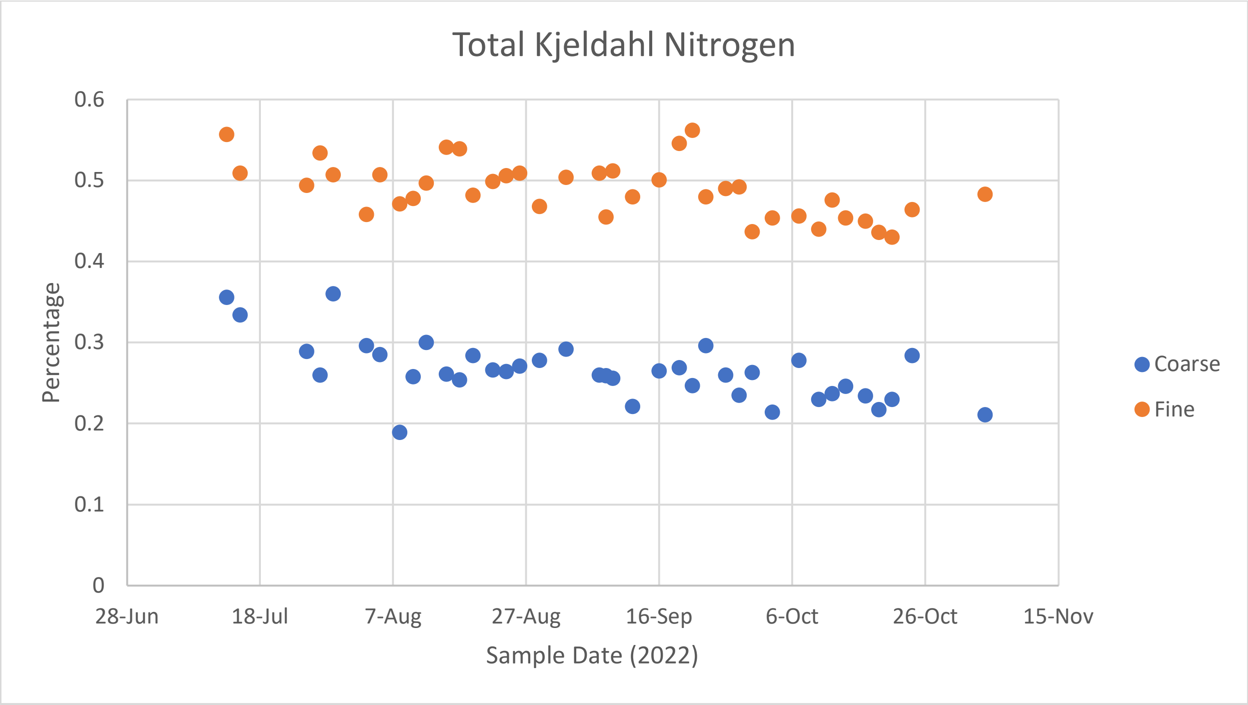
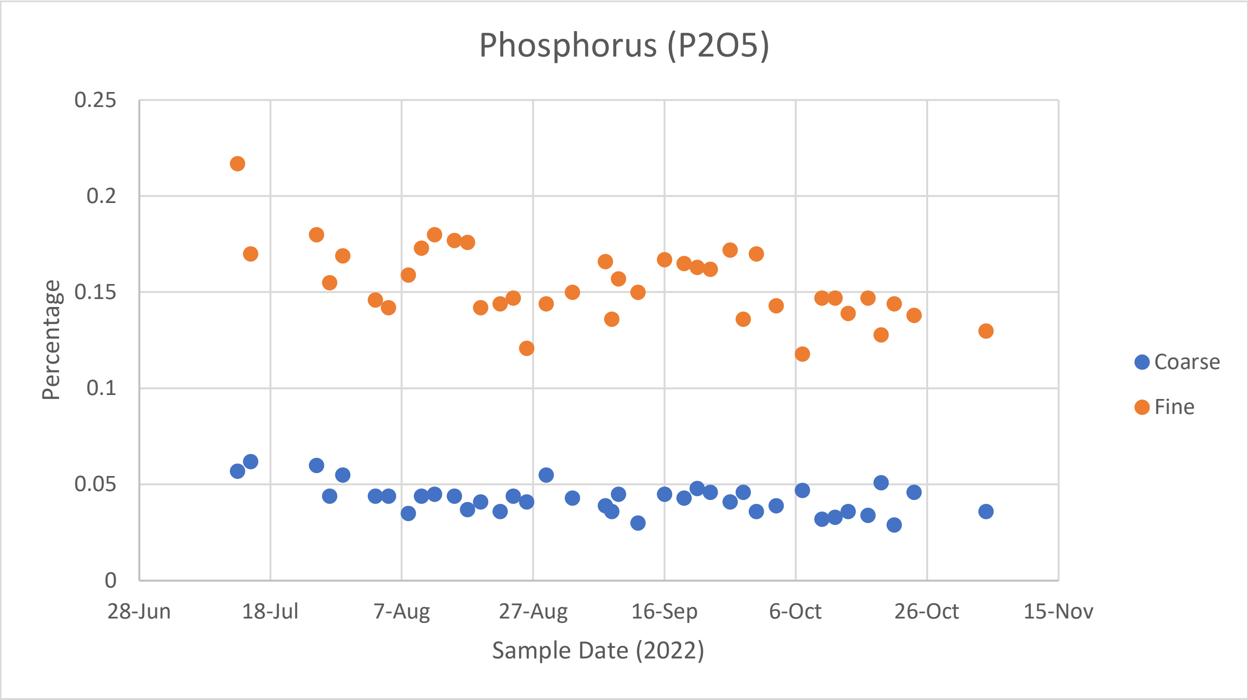
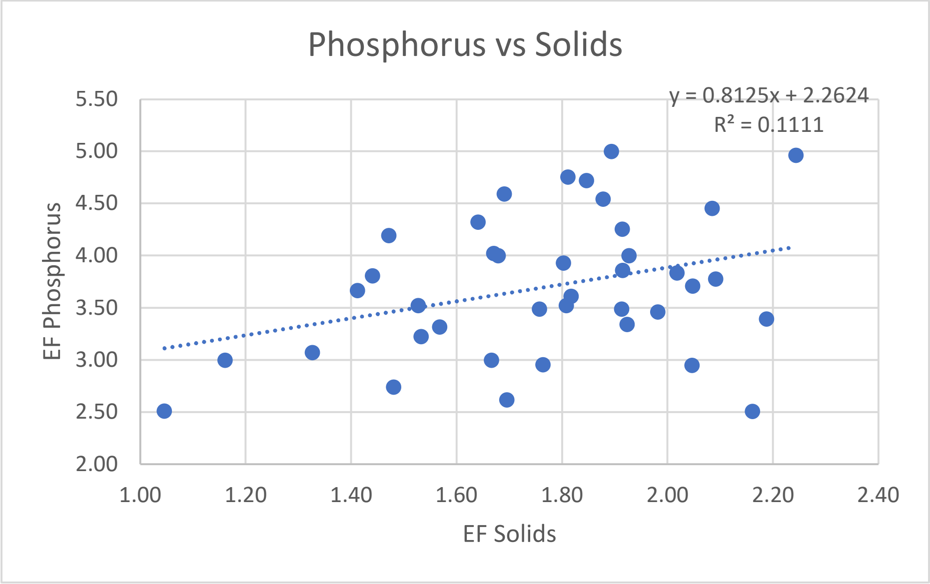


