NEWTRIENT EVALUATION SUMMARY

CONSERVATION INNOVATION GRANT (CIG):

Polymer-Enhanced Solid Separation

Dairy Manure Treatment Innovations – Enhancing Water Quality and Sustainability

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INSIDE

BACKGROUND

Effective management of manure nutrients is critical for maximizing the fertilizer value while minimizing environmental losses. As dairy operations increase in scale and animal density, the resulting manure volumes—particularly with high water content—pose significant logistical and environmental challenges. Traditional storage and land application practices can lead to nutrient losses through runoff and leaching, contributing to water quality degradation and public health concerns.

Manure processing systems have emerged as a potential solution to reduce the environmental footprint of dairy operations by concentrating nutrients and producing effluent closer to discharge quality. Mechanical separation technologies, including those that integrate slope screens, screw presses, and polymer-enhanced processes, aim to extract solids and concentrate nutrients in smaller volumes, reducing handling and application burdens. However, the separation efficiency and final effluent quality of these systems vary widely, and many still produce effluent volumes comparable to the original manure, limiting their economic advantage unless further treatment is implemented.

This study evaluated the Livestock Water Recycling (LWR) system installed at a dairy farm in Northeastern Wisconsin. The goal was to assess the system's ability to concentrate nutrients, improve separation efficiency, and generate products suitable for reuse or discharge, thereby potentially reducing land application costs and environmental risks.

INTRODUCTION

Livestock production systems are facing growing scrutiny from consumers, regulators, and environmental advocates to enhance sustainability, particularly in the area of manure management. While land application of manure can recycle nutrients and organic matter to croplands, it can also result in the loss of manure constituents to the environment—especially when application timing, nutrient loading rates, and weather conditions are not aligned with crop needs.

The challenges of manure management are further compounded by increased manure water content, driven by evolving management practices, animal housing designs, and runoff collection. This creates larger volumes of manure to store, transport, and apply—raising both economic and environmental concerns. Runoff from manure-amended fields can carry nutrients, pathogens, and organic matter into surface waters, while leaching of nitrates into groundwater presents risks to drinking water quality.

Mechanical manure processing systems play a critical role in manure management by separating manure into solid and liquid fractions, which facilitates handling, storage, and targeted nutrient application. These systems are often the first step in broader treatment strategies and can contribute to greenhouse gas (GHG) reductions by removing volatile solids. While traditional mechanical separators are effective at reducing volume and improving manageability, their nutrient removal efficiencies—particularly for dissolved nutrients—can be limited. As a result, additional treatment steps are often needed to enhance nutrient recovery and further reduce environmental impacts.

The LWR system evaluated in this study represents an advanced approach to manure processing. By combining mechanical separation with chemical treatment, the system seeks to improve nutrient recovery. This study assessed the performance of the LWR "First Wave" system on a commercial dairy in Northeastern Wisconsin over a 49-week period, evaluating its ability to remove total solids (TS), volatile solids (VS), Total Kjeldahl Nitrogen (TKN), phosphorus (P), and potassium (K). The study also considered the system's operational demands, maintenance requirements, and the quality of treated outputs with respect to potential discharge or reuse. This dairy also had the LWR reverse osmosis (RO) portion of the system, known as the “PLANT,” but this was not operational during the evaluation period and not included in the assessment.

The Process

The manure processing system (Figure 1) evaluated in this study is located on a dairy farm near Kiel, Wisconsin, which houses approximately 2,000 cows and generates an estimated 80,000 gallons of raw manure daily. As part of the farm’s broader manure management infrastructure, an initial sand separation system is used to recover bedding material; however, this component was not included in the scope of this evaluation.

Following sand separation, a significant volume of additional liquid—including parlor wash water, recycled effluent from previous treatment steps, and fresh water—is added to the manure. This results in a substantially diluted manure stream totaling approximately 230,000 gallons per day. This diluted stream is then sent through a multi-stage processing system designed to concentrate nutrients, separate solids, and reduce the volume of material requiring land application.

