NEWTRIENT™

APPLICATION FOR COMPONENT ADDITION TO NRCS

NRCS Practice Standard 632

For Acceptance of Sand-Manure Separation Technology

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APPLICATION FOR COMPONENT ADDITION TO NRCS Practice Standard 632:

Sand-Manure Separation 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 aligns with the NRCS Conservation Practice Standard (CPS) Waste Treatment (629), and Newtrient has utilized this framework to assess sand-manure separation technology for CPS Waste Separation 632.

Sand-manure separation technology offers a promising approach to managing dairy waste by efficiently separating sand from manure, reducing volume and improving nutrient recovery. This technology enhances manure handling, reduces environmental risks such as nutrient runoff and groundwater contamination, and promotes the reuse of sand bedding materials, thus supporting both economic and environmental sustainability on dairy operations.

Newtrient submits this report for consideration under NRCS Conservation Practice Standard 632, Waste Separation Facility, highlighting the potential benefits of sand-manure separation technology in advancing sustainable nutrient management and waste treatment practices on dairy farms. We believe these systems align with NRCS objectives by improving manure handling and waste treatment efficiency, minimizing nutrient losses, protecting water quality, and supporting resource conservation goals critical to maintaining the health and productivity of agricultural lands.

BRIEF DESCRIPTION OF COMPONENT CLASS

Sand-manure separators are mechanical systems designed to settle out and wash bedding sand from dairy manure. These systems recover clean, reusable sand with minimal organic content and can be configured to suit various manure conveyance methods, improving manure handling efficiency and supporting nutrient management efforts.

DETAILED DESCRIPTION

Sand-manure separators serve as the core component in systems designed to recover and clean sand bedding from manure. These separators use gravity and mechanical processes to settle out and wash sand particles, producing a sand product suitable for reuse as bedding. Sand bedding is often used as a safe and comfortable bedding for livestock, particularly dairy cattle.

The separation systems can be configured in various ways depending on how manure is collected, treated, and transported on the farm. In operations that scrape manure from alleys, sand-laden manure can be loaded directly into the separator for immediate processing. In flush systems, the separator is typically used after the sand has been settled in a channel or collected from a sand lane.

In all cases, the separator yields clean sand with low organic content, reducing the need for new bedding material and transportation, disposals, and lowering the overall volume and solids load of manure waste streams requiring further treatment. This supports improved operational efficiency, cost savings, and environmental stewardship, aligning with broader conservation and nutrient management goals in a circular manner.

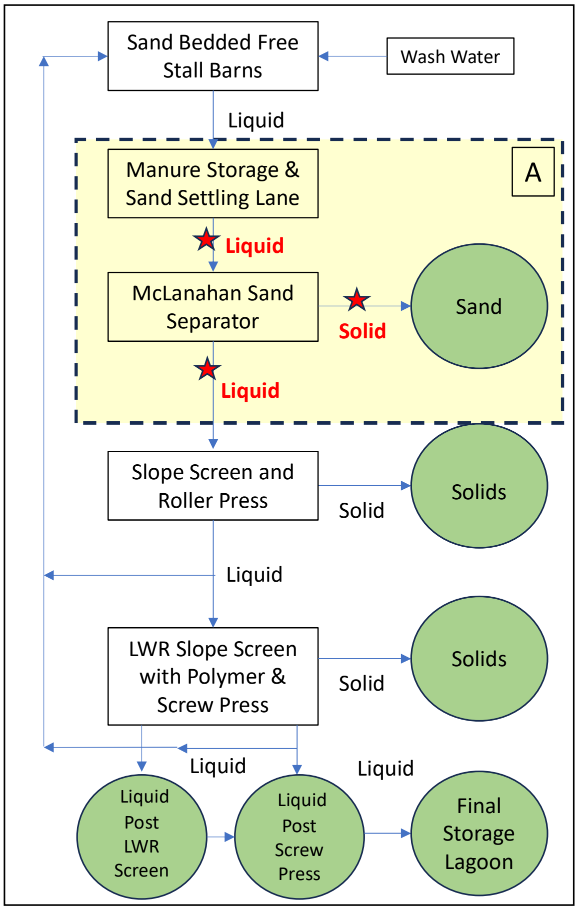


Figure 1: Flow diagram of the manure processing system, area A highlighted in yellow consisted of the sand recovery and designated sample collection area for the two liquid streams and one solid stream highlighted in red. Sample locations indicated by red stars.

THE PROCESS

Sand separation is a critical component within a larger, integrated manure management system designed to recover reusable bedding material and streamline nutrient handling. Newtrient evaluated a full-scale sand separation system at a commercial dairy farm in Northeastern Wisconsin, where approximately 230,000 gallons of diluted manure are processed daily. On the evaluated dairy farm, manure mixed with sand bedding is first collected and directed to a manure storage and sand settling lane, where initial gravity-based settling allows large particles like sand to begin separating from the liquid manure (Figure 1).

The partially settled material then flows into a McLanahan sand-manure separator, a mechanical system that further separates sand from the manure slurry (Figure 2). This unit produces two primary outputs: a sand-rich solid fraction, which is routed for drying and reuse as bedding, and a slurry stream, which carries suspended solids and dissolved nutrients for further treatment, such as coarse and in some cases, fine solid separation.

Following sand recovery, the liquid manure progresses through a series of solids separation stages, typically involving mechanical screens or presses. These systems extract additional coarse solids from the liquid fraction, producing more concentrated solids suitable for storage or land application. The remaining liquid stream continues through advanced separation units, such as a screw press and specially designed slope screens used with polymer to further reduce fine solids content before the effluent is directed to final storage.

Figure 2: Sand Recovery System A) McLanahan system, B) close up of sand washing and recovery, and C) separated wet sand post recovery.

HOW PROPOSED SYSTEM ACCOMPLISHES PURPOSES OF THE STANDARD

The proposed sand-manure separation system fulfills the purposes of NRCS Conservation Practice Standard 632 by effectively treating dairy manure to improve its handling, reduce environmental risk, and support sustainable nutrient management. By separating sand and coarse solids (not evaluated in the sand separation study) early in the process, the system reduces the volume and solids content of the manure stream, improving flow characteristics and minimizing storage, agitation, and pumping challenges. The removal of sand also enhances downstream treatment efficiency and extends the operational life of equipment. The recovered sand, with low organic content, is suitable for reuse as bedding, reducing input costs and promoting resource recycling. Overall, the system advances key objectives of CPS 632 by reducing potential impacts to water quality, improving the utilization and treatment of agricultural waste, and contributing to the long-term environmental and economic viability of manure management on dairy farms.

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 the sand-manure separation technology on a farm located in Northeastern Wisconsin.

In support of this discussion, Appendix A provides a brief overview of the environmental benefits of sand-manure separation technology, focusing on key indicators such as water quality, nutrient retention, and resource recovery, all of which align with the objectives of NRCS Conservation Practice Standard 632. Appendix B presents data from a sand-manure separation technology evaluation, offering visual representations and nutrient profiles comparing intended versus measured nutrient application rates, along with nitrogen leaching data used to assess the environmental performance of the system within a comprehensive manure management approach. Appendix C contains the final report of the study conducted by the University of Wisconsin-Madison, detailing the study's findings across 45 sampling events conducted over a 30-week period, and offering further insight into the effectiveness, nutrient partitioning, and operational benefits of sand-manure separation technology.

Reducing nutrient content, organic strength

Sand-manure separation technology best facilities reductions in nutrient content and organic strength by removing sand from the liquid waste stream which allows for downstream treatment. The average volatile solids content in the separated sand from the evaluated technology was less than 3.5% with a target of less than 2%. Although it is true that phosphorus (P) tends to bind to solid particles, a relatively small amount of P is captured with the separated sand. Also, a very small portion of fiber-bound nitrogen (N) and organic matter as part of the volatile solids are retained in the separated sand. The low organic content of the separated sand is key to creating the conditions that minimize pathogen survival and growth when the sand is reused for bedding. The effluent following sand separation is more stable and partitioned, making it easier to manage, treat, or apply to fields with reduced risk of nutrient overloading, runoff, leaching, or other environmental degradation challenges.

Reducing odor and gaseous emissions

Removal of sand from the liquid waste stream has minimal impact on reducing odors and air emissions from the liquid waste stream. The lower organic content of the separated sand should result in lower odors and air quality issues from the sand. Sand-manure separation enhances downstream manure management systems capable of reduced greenhouse gas emissions such as coarse solids separation and anaerobic digestion.

Facilitating desirable waste handling and storage

Sand-manure separation enhances manure handling and storage efficiency by reducing the accumulation of and abrasion from sand in storage structures, transfer pipes, and downstream treatment systems. The separation of large, heavy solids results in a more uniform, pumpable liquid that is less prone to clogging or sediment buildup. This simplifies manure transfer and increases storage capacity by reducing the volume of settled solids in waste storage facilities. Additionally, by removing this material prior to treatment or storage, the system prolongs equipment life, minimizing wear, and lowers maintenance costs, allowing for more flexible and reliable manure management across the operation. A lower-volume manure stream, resulting from sand separation, decreases application hauling costs, particularly for farther fields.

<u>Producing value added byproducts that facilitate manure and waste utilization</u>

One of the key benefits of sand-manure separation technology is the generation of clean, reusable sand bedding and a more manageable solids stream. The recovered sand, typically low in organic content and moisture, can be recycled as clean bedding material, reducing the need for costly bedding replacement and supporting circular, closed-loop resource use on the farm. The effluent post-sand separation is suitable for further downstream treatment such as solid-liquid separation, with solids composting, and anaerobic digestion, presenting the opportunity for biogas production. Nutrients partitioned in the effluent after sand removal enhance the fertilizer value of manure. These value-added byproducts support sustainable waste utilization and create economic incentives for adopting advanced manure treatment systems.

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 sand-manure separation technology in manure management, based on the study site from Newtrient's evaluation:

- *Volumetric Flow*: The sand separator receives approximately 230,000 gallons per day (GPD) of diluted manure, which includes flushed manure from freestall barns, recycled flush water, parlor wash water, and process liquids. While this total flow represents the full system input, the portion entering the actual sand separator unit is metered from a collection pit following an initial gravity-settling stage. Although exact flow metering data into the sand separator is not available, it is reasonable to estimate that the majority of the 230,000 GPD ultimately passes through the separator, as it operates as the primary sand recovery unit.

Therefore, the sand separator likely handles a volumetric flow of roughly 200,000–230,000 GPD, depending on recirculation rates and operational cycles.

- *Mass Flow*: The estimated mass flow entering the sand separator is based on a volumetric input of approximately 230,000 GPD and a manure density of 8.4 pounds per gallon. This results in a total daily mass flow of roughly 1,932,000 pounds per day. When converted to a time-based flow rate, this equates to approximately 1,342 pounds per minute moving through the sand separator under steady-state conditions. Of this total, about 30 tons of wet sand (or 60,000 pounds) are recovered per day, representing a small but significant fraction of the total mass—about 3.1%. This represents a sand recovery percentage of approximately 81%, based on an estimated sand usage of 36 pounds of sand per cow per day. The remaining mass, consisting largely of diluted liquid manure and suspended fine organic matter, continues through the manure management system.
- *Hydraulic Retention Times (HRT):* Hydraulic retention time (HRT) in the sand separator depends on the internal volume of the unit and the flow rate of influent manure. While the exact holding capacity of the sand separator is not provided, systems of this scale typically range from 10,000 to 20,000 gallons in working volume. Assuming a flow rate of 230,000 GPD, and an estimated separator volume of 15,000 gallons, the HRT can be approximated as 1.5 hours, which is consistent with the needs of mechanical sand separation systems that require sufficient residence time for settling, agitation, and discharge. More precise HRT calculations would require detailed equipment specifications or on-site measurements.

DESIRED FEEDSTOCK CHARACTERISTICS

To ensure optimal performance of sand-manure separation systems, the incoming manure feedstock should meet the following key characteristics:

1. **Total Solids (TS) of 3–6%** – Provides the right balance of flowability and settling efficiency for sand recovery.
2. **Consistent slurry texture** – Homogeneous mixing of manure, flush water, and wash water prevents separation inefficiencies.

