



APPLICATION FOR COMPONENT ADDITION TO NRCS

NRCS Practice Standard 632

For Acceptance of Membrane-Based
Nutrient Partitioning Technology

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APPLICATION FOR COMPONENT ADDITION TO NRCS Practice Standard 632:

Membrane-Based Nutrient Partitioning Technology

REQUEST

As environmental, regulatory, and legal pressures surrounding nutrient management on dairy farms continue to grow, an increasing number of technologies are being introduced as potential solutions. However, dairy producers often navigate these options with information primarily provided by technology vendors, making it challenging to assess their effectiveness objectively. To address the needs identified by both the USDA's Natural Resources Conservation Service (NRCS) and dairy farmers, Washington State University, in partnership with Newtrient, developed a standardized evaluation framework. This framework, originally aligned with the NRCS Conservation Practice Standard (CPS) Waste Treatment (629), has been adapted by Newtrient to assess technologies under the Waste Separation Facility Practice Standard (632).

Membrane-based nutrient partitioning technology offers a highly targeted method for separating and concentrating nutrients from livestock manure, producing cleaner effluent and more concentrated byproducts. These systems represent a significant advancement over traditional mechanical separation technologies, which often yield lower-value products and leave behind effluent that must still be managed as manure. When used together Ultrafiltration (UF) and Reverse Osmosis (RO) membranes can improve the potential for discharge-quality water, reducing the need for land application and lowering associated costs and environmental risks.

To assess the performance and viability of this technology, Newtrient conducted an on-farm evaluation in Middleton, Wisconsin, focusing on nutrient recovery efficiency, water quality improvements, and the operational feasibility of integrating membrane systems into existing manure management infrastructure. The assessment also considered the marketability of separated products and the system's contribution to broader sustainability goals.

Newtrient submits this report for consideration under NRCS Conservation Practice Standard 632, highlighting the potential benefits of membrane systems in treating manure to discharge quality. We believe these systems align with NRCS objectives by improving water quality and manure handling methods, warranting further evaluation for broader adoption.

BRIEF DESCRIPTION OF COMPONENT CLASS

This system integrates multiple manure separation technologies—including screw presses, a centrifuge, UF membranes, and RO membranes—to partition and concentrate

nutrients while producing discharge-quality water. Each component contributes incrementally to nutrient separation, with solids primarily extracted by the screw press and centrifuge, and dissolved nutrients partitioned through membrane filtration. Operating this system requires regular maintenance and oversight to maintain performance and uptime.

DETAILED DESCRIPTION

Membrane-based nutrient partitioning technology expands the capabilities of traditional manure management by integrating solid-liquid separation and advanced filtration to extract nutrients and recover clean water. These systems are typically implemented downstream of anaerobic digestion and mechanical separation to enhance overall treatment efficiency and environmental performance. In the system evaluated in Middleton, Wisconsin, manure from approximately 4,500 cows is processed through a digester, followed by a series of components that include screw presses, a centrifuge, two UF units, and an RO system.

A key function of this integrated system is its ability to partition both suspended and dissolved nutrients, reducing the environmental risks associated with land application of raw manure and enabling the production of discharge-quality water. Coarse solids are first removed through mechanical means—the screw presses and centrifuge—which reduces the load on the membrane filtration units. The UF and RO stages then polish the liquid fraction, separating out remaining solids, nitrogen (N) compounds, and potassium (K). These membrane-based processes offer significantly higher separation efficiency compared to conventional systems, though they require low suspended solids influent, careful system design, and ongoing maintenance to operate effectively.

Beyond nutrient separation, this system provides a scalable solution for farms aiming to partition nutrient loads, comply with water quality regulations, and generate reusable water. The multi-stage process concentrates valuable nutrients into manageable byproducts while enabling recovery of clean water, thereby supporting sustainable nutrient recycling and resource conservation. The inclusion of anaerobic digestion upstream also enhances treatment efficiency and system integration, making this approach suitable for large livestock operations seeking comprehensive environmental solutions.

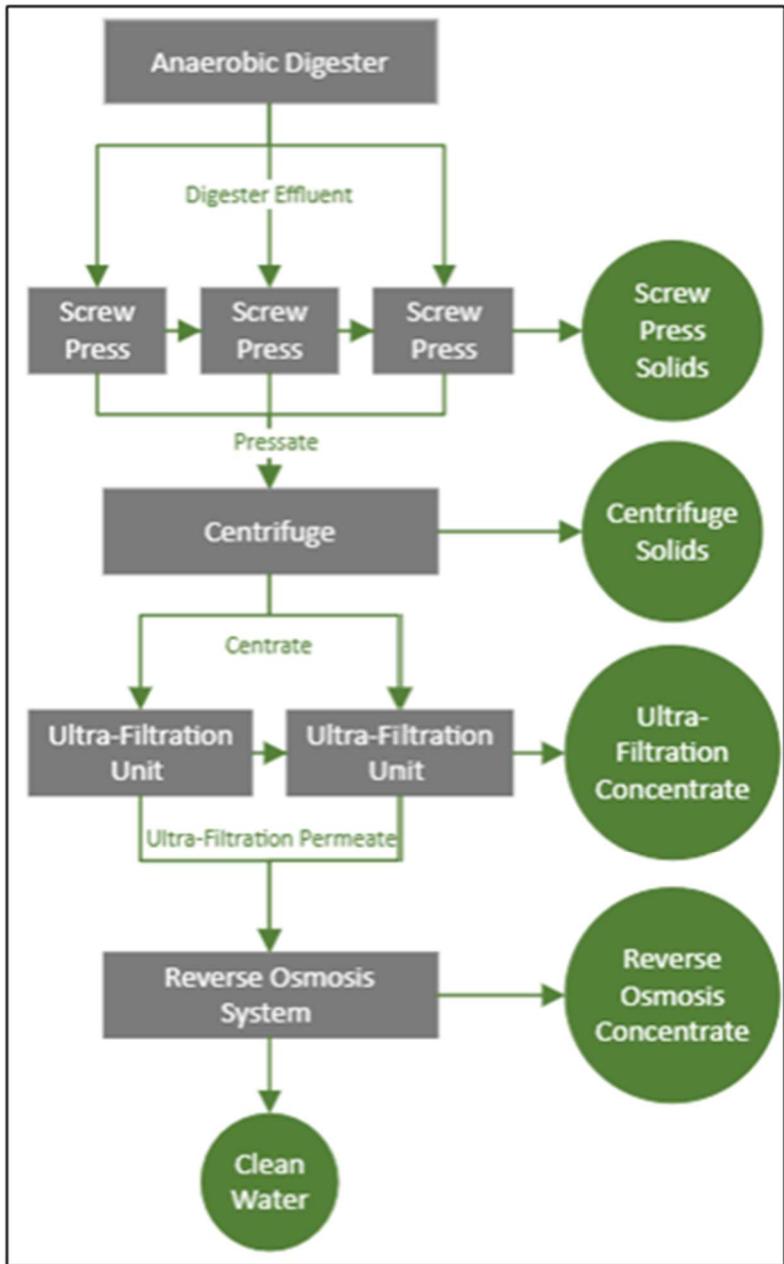


Figure 1: Flow diagram of the manure processing system, green circles represent recovered products.

THE PROCESS

The membrane-based nutrient partitioning technology operates through a coordinated sequence of treatment stages, each designed to progressively separate and refine manure constituents for improved handling, nutrient recovery, and water reuse. The major stages include:

Stage 1: Anaerobic Digestion – Optional Pre-Treatment for Enhanced Separation

In the system evaluated, manure is first processed through an anaerobic digester to stabilize organic matter, reduce odors and pathogens, and improve separation efficiency in downstream components. While anaerobic digestion is not a required component of all membrane systems, its inclusion in this system enhances nutrient recovery and overall performance. In other configurations, raw or minimally processed manure may be routed directly to the solid-liquid separation stage.

While the system evaluated in this study includes anaerobic digestion upstream of the membrane-based nutrient partitioning technology, this component is not universally required. System configurations may vary depending on operational goals, nutrient recovery targets, and available infrastructure.

Stage 2: Mechanical Separation – Coarse and Fine Solids Removal

Digested manure flows into a set of three screw presses operating in parallel, which remove coarse fibrous solids. These solids, composed mainly of undigested fiber and organic matter, typically contain a lower proportion of total phosphorus (P), as much of the P remains in the liquid or is associated with finer particles. The remaining liquid effluent is then treated with a centrifuge, which targets finer solids and additional nutrient fractions. Together, the screw press and centrifuge remove approximately 50% of total solids (TS), volatile solids (VS), and total phosphorus (TP). These combined solids are rich in P and organic matter and are collected for storage or beneficial reuse.

Stage 3: Ultrafiltration – Suspended Solids and Pathogen Reduction

The clarified liquid passes through two UF units in parallel. These membrane filters remove suspended solids, bacteria, and colloidal particles, producing a cleaner liquid stream, partitioning nutrients, and reducing pathogens on the final polishing step. This stage is essential for protecting the RO membranes and enhancing overall system efficiency.

Stage 4: Reverse Osmosis – Concentration of Dissolved Nutrients and Water Recovery

In the final stage, the ultrafiltered liquid enters the RO unit (Aqua Innovations Nutrient Concentration System), which separates dissolved salts, N (primarily ammoniacal), and K from the water. This process produces two distinct streams: an N- and K-rich concentrate and a clean water effluent that approaches or meets discharge quality. The RO stage enables water reuse and significantly reduces the volume requiring land application.

Stage 5: Product Management – Storage, Reuse, and Environmental Compliance

Following treatment, the separated solids and concentrates are managed through on-farm storage systems and land application. The clean water may be reused on the farm or discharged, depending on regulatory guidelines and water quality. System outputs are tailored to align with crop nutrient demand and regional environmental goals.

HOW PROPOSED SYSTEM ACCOMPLISHES PURPOSES OF THE STANDARD

The membrane-based nutrient partitioning technology supports the objectives of NRCS Conservation Practice Standard 632 (Waste Separation Facility) by effectively separating and concentrating manure constituents to improve handling, nutrient recovery, and water management. This system utilizes a multi-stage treatment approach—including mechanical solid-liquid separation, UF, and RO—to remove solids, concentrate nutrients, and produce a clean water stream suitable for reuse or potential discharge.

By removing coarse solids and partitioning the remaining nutrients in the liquid waste stream, the system improves the efficiency of land application in meeting crop nutrient needs while reducing the volume of manure requiring application and concentrating nutrients into more manageable forms. This enhances on-farm nutrient management flexibility and lowers the risk of nutrient runoff and leaching. It also creates separate nutrient streams (solids and liquid concentrate) that can be more precisely applied or transported offsite, aligning with the standard's purpose to facilitate better nutrient distribution and environmental protection.

In addition, the production of high-quality water from the RO stage reduces freshwater demand and supports sustainable resource use. While anaerobic digestion is included upstream in the studied system, its inclusion is optional and may vary by site. Overall, the membrane system demonstrates significant potential to meet the goals of Practice Standard 632 by improving nutrient separation efficiency, enhancing water quality outcomes, and supporting environmentally sound manure management practices.

Newtrient (<https://www.newtrient.com/>), a company sponsored by the dairy industry and committed to enhancing value and sustainability in manure management, has conducted a thorough assessment of technology systems and practices within the field, focusing on their impact on critical environmental metrics, specifically water quality. The information in this report is based on a University of Wisconsin-Madison evaluation of membrane technology on a farm located in Wisconsin.

In support of this discussion, Appendix A offers a brief discussion on the significant impact of membrane technology on key environmental indicators related to water quality, air emissions, and other relevant factors aligned with the objectives of Standard 632. Also, Appendix B presents data from a membrane technology evaluation, investigating the performance of a manure processing system designed to treat manure to discharge quality. Additionally, Appendix C contains the final report of the study

conducted by the University of Wisconsin-Madison, providing further insights into the effectiveness and benefits of membrane technology.

Reducing nutrient content, organic strength

The system significantly partitions the nutrient content and organic strength of manure through a multi-stage treatment process that includes mechanical separation, UF, and RO. As manure progresses through each stage, concentrations of TS, VS, total Kjeldahl nitrogen (TKN), TP, ammonium nitrogen ($\text{NH}_4\text{-N}$), and K decline in the liquid fraction, demonstrating effective separation and concentration of key constituents.

Over the 37-week sampling period, separated liquids showed consistent reductions in solids and partitioned nutrients at each treatment stage. RO concentrate was enriched in $\text{NH}_4\text{-N}$ with minimal TP, producing a nutrient stream suitable for targeted application where N is needed without adding P. The centrifuge and UF concentrates also retained distinct nutrient profiles, supporting more precise and efficient nutrient reuse strategies.

Reducing odor and gaseous emissions

Membrane-based nutrient partitioning technology contributes to reduced odor and gaseous emissions by removing volatile and odorous components from the manure stream during processing. By separating solids early in the treatment process through mechanical means such as screw presses and centrifuges, a substantial portion of organic material—particularly VS—is removed from the liquid stream. These materials are primary contributors to odor from volatile organic carbons (VOCs) and the generation of gases such as ammonia (NH_3), methane (CH_4), and hydrogen sulfide (H_2S).

Downstream treatment through UF and RO further reduces the concentration of dissolved organics and nutrients in the resulting permeate, particularly $\text{NH}_4\text{-N}$, which is a precursor to NH_3 emissions. With fewer volatile compounds remaining in the final effluent and concentrate streams, the system limits the potential for gaseous release during storage and application.

While the system does not eliminate the need for odor management entirely—especially for separated solids and concentrate storage—it reduces the odor intensity and emission potential of the bulk manure volume. When operated consistently and effectively, the membrane system supports overall improvements in air quality and odor control on dairy farms.

Facilitating desirable waste handling and storage

By efficiently separating manure into distinct solid and liquid fractions, the Membrane-based nutrient partitioning technology enhances waste handling and storage, each of

which can be managed more effectively according to its physical and chemical characteristics. Mechanical separation through screw presses and centrifuges concentrates solids, producing a manageable solid fraction with reduced volume and increased nutrient density. This solid fraction is easier to handle, transport, and store, often enabling more cost-effective use as a soil amendment or for composting.

The liquid fractions treated through UF and RO produce nutrient-rich concentrates and a clean water stream, suitable for discharge. Concentrates retain valuable nutrients like $\text{NH}_4\text{-N}$ and TP in reduced volumes, facilitating targeted nutrient recycling while minimizing storage requirements. The production of clean water suitable for discharge or reuse substantially decreases the volume of waste needing storage and land application, thereby reducing handling complexity and environmental risks.

Producing value added byproducts that facilitate manure and waste utilization

Membrane-based nutrient partitioning technology produces several value-added byproducts that enhance manure and waste utilization by concentrating nutrients and improving the quality and handling characteristics of separated fractions. The mechanical separation units—screw presses and centrifuges—generate solid byproducts with elevated concentrations of TS, TKN, and TP, which can be repurposed on-farm or sold off-farm as nutrient-rich soil amendments or feedstock for composting and bioenergy production.

Following mechanical separation, the UF and RO units further refine the liquid fraction, producing nutrient concentrates rich in $\text{NH}_4\text{-N}$, soluble P, and K. These concentrated streams enable more precise nutrient application on crops, improving fertilizer efficiency and reducing dependence on synthetic inputs. The segregation of nutrients into discrete streams facilitates customized nutrient management plans that align with crop needs and soil nutrient status, promoting sustainable agriculture.

In addition, the system produces a treated water byproduct that meets water quality standards for reuse or discharge, reducing the overall environmental footprint of manure management. By transforming raw manure into marketable or agronomically valuable products, the membrane system adds economic value for producers, supports nutrient recycling, and advances circular economy principles in livestock operations.

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 the membrane-based nutrient partitioning technology in manure management:

- Volumetric Flow:* The manure processing system receives approximately 126 gallons per minute (GPM) of digestate at the influent stage, with the screw press stage processing an average of 116 GPM. Assuming 80% uptime (19.2 hours/day), this equates to roughly 145,000 gallons/day (53 million gallons/year) processed by the screw press and 134,000 gallons/day (49 million gallons/year) by the centrifuge. The Aqua Innovations Nutrient Concentration System, which includes two parallel UF units, is designed to operate at a combined capacity of 100 GPM (50 GPM each), with an estimated maximum throughput of 115,000 gallons/day or 42 million gallons/year under continuous operation at 80% uptime. However, during the study period, only one UF unit was typically operational, processing 45 GPM. Downstream, the RO unit intermittently processed approximately 50 GPM of UF permeate, producing equal parts treated clean water and RO concentrate at 25 GPM each. Based on estimated annual flows of 49 million gallons, this would result in approximately 16 million gallons each of UF concentrate, RO concentrate, and treated water.
- Mass Flow:* The centrifuge produced approximately 60 pounds per minute (3,600 pounds/hour) of separated solids, as measured directly. Calculations using influent volumes, TS concentrations, and separation indices yielded a slightly lower estimate of 53 pounds/minute. The screw press solids production rate could not be directly measured but was estimated at 93 pounds/minute using comparable methods. These estimates suggest that the screw press and centrifuge could collectively produce approximately 132,480 pounds (66.2 tons) of separated solids per 24-hour operational day, supporting the management of manure from roughly 7,800 and 7,100 cows, respectively.
- Hydraulic Retention Times (HRT):* This system is designed for continuous flow, with no significant storage or batch processing stages beyond short buffering between unit operations. Therefore, HRTs are relatively short and dependent on system design and flow rates. For example, the digester likely has a separate and much longer HRT not captured in this specific analysis. Within the separation system itself (screw press through RO), HRTs are likely on the order of minutes, as materials move rapidly through each treatment component. The exact HRTs would vary slightly based on system configuration, pump rates, and any temporary hold times in feed or balance tanks but are not expected to exceed 1–2 hours in total for any single stage in the membrane system.

DESIRED FEEDSTOCK CHARACTERISTICS

The performance and longevity of membrane-based nutrient partitioning technology depends heavily on the quality and consistency of the feedstock entering the system. In

the system evaluated, the feedstock consists of separated liquid manure that has undergone prior treatment through anaerobic digestion, mechanical solids separation via screw press, and centrifugation. These pretreatment stages are critical to reduce the solid content, organic loading, and variability of the influent, all of which directly affect membrane fouling, throughput, and system reliability.

Key desired feedstock characteristics include:

1. **Low Total Solids (TS):** Membrane systems require low suspended solids content to prevent clogging and minimize membrane fouling. The feedstock should have undergone sufficient solids separation (e.g., TS < 1%) prior to UF.
2. **Stable Flow and Composition:** Consistent flow rates and nutrient concentrations help maintain optimal membrane performance. Large fluctuations in solids content, N or P concentrations can challenge system operation and nutrient recovery efficiency.
3. **Reduced Biological Oxygen Demand (BOD):** Lower organic strength reduces the risk of biological fouling and extends membrane lifespan. Anaerobic digestion upstream of the membrane system helps achieve this by reducing BOD and VS.
4. **Minimal Large Particulates and Fibers:** Mechanical screening or effective screw press and centrifuge treatment is essential to remove coarse material that could physically damage membranes, reduce separation efficiency or block flow paths.
5. **pH and Temperature within Design Range:** The system is designed to operate within specific pH and temperature ranges (typically near-neutral pH and moderate temperatures), both of which influence membrane chemistry and separation performance.
6. **Low Oil, Grease, and Chemical Loadings:** Excessive fats, oils, and greases (FOG), or residual chemicals from cleaning or processing activities, can interfere with membrane separation and reduce water quality in the treated effluent.

EXPECTED SYSTEM PERFORMANCE

Membrane-based nutrient partitioning technology is designed to improve manure management by separating liquid manure into distinct nutrient laden and clean water streams. When paired with effective pretreatment—such as anaerobic digestion, screw press separation, and centrifugation—these systems can significantly reduce TS, VS, and nutrient concentrations in the treated liquid. The system enhances nutrient recovery by

concentrating P in the solids fraction and UF concentrate and producing a cleaner liquid suitable for further processing via RO.

- *Changes in form or handling characteristics*

- Membrane-based nutrient partitioning technology (with initial solid separation) substantially alters the form and handling characteristics of dairy manure by separating it into distinct solid, concentrate, and clean water fractions. These systems convert raw manure—typically a homogenous slurry—into more manageable streams: stackable solids with higher dry matter content, concentrated nutrient-rich liquids, and clarified water suitable for reuse or further treatment. This transformation reduces the volume of material requiring land application, lowers hauling costs, and allows for more strategic nutrient placement. The resulting outputs, especially the nutrient concentrates, can be more easily aligned with agronomic rates and transported off-farm if necessary.

Data from the University of Wisconsin–Madison study of a full-scale system in Middleton, WI, illustrates how these transformations occur. Over a 37-week sampling period, separated solids from both the screw press and centrifuge reached TS concentrations of 23–30%, with centrifuge solids containing higher concentrations of N and P, making them better suited for targeted nutrient applications or off-farm export. Liquid streams became progressively more refined: the UF concentrate had a higher proportion of P, while the RO concentrate was dominated by $\text{NH}_4\text{-N}$ with minimal P, a form favorable for crop uptake during critical growth stages. These changes in nutrient form and physical properties support more efficient nutrient utilization and open additional options for storage, transport, and reuse, while also contributing to reduced environmental risk.

- *Nutrient fate or end use projections*

- The membrane system routes nutrients into distinct output streams with varying concentrations and usability, creating opportunities for targeted nutrient reuse. The manure treatment process results in three primary end products: treated clean water suitable for discharge, nutrient-rich concentrates (from both the UF and RO stages), and separated solids (from the screw press and centrifuge). These fractions each hold a portion of the original nutrient load, depending on the stage of separation and nutrient form.

N, P, and K partition differently based on their chemical forms and solubility. P is often associated with solids, especially in organic or particulate-bound forms, and is largely captured in the screw press and centrifuge stages. However, a portion of soluble P remains in the liquid and is concentrated during UF. N is primarily present in soluble forms such as NH_4^+ , which passes through early separation stages and is retained in the RO concentrate. K is highly soluble and remains in the liquid throughout the process, becoming concentrated in later membrane stages. Understanding how these nutrients partition allows for more strategic reuse or offsite transport based on nutrient content and crop requirements.

Removal efficiency (RE) data from the system show that nutrient separation improves progressively across the treatment train. Total solids, VS and P begin separating effectively in the screw press and centrifuge stages, while N—particularly available N ($\text{NH}_4\text{-N}$)— and K requires the RO stage to reach high removal efficiency. The system consistently produces clean water that represents roughly 36% of the influent manure volume and meets quality targets for discharge. Meanwhile, 62% of the total influent volume is retained as nutrient-dense concentrate: 26% from UF and 36% from RO.

- *Macro-nutrient reductions or transformations*

The membrane-based nutrient partitioning technology demonstrated strategic concentration of key macro-nutrients—N (TKN and $\text{NH}_4\text{-N}$), P, and K—across its multiple treatment stages. As the manure passed through the screw press, centrifuge, UF, and RO units, the system increasingly partitioned these nutrients into concentrated streams or removed them entirely through treated water production.

P remaining after solid separation was effectively concentrated in the UF concentrate, while available $\text{NH}_4\text{-N}$ was more strongly retained in the RO concentrate. This separation enables downstream use of nutrient-rich streams in ways that align with crop needs, for instance, applying the high-N RO concentrate during periods of rapid crop uptake. K, though more uniformly distributed across fractions, was also effectively concentrated in the later stages of treatment.

While the system does not chemically alter nutrient forms (i.e., it does not perform transformations such as nitrification or denitrification), it does enable separation based on solubility and particle size. Understanding this distinction is essential: soluble nutrients—such as NH_4^+ and K^+ —are

dissolved in water and pass through coarse separation steps, while insoluble, particulate-bound nutrients—such as organic N and a portion of P—are associated with suspended solids. The system sharpens this distinction through its sequential treatment steps: the screw press and centrifuge primarily remove particulate-bound nutrients, while UF and RO target dissolved, soluble forms.

This enhanced separation makes the end products more manageable and enables selective land application strategies that better align with crop nutrient uptake patterns, reducing the risk of nutrient leaching or runoff. The ability to isolate macro-nutrients into targeted, usable forms significantly supports more refined nutrient management.

- *Pathogen reductions or eliminations*
 - The membrane-based nutrient partitioning technology contributes to pathogen reduction primarily through physical separation mechanisms. UF membranes are designed with pore sizes small enough to remove suspended solids, as well as microorganisms as small as bacteria, acting as a physical barrier to a wide range of microbial pathogens. This size-exclusion process significantly reduces pathogen load in the treated water, making it more suitable for discharge or reuse in land application systems with lower public health and environmental risk.

Although the system does not incorporate chemical disinfection (e.g., chlorination) or thermal treatment, the UF stage alone can achieve notable reductions in microbial concentrations. RO, which follows UF, further refines the treated liquid and contributes additional pathogen reduction by rejecting even smaller solutes and microbial fragments, depending on membrane performance and system maintenance.