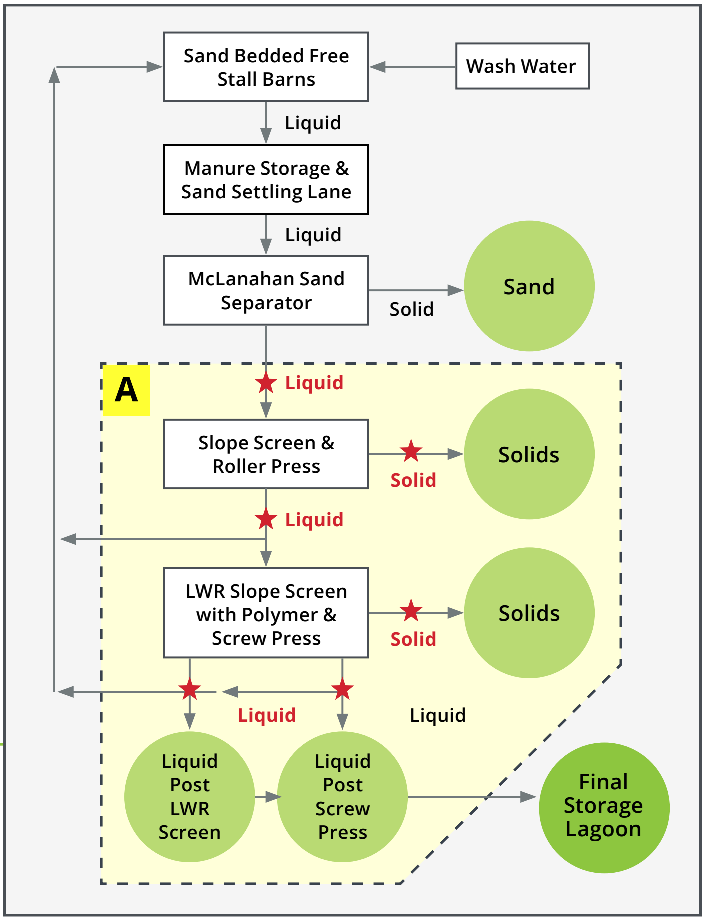


FIGURE 1: FLOW DIAGRAM OF THE MANURE PROCESSING SYSTEM.

Area A highlighted in yellow consisted of the manure separation system and designated sample collection area for four liquid streams and two solid streams highlighted in red.

The initial processing step includes a combined slope screen and roller press, which removes a portion of the solids (Figure 2). The partially clarified liquid then undergoes further treatment using the LWR "First Wave" system (Figure 3), which incorporates a second slope screen with polymer addition, followed by a screw press for enhanced solid-liquid separation.

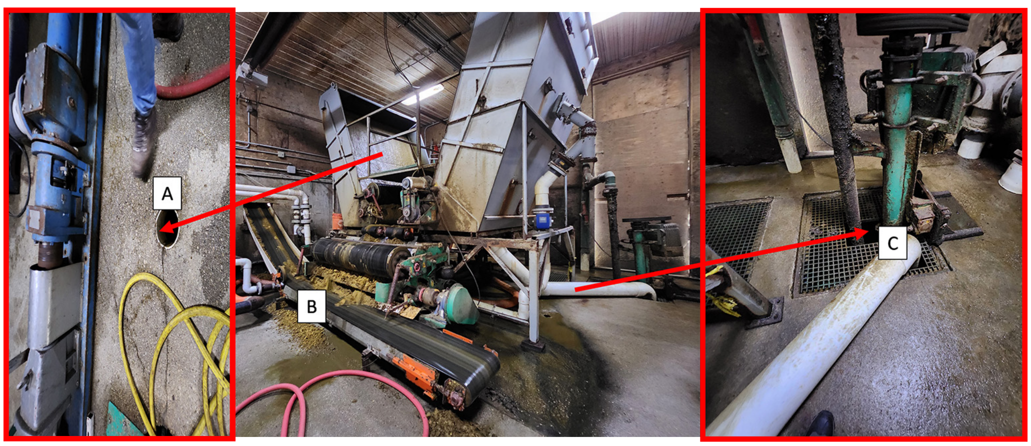
The process yields three primary end products that require management:

- **Separated solids** from the slope screen and roller press,
- **Separated solids** from the LWR "First Wave" slope screen with polymer and screw press, and
- **Effluent liquid** from the LWR "First Wave" system.

Both liquid fractions—from the initial and LWR "First Wave" treatment stages—are combined and discharged into the farm's final holding pond. From there, the effluent is stored until it can be land applied in accordance with the farm's nutrient management plan.

This evaluation focused on field-collected data from the LWR "First Wave" system's solid separation stages. According to LWR documentation, the full system includes two main components: the "First Wave" for fine solid separation and the "PLANT" system for further fine solids removal, filtration, and RO to remove dissolved solids. In this study, the evaluated process included the initial slope screen and roller press, followed by the LWR "First Wave" slope screen with polymer addition and screw press. The evaluation focused on nutrient partitioning and separation efficiency through these solids removal stages and did not include direct performance testing or water quality analysis of the "PLANT" system.