3. **Medium to coarse sand particle size** – Bedding materials such as *washed concrete sand* are preferred, as they meet particle size requirements that promote effective settling and high recovery rates.

4. **Minimal organic contamination in bedding** – Reduces volatile solids in recovered sand and improves bedding reusability.

5. **Free of large debris or foreign material** – Prevents clogging, equipment wear, and system interruptions.

6. **Stable flow rate to the system** – Promotes predictable separation dynamics and consistent system performance.

EXPECTED SYSTEM PERFORMANCE

The sand-manure separation system is expected to effectively recover a significant portion of the sand bedding material while producing a cleaner liquid manure stream for downstream handling and treatment. Based on field evaluation data, the system can recover approximately 30 tons of wet sand per day with an average TS content of 91%, making it suitable for reuse as bedding following drying or further treatment. Although the system does not substantially alter nutrient concentrations in the liquid manure, it reduces TS, VS, and grit load, which improves pumpability, storage efficiency, agitation ease, and the performance of subsequent separation or treatment technologies. The consistent removal of sand from the raw manure stream supports operational reliability and aligns with the waste treatment goals outlined in NRCS Conservation Practice Standard 632.

- *Changes in form or handling characteristics*
    - The sand-manure separation process substantially alters the physical characteristics of manure, improving its handling properties. By removing coarse sand particles, the remaining liquid fraction becomes more pumpable, easier to agitate, and suitable for further downstream mechanical separation or treatment. In the University of Wisconsin-Madison evaluation, TS decreased slightly from 4.09% to 3.94% following sand separation. This reduction in sand plays a critical role in reducing wear on equipment, reducing the grit in the waste stream, minimizing clogging, and enhancing flow characteristics, which can ultimately lower operational costs and improve system reliability.

- *Nutrient fate or end use projections*

Because the sand separation system is designed to isolate inorganic bedding material rather than extracting nutrients, most nutrient constituents remain in the liquid fraction and continue downstream in the manure management system. This was confirmed by the UW evaluation, which found little to no change in key nutrient parameters such as Total Kjeldahl Nitrogen (TKN), Ammonium-N (NH_4-N), P (in the form of P_2O_5), and K (in the form of K_2O) through the sand separation process. The nutrient-rich effluent remains suitable for land application or further treatment and allows for more targeted nutrient planning. The minimal nutrient loss in the recovered sand—confirmed by an ash content of 85.8% and low organic carbon (<2.0%)—supports clean bedding reuse while concentrating nutrients where they can be more effectively managed.

- *Macro-nutrient reductions or transformations*
  - There is minimal macro-nutrient reduction or transformation during sand separation. According to the UW-Madison study, nutrient concentrations in manure remained virtually unchanged through the system, with TKN holding steady at 0.224%, Ammonium-N at 0.10%, and K_2O at 0.15%. The low separation index (SI) values for TS (0.002) and VS (0.036) further confirm that the sand separator is not designed to capture nutrients, and most remain in the liquid stream for downstream handling.
- *Pathogen reductions or eliminations*
  - While the sand-manure separation system is not specifically designed for pathogen removal in the effluent, it does offer direct benefits by reducing organic matter in the recovered sand bedding. With an average VS content of 3.45% in recovered sand (down from typical values of 13–14% in raw manure), there is less organic substrate available to support bacterial growth. Farms using additional treatment methods, such as drying or composting, can further reduce pathogen levels in sand before they are used for bedding. At the evaluated site, the use of a natural gas dryer to reduce VS content below 2% aims to lower bacterial loads, promoting healthier bedding conditions and reducing mastitis risk in dairy herds.
- *Air quality*
  - Direct impacts on air quality from sand-manure separation are limited; however, the system indirectly supports better air quality by lowering the organic load in the separated sand. Reduced volatile solids in the

recovered sand (3.45% VS) mean lower potential for microbial activity and anaerobic decomposition, which are key contributors to odor and gas emissions like ammonia and methane. Furthermore, improved manure handling and storage resulting from reduced solids content can reduce agitation requirements and associated emissions during storage or land application.

- *Water quality*
  - The system supports water quality objectives by improving the separation of sand and minimizing solids accumulation in downstream storage or treatment systems. By maintaining nutrient concentrations in the liquid fraction and ensuring that recovered sand is free of significant nutrient or organic contamination, the system enables more accurate nutrient application planning and minimizes the risk of nutrient runoff or leaching. However, the addition of significant flush water—estimated at 150,000 GPD—dilutes manure and increases the total volume that must be stored or applied, which can pose logistical and water quality challenges if not managed carefully. Downstream treatment processes can be utilized to partition and concentrate nutrients in the waste stream.

PROCESS MONITORING AND CONTROL SYSTEM REQUIRMENTS

Effective operation of a sand-manure separation system requires both process monitoring and control to ensure system performance, operational efficiency, and product quality. The following outlines the general requirements and components associated with monitoring and control for such systems:

- *Required monitoring*— While the system is operating, the owner must actively monitor the following:
  - **Influent and Effluent Flow Rates:** Track the volume of manure and liquid moving into and out of the system to ensure process consistency.
  - **Solids Content Monitoring:** Measure total solids in influent, recovered sand, and effluent to assess separation performance.
  - **System Pressure Readings:** Monitor pump and pipeline pressure to detect clogging or mechanical issues.

    - **Sand Recovery Volume:** Measure or estimate the amount of sand recovered to evaluate system efficiency for bedding reuse.
    - **Operational Timing:** Log cycle times, downtimes, and operating hours to schedule maintenance and optimize energy use.
    - **Visual Inspections:** Periodic checks for mechanical wear, clogging, or inefficiencies in separation.
- *Required control*— During operation, the owner must actively control the following:
    - **Pump Operation:** Adjust pump speeds or timing to control the flow of manure and water into the separator.
    - **Auger/Conveyor Speed:** Regulate the movement of recovered sand to storage or drying areas.
    - **Start/Stop Sequences:** Automate system activation based on tank levels or manure availability.
    - **Water Addition Rates:** Manage dilution or flushing water flow for optimal solids separation.
    - **Alarm Thresholds:** Set triggers for system faults, high pressure, or overflow events.
- *Equipment included for monitoring*— The system includes the following tools for monitoring performance:
    - **Flow Meters:** Measure influent and effluent flow rates accurately (e.g., magnetic or ultrasonic meters).
    - **Load Cells or Scales:** Quantify the weight of recovered sand in hoppers or on conveyors.
    - **Pressure Sensors:** Monitor system pressure for early detection of blockages or pump issues.

    - **Solids Sensors (Optional):** In-line sensors or lab sampling to measure percent total solids or turbidity.

    - **Visual Cameras (Optional):** Allow remote inspection of key system components and operation.

    - **Data Loggers or Supervisory Control and Data Acquisition (SCADA) Systems:** Record system parameters for trend analysis and performance evaluation.

- *Equipment included for controlling*— The system includes the following tools for controlling operations:

    - **Programmable Logic Controllers (PLCs):** Automate and coordinate system functions with user-defined logic.

    - **Variable Frequency Drives (VFDs):** Adjust motor speeds for pumps and augers to match operating conditions.

    - **Automated Valves:** Control flow direction and flushing sequences based on preset conditions.

    - **Alarm Systems:** Notify operators of abnormal conditions or failures to enable quick response.

    - **Manual Overrides:** Provide manual control capabilities for maintenance or emergency operation.

TYPICAL OPERATIONS/MAINTENANCE PLAN WITH MONITORING REQUIREMENTS AND REPLACEMENT SCHEDULE

A well-structured operations and maintenance (O&M) plan is essential to ensure the reliable, efficient, and long-lasting performance of a sand-manure separation system. Routine monitoring, scheduled maintenance, and timely equipment replacement minimize downtime, optimize sand recovery, and maintain system integrity. The following outlines the typical operational tasks, monitoring requirements, and replacement schedules recommended for such systems.

System Monitoring

Regular monitoring is essential for reliable system operation. Key areas to monitor include:

- **Routine Visual Inspections:** Conduct daily checks of pumps, conveyors, screens, and separator components for wear, blockages, or leaks.
- **Flow Rate Verification:** Monitor influent and effluent flow rates weekly to detect deviations from expected performance.
- **Solids Content Testing:** Sample manure and sand at least monthly to confirm solids separation efficiency and bedding quality.
- **Pressure and Motor Monitoring:** Track system pressures and motor currents continuously or during operation to identify mechanical issues early.
- **Data Recording and Review:** Maintain logs of operational parameters, maintenance activities, and performance metrics for trend analysis and troubleshooting.

Replacement Schedule

To maintain optimal performance, follow this replacement schedule:

- **Wear Parts (Screens, Seals, Belts):** Replace every 6 to 12 months, depending on usage intensity and material abrasiveness.
- **Pumps and Motors:** Inspect annually; plan for major overhauls or replacement every 5 to 7 years.
- **Control System Components:** Update software and replace sensors or controllers every 3 to 5 years or as technology advances.
- **Structural Components:** Inspect sand settling lanes and collection pits for corrosion or damage annually; repair or replace as needed.
- **Conveyors and Augers:** Check for wear yearly; replace worn parts proactively to prevent failures.

CHEMICAL INFORMATION

- Sand-manure separation systems do not use chemicals in the separation process. They rely primarily on mechanical and physical methods—gravity settling, washing, and mechanical separation—to separate sand from manure slurry. The process focuses on washing and recovering clean sand for reuse without the addition of chemical agents.

ESTIMATED INSTALLATION AND OPERATION COST

Equipment and Installation Capital Costs

As of 2025, a McLanahan SMS flush-compatible system costs an estimated $936,855 for 1,500 cows, excluding freight or shipping, electrical, plumbing, installation, building, concrete, and startup. Costs may vary based on farm size, capacity, project specifics, market conditions, existing infrastructure, and additional features.

Operation and Maintenance Costs (O&M)

Annual operation and maintenance costs typically range from $5,000 to $10,000 in the first five years, with years four and five being on the higher end of that scale.

- ***Electrical—*** Electrical costs include the power consumption of pumps, motors, separators, and control systems used in the sand-manure separation process. These costs vary based on system size, operating hours, and local electricity rates.
- ***Labor—*** Labor costs cover the time required for daily system operation, monitoring, cleaning, and troubleshooting. Skilled personnel may be needed for system adjustments and ensuring efficient operation.
- ***Maintenance Replacement—*** Maintenance replacement costs involve periodic repair or replacement of worn parts such as screens, bearings, seals, and mechanical components. Scheduled inspections help minimize unexpected downtime and extend equipment lifespan.

EXAMPLE WARRANTY

- **Warranty Coverage:** Typically, a standard 1-year warranty is provided for all major system components, excluding routine wear items such as bearings, seals, and screens. This warranty covers defects in materials and workmanship under normal operating conditions.

- **Wear Items:** Components considered subject to regular wear and tear are not included in the warranty coverage. These include but are not limited to, pump seals, nozzles, screens, and conveyor belts. These parts are expected to be replaced periodically as part of routine maintenance.

- **Performance Guarantee:** Upon request, a performance guarantee may be offered based on agreed-upon operating conditions and design specifications. This ensures that the system meets expected performance benchmarks such as sand recovery efficiency or throughput under defined conditions.

- **Warranty Claims Process:** All warranty claims must be submitted in writing within the warranty period and must include supporting documentation, including evidence of proper installation, operation, and maintenance.

RECOMMENDED RECORD-KEEPING FOR SAND-MANURE SEPARATION TECHNOLOGY

Maintaining comprehensive records is crucial for ensuring the effective operation, maintenance, and performance evaluation of sand-manure separation systems. Proper documentation supports troubleshooting, optimization of manure management practices, and verification of system benefits. The following record types are recommended for ongoing management:

- **Installation Records:** Document details of equipment installation, including model numbers, installation dates, and system layout for future reference.
- **Operational Logs:** Track daily or weekly system operating hours, throughput volumes, and flow rates to monitor performance trends and identify irregularities.
- **Maintenance Records:** Record all routine maintenance activities, cleaning schedules, part replacements, and repairs to ensure timely upkeep and prolong system lifespan.
- **Sand Recovery Data:** Log quantities of sand recovered, moisture and solids content, and any drying processes to assess efficiency and bedding quality.
- **Manure and Effluent Sampling Results:** Maintain records of manure and effluent analyses, including solids content and nutrient concentrations, to evaluate system impact on nutrient management.
- **Performance Monitoring:** Document separation efficiency metrics and any operational adjustments made to improve system function.