Chart 3: Time Series for Phosphorus



It should be noted that the largest enhancements in absolute numbers were observed in organic matter and organic carbon, due to the much larger fraction of total mass that they are responsible for. The Carbon to Nitrogen ratio (C: N) decreased in the fine manure even though both species were enriched. This was due to the enrichment of nitrogen being greater than the enrichment of carbon. The nearly four-fold enrichment of phosphorus is also noteworthy since it was achieved without the use of polymers.

Chart 4 Linear Regression of Phosphorus vs Solids

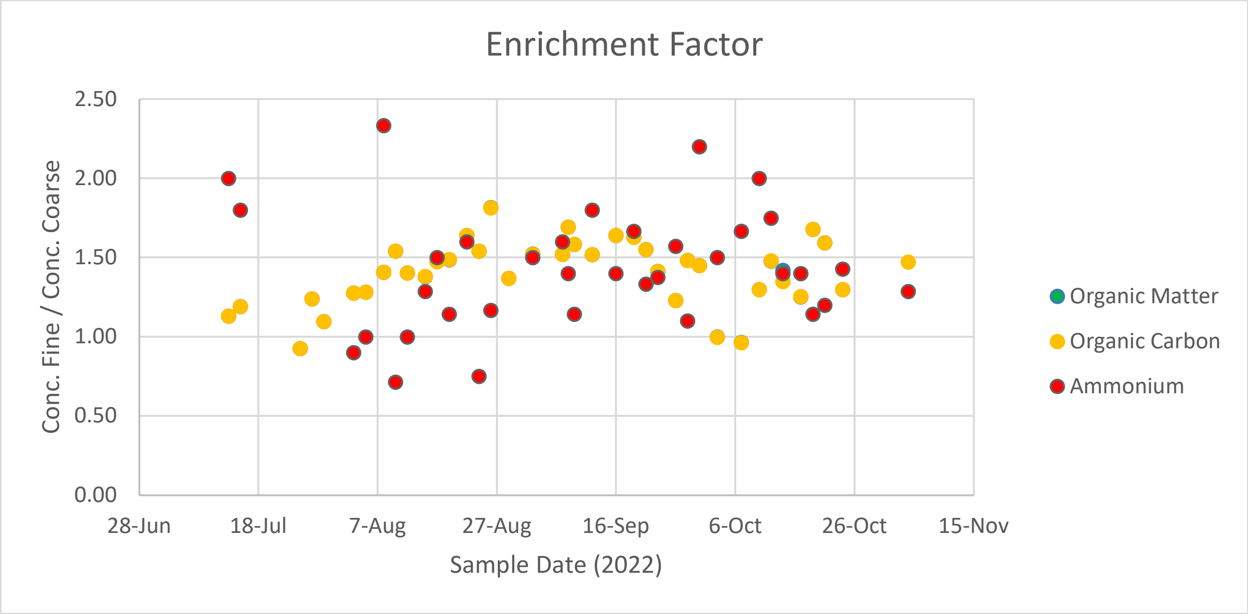


The observed enrichment factor of phosphorus displays a positive correlation with the enrichment factor of solid material This correlation was also observed with organic carbon and organic nitrogen, but both weaker ($R^2 < 0.05$) than the correlation with solids. Although there was no discrimination of samples by size, it is not unreasonable to suggest that the smaller particulate matter removed by the centrifuge was enriched in organic matter.

