NEWTRIENT EVALUATION SUMMARY

CONSERVATION INNOVATION GRANT (CIG):

Sand-Manure Separation Technology

Dairy Manure Treatment Innovations – Enhancing Water Quality and Sustainability

University Partner
Brian Langolf
Dr. Rebecca Larson
University of Wisconsin-Madison
Nelson Institute for
Environmental Studies
122 Science Hall
550 North Park St.
Madison, WI 53706

MARCH 2025

INSIDE

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.

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 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.

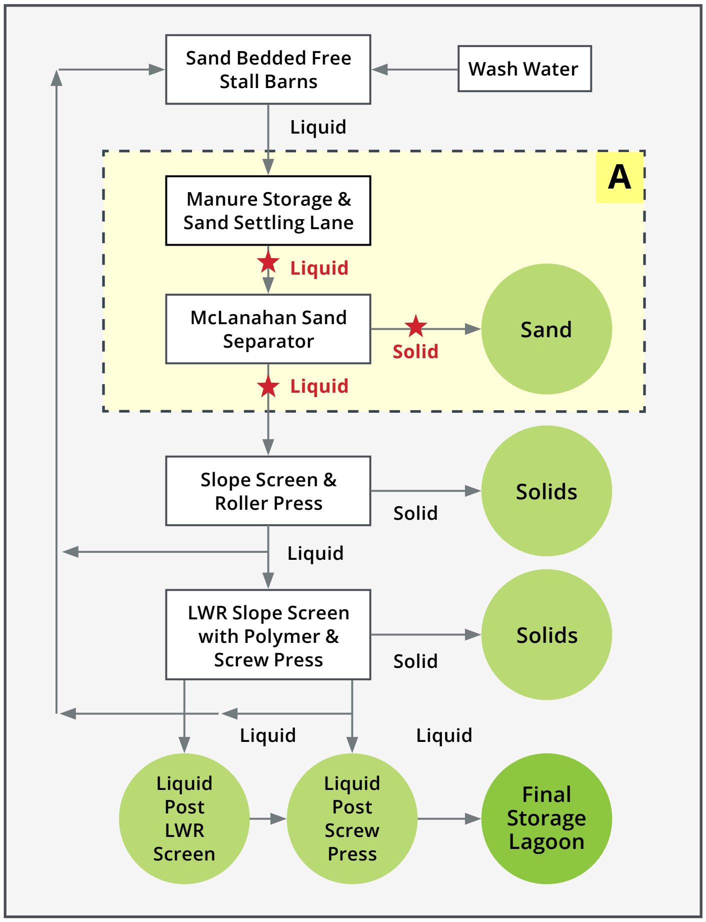
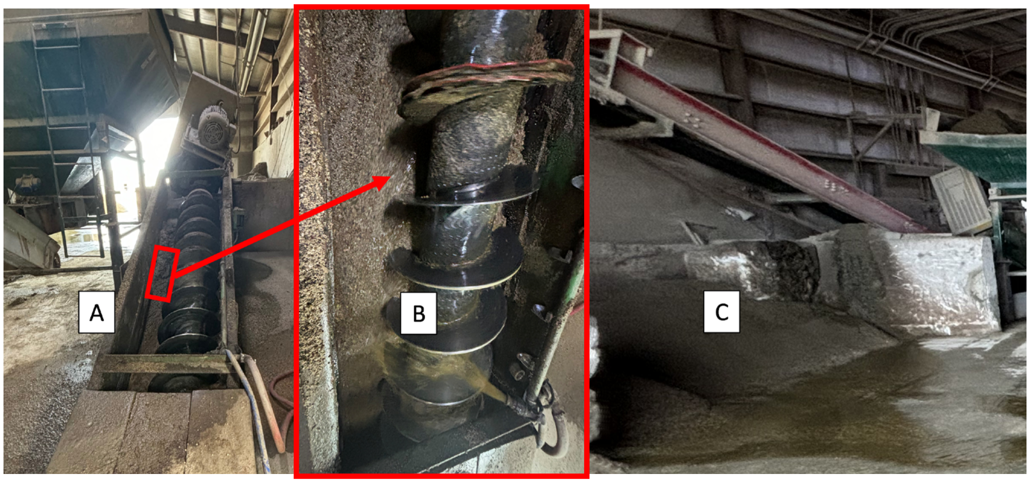


FIGURE 2: SAND RECOVERY SYSTEM.