- **Incident Reports:** Note any equipment failures, operational disruptions, or anomalies along with corrective measures implemented.

ALTERNATIVES FOR THE USE OF BYPRODUCTS

The byproducts generated from sand-manure separation systems offer multiple opportunities for beneficial reuse beyond their primary function as recycled bedding. Exploring alternative uses can improve overall farm sustainability, reduce waste disposal costs, and contribute to resource recovery. Key alternatives include:

- **Recycled Sand Bedding:** The primary use of recovered sand is as clean, reusable bedding material for dairy cows, helping reduce the need for purchasing new sand and disposal and transportation costs.
- **Construction Material:** Clean sand byproducts may be repurposed for non-agricultural uses such as fill material or base layers in construction projects, subject to local regulations.
- **Composting Input:** Sand mixed with organic matter can be incorporated into composting operations to enhance aeration and support microbial activity, improving compost quality.
- **Dust Control:** In some cases, dried sand byproducts may be used for dust suppression on farm roads or other unpaved surfaces.

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 sand-manure separation at a farm located in Northeastern 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 at a farm located in Northeastern Wisconsin.

CONTACT INFORMATION—VENDOR

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

1. **McLanahan Corporation**
   Address: 200 Wall St., Hollidaysburg, PA 16648
   Phone: 814-695-9807
   Website: https://www.mclanahan.com/solutions/bedding-management
   Contact: sales@mclanahan.com
   Company Information: McLanahan Corporation provides complete manure management solutions for the agricultural industry. McLanahan's custom engineered systems help dairies minimize the challenges of manure handling with safer, simpler, and smarter solutions.

2. **DariTech, Inc.**
   Address: 8540 Benson Rd. Lynden, WA 98264
   Phone: 360-354-6900
   Website: https://www.daritech.com/manure-management.html
   Contact: info@daritech.com
   Company Information: DariTech was founded in 1990 and has grown to be a top to bottom dairy service and supply company worldwide. Taking what we've learned in the field, DariTech's design team has developed a diversified product line that meets the needs of today's modern dairies. DariTech's ability to design and manufacture DariTech's own components lets us personally ensure the quality of each product. DariTech's equipment is built to be durable and functional not only today, but also for years to come. DariTech's goal is to provide every customer with a long-term value for their investment.

3. **Stjernholm**
   Address: 875 North Michigan Avenue, Chicago, IL 60611
   Phone: 346-388-2791
   Website: https://stjernholm.dk/en/
   Contact: stjernholm@stjernholm.dk
   Company Information: In close co-operation with agricultural experts, dairy industry consultants, veterinarians, and dairy farmers, Stjernholm has developed a range of products and acquired unique process knowledge, which allows them to offer a turn-key solution in sand separation, cleaning and reuse in the stalls for larger dairy operations. Common difficulties pertaining to handling manure containing sand can now be eliminated resulting in improved animal welfare and

increased profitability. Stjernholm's focus is to develop and market technical solutions and systems for the treatment of manure-laden sand, for farmers in Denmark and abroad. With Stjernholm, you will find a professional partner capable of delivering high quality and reliable machinery working to your benefit and to the welfare of your livestock.

CONTACT INFORMATION—USER

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

<u>Sand-Manure Separation Technology</u>

Robinway Dairy – Kiel, WI

Car-Min-Vu Dairy – Webberville, MI

Dutch Made Holsteins Dairy– Lake Geneva, WI

Prairieland Dairy – Belleville, WI

SwissLane Dairy – Alto, MI

Werkhoven Dairy – Monroe, WA

Paradise Jerseys – Everson, WA

OTHER CONSIDERATIONS

The NRCS documentation specifies that a third-party review shall contain 15 specific items that comprise the report above, but as part of working with the farm and the technology provider during the evaluation period there are often other important and valuable learnings that may be helpful for NRCS and others as they consider this technology. Below is a list of Other Considerations that should be included in the evaluation of this technology. These points offer valuable insight into both the practical application and future refinement of sand-manure separation technology:

- **Increased Manure Volume from Water Use:** A significant challenge associated with the system is the volume of water required to operate the flush collection and sand separation processes. The farm reported using an additional 15,000 gallons of water daily, contributing to a total of approximately 230,000 gallons of diluted manure processed each day. While nutrient concentrations remained stable, this increase in volume places added pressure on manure storage, handling, and land application logistics—potentially raising costs and complicating nutrient management planning.

- **Residual Organic Matter in Recovered Sand:** Although the recovered sand showed reduced organic content compared to raw manure, the average VS content of 3.45% still exceeds the recommended threshold of less than 2% for optimal bedding hygiene. Organic residues can support bacterial growth, potentially increasing the risk of mastitis or other health issues if the sand is reused without further treatment. While the farm mitigates this risk by using a natural gas dryer, this post-processing step was outside the scope of this study. Therefore, the full effectiveness of the system in producing pathogen-safe bedding relies in part on additional treatment beyond mechanical separation.

- **Sand Quality and Particle Size:** Readily available washed concrete sand should be utilized to meet particle size requirements for effective separation and bedding quality. Consulting a particle size distribution chart can help determine if your sand source falls within the ideal range. Using sand that is too fine, too coarse, or well-graded (multiple sand sizes) can reduce separation efficiency and impact animal comfort.

- **Equipment Wear and Maintenance:** Sand separation systems operate under abrasive conditions due to the presence of sand particles. This leads to accelerated wear on mechanical components and necessitates regular maintenance and replacement of wear parts to ensure system longevity and consistent performance.

- **System Integration:** Successful operation depends on integrating the sand separator within the broader manure management system. Coordination with solids separation, storage, and land application processes is critical to handle the changes in manure volume and composition effectively.

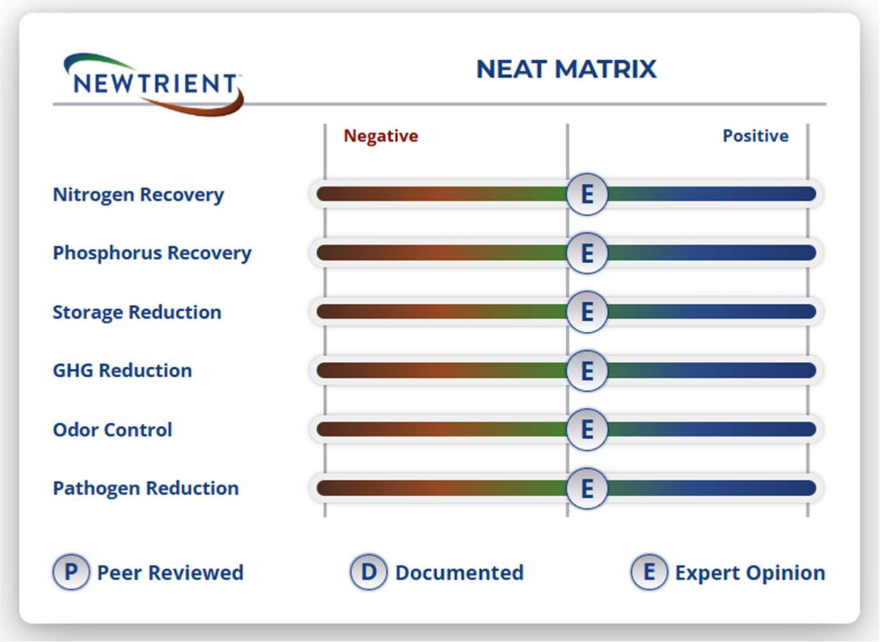
- **Environmental Impacts:** While sand separation reduces solids in the bedding material, attention must be paid to the downstream handling of liquid manure to prevent nutrient runoff or leaching, ensuring overall environmental stewardship.

Conclusion

Sand-manure separation technology offers an effective mechanical solution for recovering clean sand bedding from manure slurry while maintaining nutrient integrity in the liquid fraction for downstream management. The system's ability to reduce organic content in recovered sand enhances bedding quality, though additional drying or treatment may be necessary to minimize pathogen risks. While the technology can increase overall liquid manure volume due to flush water usage, careful operational planning can address storage and handling challenges. Selecting appropriate washed concrete sand that meets particle size requirements is essential for optimal system performance. Overall, sand separation systems play a valuable role in improving manure management efficiency, animal comfort, and environmental outcomes when properly integrated, managed, and maintained within a dairy farm's waste management program.

Appendix A

NEWTRIENT CRITICAL ANALYSIS – SAND SEPARATION



Overall Summary

Sand-manure separation systems are flexible in that they can be used with vacuumed or scraped manure and manure slurries with limited water addition as well as flushed dairies with added water volume. The economics of these systems can be attractive, depending largely on the costs of post-treatment and the price of sand. Many dairies that use sand for bedding believe that it improves the comfort and productivity of the milking herd. Removing sand particles from manure can also save significant wear and tear on downstream equipment. Reusing sand recovered from the separator as bedding can help reduce a farm's total bedding costs. However, the process can increase manure volume depending on the amount and source of water used for dilution. It is essential that reused sand be handled properly to prevent the reintroduction of pathogens and moisture into the barn environment.

Appendix B

Third-Party Review of Sand-Manure Separation Technology at Robinway Dairy – Kiel, WI (Report Summary)

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Dr. Rebecca Larson
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Nelson Institute for Environmental Studies
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550 North Park St.
Madison, WI 53706

MARCH 2025

BACKGROUND

Effective manure management is central to the sustainability of modern dairy operations, balancing the needs of animal care, operational efficiency, and environmental stewardship. Sand bedding is widely used in the dairy industry due to its benefits for cow comfort and herd health when properly stored and handled, potentially increasing milk production. However, its integration into manure handling systems presents significant technical and logistical challenges. Sand's abrasive properties, particularly when mixed with manure, accelerate wear on equipment, contribute to system blockages, and complicate the resuspension and removal of solids from storage facilities. Additionally, the continuous purchase and transport of clean bedding material can create economic burdens for producers.

Recycling sand through mechanical separation systems offers a potential solution, providing both cost savings and reduced environmental impact. For sand reuse to be viable, the recovered material must meet specific quality standards, particularly with respect to organic matter content, to ensure that it does not compromise animal health, environmental compliance, or bedding performance.

INTRODUCTION

Beyond bedding recovery, manure characteristics following sand separation carry implications for the environment. Manure that is high in water content and nutrient load presents logistical challenges for storage, transport, and field application. If not properly managed, nutrients such as nitrogen (N) and phosphorus (P) can leach into groundwater or be lost to surface runoff, degrading water quality.

This study evaluated a full-scale sand separation system at a commercial dairy farm in Northeastern Wisconsin, where approximately 230,000 gallons of diluted manure are processed daily. By analyzing both liquid manure and recovered sand over a 30-week period, the research quantified nutrient partitioning and evaluated the separation system's performance in terms of both nutrient retention and sand quality. The results contribute to a better understanding of how mechanical separation affects manure composition and offer insights to optimize nutrient management and bedding reuse strategies.