The overall pathogen reduction across the full system is enhanced by the multi-stage design, where upstream solid separation (screw press and centrifuge) removes a significant portion of pathogen-associated particulate matter. While specific pathogen log reduction values were not measured in the study, the treatment configuration aligns with industry practices known to reduce pathogen loads substantially.

For applications requiring high sanitary standards, this system configuration offers a reliable base level of pathogen removal and can be

paired with further treatment (e.g., UV or chemical disinfection) if higher-level pathogen elimination is required.

- *Air quality*

- The membrane-based nutrient partitioning technology helps reduce potential air quality impacts from manure management by effectively separating and concentrating nutrients and solids. This process minimizes the volume and organic strength of liquid waste that must be stored. By removing a significant portion of VS upstream through screw press and centrifuge separation, the system limits the organic material available for microbial degradation during storage, thereby reducing the potential for CH₄ and other greenhouse gas (GHG) generation.

Additionally, the system lowers NH₃ volatilization potential by isolating total ammoniacal nitrogen (TAN) in liquid concentrate streams for more targeted applications. When managed properly, these concentrated streams can be incorporated into soil more efficiently, reducing surface exposure and associated N losses to the atmosphere. The production of treated clean water further reduces the total volume of high-nutrient liquid requiring storage, indirectly minimizing the risk of gaseous losses from open holding ponds or tanks.

While the system itself does not directly capture or treat gaseous emissions, its ability to partition and concentrate manure components supports broader nutrient management strategies that mitigate emission potential during storage and land application.

- *Water quality*

- The membrane-based nutrient partitioning technology protects water quality by converting raw manure into more manageable and targeted nutrient streams. As manure progresses through each treatment stage—screw press, centrifuge, UF, and RO—both solids and dissolved nutrients are partitioned, resulting in a final treated water product that often meets discharge standards. This treated clean water, which can account for approximately 36% of the original manure volume, can be discharged or reused with minimal risk to surface or groundwater resources. Additionally, by concentrating nutrients into smaller, well-defined streams (UF and RO concentrates), the system reduces the volume and nutrient density of material requiring storage or land application, thereby minimizing the potential for nutrient leaching and runoff. When properly

managed, these concentrated products can be applied in accordance with nutrient management plans, further protecting water quality.

PROCESS MONITORING AND CONTROL SYSTEM REQUIREMENTS

Effective process monitoring and control are essential to optimize the performance and reliability of membrane-based nutrient partitioning technology. Given the complexity and sensitivity of membrane-based nutrient separation systems, continuous oversight ensures that operational parameters remain within designed ranges, preventing system downtime, membrane fouling, or reduced separation efficiency.

- *Required monitoring*— While the system is operating, the owner must actively monitor the following:
 - **Influent and effluent flow rates** to ensure hydraulic balance and system capacity adherence.
 - **Pressure differentials across membranes** to detect membrane fouling or blockage.
 - **Concentration of key nutrients and solids (e.g., TS, VS, TKN, TAN, TP, K)** at various stages, especially influent, UF concentrate, and permeate streams.
 - **Water quality parameters of treated effluent**, including turbidity and total dissolved solids (TDS), to confirm discharge compliance.
 - **Operational uptime and downtime logs**, including maintenance events and any system alarms.
 - **Temperature and pH** of the influent and membrane feed streams, as these can affect membrane performance.
- *Required control*— During operation, the owner must actively control the following:
 - **Flow rate adjustments** to balance feed to UF and RO units, preventing overloading or underutilization.
 - **Backflush and cleaning cycles** for membranes to reduce fouling and maintain permeability.
 - **Pressure regulation** within system limits to avoid membrane damage.
 - **Chemical dosing controls**, if applicable, to aid in fouling prevention or nutrient stabilization.
 - **Alarm and fault management systems** to enable prompt operator response to deviations.
- *Equipment included for monitoring*— The system includes the following tools for monitoring performance:

- **Inline flow meters** at key points, including influent, concentrate, and permeate streams.
- **Pressure sensors** positioned before and after membrane modules to measure differential pressure.
- **Water quality sensors** for turbidity, TDS, and nutrient concentrations.
- **Data logging and telemetry systems** to record operational parameters and transmit data remotely for analysis.
- **Automated uptime/downtime tracking** integrated with maintenance scheduling.
- *Equipment included for controlling*— The system includes the following tools for controlling operations:
 - **Automated flow control valves** for regulating feed and concentrate flow rates.
 - **Programmable logic controllers (PLCs)** that manage cleaning cycles, pressure control, and system alarms.
 - **Remote operation interfaces** which allow operators the ability to adjust settings and respond to alerts in real time.
 - **Chemical feed pumps** (if used) with adjustable dosing rates linked to monitoring feedback.
 - **Safety interlocks and emergency shut-off mechanisms** to protect equipment and personnel.

TYPICAL OPERATIONS/MAINTENANCE PLAN WITH MONITORING REQUIREMENTS AND REPLACEMENT SCHEDULE

The membrane-based nutrient partitioning technology is designed to provide efficient separation of nutrients and solids from manure and process water, enabling improved nutrient management and water reuse. Maintaining optimal performance requires consistent operation, vigilant monitoring, and timely maintenance to prevent membrane fouling, system downtime, and deterioration of treatment efficiency. The following outlines a typical operations and maintenance plan, including monitoring requirements and a recommended replacement schedule for key components.

System Monitoring

1. **Influent and effluent flow rates:** Continuous measurement to ensure system capacity is maintained and to detect flow imbalances.
2. **Differential pressure across membranes:** Monitored in real time to identify early signs of membrane fouling or clogging, triggering cleaning cycles as needed.

3. **Water quality parameters:** Regular sampling of permeate and concentrate streams to confirm nutrient removal efficiency and discharge compliance. Key parameters include TS, TN, TP, NH₄-N, and K.
4. **Membrane integrity checks:** Periodic integrity testing to detect membrane breaches or damage that could compromise treatment performance.
5. **Operational uptime and downtime logs:** To track system availability and identify trends requiring preventive maintenance.
6. **Cleaning cycle frequency and effectiveness:** Documentation of backflush and chemical cleaning cycles, adjusting frequency based on fouling rates.

Typical Maintenance Activities

1. **Membrane cleaning:** Routine chemical cleaning (CIP - clean-in-place) scheduled based on pressure differential thresholds or fouling rates, typically every 2-4 weeks depending on feed water quality.
2. **Inspection and replacement of pre-filters:** Pre-filters should be inspected weekly and replaced monthly or as needed to protect membranes from particulate damage.
3. **Pump and valve maintenance:** Regular lubrication, inspection, and functional testing of pumps and control valves to ensure reliable operation.
4. **Sensor calibration:** Periodic calibration of flow meters, pressure sensors, and water quality sensors to maintain accurate monitoring.
5. **System flushing:** Scheduled flushing to remove residual solids and prevent buildup in piping and membranes.

Replacement Schedule

1. **Membrane modules:** Typically replaced every 3-5 years, depending on operational conditions, feedwater quality, and maintenance adherence. Membrane life can be extended with proper cleaning and operation.
2. **Pre-filters and cartridge filters:** Replacement every 1-3 months or based on differential pressure increase.
3. **Pumps and valves:** Replacement as needed based on wear and performance, generally every 5-7 years.
4. **Sensors and instrumentation:** Calibration every 6 months; replacement every 3-5 years or sooner if faulty.
5. **Chemical dosing equipment:** If applicable, replacement or major servicing every 3-5 years.

CHEMICAL INFORMATION

- Membrane-based nutrient partitioning technology operates without the addition of chemicals during the manure and water treatment process. Nutrient concentration and solid separation are achieved solely through physical membrane filtration technologies. Chemicals are used only occasionally for membrane cleaning and maintenance to ensure optimal system performance and prolong membrane lifespan. These cleaning agents are not introduced into the manure or treated water streams but are applied during scheduled maintenance cycles.

ESTIMATED INSTALLATION AND OPERATION COST

Equipment and Installation Capital Costs

Industry averages provide a general estimate of the capital investment required to acquire and install UF and RO systems for manure treatment. These figures should be considered approximate, as actual costs may vary depending on site-specific conditions, system design, market pricing, and project goals. Importantly, the estimates below do **not include** the cost of preparatory systems such as coarse solid separation (e.g., screw presses or centrifuges), which are typically required upstream of membrane systems.

Estimated Capital Costs (2025 figures):

- **Membrane system for ~3,000 cows (single UF unit):**
Approx. **\$750,000**
- **Membrane system for ~5,000 cows (two UF units, similar to Middleton site):**
Approx. **\$1,600,000**
- **Membrane system for ~5,000 cows + RO unit:**
Approx. **\$2,500,000**
(The addition of an RO unit generally increases capital costs by \$900,000 to \$1,000,000 or more, depending on system size and complexity.)

These cost estimates typically include the UF system itself, controls, piping, instrumentation, and other essential ancillary equipment. They reflect turnkey installation pricing and assume standard configurations. These costs are based on dairies ranging from 3,000 to 5,000 animals.

Operation and Maintenance Costs (O&M)

- **Electrical**— The membrane-based nutrient partitioning technology requires a continuous power supply to operate pumps, membranes, and control systems. Electrical consumption varies depending on system throughput and runtime, and it typically represents the most significant portion of ongoing operational costs.

Although the overall cost is generally less than \$0.01 per gallon treated, it is highly sensitive to local utility rates and system usage patterns. Incorporating energy-efficient components and implementing optimized system scheduling strategies—such as aligning operation with off-peak electricity pricing—can significantly reduce power consumption and associated costs.

- **Labor**— Labor costs include the personnel needed to monitor, maintain, and occasionally operate the system. While UF and RO systems are largely automated and do not typically require full-time dedicated staff, skilled technicians are required for periodic membrane cleaning, system checks, troubleshooting, and responding to alarms or other maintenance needs. Labor demands may fluctuate depending on system complexity and runtime, with additional support needed during maintenance and repair events.
- **Maintenance Replacement**— Routine maintenance includes periodic membrane cleaning, replacement of worn or fouled membranes, and upkeep of ancillary components such as pumps and sensors. Membrane lifespan depends on feedstock characteristics and cleaning frequency but generally requires replacement every few years. Proactive maintenance minimizes downtime and helps sustain system performance and efficiency.

EXAMPLE WARRANTY

Warranty information specific to membrane-based nutrient partitioning technology is not currently available. However, a typical warranty from system manufacturers may include the following general provisions:

1. Warranty Coverage

- This warranty typically covers defects in materials and workmanship for the membrane-based nutrient partitioning technology for a period of 1 to 3 years from the date of installation or purchase, depending on the manufacturer.

2. What Is Covered

- **System Components:** Coverage includes major system components such as pumps, control panels, and membrane housings, as well as the membranes themselves (often with prorated coverage based on expected lifespan).
- **Repair or Replacement:** If a covered issue arises during the warranty period, the manufacturer will repair or replace defective parts. Labor, shipping, and

installation costs may or may not be included, depending on the terms of the warranty.

3. What Is Not Covered

- **Damage Due to Improper Use:** Any malfunction or damage resulting from misuse, incorrect operation, or failure to adhere to prescribed maintenance protocols.
- **External Factors:** Incidents caused by external conditions such as flooding, freezing, fire, power surges, or acts of nature.
- **Wear and Tear:** Normal degradation of membrane performance and other components due to expected wear and chemical cleaning cycles.
- **Unauthorized Modifications:** Any failure caused by modifications, repairs, or servicing performed by non-certified technicians or third parties.

The actual warranty terms must be confirmed directly with the system manufacturer or vendor at the time of purchase.

RECOMMENDED RECORD-KEEPING FOR MEMBRANE-BASED NUTRIENT PARTITIONING TECHNOLOGY

Effective record-keeping is essential for ensuring the optimal performance, reliability, and longevity of membrane-based nutrient partitioning technology. Maintaining detailed records enables timely identification of operational issues, supports regulatory compliance, and helps optimize maintenance schedules. The following record-keeping practices are recommended:

- **Operational Parameters**
Record daily flow rates, pressures, and volumes of influent and permeate streams to monitor system performance and detect deviations from normal operation.
- **Cleaning and Maintenance Logs**
Document all cleaning cycles, including chemical agents used (type, concentration, and volume), frequency, duration, and any observed effects on membrane performance. Track routine maintenance activities such as filter replacements, pump servicing, and membrane integrity tests.
- **Membrane Performance Data**
Maintain records of membrane permeability, rejection rates, and transmembrane pressure differentials over time to assess membrane health and schedule replacements before performance deteriorates.

- **Incident Reports**
Log any operational issues, system failures, or abnormal events along with corrective actions taken and outcomes.
- **Replacement and Warranty Records**
Keep detailed records of all component replacements, warranty claims, and vendor communications.
- **Environmental and Compliance Data**
Track data relevant to discharge quality, nutrient concentrations in permeate and concentrate streams, and compliance with environmental permits or regulatory requirements.

ALTERNATIVES FOR THE USE OF BYPRODUCTS

Membrane-based nutrient partitioning technology separates liquid dairy manure into multiple nutrient-rich fractions that offer diverse opportunities for beneficial reuse. These byproducts include UF concentrate, RO concentrate, and treated clean water suitable for discharge, each with distinct characteristics that can be matched to specific agricultural or industrial applications.

- **Ultrafiltration Concentrate**
This stream is typically high in P and volatile solids, making it suitable for land application on fields with low P levels or for blending with other effluents for more balanced nutrient application. With additional stabilization, it may also be used as a feedstock for composting or anaerobic digestion.
- **Reverse Osmosis Concentrate**
High in readily available N (primarily as $\text{NH}_4\text{-N}$) and low in P, this fraction is ideal for precision fertigation, particularly during stages of crop growth with high N demand. It may also be used in nutrient blending systems to support site-specific nutrient management strategies.
- **Treated Clean Water**
The treated water produced through RO is low in nutrients and solids and can be reused for flushing, cleaning, irrigation, or even animal consumption if properly managed and permitted. This can help reduce freshwater withdrawals and support water conservation goals on the farm.

INDEPENDENT VERIFIABLE DATA DEMONSTRATING RESULTS/CREDENTIALS

Appendix A is a summary of the expert opinion and technical data available for this class of technology and how it relates to key performance indicators within NRCS Standard 632. This information is available through Newtrient.

Appendix B provides a summary of data from a Newtrient-managed third-party review of a membrane-based nutrient partitioning technology unit within a manure processing system located on a dairy farm in Middleton, Wisconsin. The data comes from a system performance analysis conducted by the University of Wisconsin-Madison but has not been peer-reviewed.

Appendix C contains the full University of Wisconsin-Madison report detailing the third-party review in Middleton, Wisconsin.

CONTACT INFORMATION—VENDOR

While not an exhaustive list, the list below identifies vendors that are active in the application of membrane-based nutrient partitioning technology.

1. **Aqua Innovations Plus – Membrane System**

Address: 210 New Factory Rd., Sharon, WI 53585

Phone: 262-388-5335

Website: <https://www.aquainnovationsplus.com/>

Company Information: The AQUA Innovations Plus nutrient management system eases the pain of managing dairy manure with a liquid/solid partitioning system that reduces storage and hauling costs, and minimizes odors. The system is cost-effective, environmentally compliant, customizable to any dairy operation and provides 24/7 monitoring and support from AQUA Innovations.

2. **McLanahan Corporation – Membrane System**

Address: 200 Wall St., Holidaysburg, PA 16648

Phone: 814-695-9807

Website: <https://www.mclanahan.com>

Company Information: The challenges and regulations in today's tough marketplace require producers to be more efficient, more productive and more profitable. The McLanahan Nutrient Separation System allows dairies to do more with their valued manure stream. For more on how this tested and proven technology can economically benefit your operation, contact McLanahan today.

3. **New Logic Research VSEP – VSEP Membrane**

Address: 2527 Aviation Way Minden, NV 89423

Phone: 775-783-7600

Website: <https://www.vsep.com/product/vsep-membrane-cleaners/>

Company Information: The VSEP filtration system consists of 6 major components: the VSEP (Frame, Drive System, Plumbing), Filter Pack, Interconnecting Piping, Feed Pump Skid, and Metering Pump Skid (with Cleaning Chemical Totes). At startup, the VSEP system is fed with a slurry and the concentrate valve is closed. Permeate is produced and suspended solids in the

feed are collected inside the VSEP filter pack. After a programmed time interval, valve one is opened to release the accumulated concentrated solids. The valve is then closed to allow the concentration of additional feed material. This cycle repeats indefinitely.

4. **Digested Organics – Membrane System**

Address: 14601 Keel St., Plymouth, MI 48170

Phone: 734-545-8016

Website: <https://digestedorganics.com/nutrient-water-reclamation-system/>

Company Information: Digested Organics has developed an exclusive UF and RO solution for wastewater nutrient concentration and water reclamation. The Nutrient Concentration & Water Reclamation (NCWR)[™] System can process raw manure and digestate (from any digester, including their BioEliminator[™]), along with other wastewater such as landfill leachate and food/beverage wastewater, and separate the flow into clean, reusable water—ideal for facility reuse or discharge—and concentrated liquid fertilizer. With most materials, they state that they can recover more than 70% of the total volume as clean water while concentrating the nutrients about 3x.

5. **ATD Waste Systems Inc. – Manure Management Systems**

Address: 3099 West 24th Ave., Vancouver, British Columbia, Canada

Phone: 604-736-4474

Website: <https://livestockmanuremanagement.com/the-atd-manure-system/>

Company Information: ATD will integrate their system to existing installed processes with the goal of reducing fresh water consumption by up to 70% and capturing virtually all solids in the form of cake or bedding for use or sale off-site. A by-product of that is a concentrated stream of dissolved nutrients taken from the water that will reduce lagoon contents and subsequent application costs by up to 70% as well or sold off-site.

6. **Quality Flow Environmental, LLC – Manure Processing System**

Address: 3691 Commercial Ave., Northbrook, IL 60062

Phone: 847-291-7674

Website: <https://www.qualityflowenvironmental.com/>

Company Information: QFE's patent-pending technology can be customized to operate successfully onsite for CAFOs using lagoons or in tandem with an anaerobic digester. A multi-step process diverts manure from lagoons and separates manure solids from its liquids. Then, using state of the art membrane filtration technology, the dairy wastewater is cleaned, recycled and the nutrients captured. The solids and liquids will be purchased by QFE and removed. This system qualifies for USDA REAP and EQIP funds.

7. Dynatec – Containerized MBR System

Address: 360 Connecticut Drive Burlington, NJ 08016

Phone: 609-387-0303

Website: <https://www.dynatecsystems.com/technologies/>

Company Information: Our Mission is to create value by providing high quality wastewater and purification treatment systems and excellent service at below average cost. The pursuit of this mission has enabled us to earn and retain the trust, confidence and business of our customers. Value is the primary force that fuels our growth. While the size and scope of our projects have grown over the years, we have maintained our small company qualities that allow us to give personal attention to every project. The principals of the corporation are intimately integrated in all project work. We will continue to pursue work for small and large companies alike and provide solutions to industrial and domestic wastewater problems. Our goal remains providing quality through products and services that produce reasonable growth.

CONTACT INFORMATION—USER

Commercial facilities presently operating in the U.S. with this class of technology are identified below. The following list is a best effort but may not be completely inclusive of all installations.

Membrane-based nutrient partitioning technology

Northern Biogas – Middleton, Wisconsin

Majestic Crossing Dairy – Sheboygan Falls, Wisconsin

Foodbuy, LLC – Charlotte, North Carolina

Dairy Dreams, LLC – Casco, WI

OTHER CONSIDERATIONS

While the preceding sections address the 15 core items required in a third-party technical evaluation per the 632 methodology, additional insights gathered during the evaluation process may inform broader adoption and implementation decisions for membrane-based nutrient partitioning technology. The following considerations are provided to help NRCS and other stakeholders better understand practical, operational, and strategic factors associated with the technology:

- **Integration with Existing Manure Systems:**

This UF system was evaluated as part of a larger manure treatment system that included upstream separation (screw press, centrifuge) and downstream RO. The effectiveness and feasibility of the system may vary depending on the configuration of the broader manure management system. Farms without anaerobic digestion or pre-treatment may require additional infrastructure investments.

- **Uptime and Reliability:**

During the 37-week evaluation period, system uptime was variable due to maintenance and operational challenges. Consistent operation is critical for achieving expected nutrient concentrations and water recovery volumes. Factors such as membrane fouling, pump wear, and control system sensitivity should be monitored closely.

- **Farm Labor and Training Requirements:**

Operating this system requires skilled labor familiar with membrane filtration, monitoring instrumentation, and troubleshooting. Additional staff training and technical support from the vendor may be necessary for successful adoption.

- **Data Management and Monitoring:**

The system generates large volumes of flow and quality data that are critical for optimization, regulatory compliance, and nutrient tracking. Farms may need support in integrating data streams into nutrient management planning tools or reporting frameworks.

- **Vendor Engagement and Support:**

The system evaluated was provided by a specific technology vendor, Aqua Innovations, with proprietary equipment and controls. Long-term support, parts availability, and responsiveness from the vendor will impact operational success.

- **Nutrient Management Implications:**

The ability to isolate specific nutrient fractions—such as $\text{NH}_4\text{-N}$ in RO concentrate—can greatly improve precision application. However, farms will need support to adapt current nutrient management plans to incorporate these new streams effectively and safely.

- **Regulatory and Permitting Alignment:**

The treated water from the system can meet discharge standards, but actual discharge or reuse may require site-specific permitting. Clarity around regulatory pathways and water quality thresholds will be important for widespread implementation.

Conclusion

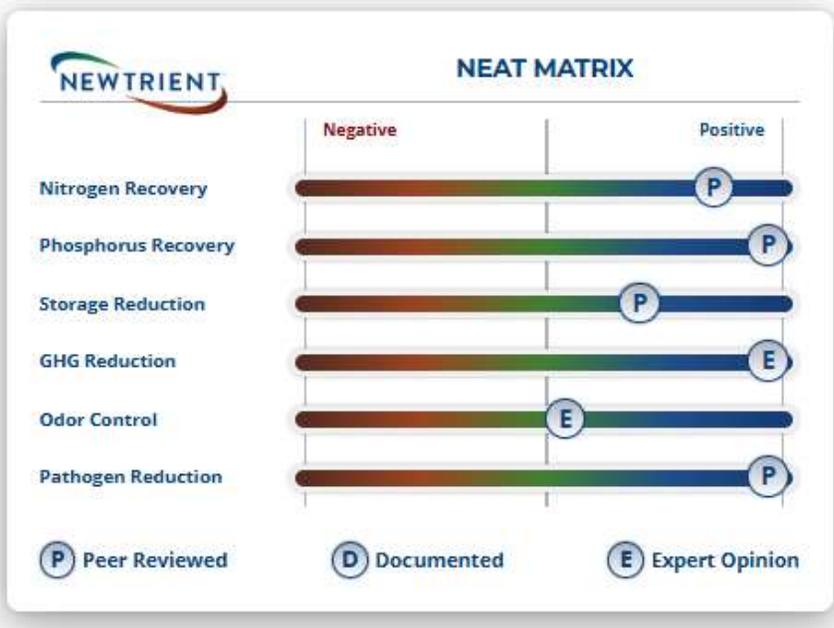
The membrane-based nutrient partitioning technology evaluated in this report demonstrates strong potential as an advanced nutrient recovery and water treatment solution for dairy operations. When integrated with upstream solid-liquid separation technologies and downstream RO, the system can significantly concentrate and partition the nutrient load and organic strength of manure effluent, producing multiple valuable byproducts, including treated water suitable for reuse or discharge.

While this system meets or exceeds many of the objectives outlined under NRCS Practice Standard 632 (Waste Separation Facility), its success depends on appropriate design integration, reliable operation, and committed management. The technology is most effective when installed as part of a broader, well-managed manure handling system and supported by trained personnel and responsive vendor service.

As interest grows in improving nutrient efficiency, reducing environmental impact, and enabling water reuse in dairy systems, membrane-based nutrient partitioning technology represents a compelling tool. Continued evaluation, support, and refinement of system designs, especially regarding cost, maintenance, and nutrient end use, will be key to encouraging wider adoption and ensuring long-term performance across diverse farming contexts.

Appendix A

NEWTRIENT CRITICAL ANALYSIS – MEMBRANE-BASED NUTRIENT PARTITIONING TECHNOLOGY



Overall Summary

The membrane-based nutrient partitioning technology is an emerging nutrient separation system primarily used to partition low-solids manure slurries into two co-products: a concentrated slurry rich in organic N and P, and a nutrient-rich “tea water” containing soluble nutrients like NH_4^+ and K. Designed for use after primary separation of scrape or flush manure systems, this technology does not rely on chemical additives aside from periodic membrane cleaning, allowing the outputs to potentially qualify for organic certification. While UF and RO membranes are widely used in wastewater and food processing industries, adoption in U.S. dairy systems remains limited due to high capital costs, operational complexity, and the need for reliable maintenance. The system offers moderate operating costs, with energy being the primary input and minimal chemical requirements. Benefits include reduced manure management costs, potential for value-added fertilizer products, and separation of pathogens and solids, enabling downstream compliance with Food Safety Modernization Act (FSMA) standards. However, the system does not reduce volume, eliminate odors, or generate renewable energy, and the concentrated slurry still requires liquid storage. As part of a clean water membrane system or as a stand-alone unit for tea water production, the use of UF membranes holds promise but depends heavily on optimized operation, trained personnel, and the development of markets for its outputs.