As can be seen in figure 2, the fine solids sample (left side of image) is much darker than the coarse solids. Visually one can see the increased nutrient and organic matter contents due to the darker color. Additionally, even though a particle size analysis was not performed, the fine solids sample has a much smaller particle size than the material taken from the inclined screen.

Figure 2 – Fine and Coarse Solids Comparison

Chart 5: EF Time Series



Liquid Samples

As expected, there was a concomitant depletion of the analytes in the liquid samples. However, the trends did not mirror the results of the enrichment factors observed in the solid samples. The observed concentrations were significantly lower than in the solid sample, again with the notable exception of sodium.

To quantity the total loss of an analyte, the difference between Liquid #1 and Liquid #3 was calculated. This was used to calculate the fraction of loss attributed to the screen, centrifuge and the percent depletion.

$$\text{EQ. 2} \quad Total = Liquid\#1 - Liquid\#3$$

The delta between Liquid #1 and Liquid #2, listed as Filter, was used to determine the depletion due to the sloped screen. The delta between Liquid #2 and Liquid #3, labelled Centrifuge, was used to determine the depletion due to the centrifuge. The percent depletion was calculated by dividing the total loss from the concentration in sample 1.

$$\text{EQ. 3} \quad Filter = \frac{Liquid\#1 - Liquid\#2}{Total}$$

$$\text{EQ. 4} \quad Centrifuge = \frac{Liquid\#2 - Liquid\#3}{Total}$$

$$\text{EQ.5} \; Depletion = \frac{Total}{Liquid\ \#1}$$

It should be noted that there were no Liquid #2 collections for the first eight sampling dates due to issues with access. The only date the centrifuge was inoperable during that period was August 1st.

Table 2 (Liquid Measurements)

	Liquid 1 (n = 39)		Liquid 2 (n = 31)		Liquid 3 (n =39)	
	Mean	Median	Mean	Median	Mean	Median
Moisture	95.80	95.79	96.62	96.72	97.85	97.85
Organic Matter (%)	3.18	3.05	2.39	2.36	1.32	1.28
Organic Carbon (%)	1.85	1.77	1.39	1.37	0.77	0.74
C: N	10.9	10.9	8.3	8.4	5.2	5.1
Kjeldahl Nitrogen (%)	0.168	0.169	0.166	0.165	0.145	0.148
Ammonium (%)	0.064	0.070	0.064	0.070	0.067	0.070
Organic Nitrogen (%)	0.104	0.106	0.102	0.104	0.078	0.077
Phosphorus (%)	0.031	0.034	0.032	0.033	0.024	0.023
Potassium (%)	0.099	0.105	0.104	0.106	0.101	0.102
Sulfur (%)	0.03	0.03	0.02	0.03	0.02	0.02
Magnesium (%)	0.04	0.04	0.04	0.04	0.03	0.03
Calcium (%)	0.11	0.11	0.11	0.11	0.07	0.07
Sodium (%)	0.07	0.07	0.07	0.07	0.07	0.07
Aluminum (ppm)	61.41	59.00	56.81	57.00	31.85	29.00
Copper (ppm)	3.88	4.00	3.89	4.00	2.88	2.80
Iron (ppm)	59.31	54.00	49.84	48.00	23.15	22.00
Manganese (ppm)	4.84	5.00	4.87	5.00	3.18	3.20
Zinc (ppm)	9.56	9.90	9.84	10.00	7.72	8.00

The was a 60 percent depletion of both organic matter and organic carbon. The sloped filter (40%) and centrifuge (60%) both contributed significantly to the total loss. The other analytes that displayed appreciable depletion were aluminum and iron (~50%), calcium and manganese (~35%), phosphorus and organic nitrogen (~25%). Roughly one fifth of the observed organic nitrogen loss was attributed to the sloped filter. In all other cases, the centrifuge was responsible for the vast majority (>85%) of the observed loss. The liquid data is summarized in table 2.

Anomalous Observations

There were several days where the centrifuge was online and working properly, but the expected enhancements for organic matter, organic carbon, and nitrogen were not observed. These dates were July 25th (OM, OC), August 3rd (NH_4^+), August 10th (NH_4^+), August 24th (NH_4^+), October 3rd (OM, OC), and October 7th (OM, OC).

Since there was no obvious reason, from an operational standpoint, to remove the data they have been retained in this discussion. Furthermore, except for one potassium measurement, none of the other analytes displayed this behavior.

However, we have conducted a third analysis to look at how much of difference removing this data would make on our conclusions. The effect was small and is presented in Appendix 2.

Discussions

The data was consistent throughout the collection period with an absence of temporal variations. For most of the solid analytes the median and mean were similar and significantly greater than the standard deviations. The analytes (except sodium) were enhanced in the fine solids. If the fine solids are to be land applied, their application will be more cost efficient since the amount of water is significantly reduced.

In the liquid samples, which were significantly lower, the standard deviations (not shown) were often of similar magnitude to the mean and median values. There was also an observed depletion in the analytes in liquid samples as they progressed from the filter (sloped) screen to the pivot. Most of the depletion was attributed to loss after processing in the centrifuge. Overall, effluent from the centrifuge was dilute enough to add enhanced organic carbon, organic nitrogen, and potassium to irrigate crops without clogging the system.