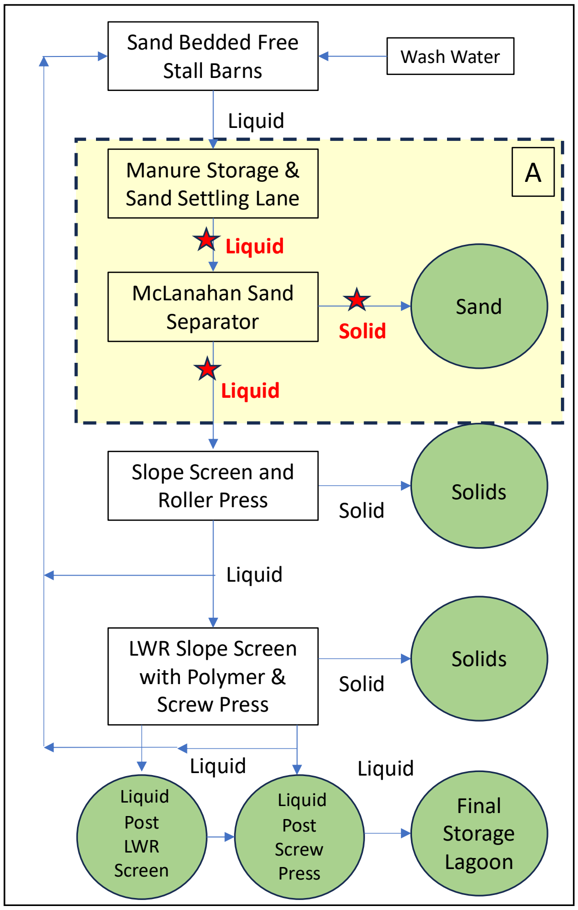


Figure 1: Flow diagram of the manure processing system, area A highlighted in yellow consisted of the sand recovery and designated sample collection area for the two liquid streams and one solid stream highlighted in red. Sample locations indicated by red stars.

THE PROCESS

Sand separation is a critical component within a larger, integrated manure management system designed to recover reusable bedding material and streamline nutrient handling (Figure 1). On the evaluated dairy farm, manure mixed with sand bedding is first collected and directed to a manure storage and sand settling lane, where initial gravity-based settling allows coarser particles like sand to begin separating from the liquid manure.

The partially settled material then flows into a McLanahan sand separator, a mechanical system that further separates sand from the manure slurry (Figure 2). This unit produces two primary outputs: a sand-rich solid fraction, which is routed for drying and reuse as bedding, and a liquid-rich stream, which carries suspended solids and dissolved nutrients for further treatment or application.

Following sand recovery, the liquid manure progresses through a series of solids separation stages, typically involving mechanical screens or presses. These systems extract additional organic solids from the liquid fraction, producing more concentrated solids suitable for storage or land application. The remaining liquid stream continues through advanced separation units, such as a screw press and Livestock Water Recycling (LWR) screen, which further reduce solids content before the effluent is directed to a final storage lagoon.

Figure 2. Sand Recovery System A) McLanahan system, B) close up of sand washing and recovery, and C) separated wet sand post recovery.

METHODOLOGY

To assess the performance of the sand separation system, a structured sampling protocol was carried out over 30 weeks, from August 19, 2024, to March 18, 2025. Samples were collected at three critical points in the manure flow: the influent liquid entering the McLanahan sand separator, the effluent liquid exiting the system, and the recovered wet sand. In total, 45 sampling events were conducted.

Liquid samples (0.5 L) and sand samples (1 L) were collected during each event, stored at 4°C, and shipped to A&L Great Lakes Laboratories for analysis. Laboratory testing followed the M7 Manure Analysis Package (plus pH), which includes parameters such as moisture, total solids (TS), total Kjeldahl nitrogen (TKN), phosphorus (P), potassium (K), total ammoniacal nitrogen (TAN), and other key nutrients and physical properties.

Data were averaged over the sampling period, with non-detects recorded as zero. To evaluate the system's nutrient separation performance, a separation index (SI) was calculated using established equations (Eq. 1&2) (Aguirre-Villegas et al., 2019; Guilayn et al., 2019), representing the distribution of specific components between solid and liquid fractions. This allowed for the quantification of both sand recovery efficiency and nutrient partitioning within the manure stream.

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

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

DISCUSSION OF RESULTS

The results of this study provide insight into the effectiveness of the sand separation system in recovering bedding material and influencing nutrient distribution within the manure stream. By examining the concentrations of solids and key nutrients before and after separation and characteristics of the recovered sand, this section evaluates the system's performance in the context of both operational efficiency and environmental sustainability. The findings are discussed in relation to nutrient retention, separation efficiency, and the potential for reusing recovered sand, with implications for improving manure management practices on similar dairy operations.

KEY BENEFITS OF SAND-MANURE SEPARATION

Virtually Clean Recovered Sand with Potential for Reuse: Based on the solids distribution and volatile solids (VS) content, approximately 96% of the sand can be recovered from the manure waste stream. The separation system consistently produced sand with high TS content—averaging 90.6%—and relatively low levels of organic contamination, including a VS content of 3.45% (Table 1). While this does not meet the ideal <2% VS target for pathogen-safe bedding, it represents a substantial reduction from the 13–14% VS typically found in raw manure. Additional metrics, such as 85.8% ash content and 2.0% organic carbon (Table 2), support the conclusion that the sand is largely inorganic and of usable quality. When paired with post-processing treatments such as drying, which was used on-site (though not evaluated in this study), the recovered sand shows strong potential for safe bedding reuse—supporting both animal health and resource recovery goals.

		Moisture [%]	Ash @ 550C [%]	Organic Carbon (LOI @ 550C) [%]	S [%]	Mg [%]	Ca [%]	Na [%]	Al [ppm]	Cu [ppm]	Fe [ppm]	Mn [ppm]	Zn [ppm]	pH
Manure at Sand Recovery	Average	95.97	1.08	1.75	0.02	0.11	0.15	0.08	19	8.3	47	5.2	7.1	7.0
	Max	98.88	1.68	2.10	0.02	0.15	0.22	0.31	30	116.0	71	6.8	9.7	7.5
	Min	94.81	0.75	1.15	0.01	0.03	0.12	0.01	11	0.7	14	3.9	5.4	6.7
	Standard Deviation	0.68	0.18	0.22	0.00	0.02	0.02	0.04	4	17.3	10	0.6	0.9	0.2
Manure Post-Sand Recovery	Average	96.06	1.06	1.69	0.02	0.12	0.16	0.07	19	5.8	50	5.0	7.3	7.0
	Max	97.12	1.48	3.01	0.02	0.18	0.25	0.09	24	26.0	74	6.2	12.0	7.6
	Min	95.15	0.51	1.15	0.01	0.08	0.11	0.04	12	1.3	35	3.8	5.1	6.7
	Standard Deviation	0.47	0.16	0.29	0.00	0.02	0.03	0.01	3	5.4	9	0.5	1.5	0.2
Recovered Sand	Average	9.38	85.82	2.00	0.02	8.91	15.22	0.04	972	10.6	3010	89.6	10.4	8.9
	Max	16.67	92.09	4.62	0.05	10.62	17.07	0.05	1572	49.0	3963	130.0	66.0	9.3
	Min	5.49	29.35	1.20	0.02	7.47	12.44	0.03	576	5.2	2386	67.0	5.8	8.2
	Standard Deviation	2.12	8.93	0.80	0.01	0.66	1.01	0.00	264	7.8	352	8.8	8.7	0.2

Table 1. Recovered sand characteristics.

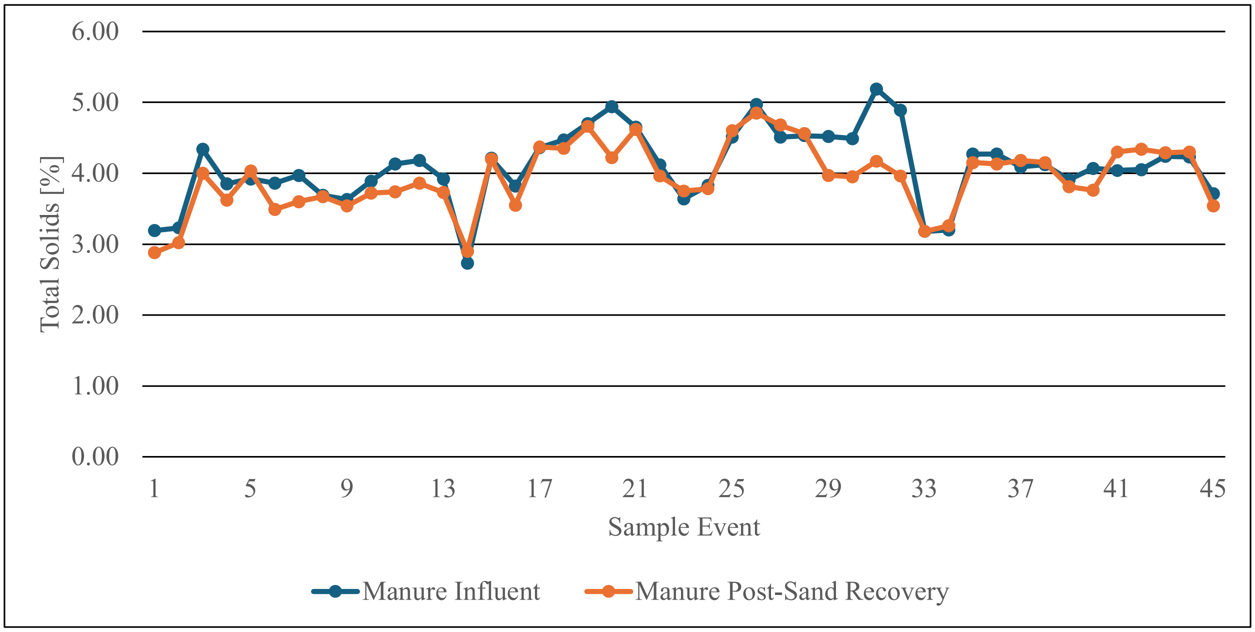
Sample	Statistics	Solids [%]	Volatile Solids [%]	Total Kjeldahl Nitrogen [%]	Ammonium Nitrogen as NH_4-N [%]	Phosphorus as P_2O_5 [%]	Potassium as K_2O [%]
Recovered Sand	Average	90.62	3.45	0.122	0.01	0.047	0.09
	Max	94.51	7.97	0.207	0.03	0.113	0.42
	Min	83.33	2.07	0.052	0.00	0.020	0.04
	Std. Dev.	2.12	1.39	0.043	0.01	0.018	0.07

Table 2. Additional manure characteristics measured by sampling location.

Nutrient Retention for Downstream Management: The system was effective at retaining nutrients in the liquid manure fraction, ensuring they remain available for downstream nutrient management. As shown in Table 3; Figure 3, there were minimal differences in key nutrient concentrations—including TKN, ammonium nitrogen (NH_4-N), phosphorus (P_2O_5), and potassium (K_2O)—before and after sand separation. This aligns with the system's design intent to recover sand without extracting valuable nutrients. The low SI values for TS (0.002) and VS (0.036) in Table 4; Figure 4 further support the conclusion that most organic and nutrient content remains in the liquid stream for land application.

Table 3: Primary manure characteristics by sampling location (non-detects were given a value of zero).