Appendix B

Third-Party Review of Membrane-Based Nutrient Partitioning Technology – Middleton, WI (Report Summary)

University Partner

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Madison, WI 53706

JULY 2025

BACKGROUND

Livestock operations are increasingly under pressure to minimize their environmental footprint while maintaining efficient nutrient cycling and farm productivity. A key challenge lies in the management of manure, which, while rich in nutrients valuable for crop production, can also be a contributor to water contamination and greenhouse gas emissions, as well as odor when mismanaged. Traditional land application practices often involve high volumes of manure with elevated water content, which complicates transport and storage and increases the risk of nutrient losses through runoff, leaching, or volatilization.

To address these challenges, manure processing technologies have emerged as promising solutions for separating and concentrating nutrients, extracting solids, and even producing discharge-quality water. These systems offer the potential to reduce the volume and environmental risk of manure by-products, while improving efficiency and opening opportunities for nutrient recovery or reuse. However, the effectiveness of these systems depends on their ability to consistently separate targeted constituents and meet environmental thresholds for discharge.

One such system, membrane-based nutrient partitioning technology, was evaluated in Wisconsin to assess its ability to treat manure from a 4,500-cow dairy into usable co-products—separated solids, nutrient-dense concentrates, and treated water suitable for discharge. The system integrated several treatment stages, including screw presses, a centrifuge, ultrafiltration (UF), and reverse osmosis (RO). Understanding the performance of these components both individually and in combination is essential to determining the viability of advanced manure treatment systems in commercial-scale livestock operations.

INTRODUCTION

Manure processing systems offer a promising solution by separating solids, concentrating nutrients, and treating effluent to reduce environmental risk and handling costs. Among these technologies, integrated systems that include mechanical separation and membrane filtration aim to produce value-added co-products—such as nutrient-rich concentrates, reusable solids, and treated water suitable for discharge. This evaluation focused on a full-scale membrane-based nutrient partitioning technology installed on a 4,500-cow dairy, designed to reduce the environmental impact of manure by improving nutrient

recovery and producing discharge-quality water. The study aimed to assess the system’s effectiveness in partitioning key manure constituents—including total solids (TS), volatile solids (VS), total phosphorus (TP), total Kjeldahl nitrogen (TKN), total ammoniacal nitrogen (TAN, NH_4^+), and potassium (K) – and to explore its potential as a scalable solution for environmentally responsible manure management. By examining nutrient partitioning performance and the consistency of treatment outcomes, this research contributes to a broader understanding of how advanced processing systems can support both economic and environmental goals in livestock agriculture, particularly dairy.

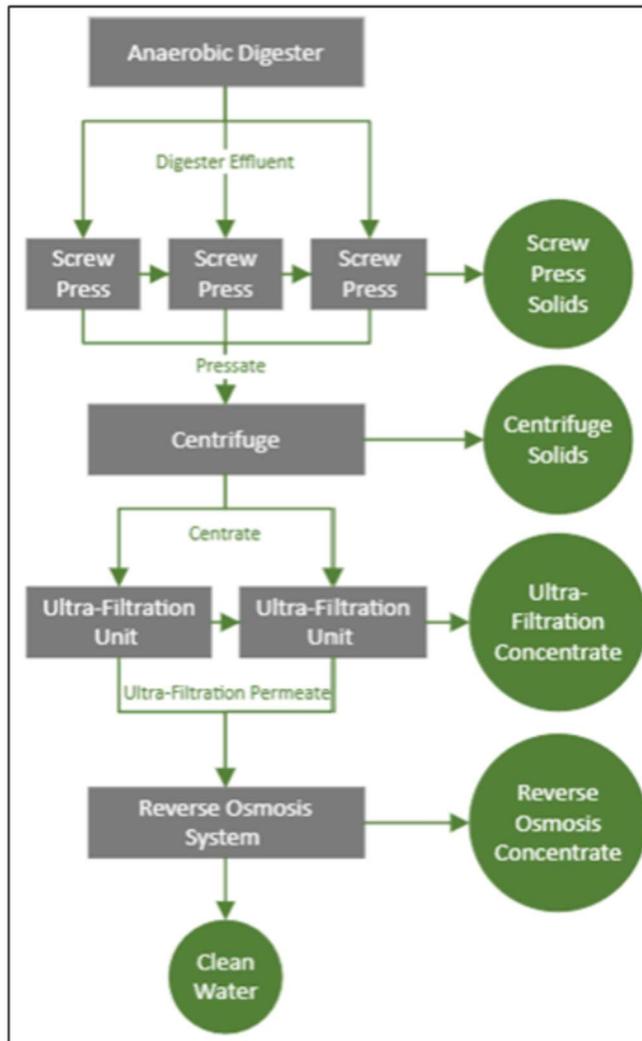


Figure 1: Flow diagram of the manure processing system. Green circles represent recovered products.

THE PROCESS

The membrane-based nutrient partitioning system operates through a coordinated sequence of treatment stages, each designed to progressively separate and refine manure constituents to improve handling, nutrient recovery, and water reuse. In the system evaluated, manure **first** undergoes anaerobic digestion (AD), a pre-treatment step that stabilizes organic matter, reduces odors and pathogens, and enhances downstream separation efficiency. Although AD is not a required component of all membrane-based nutrient partitioning systems, its inclusion in this configuration (Figure 1) improves nutrient recovery and overall system performance. In other designs, raw or minimally

processed manure may flow directly into the solid-liquid separation stage, depending on operational goals and available infrastructure.

The **second stage** involves mechanical separation, where digested manure passes through three screw presses operating in parallel to remove coarse, fibrous solids. These solids, composed mainly of undigested fiber and organic matter, typically contain a lower proportion of TP, as much of the phosphorus (P) remains in the liquid or is associated with finer particles. The remaining liquid is treated with a centrifuge to remove finer particles and additional nutrient fractions. Together, the screw press and centrifuge remove approximately 50% of TS, VS, and TP.

Next, in the UF stage, the clarified liquid flows through two UF units in parallel. These membrane filters eliminate suspended solids, bacteria, and colloidal particles, producing a cleaner stream that reduces the nutrient and pathogenic load on the final polishing step. This stage is essential for protecting the RO membranes and improving the system's overall efficiency.

In the **fourth stage**, the ultrafiltered liquid enters the RO unit (Aqua Innovations Nutrient Concentration System), where dissolved salts, nitrogen—primarily in the form of NH_4^+ —and K are partitioned. This results in two distinct outputs: a nitrogen- and potassium-rich concentrate and a clean water effluent that approaches or meets discharge quality (depending on regulatory requirements). The RO step is key to enabling on-farm water reuse and reducing the volume of material requiring land application.

Finally, the **fifth stage** focuses on product management. Separated solids and nutrient concentrates are stored and managed on-farm, often used for land application aligned with crop nutrient demands. The clean water can be reused or discharged, depending on its quality and applicable regulatory guidelines.

METHODOLOGY

This evaluation was conducted on a commercial-scale manure processing system in Middleton, Wisconsin, serving five dairy farms with a combined herd of approximately 4,500 cows. The system includes AD, mechanical separation (screw presses and centrifuge), and membrane filtration using UF and RO. While the AD and mechanical units are operated by one entity, the UF and RO units—part of the Aqua Innovations Nutrient Concentration System—are managed separately.

Over a 37-week period (July 2023 to March 2024), 45 sampling events were conducted to evaluate system performance and nutrient separation efficiency. Samples were collected at key points between treatment stages to track nutrient and solids reduction throughout the process. Due to equipment failures and maintenance, some sampling events were delayed, and certain components were offline for portions of the study.

Each sampling event included collection of liquid, slurry, and solid samples, along with flow and output rate data. Samples were sent to A&L Great Lakes Laboratories and analyzed using the M7 Manure Analysis Package plus pH, which included TS, VS, TKN, NH_4^+ , P, K, and other parameters. Treated water samples were evaluated using the W2 Water Analysis Package plus NH_4^+ , capturing metrics such as Sodium Adsorption Ratio (SAR), Total Dissolved Solids (TDS), hydrogen ion concentration (pH), and nutrient concentrations.

DISCUSSION OF RESULTS

The evaluation of the membrane-based nutrient partitioning system revealed meaningful progress toward more efficient and environmentally responsible manure management. The multi-stage

approach—combining mechanical and membrane separation—enabled significant reductions in solids, P, and dissolved nutrients like NH_4^+ and K, while producing a cleaner water stream suitable for reuse or discharge. Although system reliability was impacted by mechanical failures, the performance data collected during operational periods highlight both the potential benefits and practical limitations of this technology. The following sections outline the system’s most significant advantages, as well as the key operational and logistical challenges that must be addressed for successful long-term implementation.

KEY BENEFITS OF ULTRAFILTRATION MEMBRANE-BASED NUTRIENT PARTITIONING SYSTEMS

Effective Multi-Stage Nutrient and Solids Separation with High Throughput Capacity: The manure processing system demonstrated strong performance in separating nutrients and solids across its multi-stage design. Operating at average influent flow rates of 126 gallons per minute (GPM) into the screw press and 116 GPM into the centrifuge (Figure 2), the system has the potential to treat approximately 145,000 gallons per day via the screw press and 134,000 gallons per day through the centrifuge—equivalent to manure from ~7,800 and ~7,100 cows, respectively. The separation index (SI) for solids and P improved substantially when the screw press and centrifuge were operated in series, achieving high-efficiency benchmarks. Removal efficiency (RE) also followed this trend, with VS and P removal reaching high-efficiency thresholds (>0.53) after UF and RO stages. While centrifuge solids had the highest nutrient concentrations—0.78% total nitrogen (N) and 0.46% P_2O_5 (Table 1)—the liquid fractions, especially the RO concentrate rich in plant-available N, represent the most agronomically efficient products for targeted nutrient application. These results highlight the system’s effectiveness in optimizing both nutrient recovery and agronomic value across multiple output streams.

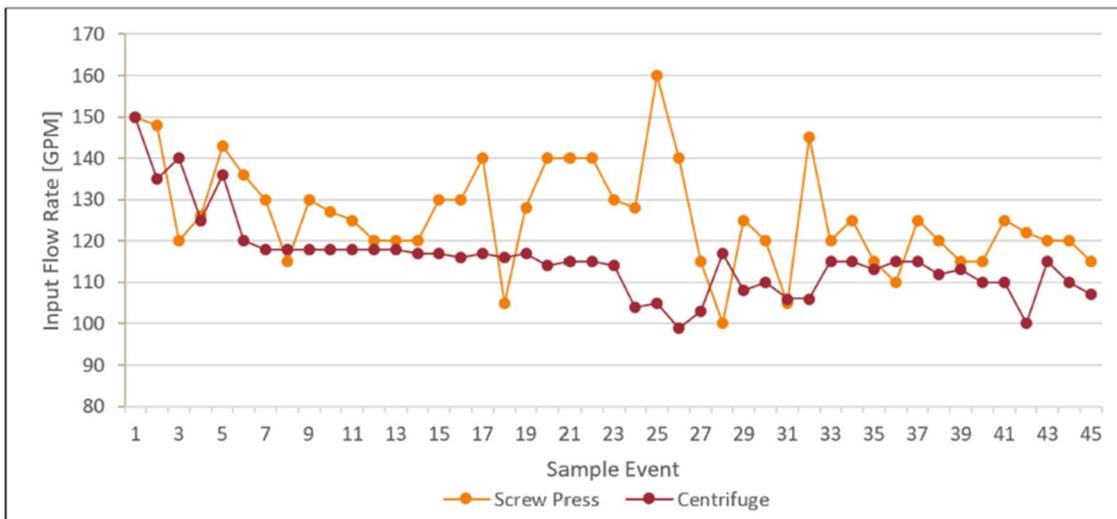


Figure 2: Screw press and centrifuge input flow rates recorded during sampling events.

Table 1: Primary manure characteristics by sampling location (non-detects were given a value of zero).

Sample	Statistics	Moisture [%]	Solids [%]	Volatile Solids [%]	Total Nitrogen [%]	Ammonium Nitrogen as N [%]	Phosphorus as P ₂ O ₅ [%]	Potassium as K ₂ O [%]
Manure	Average	88.23	11.7	8.69	0.41	0.17	0.07	0.29
	Max	90.13	15.11	9.98	0.48	0.19	0.8	0.33
	Min	84.89	9.87	8.02	0.35	0.16	0.06	0.26
	Std. Dev.	1.56	1.56	0.69	0.04	0.01	0.01	0.02
Digestate	Average	93.56	6.44	4.76	0.38	0.23	0.06	0.29
	Max	94.42	6.91	5.21	0.41	0.25	0.07	0.36
	Min	93.09	5.58	3.75	0.33	0.18	0.05	0.25
	Std. Dev.	0.31	0.31	0.28	0.02	0.02	0.00	0.02
Screw Press Separated Solids	Average	73.95	26.05	22.17	0.57	0.26	0.16	0.29
	Max	76.69	29.24	25.57	0.80	0.39	0.42	0.40
	Min	70.76	23.31	12.25	0.48	0.19	0.11	0.27
	Std. Dev.	1.63	1.63	2.28	0.07	0.05	0.05	0.02
Screw Press Separated Liquids	Average	95.48	4.52	2.96	0.36	0.22	0.05	0.28
	Max	96.34	7.98	5.57	0.41	0.25	0.09	0.32
	Min	92.02	3.66	2.31	0.31	0.18	0.04	0.23
	Std. Dev.	0.77	0.77	0.59	0.03	0.02	0.01	0.02
Centrifuge Separated Solids	Average	71.72	28.28	18.35	0.78	0.37	0.46	0.30
	Max	73.87	29.76	22.67	0.88	0.43	0.56	0.33
	Min	70.24	26.13	16.32	0.60	0.25	0.15	0.21
	Std. Dev.	0.79	0.79	0.90	0.06	0.03	0.07	0.02
Centrifuge Separated Liquids	Average	97.37	2.63	1.38	0.29	0.18	0.03	0.24
	Max	99.28	3.06	1.77	0.44	0.22	0.03	0.29
	Min	96.94	0.72	0.38	0.09	0.06	0.01	0.09
	Std. Dev.	0.38	0.38	0.26	0.05	0.03	0.00	0.04
Ultra Filtration Concentrate	Average	95.99	4.01	2.73	0.37	0.18	0.05	0.22
	Max	99.27	5.61	4.08	0.83	0.22	0.07	0.30
	Min	94.39	0.73	0.37	0.09	0.05	0.00	0.06
	Std. Dev.	0.86	0.86	0.65	0.10	0.03	0.01	0.05
Ultra Filtration Permeate	Average	98.94	1.06	0.27	0.19	0.17	0.00	0.17
	Max	99.72	2.14	0.50	0.37	0.34	0.13	0.54
	Min	97.86	0.28	0.05	0.06	0.05	0.00	0.04
	Std. Dev.	0.32	0.32	0.09	0.05	0.05	0.02	0.09
Reverse Osmosis Concentrate	Average	98.26	1.74	0.42	0.30	0.27	0.00	0.23
	Max	99.52	2.48	0.75	0.63	0.34	0.00	0.42
	Min	97.52	0.48	0.12	0.09	0.08	0.00	0.08
	Std. Dev.	0.46	0.46	0.12	0.08	0.06	0.00	0.10

Consistent Production of Treated Water Suitable for Reuse or Discharge: The manure processing system produces treated clean water that consistently meets discharge quality standards, generating approximately 28% of the influent manure volume as treated water suitable for reuse or discharge (Figure 3). Over the study period, the RO unit produced clean water with an average TDS of 62.7 mg/L, well below the Environmental Protection Agency secondary standard of 500 mg/L, and NH₄-N averaged 12.1 mg/L, indicating substantial N partitioning (Table 2, Figure 4). Additionally, P concentrations exceeded detection in only 11% of samples and remained far below the typical 1 mg/L discharge threshold. Assuming full system functionality with 80% uptime, the UF unit could process approximately 42 million gallons annually, significantly enhancing water reuse capabilities on-farm and reducing pressure on land application areas.

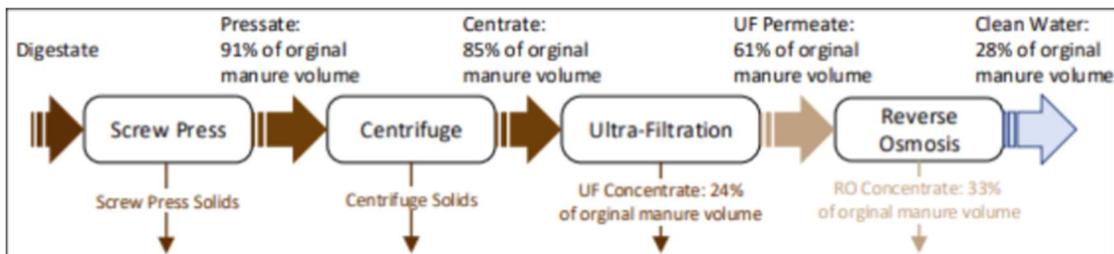


Figure 3: Volume of manure through the treatment system.

Sample	Statistics	pH	Conductivity [mmho/cm]	Total Dissolved Solids (estimated) [mg/L]	Ammonium Nitrogen [mg NH ₄ -N/L]	Phosphorus [mg P/L]	Potassium [mg/L]	Chloride [mg/L]	Manganese [mg/L]
Treated Water	Average	6.8	0.14	62.7	12.10	0.094	5.78	5.11	0.058
	Max	9.5	0.50	180.0	40.00	2.260	23.00	91.00	0.420
	Min	4.4	0.00	0.0	2.40	0.000	1.00	0.00	0.000
	Std. Dev.	0.7	0.11	53.6	6.20	0.360	3.80	13.40	0.093

Table 2: Primary treated clear water characteristics by sampling location (non-detects were given a value of zero).

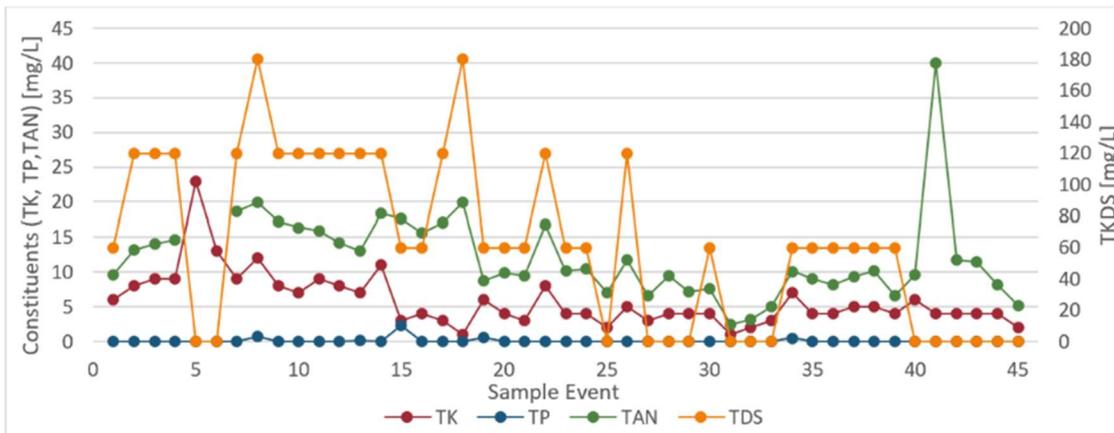


Figure 4: Treated clean water sample concentration over all sampling events (non-detects were given a value of zero), TKDS=total dissolved solids (estimated), TK=total potassium, TP=total phosphorus, and TAN=total ammoniacal nitrogen.

EVALUATION KEY CHALLENGES AND ISSUES

Operational Downtime and Mechanical Reliability Significantly Impact Throughput: Despite the system's design capacity, actual throughput was limited by mechanical issues. Notably, UF Unit A was offline for the majority of the sampling period, and pump failures (on 7/26/2023, 11/17/2023, and early 2024) led to periods of zero flow (Methods). Sediment clogging and freeze issues in the underground pipe between buildings further disrupted operation. These interruptions reduced the effective capacity of the system from its designed 115,000 gallons per day to a functional reality of 45 GPM inflow during much of the sampling period. Without consistent uptime, the full potential for nutrient separation and clean water production could not be realized. The reliance on complex mechanical systems, such as inline pumps and membrane filters, introduces maintenance burdens that must be addressed for consistent system performance.

High Variability in Nutrient Concentrations and Removal Reduces Management Predictability: While the system achieved strong average nutrient separation, day-to-day performance showed high variability. For example, TAN removal efficiency from screw press and UF stages showed the highest coefficients of variation (Figure 5), indicating inconsistency in how ammonium was handled. Nutrient concentrations in liquid phases varied widely—e.g., NH₄-N in RO concentrate ranged from 0.08% to 0.34%, and TP in screw press solids ranged from 0.11% to 0.42% (Table 1). Moreover, separation indices for N and K remained consistently below high-efficiency thresholds (Figure 6), suggesting these nutrients were poorly captured in solids. This variability complicates nutrient budgeting and land application

planning, potentially limiting the benefits of precise nutrient recovery unless supported by frequent monitoring and adaptive management strategies.

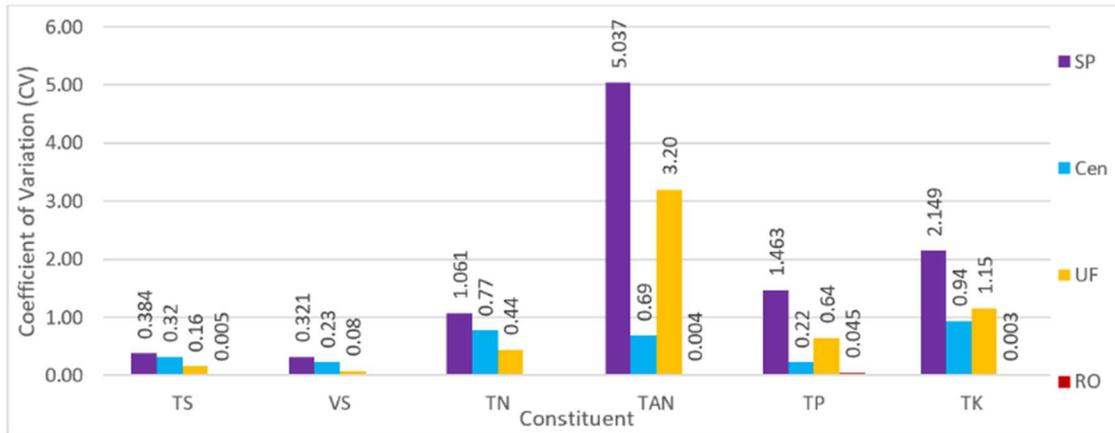
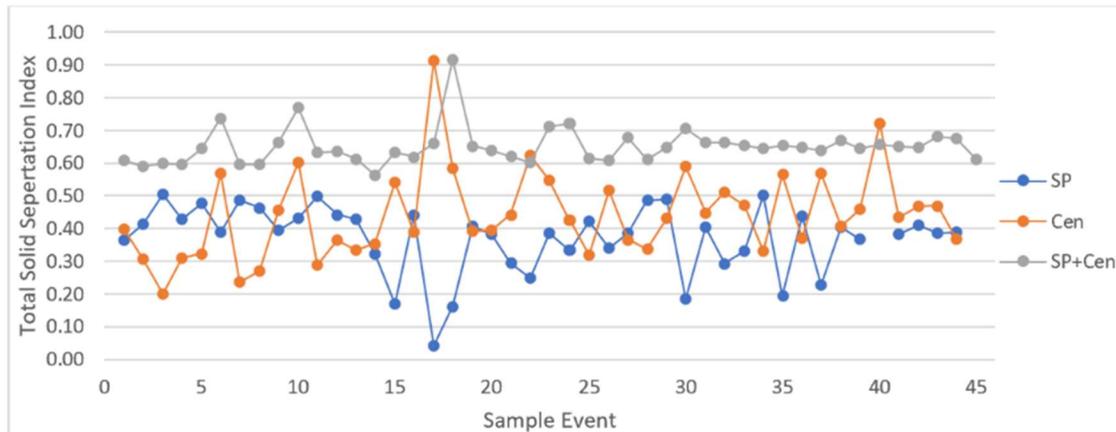


Figure 5: Coefficient of variation (CV) for the removal efficiency for total solids (TS), volatile solids (VS), total nitrogen (TN), total ammoniacal nitrogen (TAN), total phosphorus (TP), and total potassium (TK). SP=Screw Press (digestate to separated screw press liquids), Cen=Centrifuge (separated screw press liquids to separated centrifuge liquids), UF= Ultra-Filtration (separated centrifuge liquids to ultra-filtration permeate), RO=Reverse Osmosis (ultra-filtration permeate to treated clean water).