There were a few periods where the system appeared to be operating properly, but depletions of organic matter, organic carbon and/or ammonium. were not observed. It will be interesting to see if this phenomenon is observed at future sampling sites.

References

Massey, Ray and Joshua B. Payne. 2019. Costs of Manure Application and Transport. lpelc.org

Risse, L.M., M.L Cabrera, A.J. Franzluebbers, J.W. Gaskin, J.E. Gilley, R. Killorn, D.E. Radcliffe, E.W. Tollner, and H. Zhang. 2001. Land Application of Manure for Beneficial Reuse. lpelc

Appendix 1 Deer Valley Met Data

Date	Temp (F)	Humidity (%)	Pressure (inHg)	Comments
7/13/2022	80	16		fair
7/15/2022	66	25		fair/windy
7/25/2022	**53**	**64**		**cloudy**
7/27/2022	67	44		partly cloudy
7/29/2022	65	84		cloudy
8/1/2022	**73**	**42**		**partly cloudy**
8/3/2022	**73**	**51**		**partly cloudy**
8/5/2022	71	64	29.90	sunny
8/8/2022	66	90	30.17	sunny
8/10/2022	**70**	**68**	**30.19**	**sunny**
8/12/2022	70	59	30.08	sunny
8/15/2022	69	81	30.03	partly cloudy
8/17/2022	62	93	30.22	fog
8/19/2022	64	56	30.02	sunny
8/22/2022	61	78	30.11	sunny
8/24/2022	**61**	**58**	**30.09**	**sunny**
8/26/2022	65	63	30.01	sunny
8/29/2022	61	58	30.05	sunny
8/31/2022	**65**	**68**	**30.10**	**sunny**
9/2/2022	63	52	29.99	sunny
9/7/2022	59	44	30.21	sunny
9/8/2022	60	62	29.91	sunny
9/9/2022	53	80	30.00	sunny
9/12/2022	50	86	30.13	sunny
9/15/2022	**58**	**84**	**30.00**	**partly cloudy**
9/19/2022	56	81	29.98	sunny
9/21/2022	59	67	30.20	mostly cloudy
9/23/2022	46	100	30.02	light rain, fog
10/3/2022	**51**	**89**	**30.16**	**light rain, overcast**
10/5/2022	**47**	**83**	**30.30**	**sunny**
10/7/2022	**38**	**86**	**30.55**	**overcast**
10/10/2022	39	86	30.15	sunny
10/12/2022	36	89	30.14	sunny
10/14/2022	36	73	30.02	sunny
10/17/2022	33	70	30.39	sunny
10/19/2022	33	70	30.33	sunny
10/21/2022	38	65	29.88	sunny
10/24/2022	37	46	29.92	sunny
10/31/2022	**23**	**72**	**30.11**	**sunny**
11/2/2022	**35**	**54**	**29.85**	**sunny**
11/4/2022	21	92	30.12	ice fog

Dates Centrifuge was down (data removed from analysis)

Dates where Enrichment factor was inverted from expectations (data was flagged, but retained

Appendix 2 (Unfiltered Data)

Solid Measurements

	Coarse Manure (n =45)			Fine Manure (n=44)		
	Mean	Median	Std. Dev.	Mean	Median	Std. Dev.
Moisture	83.57	84.24	2.51	71.70	71.76	2.36
Organic Matter (%)	14.51	13.71	1.97	19.98	19.78	2.09
Organic Carbon (%)	8.43	8.07	1.14	11.59	11.48	1.21
C: N	31.5	3.09	4.5	23.8	23.9	2.8
Kjeldahl Nitrogen (%)	0.270	0.265	0.038	0.489	0.487	0.043
Ammonium (%)	0.060	0.060	0.024	0.081	0.080	0.015
Organic Nitrogen (%)	0.210	0.209	0.044	0.407	0.406	0.042
Phosphorus (%)	0.044	0.044	0.008	0.152	0.147	0.021
Potassium (%)	0.109	0.109	0.020	0.140	0.141	0.015
Sulfur (%)	0.05	0.05	0.01	0.10	0.10	0.03
Magnesium (%)	0.06	0.06	0.01	0.18	0.17	0.02
Calcium (%)	0.22	0.20	0.06	0.75	0.74	0.09
Sodium (%)	0.07	0.07	0.01	0.08	0.08	0.01
Aluminum (ppm)	109.6	103.0	34.0	581.0	562.5	107.0
Copper (ppm)	6.7	6.7	2.7	18.8	19.0	5.0
Iron (ppm)	130.6	122.0	43.7	610.3	591.5	93.5
Manganese (ppm)	8.7	8.2	1.9	32.6	32.0	3.7
Zinc (ppm)	15.1	15.0	3.5	39.5	39.5	6.9