Sample	Statistics	Solids [%]	Volatile Solids [%]	Total Kjeldahl Nitrogen [%]	Ammonium Nitrogen as NH_4-N [%]	Phosphorus as P_2O_5 [%]	Potassium as K_2O [%]
Manure Influent	Average	4.09	2.99	0.224	0.10	0.031	0.15
	Max	5.19	3.62	0.263	0.12	0.039	0.18
	Min	2.73	1.98	0.164	0.07	0.022	0.10
	Std. Dev.	0.51	0.38	0.022	0.01	0.004	0.02
Manure Post-Sand Recovery	Average	3.94	2.87	0.224	0.10	0.030	0.15
	Max	4.85	3.47	0.253	0.12	0.036	0.18
	Min	2.88	1.99	0.181	0.07	0.021	0.10
	Std. Dev.	0.47	0.37	0.021	0.01	0.004	0.02
Recovered Sand	Average	90.62	3.45	0.122	0.01	0.047	0.09
	Max	94.51	7.97	0.207	0.03	0.113	0.42
	Min	83.33	2.07	0.052	0.00	0.020	0.04
	Std. Dev.	2.12	1.39	0.043	0.01	0.018	0.07



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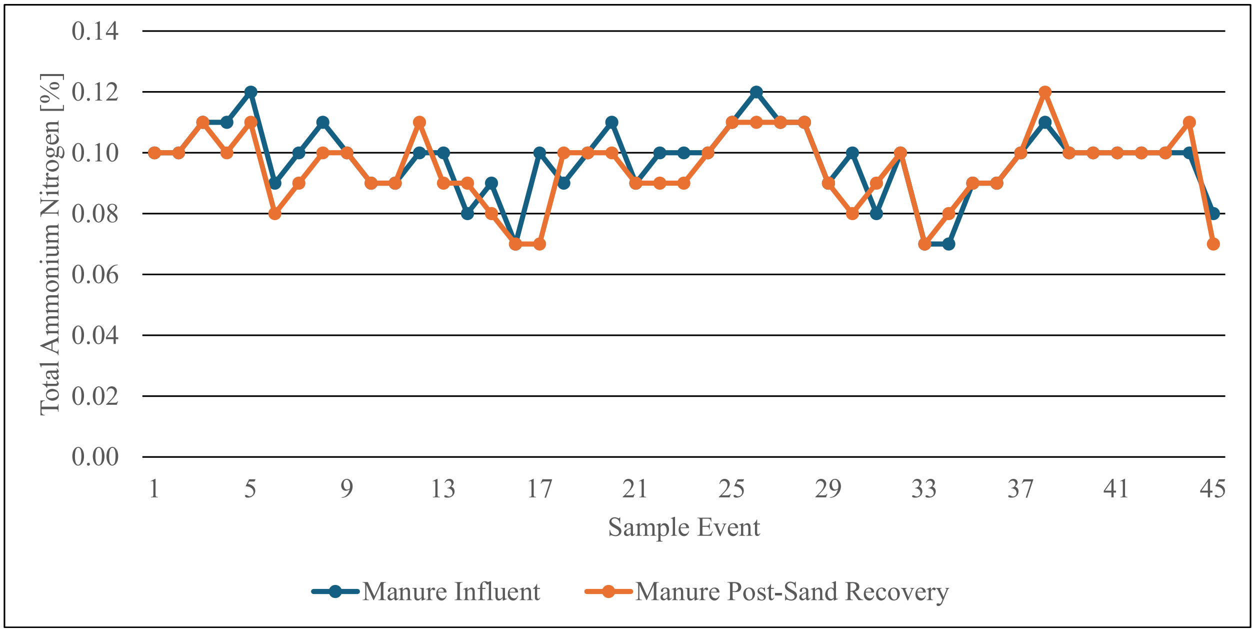
Sample Event
Manure Influent
Manure Post-Sand Recovery



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Total Ammonium Nitrogen [%]
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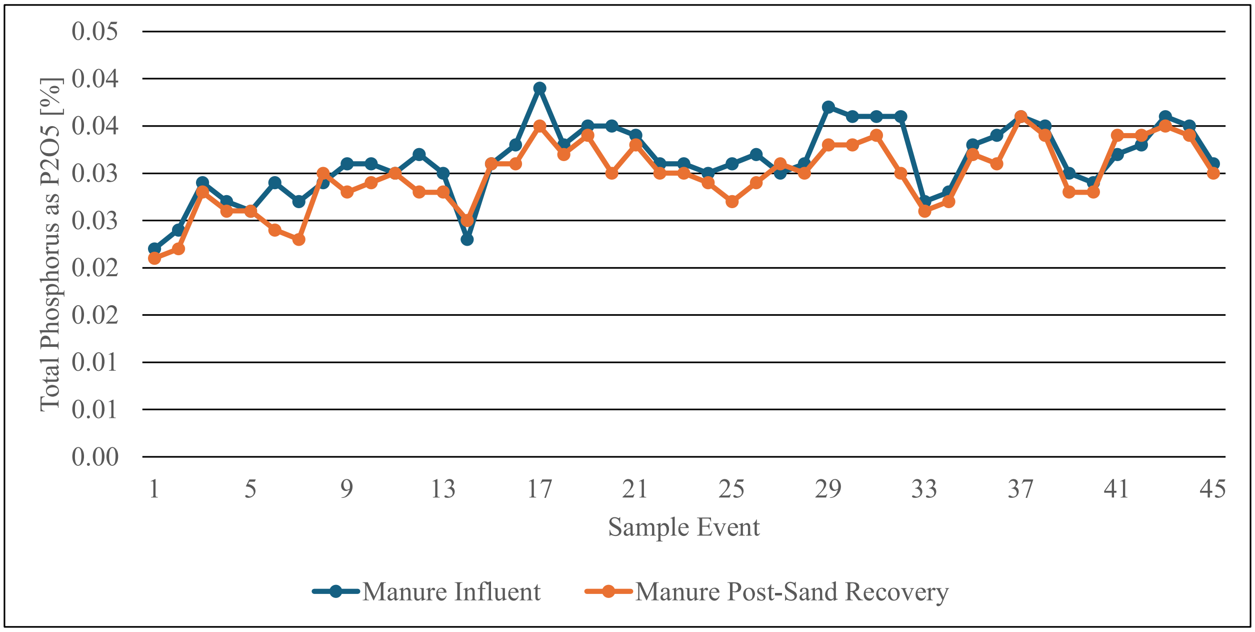
Sample Event
Manure Influent
Manure Post-Sand Recovery



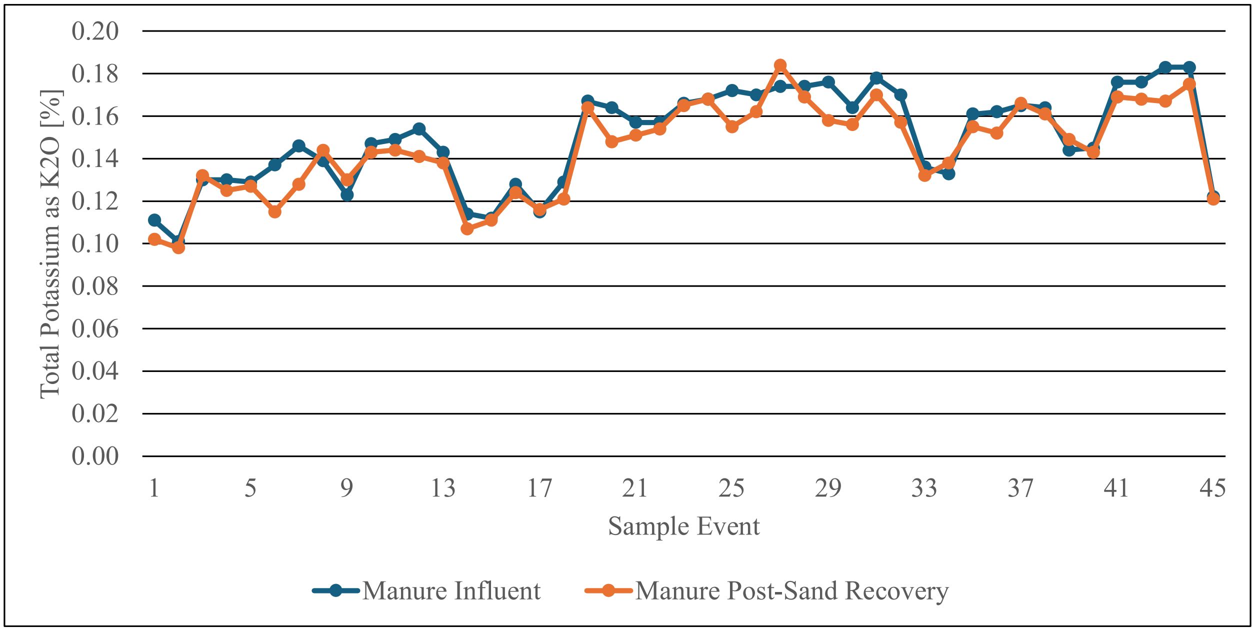


Figure 3. Manure sample concentrations over all sample events for total solids (TS, top), total ammonium nitrogen (TAN), total phosphorus (TP), and potassium (TK, bottom) by sampling location (non-detects were given a value of zero).

Table 4. Average separation index (SI) for total solids (TS) and volatile solids (VS).

	SI for TS (%)	SI for VS(%)
AVG	0.002	0.036

STDEV	0.003	0.065
CV	1.83	1.79

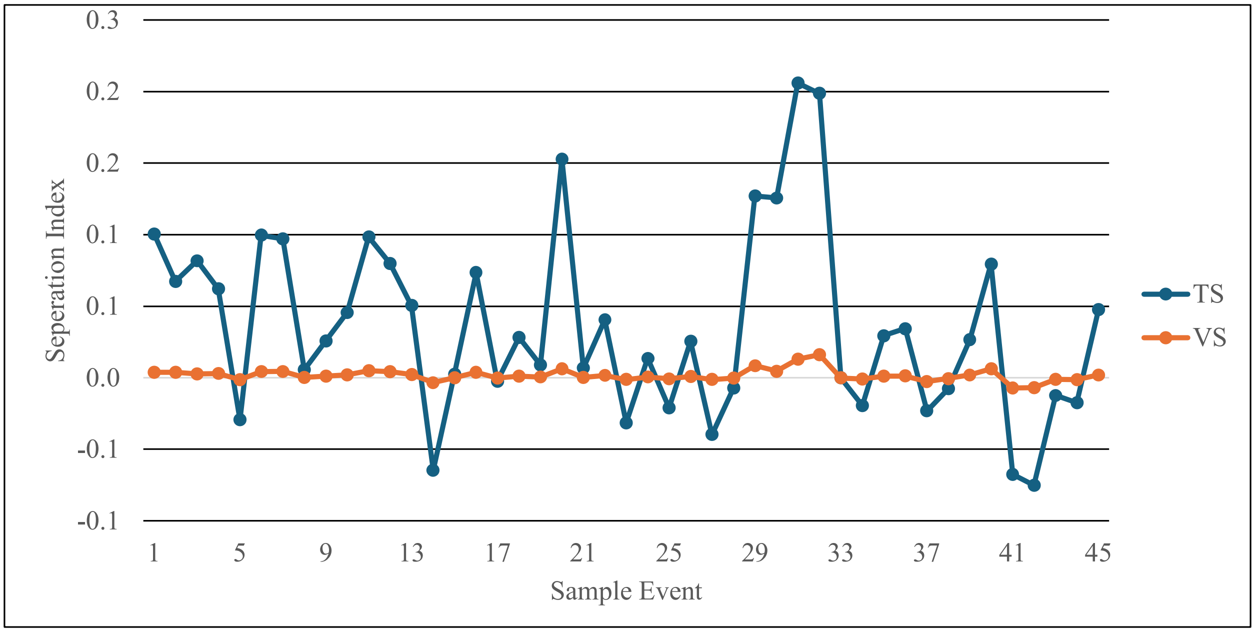


Figure 4. Separation index (SI) over time for total solids (TS) and volatile solids (VS).

EVALUATION KEY CHALLENGES AND ISSUES

Increased Manure Volume from Water Use: A significant challenge associated with the system is the volume of water required to operate the flush collection and sand separation processes. The farm reported using an additional 15,000 gallons of water daily, contributing to a total of approximately 230,000 gallons of diluted manure processed each day. While nutrient concentrations remained stable (Figure 3), this increase in volume places added pressure on manure storage, handling, and land application logistics—potentially raising costs and complicating nutrient management planning.

Residual Organic Matter in Recovered Sand: Although the recovered sand showed reduced organic content compared to raw manure, the average VS of 3.45% still exceeds the recommended threshold of <2% for optimal bedding hygiene (Table 1). Organic residues can support bacterial growth, potentially increasing the risk of mastitis or other health issues if the sand is reused without further treatment. While the farm mitigates this risk by using a natural gas dryer, this post-processing step was outside the scope of this study. Therefore, the full effectiveness of the system in producing pathogen-safe bedding relies in part on additional treatment beyond mechanical separation.

IMPLICATIONS

The findings of this study highlight both the practical value and operational considerations of integrating sand separation technology into dairy manure management systems. The ability of the McLanahan sand separation system to recover virtually clean sand—demonstrated by high TS and low organic contamination—offers a significant opportunity for farms to reduce bedding costs and improve long-term sustainability. By recycling sand on-site, producers can lower the frequency and cost of new sand purchases, reduce the volume of waste requiring off-farm disposal, and maintain cow comfort and health with minimal compromise to bedding quality.

From a nutrient management standpoint, the system's retention of N, P, and K in the liquid fraction ensures that essential nutrients remain available for precise agronomic use. This separation pattern supports better control of nutrient loading during land application and preserves the fertilizing value of the manure stream. However, the increase in total manure volume due to water use—approximately 230,000 gallons daily—presents a trade-off that farms must manage through adequate storage capacity, transport logistics, and nutrient application planning.