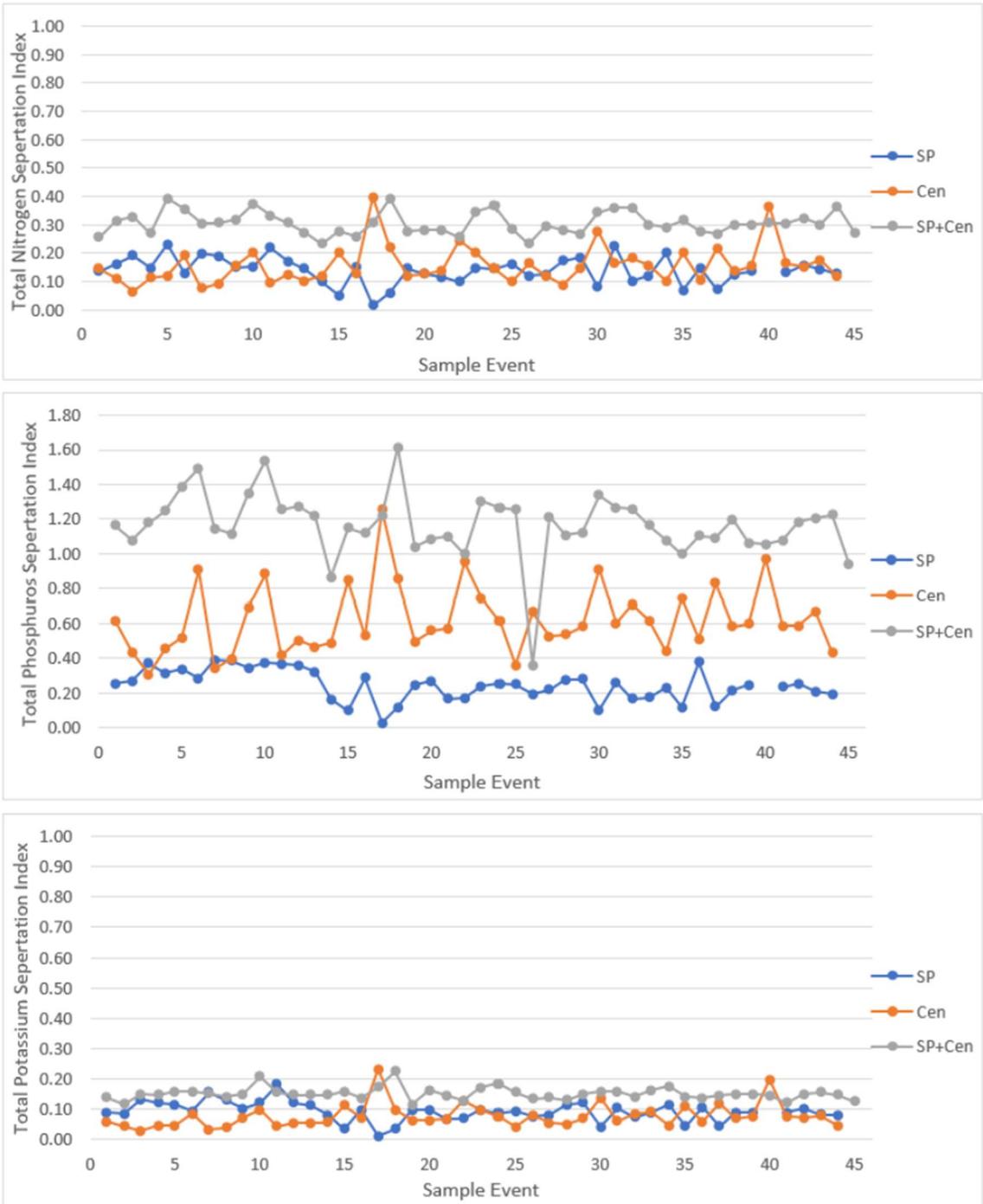


Figure 6: Separation index (SI) over time for total solids (top), total nitrogen, total phosphorus, and potassium (bottom) for the screw press and centrifuge. SP=Screw Press (digestate to screw press solids), Cen=Centrifuge (separated liquids from screw press to centrifuge solids), SP+Cen=Screw Press + Centrifuge (digestate to centrifuge solids).

IMPLICATIONS

This study demonstrates that membrane-based nutrient partitioning systems, when integrated into multi-stage manure treatment processes, offer significant potential for improving nutrient recovery,

producing clean water suitable for reuse or discharge, and enhancing the agronomic value of separated manure fractions. The system evaluated achieved high removal efficiencies for VS and P, particularly after the UF and RO stages, while producing treated water that regularly met discharge thresholds for TDS, $\text{NH}_4\text{-N}$, and P. These outcomes point to a strong alignment between system outputs and both regulatory and agronomic goals.

The ability to partition nutrients into more manageable and targeted end products—such as P-rich concentrates and $\text{NH}_4\text{-N}$ -dominant RO streams—presents a promising pathway for nutrient stewardship and land application optimization. However, the study also revealed considerable variability in system performance, particularly in $\text{NH}_4\text{-N}$ and K partitioning, which may complicate nutrient budgeting and reduce confidence in precision application strategies. This highlights the importance of real-time monitoring, operator training, and adaptive management when deploying such advanced systems at scale.

Downtime and operational inconsistencies were also notable during the study period, affecting overall throughput and reliability. While these challenges are not uncommon in pilot or early-stage commercial systems, they underscore the need for robust system design, routine preventative maintenance protocols, and improved resilience of membrane components under farm-scale conditions.

With further refinement, membrane systems could offer dairy operations a scalable and environmentally sound solution for transforming raw manure into higher-value, lower-risk inputs for crop production. Future research should focus on reducing variability, improving uptime, and validating long-term system performance under a range of environmental and operational scenarios. If these challenges are addressed, membrane systems may play a critical role in helping farms meet emerging water quality standards and nutrient efficiency goals.

For additional information on the vendor, environmental impacts, financial implications, and ultrafiltration membrane-based nutrient partitioning technology, visit the Aqua Innovations Plus, LLC Vendor Snapshot on the [Newtrient website](#).

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Appendix C

Third-Party Review of Membrane-based Nutrient Partitioning Technology at Northern Biogas – Middleton, WI (Full Report)

Aqua Innovations Nutrient Concentration System Performance Evaluation

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Final Report for Newtrient updated on February 3, 2025

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Abstract

Manure processing systems have the potential to reduce environmental impacts from livestock systems. A nutrient concentration system in Wisconsin was evaluated to assess the system components in terms of their separation efficiencies and the water quality of the final treated product for discharge. The system processed manure from approximately 7,400 cows producing separated solids from the screw presses and centrifuge, liquid concentrate from the ultra-filtration and reverse osmosis systems, and treated water for discharge. Samples were collected from the system over 45 sampling dates over a 37-week period. The separation index for the centrifuge was higher than the screw press for total solids (TS), volatile (VS), total Kjeldahl nitrogen (TKN), total ammonium nitrogen (TAN), and total phosphorus (TP). Although the TS separation index for the screw press was lower than the centrifuge, the influent concentration to the screw press were higher resulting in a 1.5 times greater production of solids compared to the centrifuge. Interestingly, the variability in separation index decreased significantly when combining the two systems, indicating the systems in series improve the consistency of the separation index. Each system component in series removed additional manure constituents from the separated liquid stream reducing overall concentrations of measured parameters as manure moved through the system. The screw press and centrifuge combined had a removal efficiency of 0.5 for TS, VS, and TP, indicating most solids and P were removed in these two components with the ultra-filtration removing the majority of the remaining manure constituents measured aside from TKN and K where most removal occurred during reverse osmosis. The system requires significant maintenance and operational supervision to maximize runtime.

Introduction

Livestock systems are under increasing pressure to enhance their sustainability. Land application of manure is designed to establish a sustainable cycle by returning nutrients and organic matter to the soil for crop production. Unfortunately, manure systems can result in losses of manure constituents to the environment resulting in negative impacts. Farm growth, increasing animal densities in specific geographical locations, and an increase in water content of manure has exacerbated challenges in managing manure to minimize environmental impacts (Sharara et al., 2022; Spiegel et al., 2020).

Higher manure water content, driven by changes in farm management practices and increased runoff collection, results in larger volumes to store and transport for field applications. While manure storage provides flexibility in timing land applications, which can mitigate water quality impacts, it also contributes to increased emissions of ammonia and greenhouse gases. Livestock are the leading source of ammonia emissions, accounting for approximately 50% of total ammonia emissions in the United States (*2020 National Emissions Inventory Data, 2023*). Furthermore, methane and nitrous oxide emissions from livestock manure management systems significantly contribute to climate change, including 9% of all methane emissions from anthropogenic sources (*Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2021, 2023*).

The land application of manure also has substantial implications for water quality. Runoff can transport pathogens, sediments, organic matter, and nutrients into surface waters, while leaching

can contaminate groundwater with pathogens and nitrates, raising public health concerns. Increased applications of manure nutrients increase the runoff risks, particularly when applications exceed agronomic recommendations.

Manure processing systems can be used to separate manure constituents to improve handling and management. Among these, mechanical manure separation systems are some of the most widely implemented, primarily aimed at nutrient extraction (Aguirre-Villegas & Larson, 2017). These systems offer the potential to enhance the value of separated products while improving manure management to reduce environmental impacts. However, the separation efficiency of existing mechanical systems for manure is often considered low (Aguirre-Villegas et al., 2019; Guilayn et al., 2019), resulting in lower-value products that can reduce the economic and environmental impacts. The effluent remaining after product extraction must still be managed as manure unless it meets standards for discharge. Since the volume of effluent is often comparable to the original manure, handling costs remain similar to traditional land application systems, making the economic success of these systems heavily reliant on the market value of the separated products. Manure treatment systems designed to achieve discharge-quality water can reduce land application costs for producers while mitigating associated environmental risks. However, these systems require additional processing components to meet water quality standards for safe discharge into surrounding waterways.

To optimize the effectiveness of such systems, it is essential to evaluate their performance, including the separation efficiency of individual components to provide the data for larger economic and environmental impacts when integrated into livestock facilities. This research investigates the performance of a manure processing system designed to treat manure to discharge quality.

Methods

Study site

A manure processing system located in Middleton, Wisconsin (7167 Schneider Rd, Middleton, WI 53562) receives manure from local dairy farms with a combined total of approximately 7,400 cows. The manure processing system includes a digester followed by a separation system that includes three screw presses in parallel (FAN/Flygt PSS 3.2-780; 0.75 mm screen), a centrifuge (Centrisys Corporation CS21-4ZPH with Skid; 1.5 differential speed, 1,864 rpm bowl speed), two ultra filtration units in parallel (Aqua Innovations 8000D Nutrient Concentration System; Pentair Compact 33 filters; 5.2 mm hydraulic membrane diameter, 30 nm nominal pore size), and a reverse osmosis unit (Aqua Innovations 8000D Nutrient Concentration System; Hydronautics SWC4-LD membranes; 99.8% NaCl rejection, 200-250 MWCO) (Figure 1). End products from the system requiring management include screw press and centrifuge separated solids, ultra-filtration and reverse osmosis concentrate, and the treated clean water. In this system, both solid streams and concentrate streams are combined after processing for storage and use. The treated clean water is discharged in the Pheasant Branch and Six Mile Creek Watershed in the Lower Rock River Basin in Dane County under the permit granted to Springfield Clean Water LLC (WPDES Permit No. WI-0065889-02-0). The main surface water requirements are listed in Appendix A. The digester, screw press, and centrifuge are owned and operated by one

private group and the additional processing units (ultra-filtration and reverse osmosis, Aqua Innovations 8000D Nutrient Concentration System) by a separate entity.

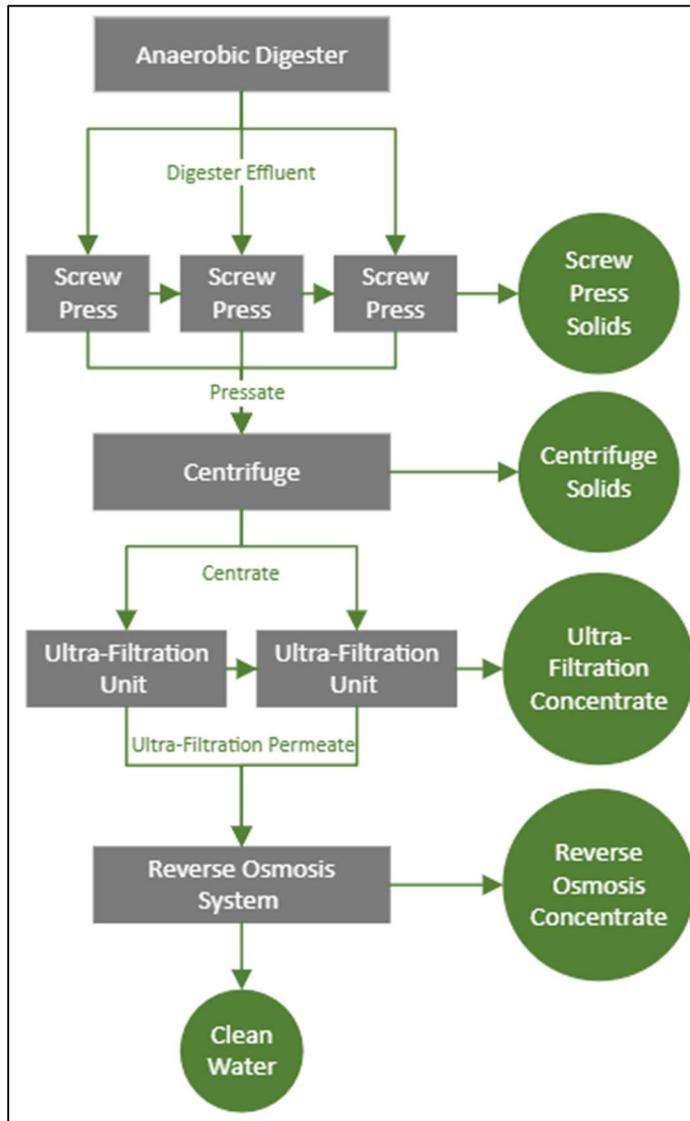


Figure 1. Flow diagram of the manure processing system, green circles represent recovered products.

The system was evaluated over a 37-week period (45 sampling points total) to assess the performance of individual components as well as the overall system in terms of their impact on manure component separation. This evaluation involved collecting manure samples at various points between system components and monitoring flow data to calculate the separation efficiencies of each processing component over time. It should be noted that the collection of manure samples prior to the digester was added later in the study period, thus has only 20 sampling points. Average, maximum, and minimum outdoor temperatures were collected from Wisconet (Wisconet).

Sampling

Samples were collected over a 37-week period (7/12/2023 to 3/27/2024) to achieve 45 sampling events (Figure 2). The 45 sampling events did not happen consecutively due to system failures that prevented full system operation. After the sampling event on 7/26/2023, a pump failed in the digestate separation room. Operation was halted until the pump was replaced and operational, sampling resumed on 10/25/2024. Upon resumption of sampling, only ultra-filtration unit B was operational through the remainder of the sampling events as the filters in unit A required replacement. After the sampling event on 11/17/2024 a pump on ultra-filtration unit B failed. A new pump was ordered and installed; sampling resumed on 1/15/2024. After the sampling event on 2/7/2024, the centrifuge was taken off-line for unscheduled maintenance. Following centrifuge maintenance, the underground pipe between the separation room and the nutrient concentration building had issues with sediment clogging and freezing, following repair, sampling resumed on 2/20/2024 and continued until 3/27/2024 when the final sample was collected.

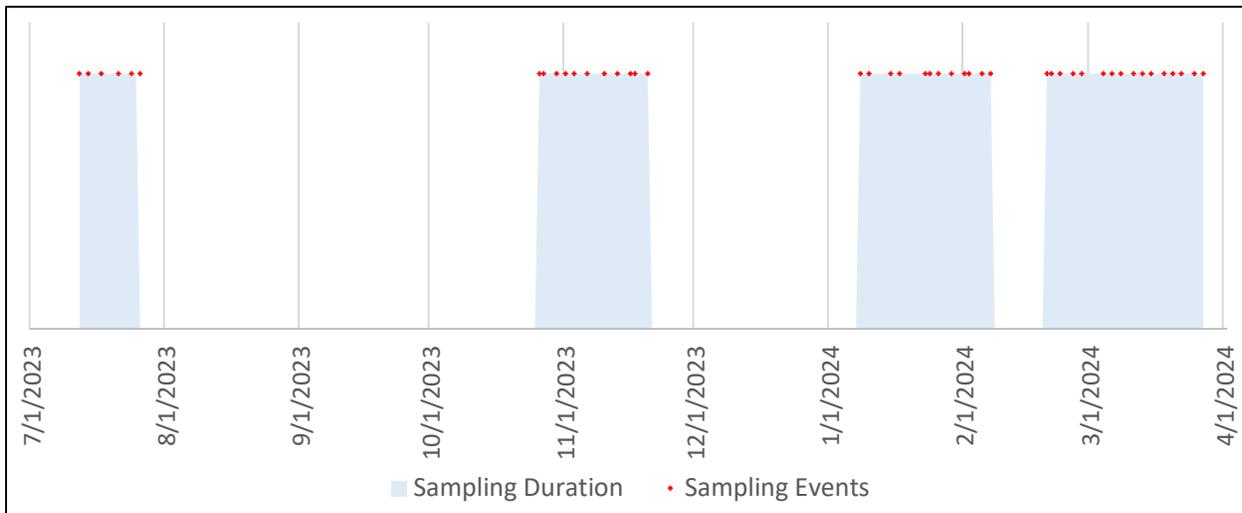


Figure 2. Manure processing sampling event dates over a 37-week period.

During each sampling event ten samples (nine initially until the unprocessed manure before the digester was added) were collected to assess each processing unit. Samples were collected from each separated product from each processing unit to assess the manure as it passed through the system as well as each recovered product. Liquid and slurry samples, 0.5 L, were collected from all sampling locations while the systems were fully operational. Solid samples, 1 L, were collected from the exit point of the screw press and centrifuge. After collection, samples were stored at 4°C until shipped to A&L Great Lakes Laboratories for analysis.

Flow rates were determined by inline flow meters where available. Solid production rates for the centrifuge were documented by recording the time to capture 11.35 L of product as excreted.

Sample analysis

All samples were shipped to A&L Great Lakes Laboratories within one week of sampling date. Samples (aside from the treated water at the end of the treatment system) were analyzed with the M7 Manure Analysis Package plus pH. The package includes moisture, total solids, total

Kjeldahl nitrogen (TKN), phosphorus (P), potassium (K), sulfur, calcium, magnesium, sodium, iron, aluminum, manganese, copper, zinc, ash, organic carbon, volatile solids, carbon to nitrogen ration (C:N), and ammonium-nitrogen (TAN).

Treated water samples were analyzed with the W2 Water Analysis Package plus TAN. The package includes sodium, calcium, magnesium, manganese, iron, chloride, conductivity, sulfate-sulfur, nitrate-nitrogen, pH, carbonate, bicarbonate, total alkalinity, P, K, boron, total dissolved solids, and Sodium Adsorption Ratio (SAR).

Data analysis

Data from the samples analyzed was averaged over the entire sampling period. All non-detectable results were assigned a value of zero throughout all analyses. Information is also presented based on system flow and products produced. Additional calculations were completed to assess the separation efficiency of each component after the digester.

Separation efficiencies for each processing step were determined using the separation index (SI) and the removal efficiency (RE) (Eq. 1, 2, & 3) (Aguirre-Villegas et al., 2019; Guilayn et al., 2019). The SI is used to assess the concentration of the manure components into the solid fraction compared to the input while the removal efficiency is the purification of the liquid fraction.

$$R_{Solid,Out} = \frac{DM_{Influent} - DM_{Liquid,Out}}{DM_{Solid,Out} - DM_{Liquid,Out}} \quad (1)$$

$$SI_X = R_{Solid,Out} * \frac{[X]_{Solid,Out}}{[X]_{Influent}} \quad (2)$$

$$RE_x = 1 - \frac{[X]_{Liquid,Out}}{[X]_{Influent}} \quad (3)$$

Where $R_{solid,out}$ is the ratio of solid fraction in relation to the input mass, DM is the dry matter, and X is the constituent concentration under evaluation.

Results

Temperature

The system is fully contained indoors in a temperature-controlled building. The outdoor temperatures were recorded in the case that the building's heating system was not functional. The outdoor temperatures ranged from -8°F to 66°F over the 37-week period of the project (Figure 3).

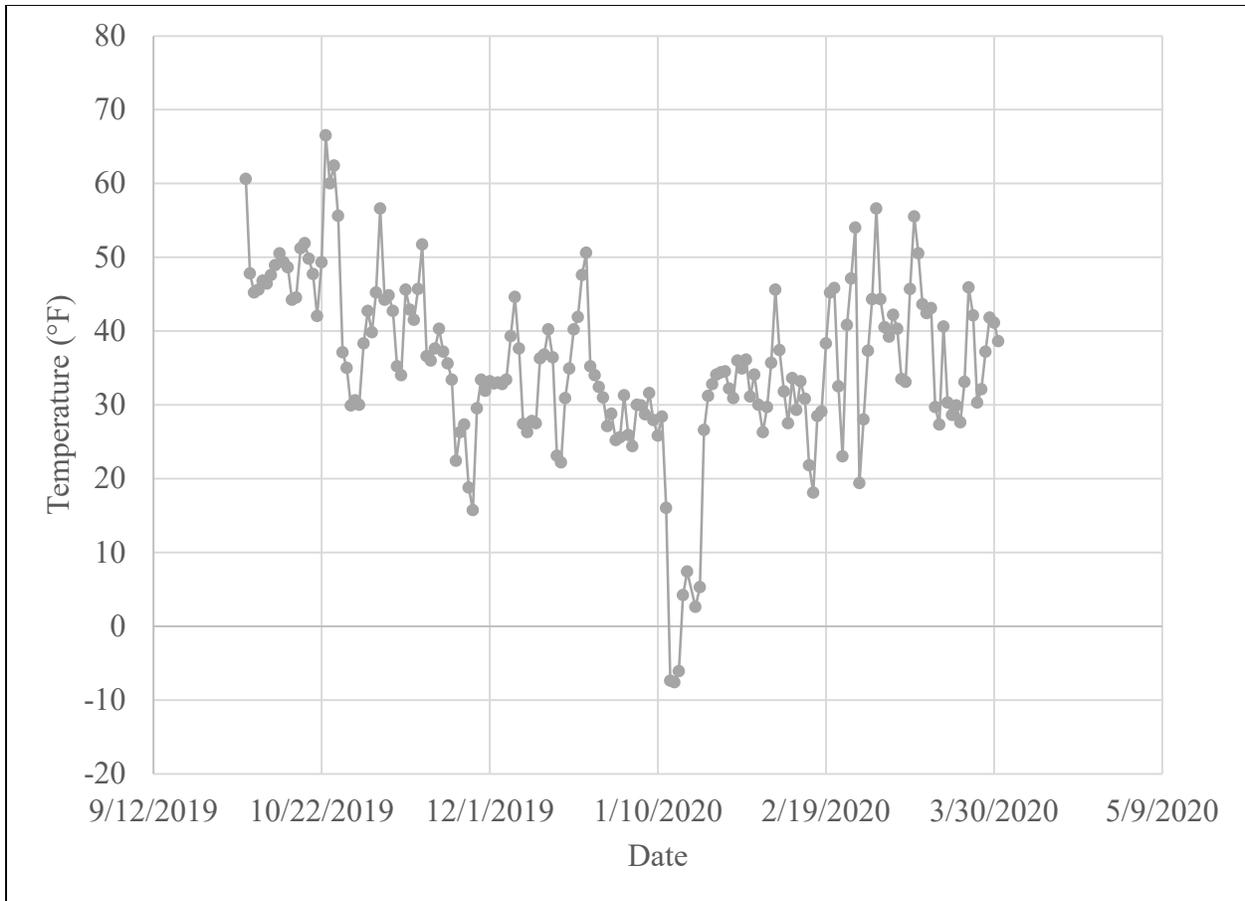


Figure 3: Outdoor temperature over the 37-week sampling period.

Manure flows

The total raw manure entering the system was on average 164,001 gallons per day (GPD), an annual average of 60 million gallons per year (GPY) using data recorded by the operation. The total digestate entering the separation room was on average 149,516 GPD (55 million GPY) with 148,773 GPD (54 million GPY) though the screw presses and 114,798 GPD (42 million GPY) though the centrifuge using data recorded by the operation.