Liquid Measurements

	Liquid 1 (n = 43)		Liquid 2 (n = 34)		Liquid 3 (n =41)	
	Mean	Median	Mean	Median	Mean	Median
Moisture	95.78	95.79	96.58	96.58	97.86	97.85
Organic Matter (%)	3.19	3.05	2.42	2.45	1.31	1.28
Organic Carbon (%)	1.85	1.77	1.41	1.43	0.76	0.74
C: N	10.9	10.8	8.4	8.5	5.2	5.1
Kjeldahl Nitrogen (%)	0.169	0.169	0.167	0.172	0.145	0.148
Ammonium (%)	0.065	0.070	0.064	0.070	0.067	0.070
Organic Nitrogen (%)	0.104	0.106	0.103	0.107	0.078	0.077
Phosphorus (%)	0.031	0.033	0.032	0.034	0.023	0.023
Potassium (%)	0.099	0.104	0.104	0.104	0.100	0.102
Sulfur (%)	0.03	0.03	0.02	0.02	0.02	0.02
Magnesium (%)	0.04	0.04	0.04	0.04	0.03	0.03
Calcium (%)	0.11	0.11	0.11	0.11	0.07	0.07
Sodium (%)	0.07	0.07	0.07	0.07	0.07	0.07
Aluminum (ppm)	61.09	59.0	57.06	57.0	31.76	29.0
Copper (ppm)	3.90	4.10	3.98	4.15	2.88	2.80
Iron (ppm)	58.91	51.0	50.29	48.50	22.98	22.0

Manganese (ppm)	4.86	5.0	4.89	5.0	3.16	3.2
Zinc (ppm)	9.60	9.90	10.00	11.0	7.66	8.0

Appendix 2 (Anomalous Behavior)

Solid Measurements

	Coarse Manure (n =33)			Fine Manure (n=33)		
	Mean	Median	Std. Dev.	Mean	Median	Std. Dev.
Moisture	84.23	84.91	2.19	71.50	71.84	2.24
Organic Matter (%)	14.07	13.56	1.80	20.10	19.66	1.84
Organic Carbon (%)	8.17	7.89	1.04	11.66	11.40	1.07
C: N	31.2	30.9	3.9	23.8	23.7	2.6
Kjeldahl Nitrogen (%)	0.264	0.260	0.038	0.492	0.492	0.035
Ammonium (%)	0.058	0.060	0.016	0.083	0.080	0.013
Organic Nitrogen (%)	0.206	0.209	0.042	0.408	0.414	0.034
Phosphorus (%)	0.042	0.043	0.008	0.155	0.150	0.019
Potassium (%)	0.108	0.107	0.018	0.142	0.142	0.013
Sulfur (%)	0.05	0.05	0.01	0.10	0.10	0.01
Magnesium (%)	0.06	0.06	0.01	0.18	0.18	0.02
Calcium (%)	0.20	0.19	0.04	0.75	0.74	0.08
Sodium (%)	0.07	0.07	0.01	0.08	0.07	0.01
Aluminum (ppm)	100.9	99.0	24,1	591.1	567.0	101.6
Copper (ppm)	6.5	6.3	2.0	18.9	18.0	5.3
Iron (ppm)	118.4	115.0	30.5	616.6	594.0	92.3
Manganese (ppm)	8.2	8.0	1.4	32.7	32.0	3.5
Zinc (ppm)	14.5	14.0	3.8	39.3	39.0	7.0

Liquid Measurements

	Liquid 1 (n = 33)		Liquid 2 (n = 27)		Liquid 3 (n =33)	
	Mean	Median	Mean	Median	Mean	Median
Moisture	95.78	95.95	96.57	96.72	97.80	97.80
Organic Matter (%)	3.23	3.05	2.43	2.36	1.35	1.28
Organic Carbon (%)	1.88	1.77	1.41	1.37	0.79	0.74
C: N	10.9	10.8	8.4	8.4	5.3	5.1
Kjeldahl Nitrogen (%)	0.170	0.169	0.168	0.165	0.146	0.148
Ammonium (%)	0.066	0.070	0.066	0.070	0.067	0.070
Organic Nitrogen (%)	0.105	0.106	0.102	0.098	0.079	0.077
Phosphorus (%)	0.032	0.034	0.033	0.033	0.024	0.023
Potassium (%)	0.102	0.105	0.107	0.106	0.102	0.105
Sulfur (%)	0.03	0.03	0.03	0.03	0.02	0.02
Magnesium (%)	0.04	0.04	0.04	0.04	0.03	0.03
Calcium (%)	0.11	0.11	0.11	0.11	0.07	0.07
Sodium (%)	0.07	0.07	0.07	0.07	0.07	0.07
Aluminum (ppm)	61.42	57.00	57.67	57.00	33.00	29.00
Copper (ppm)	3.90	4.00	3.90	4.00	2.95	2.80

Iron (ppm)	53.67	51.00	50.04	48.00	24.00	22.00
Manganese (ppm)	4.88	5.00	4.96	5.00	3.27	3.20
Zinc (ppm)	9.67	9.90	9.94	10.00	7.85	8.00

Appendix 3 – Raw Data Analysis

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To: NEWTRIENT LLC - SIG GRANT
11510 LAURIE DR
WHEATFIELD, IN 46392-7364

For: DEER VALLEY DAIRY
MORGAN COM COLLEGE

Attn: MARK STOERMAN

Purchase Order: MORGAN COM COLLEGE

Lab Number: 49387
Sample ID: COARSE SOLID
Manure Type: DAIRY, SOLID W/O BEDDING (6)

Date Sampled: 10/19/2022
Date Received: 10/27/2022
Date Reported: 10/31/2022 Page: 1 of 10