A) McLanahan system
B) Close up of sand washing and recovery
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.

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

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

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.

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 1: RECOVERED SAND CHARACTERISTICS.

Sample	Statistics	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
	Std. Dev.	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
	Std. Dev.	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
	Std. Dev.	2.12	8.93	0.80	0.01	0.66	1.01	0.00	264	7.8	352	8.8	8.7	0.2

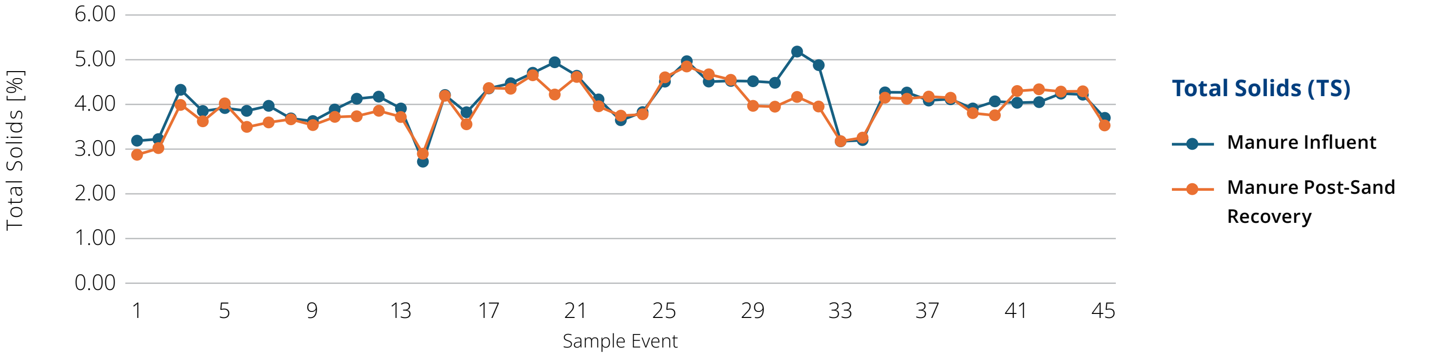
TABLE 2: ADDITIONAL MANURE CHARACTERISTICS MEASURED BY SAMPLING LOCATION.

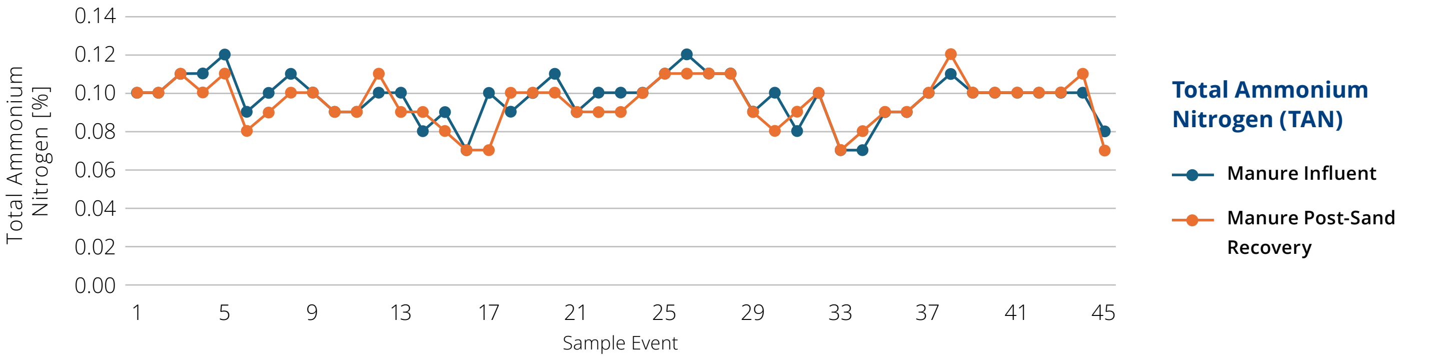
Sample	Statistics	Solids [%]	Volatile Solids [%]	Total Kjeldahl Nitrogen [%]	Ammonium Nitrogen as NH_4-N [%]	Phosphorus as P_2O_5 [%]	Potassium as K_2O [%]
Recovered Sand	Average	90.62	3.45	0.122	0.01	0.047	0.09
	Max	94.51	7.97	0.207	0.03	0.113	0.42
	Min	83.33	2.07	0.052	0.00	0.020	0.04
	Std. Dev.	2.12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