The presence of residual organic matter in the recovered sand also underscores the importance of integrating post-separation treatments, such as drying, to meet hygiene standards and reduce the risk of pathogen exposure. Although not evaluated in this study, the farm's use of a natural gas dryer illustrates how such systems can complement mechanical separation to improve bedding safety.

Overall, these results suggest that while sand separation systems can significantly enhance manure handling and bedding reuse efficiency, their success depends on proper system design, water management, and integration with complementary treatment technologies. As more farms seek to balance stewardship, animal health and comfort, and economic viability, understanding these trade-offs will be critical to optimizing manure management strategies.

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Aguirre-Villegas, H. A., Larson, R. A., & Sharara, M. A. (2019). Anaerobic digestion, solid-liquid separation, and drying of dairy manure: Measuring constituents and modeling emission. *Science of The Total Environment*, *696*, 134059. https://www.sciencedirect.com/science/article/pii/S0048969719340367

Guilayn, F., Jimenez, J., Rouez, M., Crest, M., & Patureau, D. (2019). Digestate mechanical separation: Efficiency profiles based on anaerobic digestion feedstock and equipment choice. *Bioresource Technology*, *274*, 180-189. https://www.sciencedirect.com/science/article/pii/S0960852418316274

For additional information on the vendor, environmental impacts, financial implications, and land application technology, visit the McLanahan Sand-Manure Separation (SMS) Vendor Snapshot on the Newtrient website.

This study was funded by the Natural Resources Conservation Service (NRCS) through a Conservation Innovation Grant (CIG). The views and findings presented in this publication are those of the author(s) and do not necessarily reflect the official views or policies of NRCS or the U.S. Department of Agriculture.

Appendix C

Third-Party Review of Sand-Manure Separation Technology at Robinway Dairy – Kiel, WI (Full Report)

Sand Recovery System Performance Evaluation

Langolf, B.[1] and R.A. Larson[1]

[1]Nelson Institute for Environmental Studies, University of Wisconsin-Madison

Final Report for Newtrient updated on April 25, 2025

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Abstract

A dairy farm in Northeastern Wisconsin was evaluated for manure characteristics from sand-bedded manure using a McLanahan sand separation system. The farm processes approximately 230,000 gallons of diluted manure daily, resulting in low solids manure with about 4% total solids (TS). The sand recovery system captures around 30 tons per day of wet sand, with an average total solids content of 91% TS. Over a 30-week period, 45 sample events were conducted, analyzing liquid manure and sand samples for various parameters including moisture, total solids, total Kjeldahl nitrogen (TKN), phosphorus (P), potassium (K), and others. Results showed higher levels of TKN and ammoniacal N (TAN) and potassium (K) in liquid samples compared to sand, while total phosphorus (P) was higher in sand samples. The separation index (SI) and removal efficiency (RE) were low, indicating that nutrients remained in the liquid manure stream for further downstream management, leaving behind cleaned sand suitable for bedding reuse.

Introduction

Livestock systems face challenges in sustainability including manure handling and animal welfare. Dairy producers commonly use sand bedding to improve animal welfare as it improves cow comfort and reduces herd health issues, including lameness and mastitis. However, while sand improves animal welfare it causes significant issues for manure handling systems. Sand is abrasive causing significant wear and tear on equipment and creates clogging issues throughout the manure handling system. Further, once sand reaches a manure storage resuspending the sand for land application poses operational challenges. In addition to operational issues, purchasing and transporting new clean sand for bedding can be costly. Thus, recycling sand has the potential to improve operational and economic outcomes at a farm while still maintaining animal welfare. However, systems require assessments to determine the amount of sand required as well as its quality. Recycled sand is recommended to have low organic matter content (<3%) to ensure it achieves the quality needed to maintain animal health and not promote liquid retention and pathogen growth.

Manure systems also face sustainability impacts in regard to land application of manure. Applying manure to cropping systems has 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. 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. Increased applications of manure nutrients increase the runoff risks, particularly when applications exceed agronomic recommendations. Sand recovery systems can impact losses as it alters the manure constituents and commonly increases water content as part of the cleaning system.

To optimize the effectiveness of sand recovery systems to improve animal welfare and manure handling while minimizing impacts to water quality it is essential to evaluate their performance. Here we assess the impacts to the manure characteristics pre and post sand separation as well as the sand quality after separation. The collected data can then be used to further improve overall systems goals to recovery sand for bedding reuse, aiming to enhance the value of separated products while improving manure management to reduce environmental impacts.

Methods

Study site

A dairy farm located in eastern Wisconsin collects manure from approximately 2,000 animals. The farm beds animals on sand and uses a McLanahan sand separator to recover sand from the manure. The farm collects approximately 80,000 gallons of raw manure per day from the free stall barns using a flush system three times per day during milking. The flush system integrates manure liquids from various sources, including wash water from milking parlors, recycled liquids from slope screens, and fresh water. This results in approximately 230,000 gallons per day of manure being directed to the sand separation system in a closed-loop fashion. The flush water is reused about six times per day before being discharged to the final storage lagoon. The flushed manure is routed to the sand separation system which consists of a small sand settling lane where sand settles by gravity and is collected, and then the manure follows into a collection pit and is metered into a McClanahan sand separation system to recover additional sand. The effluent from the sand separation system is then discharged to the manure storage. The farm recovers approximately 30 tons of sand per day from the manure and needs to purchase between 200 – 300 tons of sand per month due to loss through the recovery process.

The McClanahan sand separation system was assessed for its nutrient management and recovery efficiency by analyzing the manure and recovered sand over a 30-week period. This evaluation involved collecting manure and sand samples at three designated sampling points over a 30-week period (8/19/2024 to 3/18/2025), resulting in 45 sampling events in total (Figure 1).

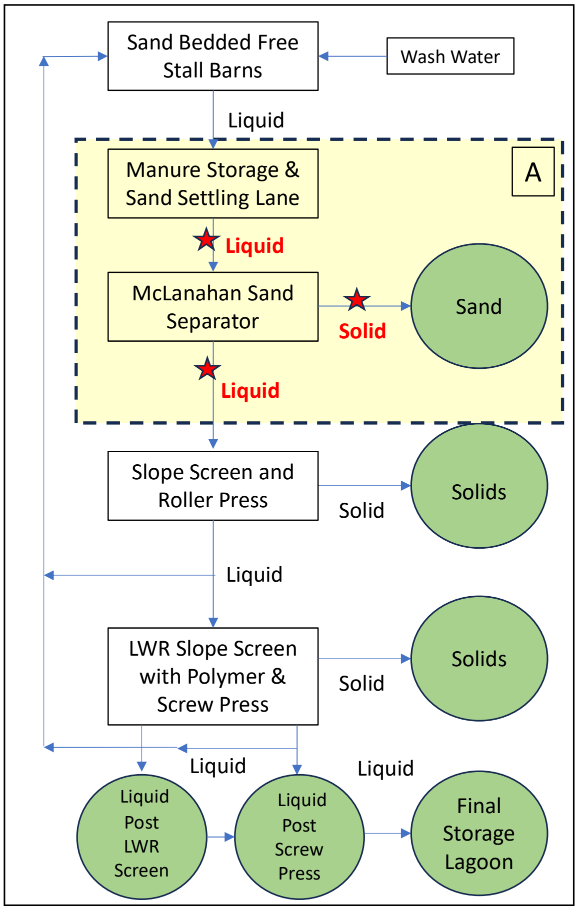


Figure 1. Flow diagram of the manure processing system, area A highlighted in yellow consisted of the sand recovery and designated sample collection area for the two liquid streams and one solid stream highlighted in red. Sample locations indicated by red star

During each sampling, 0.5 L of liquid sample was collected from both the liquid flowing through the sand settling lane (the influent to the McClanahan sand separator) and the final discharge liquid after the McClanahan sand separator (Figure 1). Solid samples, 1 L, were collected from the wet sand recovery pile (Figure 2). After collection, samples were stored at 4°C until shipped to A&L Great Lakes Laboratories for analysis.

Figure 2. Sand Recovery System A) McLanahan system, B) close up of sand washing and recovery, and C) separated wet sand post recovery.

Sample analysis

All samples were shipped to A&L Great Lakes Laboratories for analysis. Samples 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 ammoniacal-nitrogen (TAN).

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. Additional calculations were completed to assess the separation efficiency of the sand separation system.

Separation efficiency was determined using the separation index (SI) a (Eq. 1 & 2) (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.

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

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

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

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

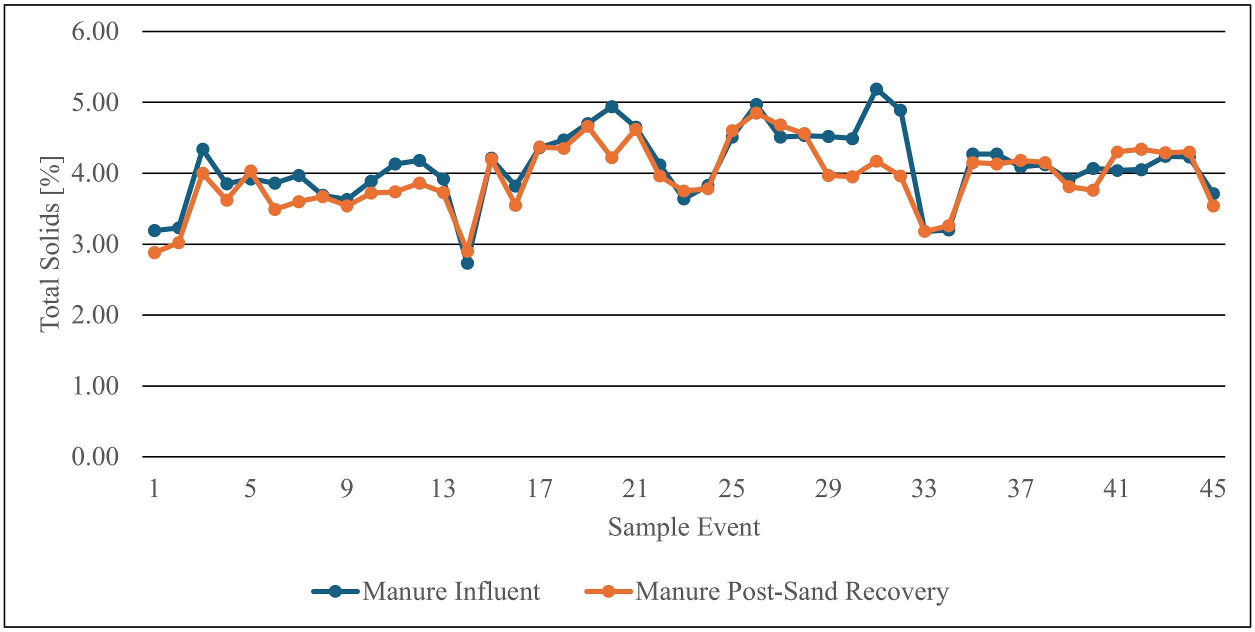
Manure impacts through sand separation

Manure sample characteristics by sample locations over the 30-week sampling period are reported below (Table 1). The remaining measured parameters are reported in Appendix A (Table A1). The manure characteristics pre and post sand separation were similar aside from the slight change in TS as expected. There was little change to the nutrients which is likely as they remain in the liquid fraction following sand separation and there are little to no nutrients in the small amount of organic matter recovered in the sand. Large shifts in nutrients would indicate that the sand quality was poor for animal welfare purposes. Analysis of the recovered bedding material showed an ash content of 85.8% and an organic carbon content of 2.0% (Appendix A1), indicating a high proportion of inorganic material and minimal organic contamination. These results suggest that the sand recovery system is performing effectively, producing clean sand suitable for reuse in cow bedding. Over time, there is little change to the manure nutrients pre and post sand separation (Figure 4) indicating there is little impact to the manure through the sand separation system, indicating little impact to land application and water quality. The main concern lies with the additional water (15,000 gallons per day according to the farm) added to the manure to assist in the collection and sand separation which increases manure volume requiring processing, storage, and land application.