MANURE ANALYSIS

Analysis	Unit	Analysis Result (As Received)	Pounds Per Ton	First Year Availability @ Pounds Per Ton
Moisture	%	85.02	1700	
Solids	%	14.98	300	
Ash @ 550 C	%	1.38	27.5	
Organic Matter (LOI @ 550 C)	%	13.60	272.1	
Organic Carbon (LOI @ 550 C)	%	7.89	157.8	
Carbon:Nitrogen Ratio (C:N)	-		36.4:1	
Nitrogen, Total Kjeldahl (TKN)	%	0.217	4.3	2.4 *
Nitrogen, Ammonium (NH_4-N)	%	0.070	1.4	1.4 *
Nitrogen, Organic (N)	%	0.147	2.9	1.0 *
Phosphorus (P)	%	0.051	2.3 (as P_2O_5)	2.3 * (as P_2O_5)
Potassium (K)	%	0.101	2.4 (as K_2O)	2.4 * (as K_2O)
Sulfur (S)	%	0.05	0.9	0.6 #

@ Estimate of first-year availability does not account for incorporation losses. Consult MWPS-18, "Livestock Waste Facilities Handbook" for additional information.
* Source: MWPS-18, Livestock Waste Facilities Handbook, 1993 # Source: A3411, "Manure Nutrient Credit Worksheet", University of Wisconsin

Report Approved By: [signature] Approval Date: 10/31/2022
David Henry - Agronomist / Technical Services - CCA

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WHEATFIELD, IN 46392-7364

For: DEER VALLEY DAIRY
MORGAN COM COLLEGE

Attn: MARK STOERMAN

Purchase Order: MORGAN COM COLLEGE

Lab Number: 49387
Sample ID: COARSE SOLID
Manure Type: DAIRY, SOLID W/O BEDDING (6)

Date Sampled: 10/19/2022
Date Received: 10/27/2022
Date Reported: 10/31/2022 Page: 2 of 10

MANURE ANALYSIS

Analysis	Unit	Analysis Result (As Received)	Pounds Per Ton	First Year Availability @ Pounds Per Ton
Magnesium (Mg)	%	0.06	1.1	0.7 #
Calcium (Ca)	%	0.18	3.6	2.0 #
Sodium (Na)	%	0.06	1.2	
Aluminum (Al)	ppm	115	0.2	
Copper (Cu)	ppm	7.0	<0.1	<0.1 #
Iron (Fe)	ppm	122	0.2	0.2 #
Manganese (Mn)	ppm	10	<0.1	<0.1 #
Zinc (Zn)	ppm	19	<0.1	<0.1 #

@ Estimate of first-year availability does not account for incorporation losses. Consult MWPS-18, "Livestock Waste Facilities Handbook" for additional information.
* Source: MWPS-18, Livestock Waste Facilities Handbook, 1993 # Source: A3411, "Manure Nutrient Credit Worksheet", University of Wisconsin

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WHEATFIELD, IN 46392-7364

For: DEER VALLEY DAIRY
MORGAN COM COLLEGE

Attn: MARK STOERMAN

Purchase Order: MORGAN COM COLLEGE

Lab Number: 49388
Sample ID: FINE SOLID
Manure Type: DAIRY, SOLID W/O BEDDING (6)

Date Sampled: 10/19/2022
Date Received: 10/27/2022
Date Reported: 10/31/2022 **Page:** 3 of 10

MANURE ANALYSIS

Analysis	Unit	Analysis Result (As Received)	Pounds Per Ton	First Year Availability @ Pounds Per Ton
Moisture	%	67.63	1353	
Solids	%	32.37	647	
Ash @ 550 C	%	9.54	190.8	
Organic Matter (LOI @ 550 C)	%	22.83	456.6	
Organic Carbon (LOI @ 550 C)	%	13.24	264.9	
Carbon:Nitrogen Ratio (C:N)	-		30.4:1	
Nitrogen, Total Kjeldahl (TKN)	%	0.436	8.7	4.1 *
Nitrogen, Ammonium (NH_4-N)	%	0.080	1.6	1.6 *
Nitrogen, Organic (N)	%	0.356	7.1	2.5 *
Phosphorus (P)	%	0.128	5.9 (as P_2O_5)	5.9 * (as P_2O_5)
Potassium (K)	%	0.153	3.7 (as K_2O)	3.7 * (as K_2O)
Sulfur (S)	%	0.09	1.9	1.0 #

@ Estimate of first-year availability does not account for incorporation losses. Consult MWPS-18, "Livestock Waste Facilities Handbook" for additional information.
* Source: MWPS-18, Livestock Waste Facilities Handbook, 1993 # Source: A3411, "Manure Nutrient Credit Worksheet", University of Wisconsin

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For: DEER VALLEY DAIRY
MORGAN COM COLLEGE

Attn: MARK STOERMAN

Purchase Order: MORGAN COM COLLEGE

Lab Number: 49388
Sample ID: FINE SOLID
Manure Type: DAIRY, SOLID W/O BEDDING (6)

Date Sampled: 10/19/2022
Date Received: 10/27/2022
Date Reported: 10/31/2022 **Page:** 4 of 10

MANURE ANALYSIS

Analysis	Unit	Analysis Result (As Received)	Pounds Per Ton	First Year Availability @ Pounds Per Ton
Magnesium (Mg)	%	0.15	3.0	1.7 #
Calcium (Ca)	%	0.74	14.8	8.1 #
Sodium (Na)	%	0.07	1.4	
Aluminum (Al)	ppm	599	1.2	
Copper (Cu)	ppm	19	<0.1	<0.1 #
Iron (Fe)	ppm	642	1.3	0.8 #
Manganese (Mn)	ppm	31	0.1	<0.1 #
Zinc (Zn)	ppm	43	0.1	0.1 #