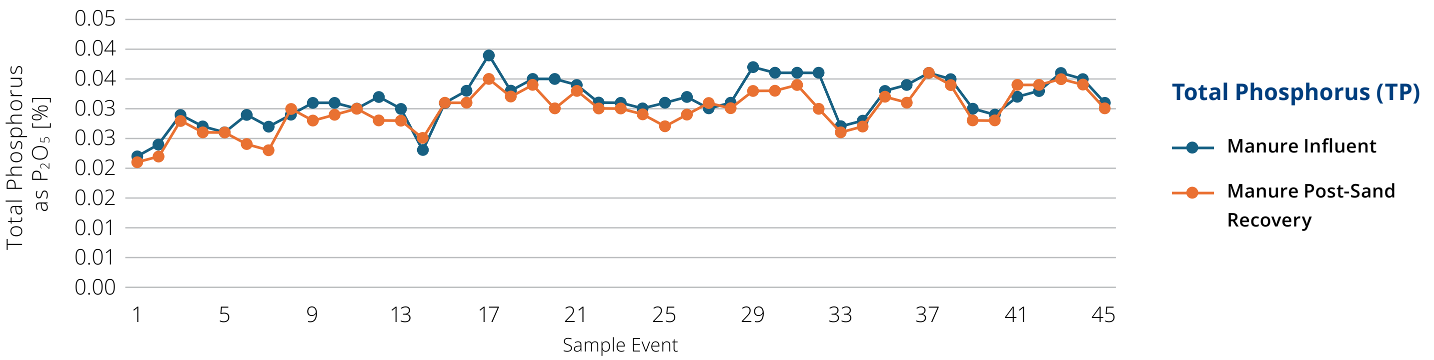
TABLE 3: PRIMARY MANURE CHARACTERISTICS BY SAMPLING LOCATION (NON-DETECTS WERE GIVEN A VALUE OF ZERO).

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

FIGURE 3: MANURE SAMPLE CONCENTRATIONS OVER ALL SAMPLE EVENTS FOR TOTAL SOLIDS (TS, TOP), TOTAL AMMONIUM NITROGEN (TAN), TOTAL PHOSPHORUS (TP), AND TOTAL POTASSIUM (TK, BOTTOM) BY SAMPLING LOCATION (NON-DETECTS WERE GIVEN A VALUE OF ZERO).