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

Sample	Statistics	Solids [%]	Volatile Solids [%]	Total Kjeldahl Nitrogen [%]	Ammonium Nitrogen as NH_4-N [%]	Phosphorus as P_2O_5 [%]	Potassium as K_2O [%]
Manure Influent	Average	4.09	2.99	0.224	0.10	0.031	0.15
	Max	5.19	3.62	0.263	0.12	0.039	0.18
	Min	2.73	1.98	0.164	0.07	0.022	0.10
	Std. Dev.	0.51	0.38	0.022	0.01	0.004	0.02

Manure Post-Sand Recovery	Average	3.94	2.87	0.224	0.10	0.030	0.15
	Max	4.85	3.47	0.253	0.12	0.036	0.18
	Min	2.88	1.99	0.181	0.07	0.021	0.10
	Std. Dev.	0.47	0.37	0.021	0.01	0.004	0.02
Recovered Sand	Average	90.62	3.45	0.122	0.01	0.047	0.09
	Max	94.51	7.97	0.207	0.03	0.113	0.42
	Min	83.33	2.07	0.052	0.00	0.020	0.04
	Std. Dev.	2.12	1.39	0.043	0.01	0.018	0.07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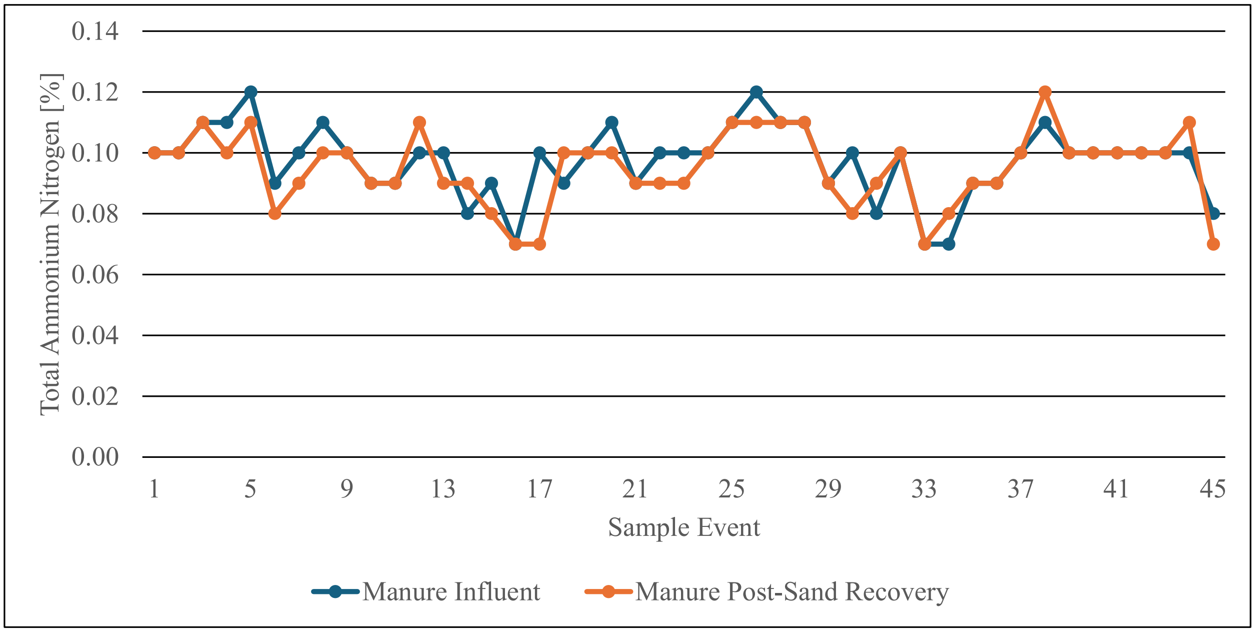
Sample Event
Manure Influent
Manure Post-Sand Recovery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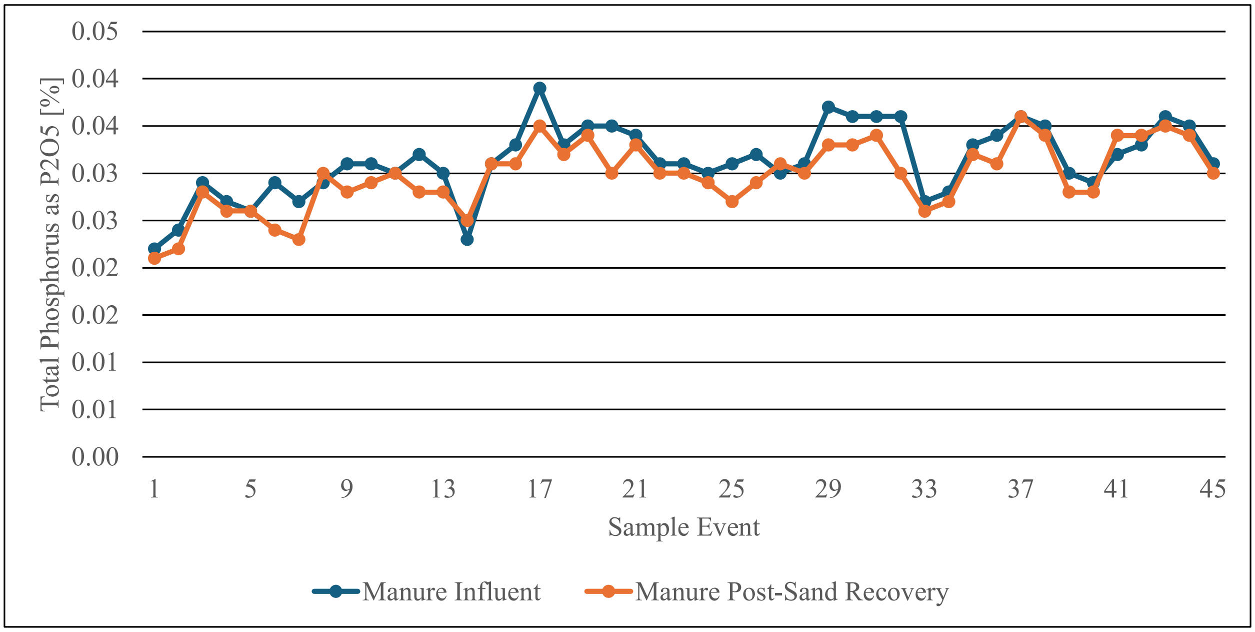
Sample Event
Manure Influent
Manure Post-Sand Recovery



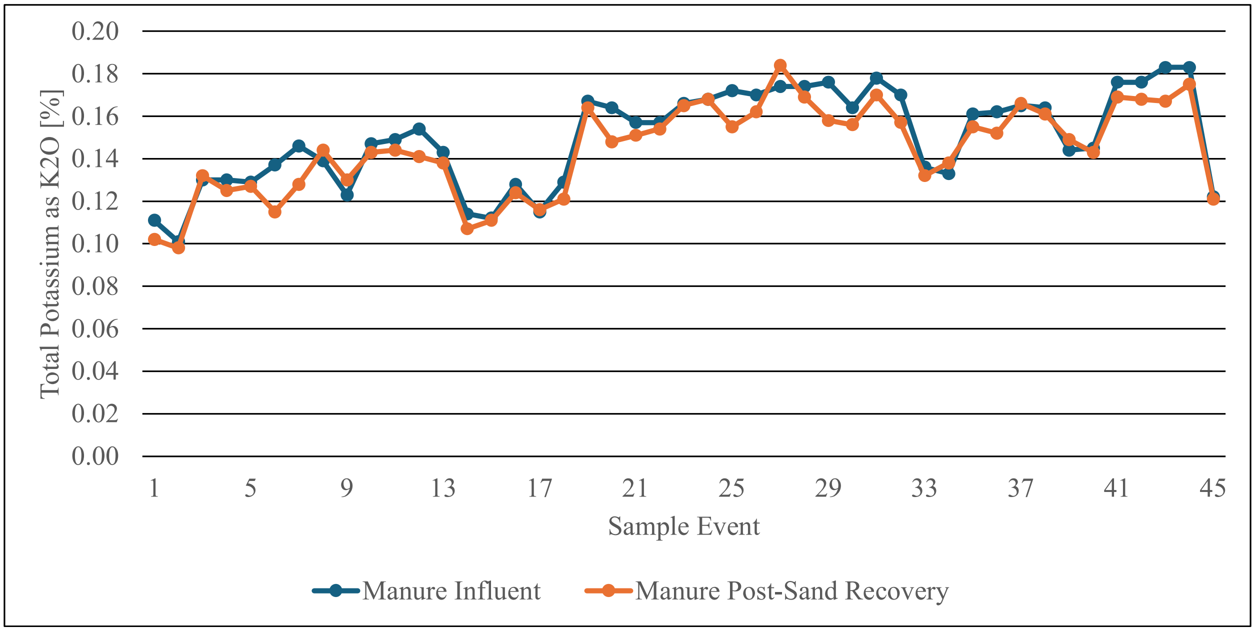


Figure 3. Manure sample concentrations over all sample events for total solids (TS, top), total Kjeldahl nitrogen (TKN), total phosphorus (TP), and potassium (TK, bottom) by sampling location (non-detects were given a value of zero).

Separation efficiencies as measured by separation index (SI)

Separation efficiencies, as measured by the Separation Index (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 the sand separator (Figure 7). Previous work indicates that an SI below 0.62 is considered a low-efficiency system (Guilayn et al., 2019). As expected, all nutrient parameters measured had low SI as the goal of the sand separation is to clean the sand for bedding reuse and to keep the majority of the nutrients in the liquid manure stream for further processing downstream in the nutrient management process, thus only data on the TS and VS are presented. The separation index for TS and VS for each of the 45 sampling events is presented in Figure 5.

Table 2. Average separation index (SI) for total solids (TS) and volatile solids (VS)

	SI for TS (%)	SI for VS(%)
AVG	0.002	0.036
STDEV	0.003	0.065
CV	1.83	1.79

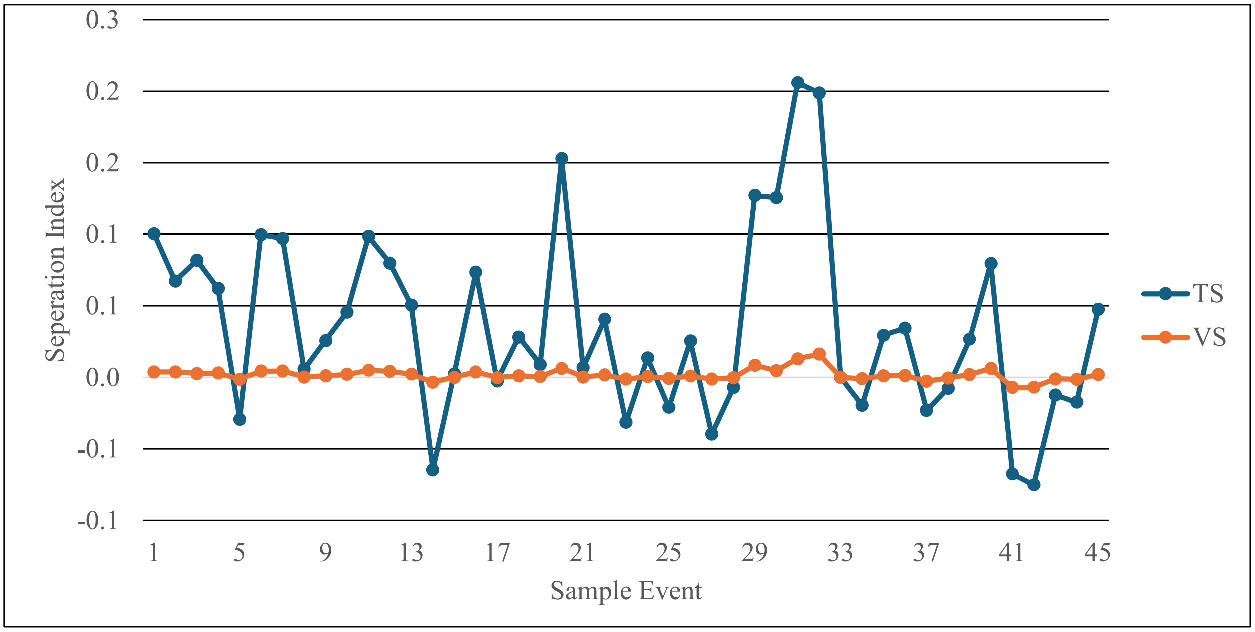


Figure 4. Separation index (SI) over time for total solids (TS) and volatile solids (VS)).