@ Estimate of first-year availability does not account for incorporation losses. Consult MWPS-18, "Livestock Waste Facilities Handbook" for additional information.
* Source: MWPS-18, Livestock Waste Facilities Handbook, 1993 # Source: A3411, "Manure Nutrient Credit Worksheet", University of Wisconsin

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WHEATFIELD, IN 46392-7364

For: DEER VALLEY DAIRY
MORGAN COM COLLEGE

Attn: MARK STOERMAN

Purchase Order: MORGAN COM COLLEGE

Lab Number: 49389
Sample ID: LIQUID-1
Manure Type: DAIRY, LIQUID PIT (20)

Date Sampled: 10/19/2022
Date Received: 10/27/2022
Date Reported: 10/31/2022

MANURE ANALYSIS

Analysis	Unit	Analysis Result (As Received)	Pounds Per 1,000 Gal**	First Year Availability @ Pounds Per 1,000 Gal
Moisture	%	96.76	8060	
Solids	%	3.24	270	
Ash @ 550 C	%	0.71	59.4	
Organic Matter (LOI @ 550 C)	%	2.53	210.5	
Organic Carbon (LOI @ 550 C)	%	1.47	122.1	
Carbon:Nitrogen Ratio (C:N)	-		9.3:1	
Nitrogen, Total Kjeldahl (TKN)	%	0.157	13.1	7.4 *
Nitrogen, Ammonium (NH_4-N)	%	0.060	5.0	5.0 *
Nitrogen, Organic (N)	%	0.097	8.1	2.4 *
Phosphorus (P)	%	0.028	5.3 (as P_2O_5)	5.3 * (as P_2O_5)
Potassium (K)	%	0.076	7.6 (as K_2O)	7.6 * (as K_2O)
Sulfur (S)	%	0.03	2.1	1.4 #

@ Estimate of first-year availability does not account for incorporation losses. Consult MWPS-18, "Livestock Waste Facilities Handbook" for additional information.
* Source: MWPS-18, Livestock Waste Facilities Handbook, 1993 # Source: A3411, "Manure Nutrient Credit Worksheet", University of Wisconsin
** Manure density assumed to be 8.33 lb/gallon

Report Number
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Attn: MARK STOERMAN

Purchase Order: MORGAN COM COLLEGE

Lab Number: 49389
Sample ID: LIQUID-1
Manure Type: DAIRY, LIQUID PIT (20)

Date Sampled: 10/19/2022
Date Received: 10/27/2022
Date Reported: 10/31/2022 Page: 6 of 10

MANURE ANALYSIS

Analysis	Unit	Analysis Result (As Received)	Pounds Per 1,000 Gal **	First Year Availability @ Pounds Per 1,000 Gal
Magnesium (Mg)	%	0.03	2.7	1.4 #
Calcium (Ca)	%	0.09	7.6	4.1 #
Sodium (Na)	%	0.05	4.2	
Aluminum (Al)	ppm	53	0.4	
Copper (Cu)	ppm	4.5	<0.1	<0.1 #
Iron (Fe)	ppm	40	0.3	0.2 #
Manganese (Mn)	ppm	4.5	<0.1	<0.1 #
Zinc (Zn)	ppm	10.0	0.1	0.1 #

@ Estimate of first-year availability does not account for incorporation losses. Consult MWPS-18, "Livestock Waste Facilities Handbook" for additional information.
* Source: MWPS-18, Livestock Waste Facilities Handbook, 1993 # Source: A3411, "Manure Nutrient Credit Worksheet", University of Wisconsin
** Manure density assumed to be 8.33 lb/gallon

Report Number F22300-6515
Account Number 63570

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3505 Conestoga Dr.
Fort Wayne, IN 46808
260.483.4759
algreatlakes.com

To: NEWTRIENT LLC - SIG GRANT
11510 LAURIE DR
WHEATFIELD, IN 46392-7364

For: DEER VALLEY DAIRY
MORGAN COM COLLEGE

Attn: MARK STOERMAN

Purchase Order: MORGAN COM COLLEGE

Lab Number: 49390
Sample ID: LIQUID-2
Manure Type: DAIRY, LIQUID PIT (20)

Date Sampled: 10/19/2022
Date Received: 10/27/2022
Date Reported: 10/31/2022 **Page:** 7 of 10

MANURE ANALYSIS

Analysis	Unit	Analysis Result (As Received)	Pounds Per 1,000 Gal**	First Year Availability @ Pounds Per 1,000 Gal
Moisture	%	97.20	8097	
Solids	%	2.80	233	
Ash @ 550 C	%	0.79	65.9	
Organic Matter (LOI @ 550 C)	%	2.01	167.3	
Organic Carbon (LOI @ 550 C)	%	1.16	97.0	
Carbon:Nitrogen Ratio (C:N)	-		7.1:1	
Nitrogen, Total Kjeldahl (TKN)	%	0.165	13.7	8.2 *
Nitrogen, Ammonium (NH_4-N)	%	0.070	5.8	5.8 *
Nitrogen, Organic (N)	%	0.095	7.9	2.4 *
Phosphorus (P)	%	0.029	5.6 (as P_2O_5)	5.6 * (as P_2O_5)
Potassium (K)	%	0.098	9.8 (as K_2O)	9.8 * (as K_2O)
Sulfur (S)	%	0.03	2.3	1.4 #