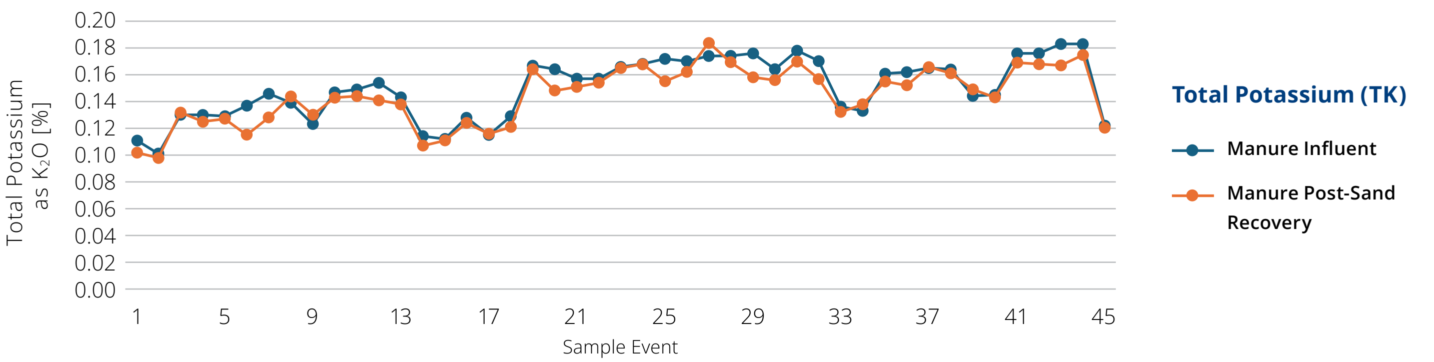
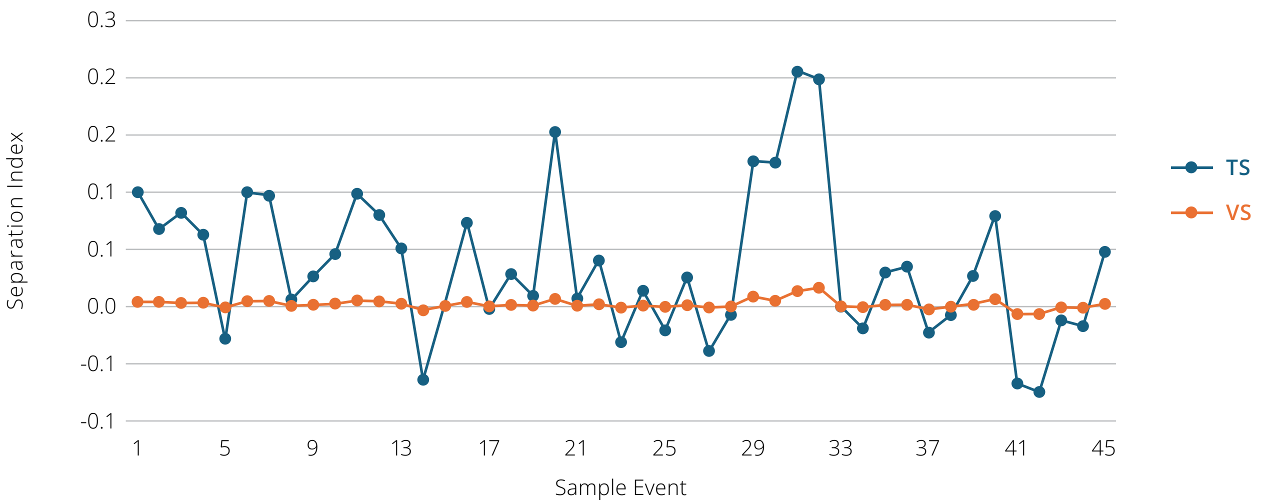


TABLE 4: AVERAGE SEPARATION INDEX (SI) FOR TOTAL SOLIDS (TS) AND VOLATILE SOLIDS (VS).

	SI for TS [%]	SI for VS [%]
Average	0.002	0.036
Std. Dev.	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.

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**.

REFERENCES

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**

Newtrient's mission is to reduce the environmental footprint of dairy while making it economically viable to do so.

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.

Newtrient, LLC
10255 W. Higgins Road
Suite 900
Rosemont, IL 60018
847-627-3855
info@newtrient.com

www.newtrient.com