The recovered wet sand had an average VS content of 3.45%, significantly lower than the typical 13-14% found in raw dairy manure (Table 3). However, the presence of some organic matter, indicated by the 3.45% VS and a separation index of 0.036 SI, can still promote bacterial growth and increase the risk of mastitis in cows (Table 2). To improve sand quality, the farm uses a natural gas dryer to reduce the VS content, ideally below 2%, ensuring cleaner and healthier bedding conditions for the cows (post-dryer samples were not part of our study). This reduction in organic matter is crucial for minimizing bacterial growth and preventing health issues. Managing and reducing VS content in recovered sand is essential for effective manure handling and utilization.

Table 3. Recovered sand characteristics

Sample	Statistics	Solids [%]	Volatile Solids [%]	Total Kjeldahl Nitrogen [%]	Ammonium Nitrogen as NH_4-N [%]	Phosphorus as P_2O_5 [%]	Potassium as K_2O [%]
Recovered Sand	Average	90.62	3.45	0.122	0.01	0.047	0.09
	Max	94.51	7.97	0.207	0.03	0.113	0.42
	Min	83.33	2.07	0.052	0.00	0.020	0.04
	Std. Dev.	2.12	1.39	0.043	0.01	0.018	0.07

In Summary

- A dairy farm in Northeastern Wisconsin was selected to evaluate manure characteristics from sand-bedded manure using a McClanahan sand separation system per and post separation.
- The farm generates approximately 80,000 gallons of raw manure at the barns and processes around 230,000 gallons per day of diluted manure due to additional water inputs from lane flushing, parlor washing, sand recovery, and manure processing. This results in low solids manure with about 4% total solids (TS).
- The farm captures approximately 30 tons per day of wet sand from the McClanahan sand recovery system, with the sand having an average total solids content of 91% TS.
- Over a 30-week period, 45 sample events were conducted, collecting liquid manure samples at the sand recovery system, post-sand recovery liquid manure samples, and post-recovery sand samples.
- Samples were analyzed for 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 ratio (C:N), ammonium-nitrogen (TAN), and pH.
- Manure nutrient characteristics were unchanged through the sand separation system indicating that the nutrient constituents remained in the liquid manure stream to be managed further downstream in the manure management system.

The recovered wet sand sample has 3.45% VS, lower than the typical 13-14% in raw manure, but still contains organic matter that can promote bacterial growth. The farm uses a natural gas dryer to reduce VS below 2%, ensuring cleaner bedding for cows. Managing VS in recovered sand is essential for effective manure handling.

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Appendix A:

Table A1. Additional manure characteristics measured by sampling location

		Moisture [%]	Ash @ 550C [%]	Organic Carbon (LOI @ 550C) [%]	S [%]	Mg [%]	Ca [%]	Na [%]	Al [ppm]	Cu [ppm]	Fe [ppm]	Mn [ppm]	Zn [ppm]	pH
Manure at Sand Recovery	Average	95.97	1.08	1.75	0.02	0.11	0.15	0.08	19	8.3	47	5.2	7.1	7.0
	Max	98.88	1.68	2.10	0.02	0.15	0.22	0.31	30	116.0	71	6.8	9.7	7.5
	Min	94.81	0.75	1.15	0.01	0.03	0.12	0.01	11	0.7	14	3.9	5.4	6.7
	Standard Deviation	0.68	0.18	0.22	0.00	0.02	0.02	0.04	4	17.3	10	0.6	0.9	0.2
Manure Post-Sand Recovery	Average	96.06	1.06	1.69	0.02	0.12	0.16	0.07	19	5.8	50	5.0	7.3	7.0
	Max	97.12	1.48	3.01	0.02	0.18	0.25	0.09	24	26.0	74	6.2	12.0	7.6
	Min	95.15	0.51	1.15	0.01	0.08	0.11	0.04	12	1.3	35	3.8	5.1	6.7
	Standard Deviation	0.47	0.16	0.29	0.00	0.02	0.03	0.01	3	5.4	9	0.5	1.5	0.2
Recovered Sand	Average	9.38	85.82	2.00	0.02	8.91	15.22	0.04	972	10.6	3010	89.6	10.4	8.9
	Max	16.67	92.09	4.62	0.05	10.62	17.07	0.05	1572	49.0	3963	130.0	66.0	9.3
	Min	5.49	29.35	1.20	0.02	7.47	12.44	0.03	576	5.2	2386	67.0	5.8	8.2
	Standard Deviation	2.12	8.93	0.80	0.01	0.66	1.01	0.00	264	7.8	352	8.8	8.7	0.2

Appendix B

Report Number
F25034-6502
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: 72158
Sample ID: A
Manure Type: DAIRY, LIQUID PIT (20)

Date Sampled: 1/29/2025
Date Received: 2/3/2025
Date Reported: 2/5/2025

MANURE ANALYSIS

Analysis	Unit	Analysis Result (As Received)	Pounds Per 1,000 Gal **	First Year Availability @ Pounds Per 1,000 Gal
Moisture	%	95.51	7956	
Solids	%	4.49	374	
Ash @ 550 C	%	1.07	89.5	
Organic Matter (LOI @ 550 C)	%	3.42	284.5	
Organic Carbon (LOI @ 550 C)	%	1.98	165.0	
Carbon:Nitrogen Ratio (C:N)	-		8.9:1	
Nitrogen, Total Kjeldahl (TKN)	%	0.223	18.6	11.4 *
Nitrogen, Ammonium (NH_4-N)	%	0.100	8.3	8.3 *
Nitrogen, Organic (N)	%	0.123	10.2	3.1 *
Phosphorus (P)	%	0.036	6.9 (as P_2O_5)	6.9 * (as P_2O_5)
Potassium (K)	%	0.164	16.4 (as K_2O)	16.4 * (as K_2O)
Sulfur (S)	%	0.02	1.9	0.9 #

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

Report Number
F25034-6502
Account Number
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11510 LAURIE DR
WHEATFIELD, IN 46392-7364

For: UW-MADISON

Attn: MARK STOERMAN

Purchase Order: UW-MADISON

Lab Number: 72158
Sample ID: A
Manure Type: DAIRY, LIQUID PIT (20)

Date Sampled: 1/29/2025
Date Received: 2/3/2025
Date Reported: 2/5/2025

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)	%	0.10	8.7	4.6 #
Calcium (Ca)	%	0.15	12.6	6.9 #
Sodium (Na)	%	0.07	5.5	
Aluminum (Al)	ppm	17	0.1	
Copper (Cu)	ppm	2.2	<0.1	<0.1 #
Iron (Fe)	ppm	43	0.4	0.2 #
Manganese (Mn)	ppm	5.4	<0.1	<0.1 #
Zinc (Zn)	ppm	7.1	0.1	<0.1 #
pH	-	7.1		

@ Estimate of first-year availability does not account for incorporation losses. Consult MWPS-18, "Livestock Waste Facilities Handbook" for additional information.
* Source: MWPS-18, Livestock Waste Facilities Handbook, 1993 # Source: A3411, "Manure Nutrient Credit Worksheet", University of Wisconsin
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WHEATFIELD, IN 46392-7364

For: UW-MADISON

Attn: MARK STOERMAN

Purchase Order: UW-MADISON

Lab Number: 72159
Sample ID: B
Manure Type: DAIRY, SOLID W/O BEDDING (6)

Date Sampled: 1/29/2025
Date Received: 2/3/2025
Date Reported: 2/5/2025

Page: 9 of 12

MANURE ANALYSIS

Analysis	Unit	Analysis Result (As Received)	Pounds Per Ton	First Year Availability @ Pounds Per Ton
Moisture	%	8.69	174	
Solids	%	91.31	1826	
Ash @ 550 C	%	88.72	1774.4	
Organic Matter (LOI @ 550 C)	%	2.59	51.8	
Organic Carbon (LOI @ 550 C)	%	1.50	30.1	
Carbon:Nitrogen Ratio (C:N)	-		9.4:1	
Nitrogen, Total Kjeldahl (TKN)	%	0.160	3.2	1.8 *
Nitrogen, Ammonium (NH_4-N)	%	0.000	1.1	1.1 *
Nitrogen, Organic (N)	%	0.107	2.1	0.7 *
Phosphorus (P)	%	0.033	1.5 (as P_2O_5)	1.5 * (as P_2O_5)
Potassium (K)	%	0.067	1.6 (as K_2O)	1.6 * (as K_2O)
Sulfur (S)	%	0.02	0.4	0.2 #

@ Estimate of first-year availability does not account for incorporation losses. Consult MWPS-18, "Livestock Waste Facilities Handbook" for additional information.
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For: UW-MADISON

Attn: MARK STOERMAN

Purchase Order: UW-MADISON

Lab Number: 72159
Sample ID: B
Manure Type: DAIRY, SOLID W/O BEDDING (6)

Date Sampled: 1/29/2025
Date Received: 2/3/2025
Date Reported: 2/5/2025

MANURE ANALYSIS

Analysis	Unit	Analysis Result (As Received)	Pounds Per Ton	First Year Availability @ Pounds Per Ton
Magnesium (Mg)	%	8.05	160.9	88.6 #
Calcium (Ca)	%	12.89	257.9	141.8 #
Sodium (Na)	%	0.03	0.7	
Aluminum (Al)	ppm	1300	2.6	
Copper (Cu)	ppm	7.5	<0.1	<0.1 #
Iron (Fe)	ppm	3115	6.2	4.0 #
Manganese (Mn)	ppm	93	0.2	0.1 #
Zinc (Zn)	ppm	8.8	<0.1	<0.1 #
pH	-	9.0		

@ Estimate of first-year availability does not account for incorporation losses. Consult MWPS-18, "Livestock Waste Facilities Handbook" for additional information.
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WHEATFIELD, IN 46392-7364

For: UW-MADISON

Attn: MARK STOERMAN

Purchase Order: UW-MADISON

Lab Number: 72160
Sample ID: C
Manure Type: DAIRY, LIQUID PIT (20)

Date Sampled: 1/29/2025
Date Received: 2/3/2025
Date Reported: 2/5/2025 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	%	96.05	8001	
Solids	%	3.95	329	
Ash @ 550 C	%	1.00	83.6	
Organic Matter (LOI @ 550 C)	%	2.95	245.4	
Organic Carbon (LOI @ 550 C)	%	1.71	142.4	
Carbon:Nitrogen Ratio (C:N)	-		8.0:1	
Nitrogen, Total Kjeldahl (TKN)	%	0.213	17.7	10.0 *
Nitrogen, Ammonium (NH_4-N)	%	0.080	6.7	6.7 *
Nitrogen, Organic (N)	%	0.133	11.1	3.3 *
Phosphorus (P)	%	0.033	6.4 (as P_2O_5)	6.4 * (as P_2O_5)
Potassium (K)	%	0.156	15.6 (as K_2O)	15.6 * (as K_2O)
Sulfur (S)	%	0.02	1.6	0.9 #

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

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WHEATFIELD, IN 46392-7364

For: UW-MADISON

Attn: MARK STOERMAN

Purchase Order: UW-MADISON

Lab Number: 72160
Sample ID: C
Manure Type: DAIRY, LIQUID PIT (20)

Date Sampled: 1/29/2025
Date Received: 2/3/2025
Date Reported: 2/5/2025

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	8.4	4.6 #
Calcium (Ca)	%	0.14	11.7	6.4 #
Sodium (Na)	%	0.04	3.6	
Aluminum (Al)	ppm	18	0.1	
Copper (Cu)	ppm	2.1	<0.1	<0.1 #
Iron (Fe)	ppm	43	0.4	0.2 #
Manganese (Mn)	ppm	4.9	<0.1	<0.1 #
Zinc (Zn)	ppm	6.9	0.1	<0.1 #
pH	-	7.1		

@ 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