@ Estimate of first-year availability does not account for incorporation losses. Consult MWPS-18, "Livestock Waste Facilities Handbook" for additional information.
* Source: MWPS-18, Livestock Waste Facilities Handbook, 1993 # Source: A3411, "Manure Nutrient Credit Worksheet", University of Wisconsin
** Manure density assumed to be 8.33 lb/gallon

Report Number
F22300-6515
Account Number
63570

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To: NEWTRIENT LLC - SIG GRANT
11510 LAURIE DR
WHEATFIELD, IN 46392-7364

For: DEER VALLEY DAIRY
MORGAN COM COLLEGE

Attn: MARK STOERMAN

Purchase Order: MORGAN COM COLLEGE

Lab Number: 49390
Sample ID: LIQUID-2
Manure Type: DAIRY, LIQUID PIT (20)

Date Sampled: 10/19/2022
Date Received: 10/27/2022
Date Reported: 10/31/2022

MANURE ANALYSIS

Analysis	Unit	Analysis Result (As Received)	Pounds Per 1,000 Gal **	First Year Availability @ Pounds Per 1,000 Gal
Magnesium (Mg)	%	0.04	3.1	1.8 #
Calcium (Ca)	%	0.09	7.8	4.1 #
Sodium (Na)	%	0.06	5.4	
Aluminum (Al)	ppm	50	0.4	
Copper (Cu)	ppm	4.7	<0.1	<0.1 #
Iron (Fe)	ppm	38	0.3	0.2 #
Manganese (Mn)	ppm	4.6	<0.1	<0.1 #
Zinc (Zn)	ppm	10	0.1	0.1 #

@ Estimate of first-year availability does not account for incorporation losses. Consult MWPS-18, "Livestock Waste Facilities Handbook" for additional information.
* Source: MWPS-18, Livestock Waste Facilities Handbook, 1993 # Source: A3411, "Manure Nutrient Credit Worksheet", University of Wisconsin
** Manure density assumed to be 8.33 lb/gallon

Report Number
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For: DEER VALLEY DAIRY
MORGAN COM COLLEGE

Attn: MARK STOERMAN

Purchase Order: MORGAN COM COLLEGE

Lab Number: 49391
Sample ID: LIQUID-3
Manure Type: DAIRY, LIQUID PIT (20)

Date Sampled: 10/19/2022
Date Received: 10/27/2022
Date Reported: 10/31/2022 Page: 9 of 10

MANURE ANALYSIS

Analysis	Unit	Analysis Result (As Received)	Pounds Per 1,000 Gal **	First Year Availability @ Pounds Per 1,000 Gal
Moisture	%	98.11	8173	
Solids	%	1.89	157	
Ash @ 550 C	%	0.91	75.9	
Organic Matter (LOI @ 550 C)	%	0.98	81.5	
Organic Carbon (LOI @ 550 C)	%	0.57	47.3	
Carbon:Nitrogen Ratio (C:N)	-		3.9:1	
Nitrogen, Total Kjeldahl (TKN)	%	0.147	12.2	7.7 *
Nitrogen, Ammonium (NH_4-N)	%	0.070	5.8	5.8 *
Nitrogen, Organic (N)	%	0.077	6.4	1.9 *
Phosphorus (P)	%	0.022	4.2 (as P_2O_5)	4.2 * (as P_2O_5)
Potassium (K)	%	0.094	9.3 (as K_2O)	9.3 * (as K_2O)
Sulfur (S)	%	0.02	1.8	0.9 #

@ Estimate of first-year availability does not account for incorporation losses. Consult MWPS-18, "Livestock Waste Facilities Handbook" for additional information.
* Source: MWPS-18, Livestock Waste Facilities Handbook, 1993 # Source: A3411, "Manure Nutrient Credit Worksheet", University of Wisconsin
** Manure density assumed to be 8.33 lb/gallon

Report Number
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Account Number
63570

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To: NEWTRIENT LLC - SIG GRANT
11510 LAURIE DR
WHEATFIELD, IN 46392-7364

For: DEER VALLEY DAIRY
MORGAN COM COLLEGE

Attn: MARK STOERMAN

Purchase Order: MORGAN COM COLLEGE

Lab Number: 49391
Sample ID: LIQUID-3
Manure Type: DAIRY, LIQUID PIT (20)

Date Sampled: 10/19/2022
Date Received: 10/27/2022
Date Reported: 10/31/2022 Page: 10 of 10

MANURE ANALYSIS

Analysis	Unit	Analysis Result (As Received)	Pounds Per 1,000 Gal **	First Year Availability @ Pounds Per 1,000 Gal
Magnesium (Mg)	%	0.03	2.5	1.4 #
Calcium (Ca)	%	0.06	5.3	2.7 #
Sodium (Na)	%	0.07	5.4	
Aluminum (Al)	ppm	43	0.4	
Copper (Cu)	ppm	3.7	<0.1	<0.1 #
Iron (Fe)	ppm	20	0.2	0.1 #
Manganese (Mn)	ppm	3.3	<0.1	<0.1 #
Zinc (Zn)	ppm	8.1	0.1	<0.1 #

@ Estimate of first-year availability does not account for incorporation losses. Consult MWPS-18, "Livestock Waste Facilities Handbook" for additional information.
* Source: MWPS-18, Livestock Waste Facilities Handbook, 1993 # Source: A3411, "Manure Nutrient Credit Worksheet", University of Wisconsin
** Manure density assumed to be 8.33 lb/gallon