During sampling events, the flow rate for the digestate and screw presses were recorded for that moment in time using preexisting inline flow meters. The digestate influent averaged 126 gallons per minute (GPM) across the 45 sample points throughout the 37-week period and the separated liquid flow from the screw press to the centrifuge averaged 116 GPM over the 45 sample points during the 37-week sampling period (Figure 4). The operational time of the system was highly variable throughout our sampling period due to the issues mentioned above. Based on data recorded by the operation, the centrifuge averaged 7,665 hours per year, or an uptime of 87.5%. Assuming the screw press and centrifuge both operated at their respective flow rates with an uptime of 87.5% (21 hours per day) that would equate to approximately 159k GPD, or 58M GPY for the screw press and 146k GPD and 53M GPY for the centrifuge, slightly higher than measured using operational data reported above. For context, if you use an average manure

production of 18.7 GPD per cow (Lorimor et al., 2004), the screw press could treat the manure of nearly 8,500 cows and the centrifuge 7,800 cows.

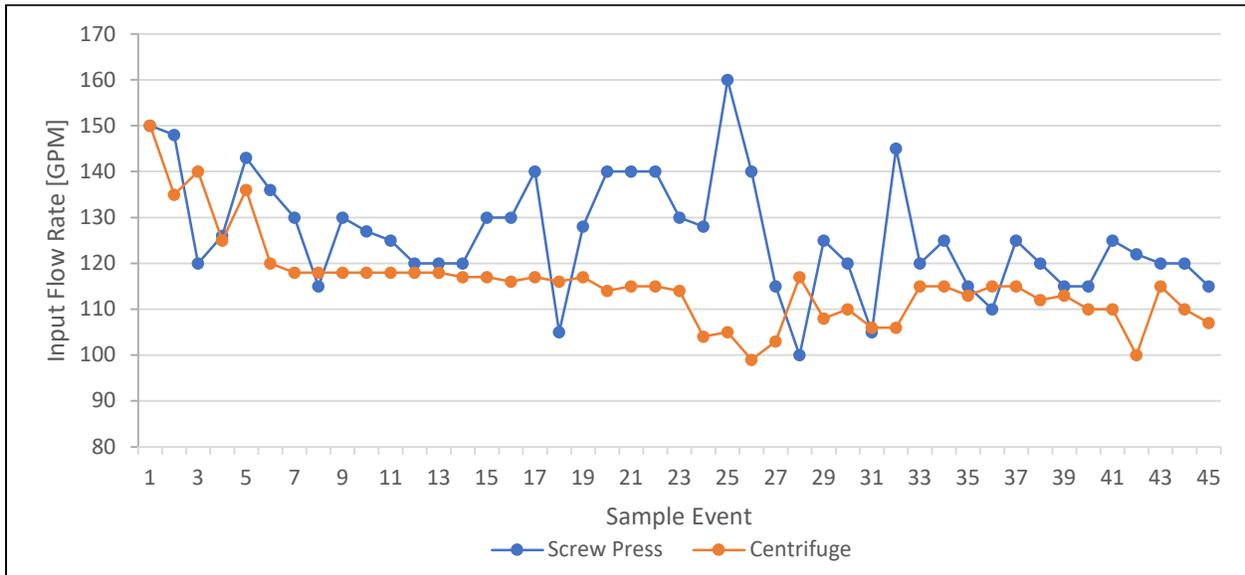


Figure 4. Screw press and centrifuge input flow rates recorded during sampling events.

The centrifuge solid production rate averaged 60 pounds per min (3,600 pounds per hour) of separated solids as measured. The production rate was also calculated to be 53 pounds per minute for the centrifuge solids based on the liquid volume and total solids entering the system, the calculated separation index (in the next step) and the separated solids total solids content. The screw presses solid production rate could not be measured due to space and safety constraints between the screw press outlet and the discharge conveyor. The screw press separated solids production rate was calculated to be 93 pounds per minute using the same calculation methods.

The Aqua Innovations 8000D Nutrient Concentration System (ultra-filtration and reverse osmosis units) are flow rate controlled. The system is designed to operate at 100 GPM inflow to the ultra-filtration units (50 GPM to each unit). This equates to a maximum capacity of 126k GPD and 46M GPY for the two ultrafiltration units combined, assuming the same 87.5% uptime (which was not achieved during this sampling period). However, for most of the sampling period the system operated with one ultra-filtration unit. Thus, the single ultra-filtration unit was fed 45 GPM of separated liquids from the centrifuge, resulting in the production of 15 GPM of ultra-filtration concentrate (33% of influent) and 30 GPM of ultra-filtration separated liquids (67% of influent) that was sent to the reverse osmosis system. The reverse osmosis unit runs at a higher flow rate than the ultra-filtration unit and thus was run intermittently processing 50 GPM of ultra-filtration permeate into 25 GPM of both treated water and reverse osmosis concentrate. If you assume the ~46M gallons enter the system annually (from the estimates presented above using the flow data and 87.5% run time) the ultrafiltration unit would produce 15M gallons of concentrate and 31M gallons would flow to the reverse osmosis, which would then produce 15.5M gallons of reverse osmosis concentrate and 15.5M gallons of treated clean water.

The total centrifuge separated liquid (influent) treated by the Aqua Innovations 8000D Nutrient Concentration System from 2021 to 2023 was on average 16,165 GPD (6.0M GPY). The nutrient concentration system was designed to treat 100,000 GPD (36.5M GPY) of influent. From the design total capacity and the average GPY of processed influent the system had a calculated uptime of 16%. The total influent processed resulted in an average of 6,287 GPD (2.3M GPY) of ultra filtration concentrate, 5,399 GPD (2.0M GPY) of reverse osmosis concentrate, and 4,479 GPD (1.6 GPY) of clean water.

Manure and treated water analysis

All manure samples were analyzed for the parameters outlined in the methods. The average, maximum, minimum, and standard deviation by sample locations over the 37-week sampling period are reported below (Table 1). The remaining measured parameters are reported in Appendix B (Table B1). Separated solids from both the screw press and the centrifuge have similar total solids concentrations between 23% and 30% total solids. However, the separated centrifuge solids had a higher concentration of both N and P.

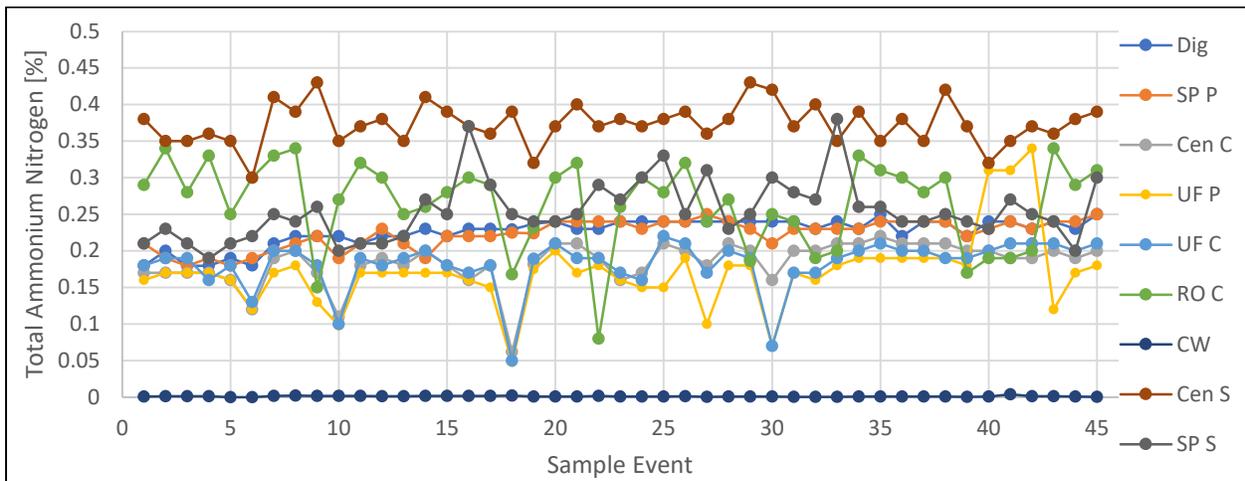
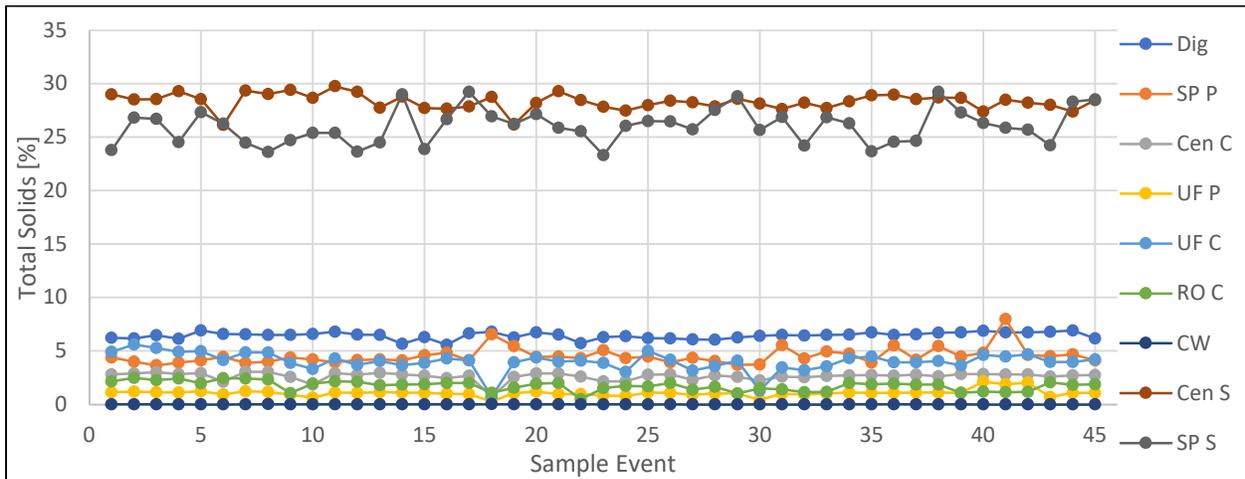
The separated liquids had decreased concentrations of solids and nutrients as they moved through each stage of the treatment unit as expected. Most notably, the reverse osmosis concentrate is primarily available N with no P which has potential for improved management and nutrient use efficiency in land application systems if the streams are stored and used separately.

Table 1. Primary manure characteristics by sampling location (non-detects were given a value of zero).

Sample	Statistics	Moisture [%]	Solids [%]	Volatile Solids [%]	Total Kjeldahl Nitrogen [%]	Ammonium Nitrogen as NH ₄ -N [%]	Phosphorus as P ₂ O ₅ [%]	Potassium as K ₂ O [%]
Manure	Average	88.23	11.7	8.69	0.41	0.17	0.07	0.29
	Max	90.13	15.11	9.98	0.48	0.19	0.8	0.33
	Min	84.89	9.87	8.02	0.35	0.16	0.06	0.26
	Std. Dev.	1.56	1.56	0.69	0.04	0.01	0.01	0.02
Digestate	Average	93.56	6.44	4.76	0.38	0.23	0.06	0.29
	Max	94.42	6.91	5.21	0.41	0.25	0.07	0.36
	Min	93.09	5.58	3.75	0.33	0.18	0.05	0.25
	Std. Dev.	0.31	0.31	0.28	0.02	0.02	0.00	0.02
Screw Press Separated Solids	Average	73.95	26.05	22.17	0.57	0.26	0.16	0.29
	Max	76.69	29.24	25.57	0.80	0.39	0.42	0.40
	Min	70.76	23.31	12.25	0.48	0.19	0.11	0.27
	Std. Dev.	1.63	1.63	2.28	0.07	0.05	0.05	0.02
Screw Press Separated Liquids	Average	95.48	4.52	2.96	0.36	0.22	0.05	0.28
	Max	96.34	7.98	5.57	0.41	0.25	0.09	0.32
	Min	92.02	3.66	2.31	0.31	0.18	0.04	0.23
	Std. Dev.	0.77	0.77	0.59	0.03	0.02	0.01	0.02
Centrifuge Separated Solids	Average	71.72	28.28	18.35	0.78	0.37	0.46	0.30
	Max	73.87	29.76	22.67	0.88	0.43	0.56	0.33

	Min	70.24	26.13	16.32	0.60	0.25	0.15	0.21
	Std. Dev.	0.79	0.79	0.90	0.06	0.03	0.07	0.02
Centrifuge Separated Liquids	Average	97.37	2.63	1.38	0.29	0.18	0.03	0.24
	Max	99.28	3.06	1.77	0.44	0.22	0.03	0.29
	Min	96.94	0.72	0.38	0.09	0.06	0.01	0.09
	Std. Dev.	0.38	0.38	0.26	0.05	0.03	0.00	0.04
Ultra Filtration Concentrate	Average	95.99	4.01	2.73	0.37	0.18	0.05	0.22
	Max	99.27	5.61	4.08	0.83	0.22	0.07	0.30
	Min	94.39	0.73	0.37	0.09	0.05	0.00	0.06
	Std. Dev.	0.86	0.86	0.65	0.10	0.03	0.01	0.05
Ultra Filtration Permeate	Average	98.94	1.06	0.27	0.19	0.17	0.00	0.17
	Max	99.72	2.14	0.50	0.37	0.34	0.13	0.54
	Min	97.86	0.28	0.05	0.06	0.05	0.00	0.04
	Std. Dev.	0.32	0.32	0.09	0.05	0.05	0.02	0.09
Reverse Osmosis Concentrate	Average	98.26	1.74	0.42	0.30	0.27	0.00	0.23
	Max	99.52	2.48	0.75	0.63	0.34	0.00	0.42
	Min	97.52	0.48	0.12	0.09	0.08	0.00	0.08
	Std. Dev.	0.46	0.46	0.12	0.08	0.06	0.00	0.10

The concentrations over the 37-week sampling period had some variability (Figure 5). When examining the coefficients of variation in the influent manure, variation in influent more was more consistent than throughout the system, indicating the treatment system adds variability in some processing steps. The TS and P became more variable after the screw press, the TAN and K became more variable after the centrifuge. In general, the ultra-filtration unit introduced the highest variability into the concentrations over the 37-week sampling period in the separated liquids.



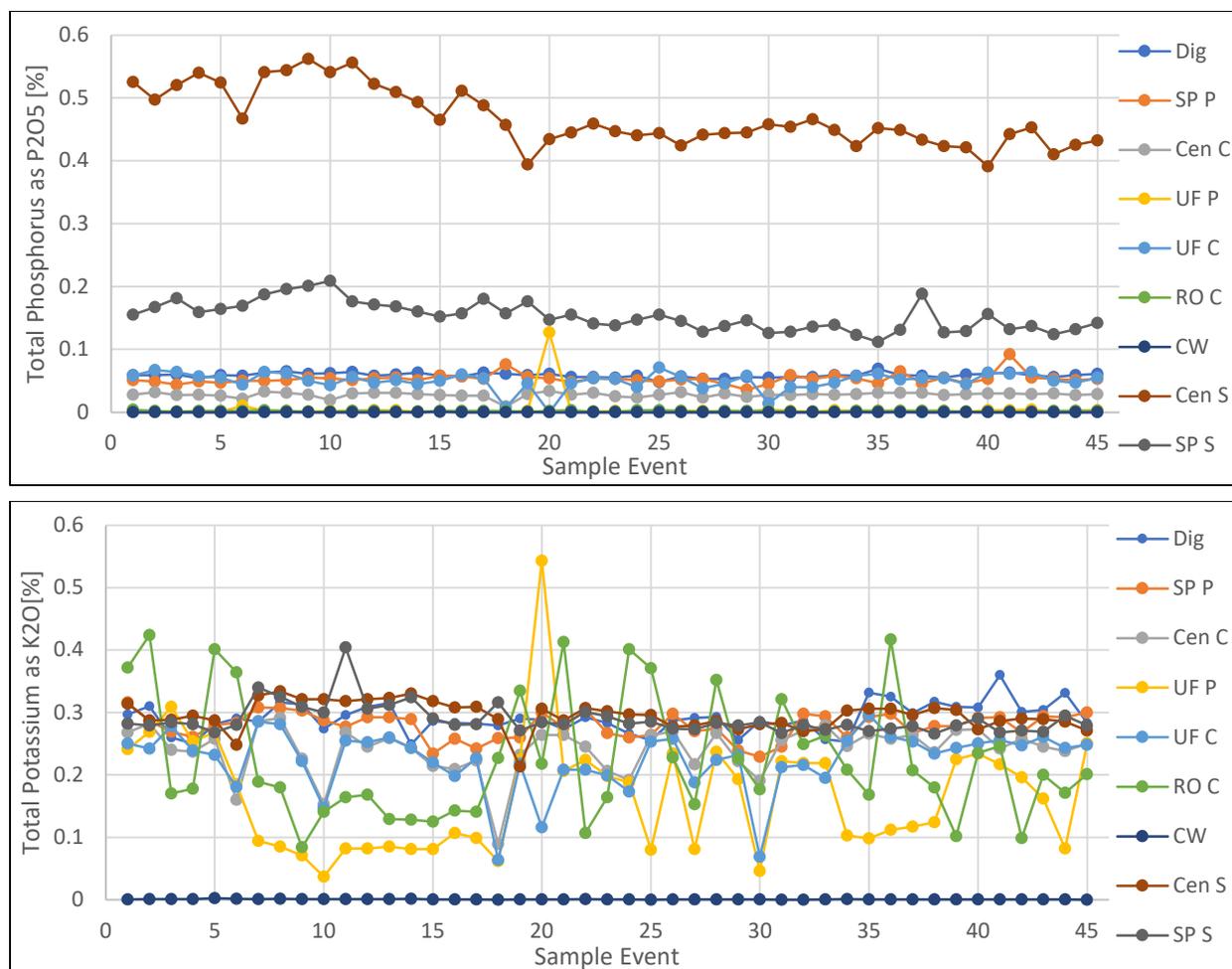


Figure 5. Manure sample concentrations over all sample events for total solids (TS, top), total Kjeldahl nitrogen (TKN), total phosphorus (TP), and potassium (TK, bottom) by sampling location (non-detects were given a value of zero), Dig=digestate, SP P=screw press separated liquid, Cen C=centrifuge separated liquids, UF P=ultra-filtration permeate, UF C=ultra-filtration concentrate, RO C=reverse osmosis concentrate, CW=treated water, Cen S=centrifuge solids, SP S=screw press solids.

All clean water samples were analyzed for the parameters outlined in the methods. The average, maximum, minimum, and standard deviation by sample locations over the 37-week sampling period are reported below (Table 2). The remaining parameters measured in the study are reported in Appendix B (Table B1). The total dissolved solids are below EPA’s secondary regulations with a maximum contamination level (MCL) of 500 mg/L even at the maximum measured concentration over the sampling period of 180 mg/L. The pH of the treated water on average meets general guidance for discharge range of 6.0 to 9.0, but maximum and minimum values fall outside of those ranges on some occasions with a max pH of 9.5, minimum pH of 4.4, and an average pH of 6.8. Total P had five samples above the detection limit of the lab, of those five samples one was above the 1 mg P/L discharge standards with a P concentration of 2.26 mg P/L (Figure 6). Nitrate concentrations were measured on nine samples with an average concentration 0.11 mg NO₃-N/L, this concentration is lower than the preventive action limit of 2 mg NO₃-N/L and enforcement standard of 10 mg NO₃-N/L.

Table 2. Primary treated clear water characteristics by sampling location (non-detects were given a value of zero).

Sample	Statistics	pH	Conductivity [mmho/cm]	Total Dissolved Solids (estimated) [mg/L]	Ammonium Nitrogen [mg NH ₄ -N/L]	Nitrate Nitrogen [mg NO ₃ -N/L]	Phosphorus [mg P/L]	Potassium [mg/L]	Chloride [mg/L]	Manganese [mg/L]
Treated Water	Average	6.8	0.14	62.7	12.10	0.022	0.094	5.78	5.11	0.058
	Max	9.5	0.50	180.0	40.00	0.300	2.260	23.00	91.00	0.420
	Min	4.4	0.00	0.0	2.40	0.000	0.000	1.00	0.00	0.000
	Std. Dev.	0.7	0.11	53.6	6.20	0.055	0.360	3.80	13.40	0.093

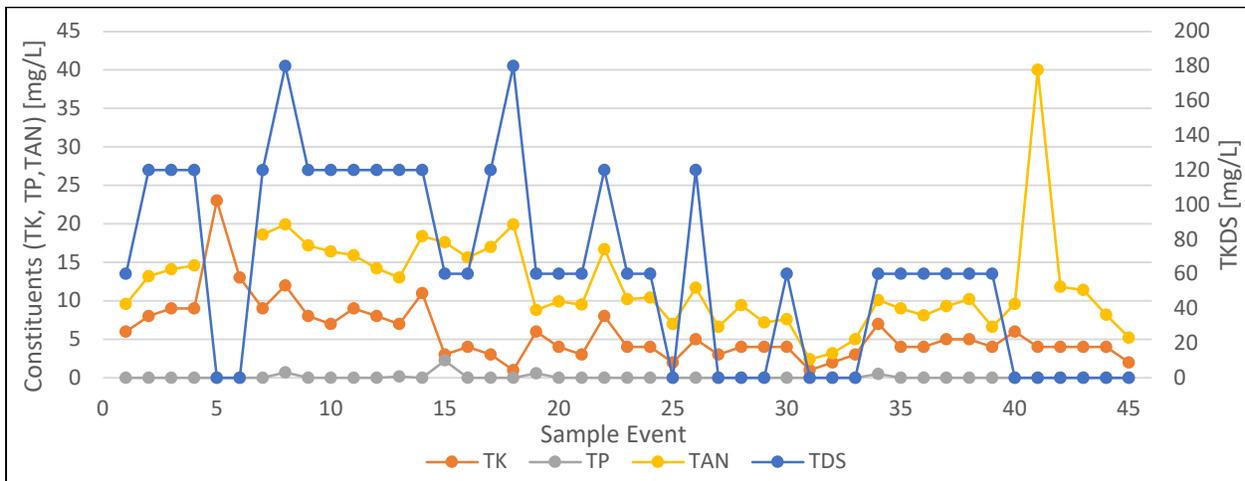


Figure 6. Treated clean water sample concentration over all sampling events (non-detects were given a value of zero), TK=total potassium, TP=total phosphorus, TAN=total ammoniacal nitrogen, and TDS=total dissolved solids (estimated).

Separation efficiencies as measured by separation index (SI)

Separation efficiencies as measured by the SI indicate the ability of a processing unit to extract various components into the separated solid fraction. In this study, the SI was calculated for both the screw press and the centrifuge (Figure 7). Previous work indicates that a SI below 0.62 is considered a low-efficiency system (Guilayn et al., 2019), thus for the screw press and centrifuge individually all parameters measured had a low efficiency. However, the combined performance of the screw press and centrifuge in series (screw press + centrifuge) indicates a high efficiency system for total solids and P. This suggests that for manure-based systems, systems in series may be capable of reaching greater performance efficiencies. Further, neither the screw press or the centrifuge resulted in large amounts of removal of N and K into the separated solids.

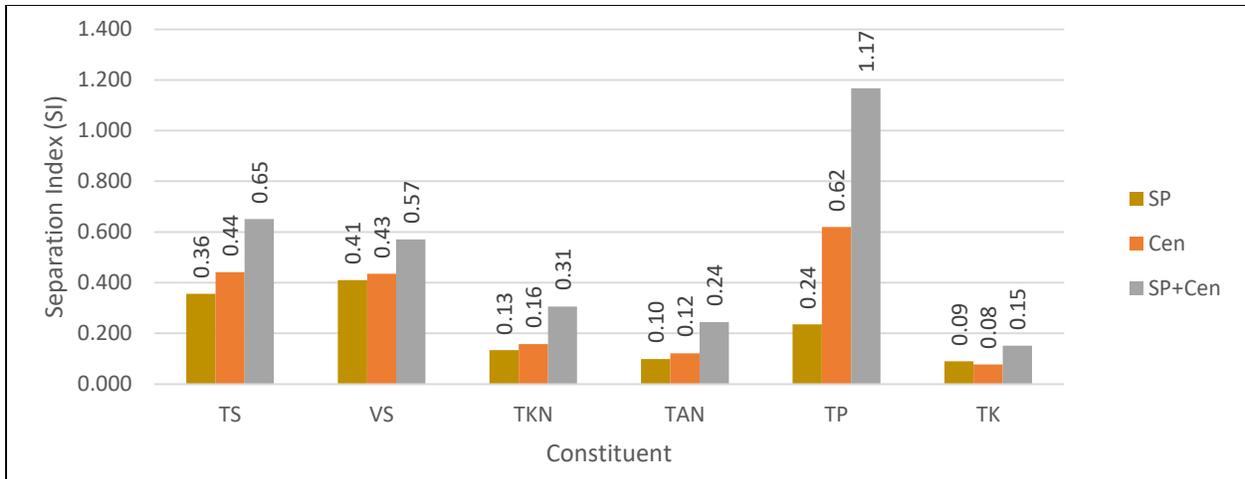
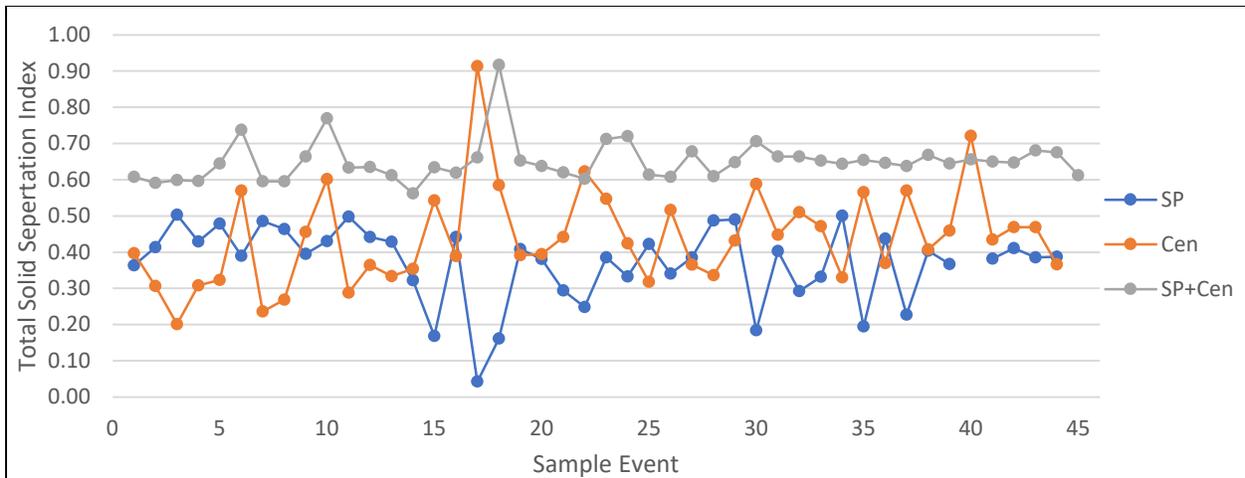
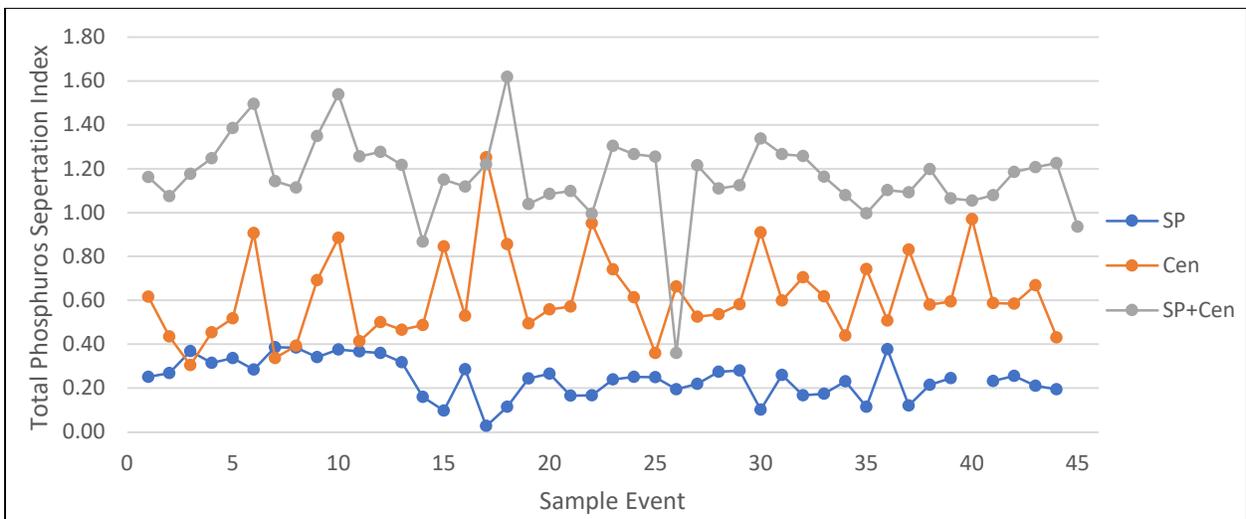
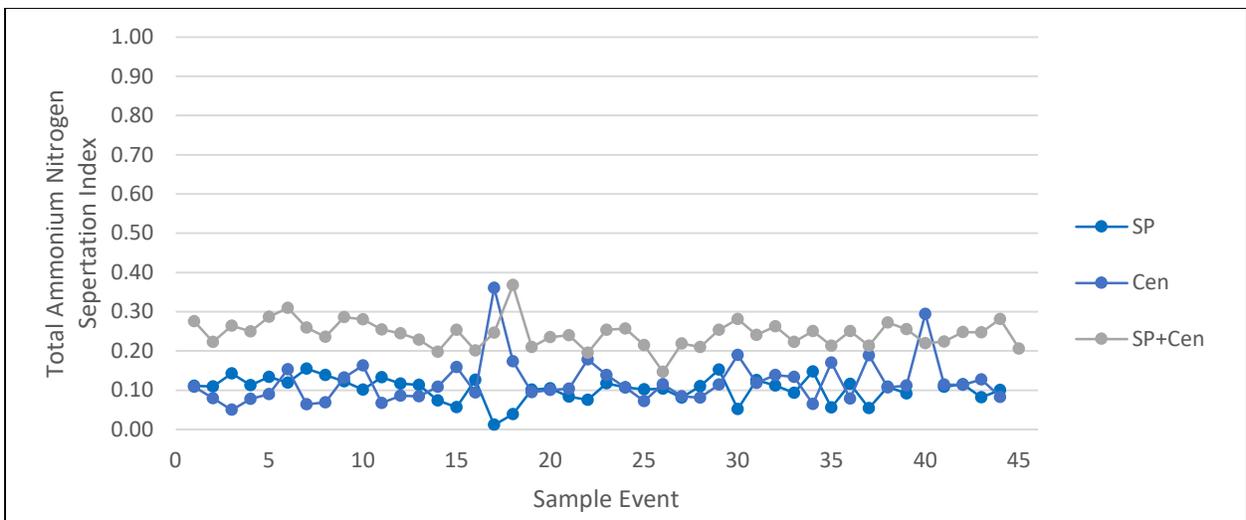
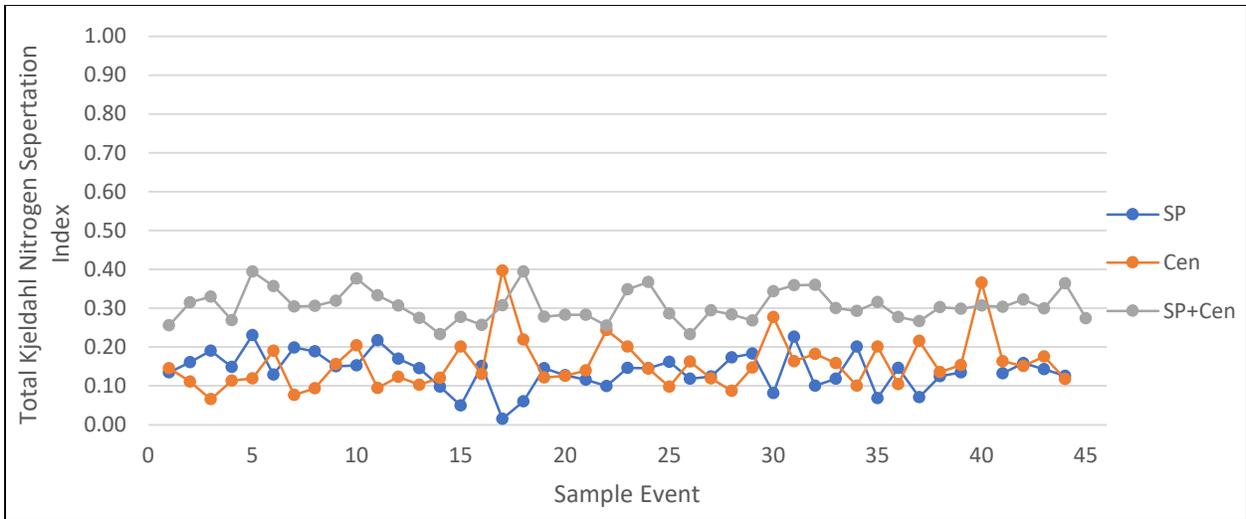


Figure 7. Separation index (SI) for total solids (TS), volatile solids (VS), total Kjeldahl nitrogen (TKN), total ammonium nitrogen (TAN), total phosphorus (TP), and total potassium (TK). SP= Screw Press (digestate to screw press solids), Cen= Centrifuge (separated liquids from the screw press to centrifuge solids), SP+Cen= Screw Press + Centrifuge (digestate to centrifuge solids).

The separation index for TS, TKN, TAN, TP, and K for each of the 45 sampling events is presented in Figure 8. Sample 41 was omitted for the screw press as there was sludge in the separated liquid sample that indicated a higher total solids content than the digestate. The SI was consistently low for TKN and K. The screw presses and centrifuge are cleaned once a week, thus there are some differences in the SI throughout the week.





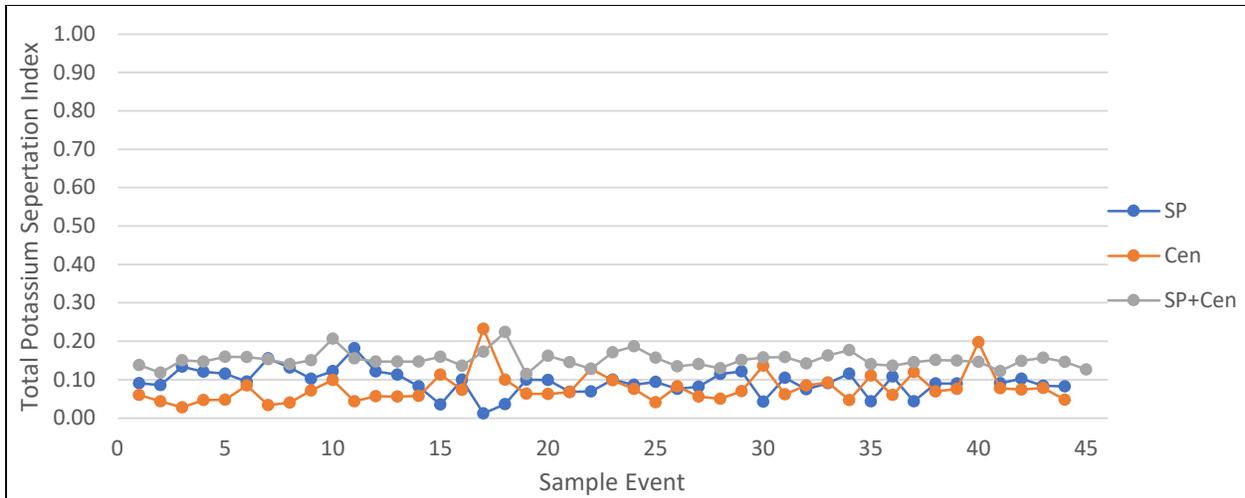


Figure 8. Separation index (SI) over time for total solids (TS, top), total Kjeldahl nitrogen (TKN), total ammonium nitrogen (TAN), total phosphorus (TP), and potassium (TK, bottom) for the screw press and centrifuge. SP=Screw Press (digestate to screw press solids), Cen=Centrifuge (separated liquids from screw press to centrifuge solids), SP+Cen=Screw Press + Centrifuge (digestate to centrifuge solids).

The coefficient of variation (CV) of the SI was calculated for each solid separation equipment and the total system solids separation (Figure 9). The centrifuge had a slightly lower CV for total solids, volatile solids and P than the centrifuge, indicating it was slightly more consistent at separating these constituents. The screw press had a slightly lower CV for TAN indicating it was slightly more consistent at separating TAN it compared to the centrifuge. For the combined screw press and centrifuge system the CV was lower than the individual components showing improved consistency in the SI for all parameters over the 37-week period. This suggests that separation systems in series may have improved consistency in SI than individual units.

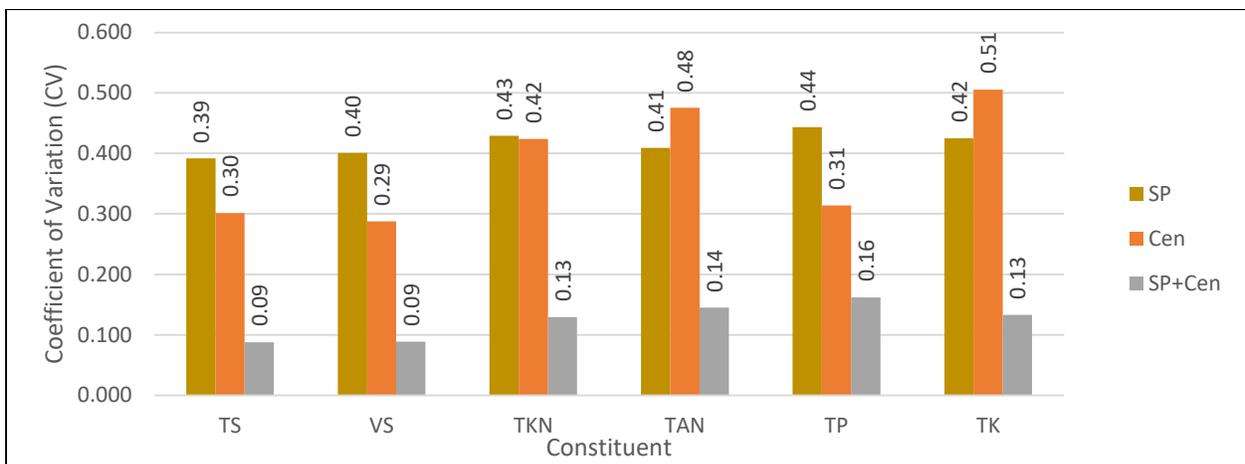


Figure 9. Coefficient of variation (CV) for the separation index for total solids (TS), volatile solids (VS), total Kjeldahl nitrogen (TKN), total ammonium nitrogen (TAN), total phosphorus (TP), and total potassium (TK). SP=Screw Press (digestate to screw press solids), Cen=Centrifuge (separated screw press liquids to centrifuge solids), SP+Cen=Screw Press + Centrifuge (digestate to centrifuge solids).

Separation efficiencies as measured by removal efficiency (RE)

The RE for total solids, volatile solids, TKN, TP, and K increased through each unit, screw press < centrifuge < ultra-filtration < reverse osmosis (Figure 10). Total available N however decreased for the ultra-filtration unit. Previous research indicates a high efficiency RE value is above 0.53 (Guilayn et al., 2019). For the individual processing units, the ultra-filtration reached a high removal efficiency for volatiles solids and P. Ther reverse osmosis is a high efficiency separation system for all parameters measured (volatile solids and TKN were not included treated water analysis package).

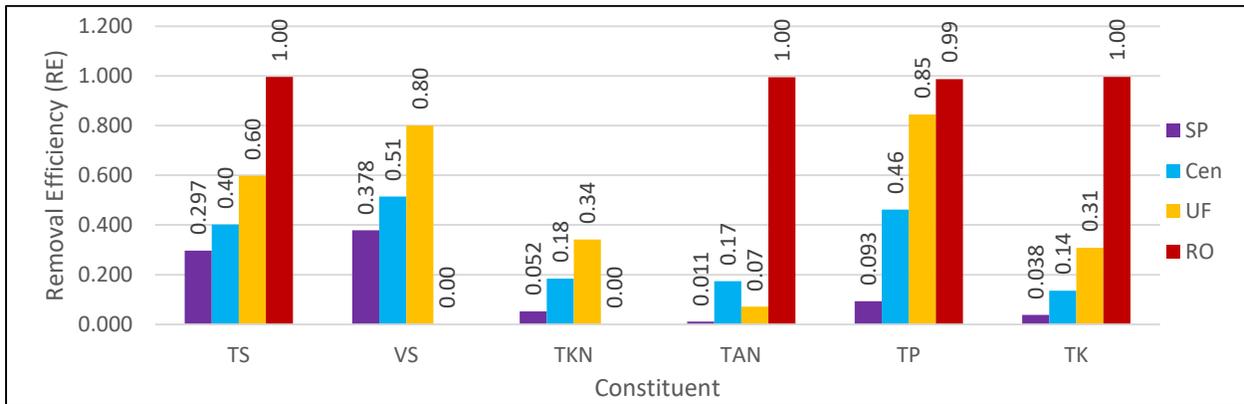


Figure 10. Removal efficiency (RE) for total solids (TS), volatile solids (VS), total Kjeldahl nitrogen (TKN), total ammonium nitrogen (TAN), total phosphorus (TP), and total potassium (TK) for the screw press, centrifuge, ultra-filtration, and reverse osmosis system. SP=Screw Press (digestate to separated screw press liquids), Cen=Centrifuge (separated screw press liquids to separated centrifuge liquids), UF= Ultra-Filtration (separated centrifuge liquids to ultra-filtration permeate), RO=Reverse Osmosis (ultra-filtration permeate to treated clean water).

As a system, RE is classified as a high efficiency system for volatile solids after the centrifuge (Figure 11), which is important for the reduction in methane production during storage. For P and K, the nutrient removal does not reach high efficiency until the manure passes through the screw press, centrifuge, and ultrafiltration. Nitrogen RE only reaches a high removal efficiency when all system components are included, highlighting the importance of the reverse osmosis system for N removal.

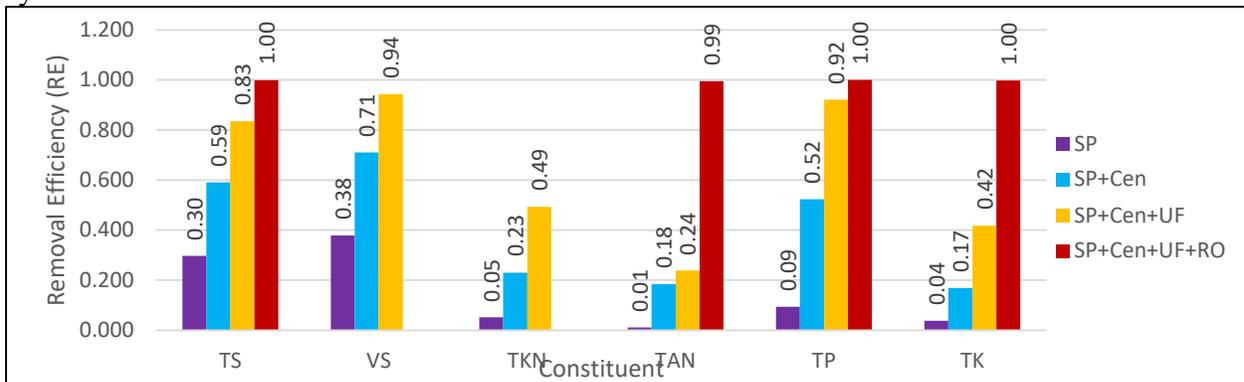
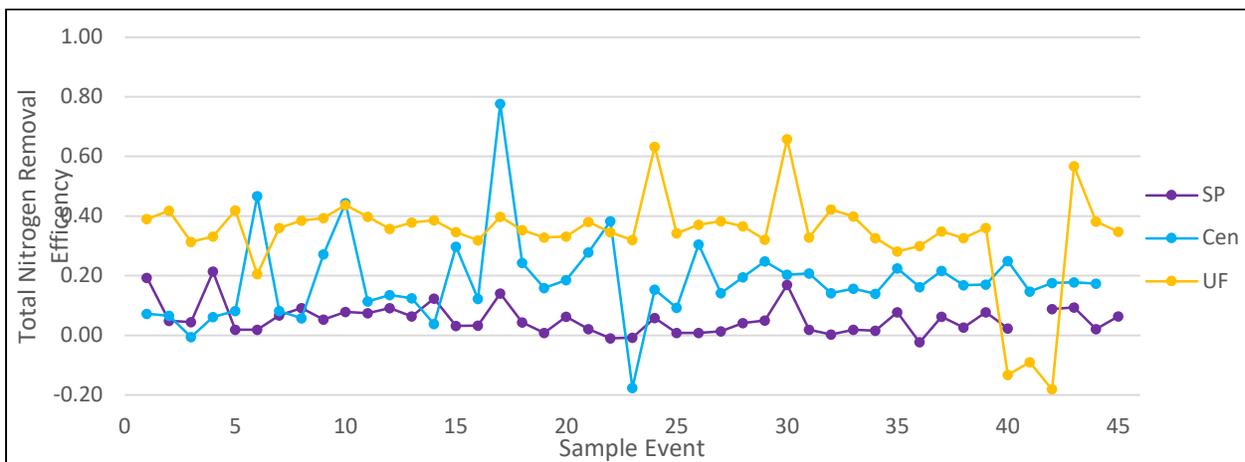
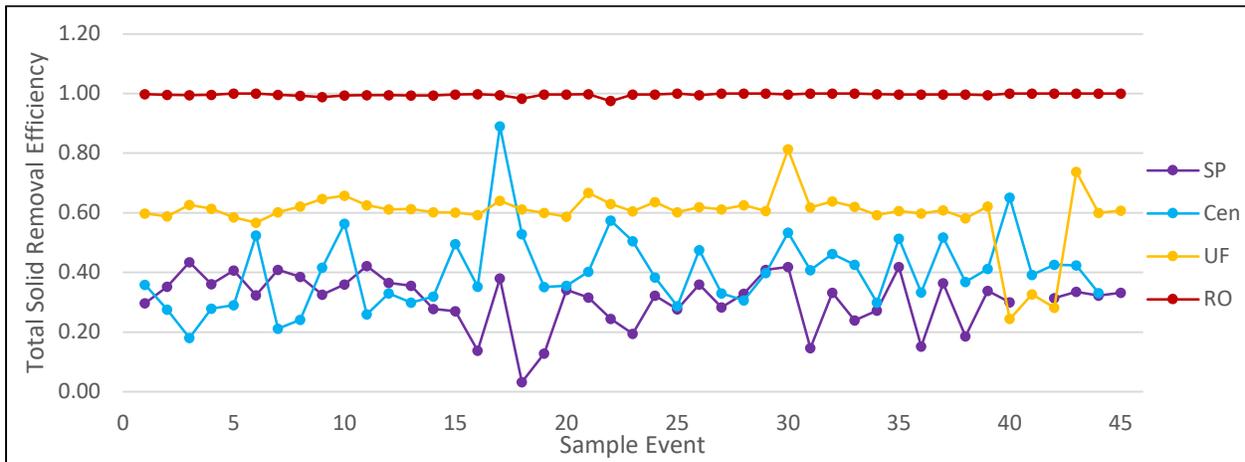


Figure 11. Cumulative removal efficiency (RE) for total solids (TS), volatile solids (VS), total Kjeldahl nitrogen (TKN), total ammonium nitrogen (TAN), total phosphorus (TP), and total potassium (TK). SP=Screw Press (digestate to separated screw press liquids), SP+Cen=Screw Press+Centrifuge (digestate to separated centrifuge liquids), SP+Cen+UF=Screw Press+Centrifuge+Ultra-Filtration (digestate to ultra-filtration permeate), SP+Cen+UF+RO=Screw Press+Centrifuge+Ultra-Filtration+Reverse Osmosis (digestate to treated clean water).

The removal efficiency for TS, TKN, TAN, TP, and K for each of the 45 sampling events are shown below (Figure 12). As mentioned previously, sample 41 was omitted due to the high total solids in the sample from sludge. Sample 20 was also omitted for the ultra-filtration unit as an outlier. Both the screw press and centrifuge had large variations in the removal efficiency across the 45 samples.



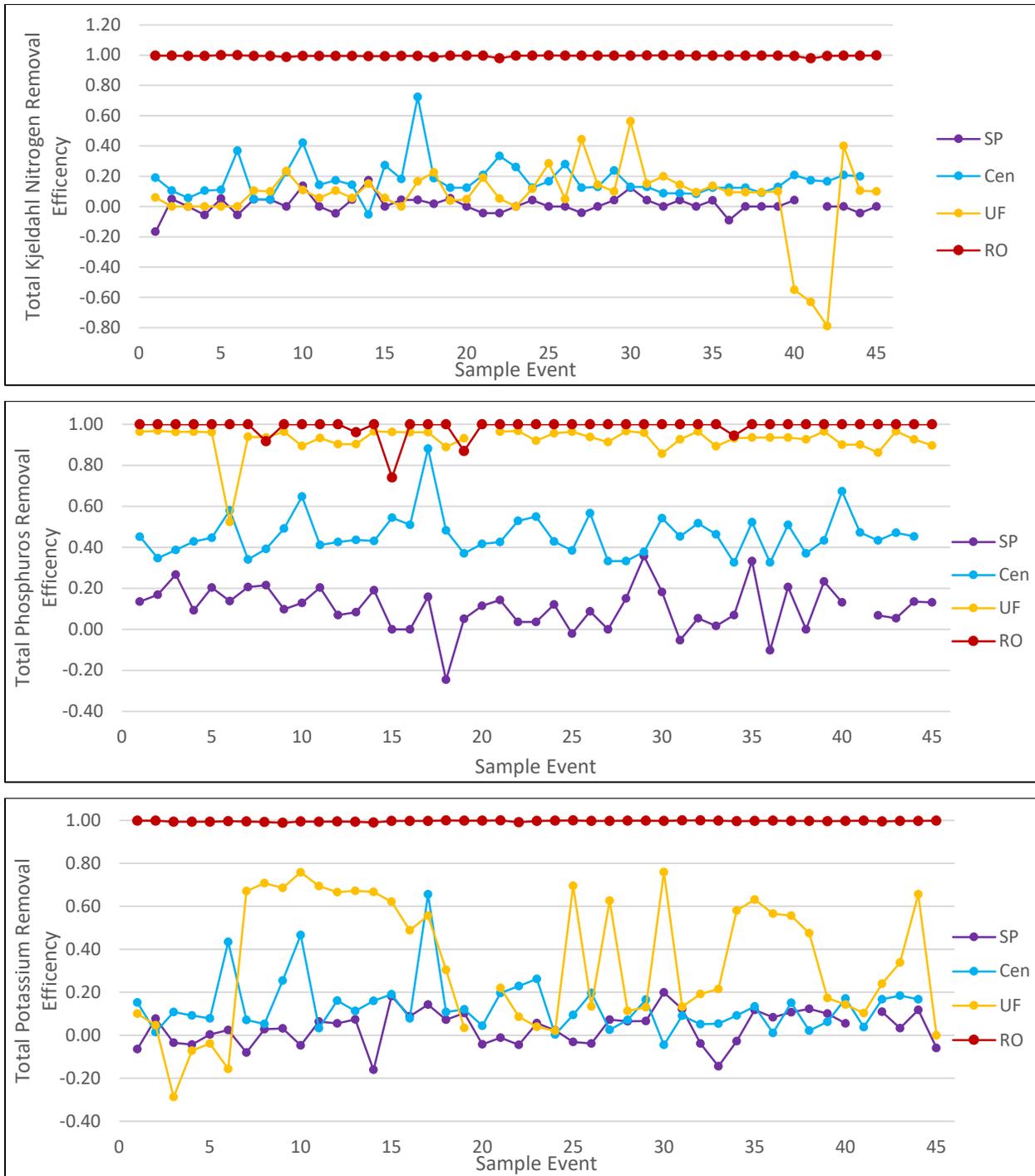


Figure 12. Removal efficiency (RE) over time for total solids (TS, top), total Kjeldahl nitrogen (TKN), total ammonium nitrogen (TAN), total phosphorus (TP), and potassium (TK, bottom) for the screw press and centrifuge. SP=Screw Press (digestate to separated screw press liquids), SP+Cen=Screw Press+Centrifuge (digestate to separated centrifuge liquids), SP+Cen+UF=Screw Press+Centrifuge+Ultra-Filtration (digestate to ultra-filtration permeate), SP+Cen+UF+RO= Screw Press+Centrifuge+Ultra-Filtration+Reverse Osmosis (digestate to treated clean water).

The CV for the RE was calculated for each piece of separation equipment and the total system solids separation (Figure 12). There was large variation in the TAN removal efficiency for the screw press and the ultra-filtration unit, highlighting the challenges with TAN removal. The ultra-filtration and screw press also had a high CV regarding the RE of K, and the screw press had a high CV for the RE for P. The screw press had the largest variation between all the separation equipment for each constituent, which is particularly interesting as the influent concentrations were most consistent into the screw press.

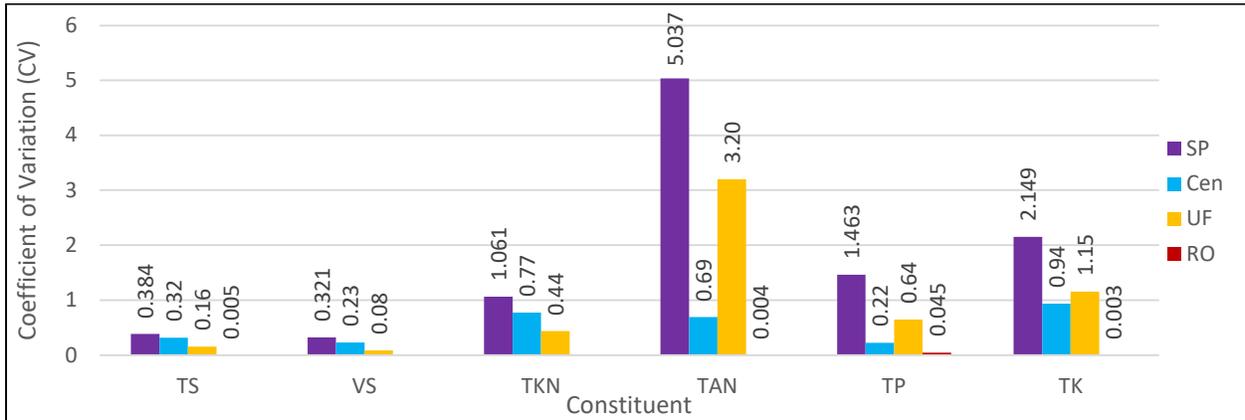


Figure 13. Coefficient of variation (CV) for the removal efficiency for total solids (TS), volatile solids (VS), total Kjeldahl nitrogen (TKN), total ammonium nitrogen (TAN), total phosphorus (TP), and total potassium (TK). SP=Screw Press (digestate to separated screw press liquids), Cen=Centrifuge (separated screw press liquids to separated centrifuge liquids), UF= Ultra-Filtration (separated centrifuge liquids to ultra-filtration permeate), RO=Reverse Osmosis (ultra-filtration permeate to treated clean water).

System Performance

The manure processing system produces treated clean water that regularly meets discharge quality. The system can produce approximately 28% of the manure that enters the system as treated clean water for discharge (Figure 14). The manure processed produces an additional 24% as ultra-filtration concentrate and 33% as reverse osmosis concentrate, or 61% of the influent manure volume. The system removes 24% of the TKN from the digestate through the solid separation stage with an additional 26% and 49% TKN removal from the ultrafiltration units and reverse osmosis. Minimal TAN is removed from the screw press (4%) and ultrafiltration (4%) while the centrifuge and reverse osmosis remove 18% and 74% respectively. Total P is removed with the screw press (17%), centrifuge (33%), ultra filtration (42%), and reverse osmosis (8%). Minimal K is removed by the screw press (3%), where more is removed through the centrifuge (14%) and even greater amounts with the ultra-filtration (24%) and reverse osmosis (59%).

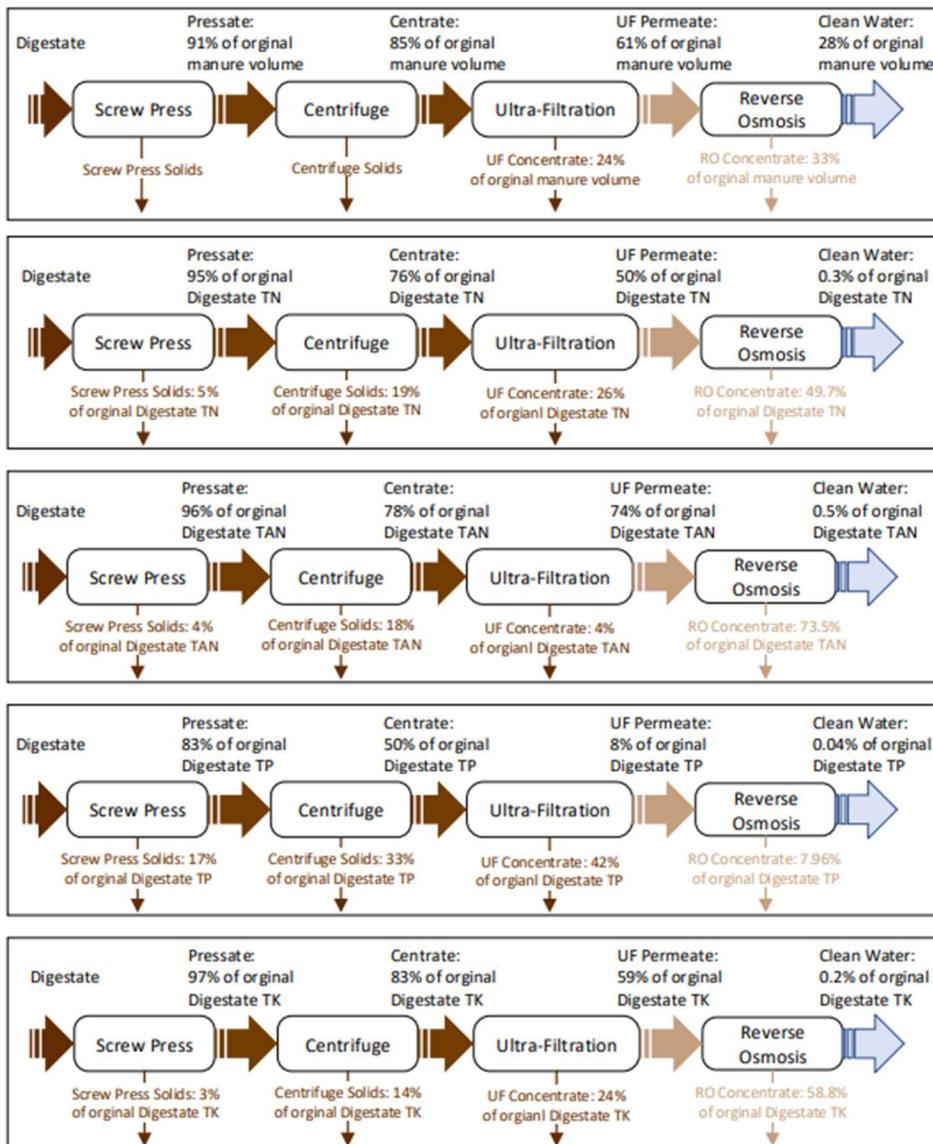


Figure 14. Fate of manure volume (top), total Kjeldahl nitrogen (TKN), total phosphorus (TP), and potassium (TP, bottom) through the treatment system.

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Appendix A:

Table A1. Monitoring Requirements for Discharge Water

Monitoring Requirements and Effluent Limitations					
Parameter	Limit Type	Limit and Units	Sample Frequency	Sample Type	Notes
Flow Rate		gpd	Daily	Total Daily	
BOD ₅ , Total	Daily Max	8.2 mg/L	3/Week	24-Hr Flow Prop Comp	Limit effective May through October.
BOD ₅ , Total	Weekly Avg	5.0 mg/L	3/Week	24-Hr Flow Prop Comp	Limit effective May through October.
BOD ₅ , Total	Monthly Avg	5.0 mg/L	3/Week	24-Hr Flow Prop Comp	Limit effective May through October.
BOD ₅ , Total	Daily Max	16 mg/L	3/Week	24-Hr Flow Prop Comp	Limit effective November through April.
BOD ₅ , Total	Weekly Avg	10 mg/L	3/Week	24-Hr Flow Prop Comp	Limit effective November through April.
BOD ₅ , Total	Monthly Avg	10 mg/L	3/Week	24-Hr Flow Prop Comp	Limit effective November through April.
pH Field	Daily Min	6.0 su	5/Week	Grab	
pH Field	Daily Max	9.0 su	5/Week	Grab	
Dissolved Oxygen	Daily Min	7.0 mg/L	5/Week	Grab	
Fecal Coliform	Geometric Mean - Monthly	400 #/100 ml	Weekly	Grab	Interim limit effective May through September annually until the final E. coli limit goes into effect per the Effluent Limitations for E. coli Schedule.

Table A2. Monitoring Requirements for Discharge Water

Monitoring Requirements and Effluent Limitations					
Parameter	Limit Type	Limit and Units	Sample Frequency	Sample Type	Notes
WQT Credits Used (TSS)	Annual Total	145,733 lbs/yr	Annual	Calculated	The sum of total monthly credits used may not exceed values specified in Table 4 and the approved WQT trading plan.
WQT Computed Compliance (TSS)	Monthly Avg	0 lbs/day	Monthly	Calculated	Report the WQT TSS Computed Compliance value using Equation 5a. in the Water Quality Trading (WQT) section. Value entered on the last day of the month.
Chloride		mg/L	Quarterly	24-Hr Flow Prop Comp	
Hardness, Total as CaCO ₃		mg/L	Quarterly	24-Hr Flow Prop Comp	
Acute WET		TU _a	See Listed Qtr(s)	24-Hr Flow Prop Comp	
Chronic WET		TU _c	See Listed Qtr(s)	24-Hr Flow Prop Comp	

Table A5. Monitoring Requirements for Discharge Water

Monitoring Requirements and Effluent Limitations					
Parameter	Limit Type	Limit and Units	Sample Frequency	Sample Type	Notes
E. coli		#/100 ml	Weekly	Grab	Monitoring only May through September annually until the final limit goes into effect per the Effluent Limitations for E. coli Schedule.
E. coli	Geometric Mean - Monthly	126 #/100 ml	Weekly	Grab	Limit Effective May through September annually per the Effluent Limitations for E. coli Schedule.
E. coli	% Exceedance	10 Percent	Monthly	Grab	Limit Effective May through September annually per the Effluent Limitations for E. coli Schedule. See the E. coli Percent Limit section below. Enter the result in the DMR on the last day of the month.
Temperature Maximum		deg F	Daily	Continuous	See Table 2 for limits.
Nitrogen, Ammonia (NH ₃ -N) Total	Daily Max	8.2 mg/L	3/Week	24-Hr Flow Prop Comp	Limit effective throughout the year.
Nitrogen, Ammonia (NH ₃ -N) Total	Weekly Avg	6.1 mg/L	3/Week	24-Hr Flow Prop Comp	Limit effective April and May.
Nitrogen, Ammonia (NH ₃ -N) Total	Weekly Avg	5.0 mg/L	3/Week	24-Hr Flow Prop Comp	Limit effective June through September.
Nitrogen, Ammonia (NH ₃ -N) Total	Weekly Avg	9.9 mg/L	3/Week	24-Hr Flow Prop Comp	Limit effective October through March.
Nitrogen, Ammonia (NH ₃ -N) Total	Monthly Avg	5.0 mg/L	3/Week	24-Hr Flow Prop Comp	Limit effective throughout the year.
Phosphorus, Total	Monthly Avg	1.0 mg/L	Weekly	24-Hr Flow Prop Comp	This limit reflects the minimum control level and must be met independent of Water Quality Trading (WQT).
Phosphorus, Total		lbs/day	Weekly	Calculated	Report daily mass discharged using Equation 1a. in the Water Quality Trading (WQT) section.
Phosphorus, Total		lbs/month	Monthly	Calculated	

Table A6. Monitoring Requirements for Discharge Water

Monitoring Requirements and Effluent Limitations					
Parameter	Limit Type	Limit and Units	Sample Frequency	Sample Type	Notes
WQT Credits Used (TP)		lbs/month	Monthly	Calculated	Report WQT TP Credits used per month using Equation 2c. in the Water Quality Trading (WQT) section. Available TP Credits are specified in Table 3 and in the approved Water Quality Trading Plan.
WQT Credits Used (TP)	Annual Total	99 lbs/yr	Annual	Calculated	The sum of total monthly credits used may not exceed values specified in Table 3 and the approved WQT trading plan.
WQT Computed Compliance (TP)	Monthly Avg	0 lbs/day	Monthly	Calculated	Report the WQT TP Computed Compliance value using Equation 4b. in the Water Quality Trading (WQT) section. Value entered on the last day of the month.
Suspended Solids, Total	Daily Max	16 mg/L	Weekly	24-Hr Flow Prop Comp	This limit reflects the minimum control level and must be met independent of Water Quality Trading (WQT).
Suspended Solids, Total	Monthly Avg	10 mg/L	Weekly	24-Hr Flow Prop Comp	This limit reflects the minimum control level and must be met independent of Water Quality Trading (WQT).
Suspended Solids, Total		lbs/day	Weekly	Calculated	Report daily mass discharged using Equation 1a. in the Water Quality Trading (WQT) section.
Suspended Solids, Total		lbs/month	Monthly	Calculated	
WQT Credits Used (TSS)		lbs/month	Monthly	Calculated	Report WQT TSS Credits used per month using Equation 3b. in the Water Quality Trading (WQT) section. Available TSS Credits are specified in Table 4. and in the approved Water Quality Trading Plan.

Appendix B

Table B7. Additional manure characteristics measured by sampling location

		Moisture [%]	Ash @ 550C [%]	Organic Matter (LOI @ 550C) [%]	Organic Carbon (LOI @ 550C) [%]	S [%]	Mg [%]	Ca [%]	Na [%]	Al [ppm]	Cu [ppm]	Fe [ppm]	Mn [ppm]	Zn [ppm]	pH
Raw Manure	Average	88.23	3.08	8.69	5.04	0.05	0.18	0.31	0.14	76.50	16.73	120.75	32.13	30.50	7.13
	Max	90.13	7.03	9.98	5.79	0.06	0.39	0.67	0.22	125.00	23.00	206.00	36.00	34.00	7.30
	Min	84.89	1.35	8.02	4.65	0.04	0.10	0.16	0.12	39.00	8.80	54.00	26.00	20.00	6.90
	Standard Deviation	1.56	1.81	0.69	0.40	0.01	0.10	0.17	0.03	28.61	5.08	49.21	3.18	5.29	0.14
Digestate	Average	93.56	1.67	4.76	2.76	0.03	0.12	0.17	0.12	55.29	33.93	65.40	25.00	31.91	7.85
	Max	94.42	1.99	5.21	3.06	0.04	0.14	0.30	0.16	83.00	67.00	83.00	35.00	37.00	8.10
	Min	93.09	1.17	3.75	2.18	0.03	0.09	0.14	0.08	41.00	29.00	50.00	22.00	27.00	7.70
	Standard Deviation	0.31	0.15	0.28	0.17	0.00	0.01	0.02	0.02	8.76	5.71	5.91	2.02	1.98	0.09
Screw Press Solids	Average	73.99	3.54	22.27	13.03	0.09	0.23	0.50	0.11	84.09	55.78	131.51	65.87	52.13	8.73
	Max	76.69	4.39	25.57	14.83	0.70	0.37	0.62	0.14	155.00	64.00	184.00	89.00	61.00	9.00
	Min	70.76	2.46	12.25	11.25	0.07	0.17	0.40	0.08	60.00	45.00	90.00	47.00	42.00	8.40
	Standard Deviation	1.60	0.42	2.19	0.93	0.09	0.05	0.06	0.01	15.97	4.75	21.66	9.86	4.51	0.15
Screw Press Liquid Effluent	Average	95.48	1.56	2.96	1.71	0.04	0.10	0.15	0.11	51.49	29.56	60.58	21.29	28.91	7.97
	Max	96.34	2.41	5.57	3.23	0.30	0.18	0.32	0.13	69.00	34.00	89.00	36.00	32.00	8.30
	Min	92.02	1.22	2.31	1.34	0.02	0.08	0.09	0.08	32.00	23.00	44.00	16.00	24.00	7.70
	Standard Deviation	0.77	0.21	0.59	0.34	0.04	0.02	0.04	0.01	7.65	2.41	8.82	3.80	2.22	0.13
Centrifuge Solids	Average	71.68	10.07	18.25	10.58	0.10	0.86	4.61	0.14	279.78	76.42	374.60	212.91	71.24	8.52
	Max	73.87	12.01	19.45	11.28	0.13	1.12	141.00	1.10	418.00	85.00	470.00	249.00	83.00	8.90
	Min	70.24	8.64	16.32	9.47	0.08	0.63	1.33	0.08	198.00	63.00	288.00	172.00	61.00	8.10
	Standard Deviation	0.74	0.85	0.62	0.36	0.01	0.13	20.56	0.21	46.28	4.40	44.67	18.52	7.49	0.17
Centrifuge Liquid Effluent	Average	97.37	1.25	1.38	0.80	0.02	0.06	0.07	0.11	35.52	23.45	39.24	9.70	22.97	8.14
	Max	99.28	1.73	1.77	1.03	0.03	0.07	0.10	0.90	51.00	28.00	57.00	13.00	27.00	8.40
	Min	96.94	0.34	0.38	0.22	0.01	0.02	0.03	0.04	7.30	5.40	10.00	2.40	6.80	8.00

	Standard Deviation	0.38	0.25	0.26	0.15	0.00	0.01	0.01	0.12	6.92	3.83	6.94	1.61	3.38	0.10
Ultra Filtration Effluent	Average	95.99	1.28	2.73	1.58	0.04	0.09	0.12	0.09	63.53	44.27	71.99	17.87	43.98	8.07
	Max	99.27	1.91	4.08	2.37	0.30	0.80	0.20	0.11	93.00	66.00	105.00	30.00	61.00	8.30
	Min	94.39	0.36	0.37	0.21	0.00	0.01	0.00	0.03	0.50	0.00	0.50	0.10	0.10	7.20
	Standard Deviation	0.86	0.28	0.65	0.38	0.04	0.11	0.04	0.02	17.54	12.52	19.79	5.51	11.73	0.17
Ultra Filtration Permeate	Average	98.94	0.79	0.27	0.16	0.01	0.03	0.02	0.10	7.18	3.41	6.05	1.38	3.07	8.17
	Max	99.72	1.64	0.50	0.29	0.08	0.17	0.26	0.25	175.00	125.00	196.00	42.00	107.00	8.50
	Min	97.86	0.21	0.05	0.03	0.00	0.01	0.00	0.02	0.40	0.00	0.06	0.10	0.10	7.30
	Standard Deviation	0.32	0.25	0.09	0.05	0.01	0.02	0.04	0.04	25.37	18.34	28.65	6.13	15.68	0.17
Reverse Osmosis Concentrate	Average	98.26	1.32	0.42	0.24	0.04	0.05	0.01	0.15	4.16	0.29	3.76	0.52	0.41	8.07
	Max	99.52	1.91	0.75	0.43	0.20	0.08	0.02	0.22	13.00	0.90	66.00	1.90	1.10	8.30
	Min	97.52	0.36	0.12	0.07	0.01	0.01	0.01	0.05	0.70	0.00	0.50	0.10	0.10	7.70
	Standard Deviation	0.46	0.36	0.12	0.07	0.04	0.01	0.00	0.04	2.41	0.20	9.59	0.33	0.23	0.12

Table B8. Additional clean water characteristics measured

	Sodium Adsorption Ratio (SAR)	NA [mg/L]	Ca [mg/L]	Mg [mg/L]	PO4 [mg/L]	NO3-N [mg/L]	SO4 [mg/L]	CO3 [mg/L]	HCO3 [mg/L]	Alkalinity (CaCO3 equiv.) [mg/L]	B [mg/L]	Fe [ppm]	S [ppm]
Average	0.204	2.511	0.001	0.444	0.281	0.022	43.267	7.200	9.644	18.556	0.181	0.038	14.978
Max	1.170	50.000	0.013	11.000	6.700	0.300	143.000	324.000	55.000	475.000	0.340	0.380	48.000
Min	0.000	0.000	0.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000	0.030	0.000	0.000
Standard Deviation	0.199	7.417	0.002	1.845	1.068	0.055	23.531	47.759	9.257	69.215	0.087	0.082	8.046

Appendix C

Report Number
F24024-6500
Account Number
63570



3505 Conestoga Dr.
Fort Wayne, IN 46808
260.483.4759
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To: NEWTRIENT LLC - SIG GRANT
11510 LAURIE DR
WHEATFIELD, IN 46392-7364

For: UW-MADISON

Attn: MARK STOERMAN
Lab Number: 62723
Sample ID: RAW MANURE
Manure Type: DAIRY, LAGOON (21)

Purchase Order: UW-MADISON
Date Sampled: 1/16/2024
Date Received: 1/24/2024
Date Reported: 1/30/2024 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	%	87.14	7259	
Solids	%	12.86	1071	
Ash @ 550 C	%	4.84	403.4	
Organic Matter (LOI @ 550 C)	%	8.02	667.8	
Organic Carbon (LOI @ 550 C)	%	4.65	387.3	
Carbon:Nitrogen Ratio (C:N)	-		11.1:1	
Nitrogen, Total Kjeldahl (TKN)	%	0.419	34.9	20.6 *
Nitrogen, Ammonium (NH ₄ -N)	%	0.190	15.8	15.8 *
Nitrogen, Organic (N)	%	0.229	19.1	4.8 *
Phosphorus (P)	%	0.073	13.9 (as P ₂ O ₅)	13.9 * (as P ₂ O ₅)
Potassium (K)	%	0.297	29.7 (as K ₂ O)	29.7 * (as K ₂ O)
Sulfur (S)	%	0.05	3.9	2.3 #

[®] 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
F24024-6500
Account Number
63570



3505 Conestoga Dr.
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To: NEWTRIENT LLC - SIG GRANT
11510 LAURIE DR
WHEATFIELD, IN 46392-7364

For: UW-MADISON

Attn: MARK STOERMAN

Purchase Order: UW-MADISON

Lab Number: 62723
Sample ID: RAW MANURE
Manure Type: DAIRY, LAGOON (21)

Date Sampled: 1/16/2024
Date Received: 1/24/2024
Date Reported: 1/30/2024 Page: 8 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)	%	0.27	22.2	12.4 #
Calcium (Ca)	%	0.47	39.1	21.5 #
Sodium (Na)	%	0.12	9.9	
Aluminum (Al)	ppm	125	1.0	
Copper (Cu)	ppm	23	0.2	0.1 #
Iron (Fe)	ppm	183	1.5	1.0 #
Manganese (Mn)	ppm	28	0.2	0.2 #
Zinc (Zn)	ppm	23	0.2	0.1 #
pH	-	7.3		

® 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
F24024-6503
Account Number
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3505 Conestoga Dr.
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To: NEWTRIENT LLC - SIG GRANT
11510 LAURIE DR
WHEATFIELD, IN 46392-7364

For: UW-MADISON

Attn: MARK STOERMAN

Purchase Order: UW-MADISON

Lab Number: 62737
Sample ID: DIGESTATE 20
Manure Type: DAIRY, LAGOON (21)

Date Sampled: 1/15/2024
Date Received: 1/24/2024
Date Reported: 2/1/2024 Page: 1 of 12

MANURE ANALYSIS

Analysis	Unit	Analysis Result (As Received)	Pounds Per 1,000 Gal ^{**}	First Year Availability [®] Pounds Per 1,000 Gal
Moisture	%	93.26	7769	
Solids	%	6.74	561	
Ash @ 550 C	%	1.73	144.4	
Organic Matter (LOI @ 550 C)	%	5.01	417.0	
Organic Carbon (LOI @ 550 C)	%	2.90	241.9	
Carbon:Nitrogen Ratio (C:N)	-		7.3:1	
Nitrogen, Total Kjeldahl (TKN)	%	0.398	33.2	23.3 *
Nitrogen, Ammonium (NH ₄ -N)	%	0.240	20.0	20.0 *
Nitrogen, Organic (N)	%	0.158	13.2	3.3 *
Phosphorus (P)	%	0.061	11.6 (as P ₂ O ₅)	11.6 * (as P ₂ O ₅)
Potassium (K)	%	0.288	28.7 (as K ₂ O)	28.7 * (as K ₂ O)
Sulfur (S)	%	0.03	2.8	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 Approved By: David Henry Approval Date: 2/01/2024
David Henry - Agronomist / Technical Services - CCA

Report Number
F24024-6503
Account Number
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To: NEWTRIENT LLC - SIG GRANT
11510 LAURIE DR
WHEATFIELD, IN 46392-7364

For: UW-MADISON

Attn: MARK STOERMAN

Purchase Order: UW-MADISON

Lab Number: 62737
Sample ID: DIGESTATE 20
Manure Type: DAIRY, LAGOON (21)

Date Sampled: 1/15/2024
Date Received: 1/24/2024
Date Reported: 2/1/2024 Page: 2 of 12

MANURE ANALYSIS

Analysis	Unit	Analysis Result (As Received)	Pounds Per 1,000 Gal**	First Year Availability® Pounds Per 1,000 Gal
Magnesium (Mg)	%	0.11	9.5	5.0 #
Calcium (Ca)	%	0.19	16.0	8.7 #
Sodium (Na)	%	0.14	11.9	
Aluminum (Al)	ppm	83	0.7	
Copper (Cu)	ppm	44	0.4	0.2 #
Iron (Fe)	ppm	83	0.7	0.4 #
Manganese (Mn)	ppm	28	0.2	0.2 #
Zinc (Zn)	ppm	33	0.3	0.2 #
pH	-	7.9		

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

For: UW-MADISON

Attn: MARK STOERMAN

Purchase Order: UW-MADISON

Lab Number: 62738
Sample ID: SCREW PRESS EFFLUENT 20
Manure Type: DAIRY, LAGOON (21)

Date Sampled: 1/15/2024
Date Received: 1/24/2024
Date Reported: 2/1/2024 Page: 3 of 12

MANURE ANALYSIS

Analysis	Unit	Analysis Result (As Received)	Pounds Per 1,000 Gal **	First Year Availability [®] Pounds Per 1,000 Gal
Moisture	%	95.56	7960	
Solids	%	4.44	370	
Ash @ 550 C	%	1.55	129.0	
Organic Matter (LOI @ 550 C)	%	2.89	240.9	
Organic Carbon (LOI @ 550 C)	%	1.68	139.7	
Carbon:Nitrogen Ratio (C:N)	-		4.5:1	
Nitrogen, Total Kjeldahl (TKN)	%	0.373	31.1	22.8 *
Nitrogen, Ammonium (NH ₄ -N)	%	0.240	20.0	20.0 *
Nitrogen, Organic (N)	%	0.133	11.1	2.8 *
Phosphorus (P)	%	0.054	10.3 (as P ₂ O ₅)	10.3 * (as P ₂ O ₅)
Potassium (K)	%	0.300	30.0 (as K ₂ O)	30.0 * (as K ₂ O)
Sulfur (S)	%	0.04	3.2	1.8 #

[®] 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
F24024-6503
Account Number
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To: NEWTRIENT LLC - SIG GRANT
11510 LAURIE DR
WHEATFIELD, IN 46392-7364

For: UW-MADISON

Attn: MARK STOERMAN

Purchase Order: UW-MADISON

Lab Number: 62738
Sample ID: SCREW PRESS EFFLUENT 20
Manure Type: DAIRY, LAGOON (21)

Date Sampled: 1/15/2024
Date Received: 1/24/2024
Date Reported: 2/1/2024 Page: 4 of 12

MANURE ANALYSIS

Analysis	Unit	Analysis Result (As Received)	Pounds Per 1,000 Gal**	First Year Availability® Pounds Per 1,000 Gal
Magnesium (Mg)	%	0.10	8.0	4.6 #
Calcium (Ca)	%	0.15	12.5	6.9 #
Sodium (Na)	%	0.12	10.1	
Aluminum (Al)	ppm	69	0.6	
Copper (Cu)	ppm	31	0.3	0.2 #
Iron (Fe)	ppm	72	0.6	0.4 #
Manganese (Mn)	ppm	21	0.2	0.1 #
Zinc (Zn)	ppm	29	0.2	0.2 #
pH	-	8.1		

® 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
F24024-6503
Account Number
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To: NEWTRIENT LLC - SIG GRANT
11510 LAURIE DR
WHEATFIELD, IN 46392-7364

For: UW-MADISON

Attn: MARK STOERMAN

Purchase Order: UW-MADISON

Lab Number: 62739
Sample ID: CENTRIFUGE EFFLUENT 20
Manure Type: DAIRY, LAGOON (21)

Date Sampled: 1/15/2024
Date Received: 1/24/2024
Date Reported: 2/1/2024

Page: 5 of 12

MANURE ANALYSIS

Analysis	Unit	Analysis Result (As Received)	Pounds Per 1,000 Gal**	First Year Availability [®] Pounds Per 1,000 Gal
Moisture	%	97.12	8090	
Solids	%	2.88	240	
Ash @ 550 C	%	1.13	93.7	
Organic Matter (LOI @ 550 C)	%	1.75	146.2	
Organic Carbon (LOI @ 550 C)	%	1.02	84.8	
Carbon:Nitrogen Ratio (C:N)	-		3.2:1	
Nitrogen, Total Kjeldahl (TKN)	%	0.314	26.2	19.7 *
Nitrogen, Ammonium (NH ₄ -N)	%	0.210	17.5	17.5 *
Nitrogen, Organic (N)	%	0.104	8.7	2.2 *
Phosphorus (P)	%	0.034	6.4 (as P ₂ O ₅)	6.4 * (as P ₂ O ₅)
Potassium (K)	%	0.264	26.4 (as K ₂ O)	26.4 * (as K ₂ O)
Sulfur (S)	%	0.03	2.2	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
F24024-6503
Account Number
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To: NEWTRIENT LLC - SIG GRANT
11510 LAURIE DR
WHEATFIELD, IN 46392-7364

For: UW-MADISON

Attn: MARK STOERMAN

Purchase Order: UW-MADISON

Lab Number: 62739
Sample ID: CENTRIFUGE EFFLUENT 20
Manure Type: DAIRY, LAGOON (21)

Date Sampled: 1/15/2024
Date Received: 1/24/2024
Date Reported: 2/1/2024 Page: 6 of 12

MANURE ANALYSIS

Analysis	Unit	Analysis Result (As Received)	Pounds Per 1,000 Gal**	First Year Availability® Pounds Per 1,000 Gal
Magnesium (Mg)	%	0.06	4.9	2.7 #
Calcium (Ca)	%	0.07	5.6	3.2 #
Sodium (Na)	%	0.11	9.0	
Aluminum (Al)	ppm	51	0.4	
Copper (Cu)	ppm	27	0.2	0.1 #
Iron (Fe)	ppm	50	0.4	0.3 #
Manganese (Mn)	ppm	11	0.1	0.1 #
Zinc (Zn)	ppm	26	0.2	0.1 #
pH	-	8.3		

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* 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
F24024-6503
Account Number
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To: NEWTRIENT LLC - SIG GRANT
11510 LAURIE DR
WHEATFIELD, IN 46392-7364

For: UW-MADISON

Attn: MARK STOERMAN

Purchase Order: UW-MADISON

Lab Number: 62740
Sample ID: ULTRA FILTRATION EFFLUENT 20
Manure Type: DAIRY, LAGOON (21)

Date Sampled: 1/15/2024
Date Received: 1/24/2024
Date Reported: 2/1/2024 Page: 7 of 12

MANURE ANALYSIS

Analysis	Unit	Analysis Result (As Received)	Pounds Per 1,000 Gal **	First Year Availability [®] Pounds Per 1,000 Gal
Moisture	%	95.62	7965	
Solids	%	4.38	365	
Ash @ 550 C	%	1.25	104.0	
Organic Matter (LOI @ 550 C)	%	3.13	260.8	
Organic Carbon (LOI @ 550 C)	%	1.82	151.3	
Carbon:Nitrogen Ratio (C:N)	-		4.7:1	
Nitrogen, Total Kjeldahl (TKN)	%	0.387	32.2	21.2 *
Nitrogen, Ammonium (NH ₄ -N)	%	0.210	17.5	17.5 *
Nitrogen, Organic (N)	%	0.177	14.7	3.7 *
Phosphorus (P)	%	0.000	0.1 (as P ₂ O ₅)	0.1 * (as P ₂ O ₅)
Potassium (K)	%	0.116	11.6 (as K ₂ O)	11.6 * (as K ₂ O)
Sulfur (S)	%	0.00	0.4	<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
F24024-6503
Account Number
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3505 Conestoga Dr.
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To: NEWTRIENT LLC - SIG GRANT
11510 LAURIE DR
WHEATFIELD, IN 46392-7364

For: UW-MADISON

Attn: MARK STOERMAN

Purchase Order: UW-MADISON

Lab Number: 62740

Date Sampled: 1/15/2024

Sample ID: ULTRA FILTRATION EFFLUENT 20

Date Received: 1/24/2024

Manure Type: DAIRY, LAGOON (21)

Date Reported: 2/1/2024

Page: 8 of 12

MANURE ANALYSIS

Analysis	Unit	Analysis Result (As Received)	Pounds Per 1,000 Gal**	First Year Availability [®] Pounds Per 1,000 Gal
Magnesium (Mg)	%	0.01	1.0	0.5 #
Calcium (Ca)	%	0.00	0.2	<0.1 #
Sodium (Na)	%	0.05	4.1	
Aluminum (Al)	ppm	0.5	<0.1	
Copper (Cu)	ppm	0.0	<0.1	<0.1 #
Iron (Fe)	ppm	0.5	<0.1	<0.1 #
Manganese (Mn)	ppm	0.1	<0.1	<0.1 #
Zinc (Zn)	ppm	0.1	<0.1	<0.1 #
pH	-	8.2		

[®] 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
F24024-6503
Account Number
63570



3505 Conestoga Dr.
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To: NEWTRIENT LLC - SIG GRANT
11510 LAURIE DR
WHEATFIELD, IN 46392-7364

For: UW-MADISON

Attn: MARK STOERMAN

Purchase Order: UW-MADISON

Lab Number: 62741
Sample ID: ULTRA FILTRATION PERMEATE 20
Manure Type: DAIRY, LAGOON (21)

Date Sampled: 1/15/2024
Date Received: 1/24/2024
Date Reported: 2/1/2024 Page: 9 of 12

MANURE ANALYSIS

Analysis	Unit	Analysis Result (As Received)	Pounds Per 1,000 Gal **	First Year Availability [®] Pounds Per 1,000 Gal
Moisture	%	98.81	8231	
Solids	%	1.19	99	
Ash @ 550 C	%	0.86	72.0	
Organic Matter (LOI @ 550 C)	%	0.33	27.1	
Organic Carbon (LOI @ 550 C)	%	0.19	15.7	
Carbon:Nitrogen Ratio (C:N)	-		0.9:1	
Nitrogen, Total Kjeldahl (TKN)	%	0.210	17.5	16.9 *
Nitrogen, Ammonium (NH ₄ -N)	%	0.200	16.7	16.7 *
Nitrogen, Organic (N)	%	0.010	0.8	0.2 *
Phosphorus (P)	%	0.127	24.2 (as P ₂ O ₅)	24.2 * (as P ₂ O ₅)
Potassium (K)	%	0.543	54.2 (as K ₂ O)	54.2 * (as K ₂ O)
Sulfur (S)	%	0.08	6.5	3.7 #

[®] 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
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3505 Conestoga Dr.
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To: NEWTRIENT LLC - SIG GRANT
11510 LAURIE DR
WHEATFIELD, IN 46392-7364

For: UW-MADISON

Attn: MARK STOERMAN

Purchase Order: UW-MADISON

Lab Number: 62741
Sample ID: ULTRA FILTRATION PERMEATE 20
Manure Type: DAIRY, LAGOON (21)

Date Sampled: 1/15/2024
Date Received: 1/24/2024
Date Reported: 2/1/2024 Page: 10 of 12

MANURE ANALYSIS

Analysis	Unit	Analysis Result (As Received)	Pounds Per 1,000 Gal**	First Year Availability® Pounds Per 1,000 Gal
Magnesium (Mg)	%	0.17	14.4	7.8 #
Calcium (Ca)	%	0.26	21.7	11.9 #
Sodium (Na)	%	0.25	20.7	
Aluminum (Al)	ppm	175	1.5	
Copper (Cu)	ppm	125	1.0	0.7 #
Iron (Fe)	ppm	196	1.6	1.1 #
Manganese (Mn)	ppm	42	0.3	0.2 #
Zinc (Zn)	ppm	107	0.9	0.6 #
pH	-	8.4		

® 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

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WHEATFIELD, IN 46392-7364

For: UW-MADISON

Attn: MARK STOERMAN

Purchase Order: UW-MADISON

Lab Number: 62742
Sample ID: REVERSE OSMOSIS CONCENTRATE 20
Manure Type: DAIRY, LAGOON (21)

Date Sampled: 1/15/2024
Date Received: 1/24/2024
Date Reported: 2/1/2024

Page: 11 of 12

MANURE ANALYSIS

Analysis	Unit	Analysis Result (As Received)	Pounds Per 1,000 Gal**	First Year Availability® Pounds Per 1,000 Gal
Moisture	%	98.06	8168	
Solids	%	1.94	162	
Ash @ 550 C	%	1.40	116.6	
Organic Matter (LOI @ 550 C)	%	0.54	45.0	
Organic Carbon (LOI @ 550 C)	%	0.31	26.1	
Carbon:Nitrogen Ratio (C:N)	-		1.0:1	
Nitrogen, Total Kjeldahl (TKN)	%	0.323	26.9	25.5 *
Nitrogen, Ammonium (NH ₄ -N)	%	0.300	25.0	25.0 *
Nitrogen, Organic (N)	%	0.023	1.9	0.5 *
Phosphorus (P)	%	0.002	0.3 (as P ₂ O ₅)	0.3 * (as P ₂ O ₅)
Potassium (K)	%	0.218	21.8 (as K ₂ O)	21.8 * (as K ₂ O)
Sulfur (S)	%	0.03	2.2	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
F24024-6503
Account Number
63570



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: UW-MADISON

Attn: MARK STOERMAN

Purchase Order: UW-MADISON

Lab Number: 62742
Sample ID: REVERSE OSMOSIS CONCENTRATE 20
Manure Type: DAIRY, LAGOON (21)

Date Sampled: 1/15/2024
Date Received: 1/24/2024
Date Reported: 2/1/2024 Page: 12 of 12

MANURE ANALYSIS

Analysis	Unit	Analysis Result (As Received)	Pounds Per 1,000 Gal**	First Year Availability® Pounds Per 1,000 Gal
Magnesium (Mg)	%	0.06	4.8	2.7 #
Calcium (Ca)	%	0.01	1.0	0.5 #
Sodium (Na)	%	0.17	14.1	
Aluminum (Al)	ppm	4.8	<0.1	
Copper (Cu)	ppm	0.4	<0.1	<0.1 #
Iron (Fe)	ppm	4.2	<0.1	<0.1 #
Manganese (Mn)	ppm	0.4	<0.1	<0.1 #
Zinc (Zn)	ppm	0.5	<0.1	<0.1 #
pH	-	8.2		

® 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
F24024-8004
Account Number
63570



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

For: NEWTRIENT SAMPLING PROJ.
AQUA INNOVATIONS

Purchase Order: AQUA INNOVATIONS
Lab Number: 31285
Date Sampled: 1/12/2024
Date Received: 1/24/2024
Date Reported: 1/26/2024

Attn: MARK STOERMAN

Sample ID: CLEAN WATER 20

IRRIGATION WATER ANALYSIS

Page: 5 of 8

Analysis	Result	Unit	Desired Range	Irrigation Use Restriction*
pH	7.1	Std. Unit	5.5 - 7.5	None
Conductivity (Soluble Salts)	0.1	mmho/cm	<0.75	None
Total Dissolved Solids (est.)	60	mg/L	<450	None
Sodium Adsorption Ratio (SAR)	0.17	-	<3	None
Sodium (Na)	1	mg/L	<70	None
Calcium (Ca)	< 1	mg/L	-	-
Magnesium (Mg)	< 1	mg/L	-	-
Potassium (K)	4	mg/L	-	-
Phosphorus - Total (P)	< 0.10	mg/L	-	-
Phosphorus - Phosphate (PO4)	< 0.01	mg/L	-	-
Nitrogen - Nitrate (NO3-N)	0.1	mg/L	<5	None
Nitrogen - Ammonium (NH4-N)	9.9	mg/L	-	-
Sulfur - Sulfate (SO4)	30	mg/L	-	-
Chloride (Cl)	1	mg/L	<70	None
Carbonate (CO3)	< 1	mg/L	<15	None

*For additional information Refer to Fact Sheet No. 20, Interpreting Irrigation Water Analysis.

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

For: NEWTRIENT SAMPLING PROJ.
AQUA INNOVATIONS

Purchase Order: AQUA INNOVATIONS
Lab Number: 31285
Date Sampled: 1/12/2024
Date Received: 1/24/2024
Date Reported: 1/26/2024 Page: 6 of 8

Attn: MARK STOERMAN

Sample ID: CLEAN WATER 20

IRRIGATION WATER ANALYSIS

Analysis	Result	Unit	Desired Range	Irrigation Use Restriction*
Bicarbonate (HCO ₃)	12	mg/L	<40	None
Alkalinity (CaCO ₃ equiv.)	10	mg/L	-	-
Boron (B)	0.14	mg/L	<0.3	None
Iron (Fe)	< 0.01	mg/L	<5	None
Manganese (Mn)	< 0.01	mg/L	<0.20	None
Sulfur (Total)	10	ppm	-	-

*For additional information Refer to Fact Sheet No. 20, Interpreting Irrigation Water Analysis.

Report Number
F24024-6505
Account Number
63570



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

For: UW-MADISON

Attn: MARK STOERMAN
Lab Number: 62751
Sample ID: SCREW PRESS SOLIDS 20
Manure Type: DAIRY, SOLID WITH BEDDING (7)

Purchase Order: UW-MADISON

Date Sampled: 1/15/2024

Date Received: 1/24/2024

Date Reported: 1/30/2024 Page: 9 of 16

MANURE ANALYSIS

Analysis	Unit	Analysis Result (As Received)	Pounds Per Ton	First Year Availability [®] Pounds Per Ton
Moisture	%	72.86	1457	
Solids	%	27.14	543	
Ash @ 550 C	%	3.58	71.5	
Organic Matter (LOI @ 550 C)	%	23.56	471.3	
Organic Carbon (LOI @ 550 C)	%	13.67	273.3	
Carbon:Nitrogen Ratio (C:N)	-		23.9:1	
Nitrogen, Total Kjeldahl (TKN)	%	0.572	11.4	6.4 *
Nitrogen, Ammonium (NH ₄ -N)	%	0.240	4.8	4.8 *
Nitrogen, Organic (N)	%	0.332	6.6	1.6 *
Phosphorus (P)	%	0.147	6.7 (as P ₂ O ₅)	6.7 * (as P ₂ O ₅)
Potassium (K)	%	0.284	6.8 (as K ₂ O)	6.8 * (as K ₂ O)
Sulfur (S)	%	0.09	1.8	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

Report Number
F24024-6505
Account Number
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To: NEWTRIENT LLC - SIG GRANT
11510 LAURIE DR
WHEATFIELD, IN 46392-7364

For: UW-MADISON

Attn: MARK STOERMAN

Purchase Order: UW-MADISON

Lab Number: 62751
Sample ID: SCREW PRESS SOLIDS 20
Manure Type: DAIRY, SOLID WITH BEDDING (7)

Date Sampled: 1/15/2024
Date Received: 1/24/2024
Date Reported: 1/30/2024 Page: 10 of 16

MANURE ANALYSIS

Analysis	Unit	Analysis Result (As Received)	Pounds Per Ton	First Year Availability [®] Pounds Per Ton
Magnesium (Mg)	%	0.22	4.3	2.4 #
Calcium (Ca)	%	0.51	10.2	5.6 #
Sodium (Na)	%	0.10	2.1	
Aluminum (Al)	ppm	90	0.2	
Copper (Cu)	ppm	59	0.1	0.1 #
Iron (Fe)	ppm	145	0.3	0.2 #
Manganese (Mn)	ppm	74	0.1	0.1 #
Zinc (Zn)	ppm	56	0.1	0.1 #
pH	-	8.9		

[®] 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

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

For: UW-MADISON

Attn: MARK STOERMAN

Purchase Order: UW-MADISON

Lab Number: 62752
Sample ID: CENTRIFUGE SOLIDS 20
Manure Type: DAIRY, SOLID WITH BEDDING (7)

Date Sampled: 1/15/2024
Date Received: 1/24/2024
Date Reported: 1/30/2024 Page: 11 of 16

MANURE ANALYSIS

Analysis	Unit	Analysis Result (As Received)	Pounds Per Ton	First Year Availability [®] Pounds Per Ton
Moisture	%	71.81	1436	
Solids	%	28.19	564	
Ash @ 550 C	%	10.68	213.6	
Organic Matter (LOI @ 550 C)	%	17.51	350.2	
Organic Carbon (LOI @ 550 C)	%	10.16	203.1	
Carbon:Nitrogen Ratio (C:N)	-		13.8:1	
Nitrogen, Total Kjeldahl (TKN)	%	0.738	14.8	9.3 *
Nitrogen, Ammonium (NH ₄ -N)	%	0.370	7.4	7.4 *
Nitrogen, Organic (N)	%	0.368	7.4	1.9 *
Phosphorus (P)	%	0.434	19.9 (as P ₂ O ₅)	19.9 * (as P ₂ O ₅)
Potassium (K)	%	0.306	7.3 (as K ₂ O)	7.3 * (as K ₂ O)
Sulfur (S)	%	0.11	2.2	1.2 #

[®] 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 Number
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Account Number
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To: NEWTRIENT LLC - SIG GRANT
11510 LAURIE DR
WHEATFIELD, IN 46392-7364

For: UW-MADISON

Attn: MARK STOERMAN

Purchase Order: UW-MADISON

Lab Number: 62752

Date Sampled: 1/15/2024

Sample ID: CENTRIFUGE SOLIDS 20

Date Received: 1/24/2024

Manure Type: DAIRY, SOLID WITH BEDDING (7)

Date Reported: 1/30/2024 Page: 12 of 16

MANURE ANALYSIS

Analysis	Unit	Analysis Result (As Received)	Pounds Per Ton	First Year Availability® Pounds Per Ton
Magnesium (Mg)	%	0.69	13.7	7.6 #
Calcium (Ca)	%	1.56	31.2	17.2 #
Sodium (Na)	%	0.10	2.0	
Aluminum (Al)	ppm	337	0.7	
Copper (Cu)	ppm	76	0.2	0.1 #
Iron (Fe)	ppm	417	0.8	0.5 #
Manganese (Mn)	ppm	220	0.4	0.3 #
Zinc (Zn)	ppm	72	0.1	0.1 #
pH	-	8.7		

® 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