FIGURE 2: SLOPE SCREEN AND ROLLER PRESS.



A) Liquid manure pre slope screen

B) Solids post slope screen and roller press

C) Liquid manure post slope screen and roller press

FIGURE 3: LWR SLOPE SCREEN AND SCREW PRESS.

A) Liquid manure pre LWR "First Wave" slope screen

B) Liquid manure post LWR "First Wave" slope screen

C) Liquid manure post screw press

D) Final solids post LWR screw press

METHODOLOGY

The manure processing system at the study site was evaluated over a 49-week period, from March 19, 2024, to February 28, 2025. A total of 45 sampling events were conducted during periods when the system was operational, as determined by the farm. The primary objective of the evaluation was to assess the characteristics of various manure products and determine the separation efficiency of individual processing components, including the combined slope screen and roller press, as well as the LWR "First Wave" system (slope screen with polymer addition and screw press).

During each sampling event, seven samples were collected from key points in the system to capture manure characteristics at different stages of processing and to evaluate the composition of the recovered products (Figures 2 and 3). Liquid and slurry samples (0.5 L) were collected while systems were fully operational, and solid samples (1 L) were collected directly from the outlets of the roller press and screw press. All samples were stored at 4°C and shipped to A&L Great Lakes Laboratories for analysis.

Samples were analyzed using the M7 Manure Analysis Package plus pH, which includes a comprehensive suite of parameters: moisture, TS, VS, TKN, Total Ammonium Nitrogen (TAN), P, K, sulfur (S), calcium (Ca), magnesium (Mg), sodium (Na), iron (Fe), aluminum (Al), manganese (Mn), copper (Cu), zinc (Zn), ash, and organic carbon (OC), as well as the carbon-to-nitrogen ratio (C:N).

To evaluate system performance, data from all 45 sampling events were averaged. Non-detect values were treated as zero for analysis purposes. Separation efficiency was assessed using two key metrics:

- **Separation Index (SI) –** to evaluate how well each component concentrated constituents into the solid fraction.
- **Removal Efficiency (RE) –** to measure the purification of the liquid fraction.

These metrics were calculated based on established equations (Eq. 1, 2, & 3) (Aguirre-Villegas et al., 2019; Guilayn et al., 2019) using dry matter (DM) and constituent concentrations in influent and separated streams. Together, these methods provide a comprehensive understanding of the LWR system's nutrient partitioning and overall performance at this specific dairy operation.

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

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

3 $$RE_X = 1 - \frac{[X]_{Liquid,Out}}{[X]_{Influent}}$$

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.

DISCUSSION OF RESULTS

The results from the evaluation of the LWR "First Wave" system provide valuable insights into its effectiveness as a manure treatment and nutrient management tool. Data from this study offers a clear understanding of the system's ability to separate solids and concentrate nutrients under real-world operating conditions. In this section, we examine the system's performance in nutrient partitioning, operational reliability, and its potential to improve environmental outcomes compared to traditional manure management practices.

Key Benefits of Polymer-Enhanced Solid Separation

Improved Solid-Liquid Separation Efficiency: The LWR "First Wave" system demonstrated significantly improved solid-liquid separation efficiency compared to the farm's existing slope screen and roller press setup. Separated solids from the LWR system averaged 21.67% TS, compared to 17.72% TS from the roller press solids, indicating a drier, more manageable product (Table 1). This enhanced separation is further supported by the higher Separation Index (SI) values for TS, VS, and total phosphorus (TP) observed in the LWR system (Figures 4 and 5), highlighting its effectiveness in partitioning key nutrients into the solid fraction. This improvement aids in nutrient recovery and simplifies manure handling and storage.

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 Liquid Pre Slope Screen	Average	4.06	2.98	0.222	0.11	0.029	0.14
	Max	7.21	5.28	0.276	0.15	0.046	0.18
	Min	2.52	1.91	0.154	0.06	0.018	0.08
	Std. Dev.	0.88	0.65	0.031	0.01	0.005	0.03
Manure Liquid Post Slope Screen & Roller Press	Average	3.97	2.86	0.222	0.11	0.028	0.14
	Max	5.81	4.16	0.267	0.14	0.037	0.19
	Min	2.32	1.70	0.154	0.06	0.018	0.09
	Std. Dev.	0.78	0.58	0.030	0.01	0.004	0.03
Manure Solids Post Slope Screen & Roller Press	Average	17.72	16.12	0.331	0.10	0.033	0.15
	Max	20.17	19.94	0.452	0.23	0.042	0.21
	Min	15.22	13.77	0.217	0.03	0.024	0.09
	Std. Dev.	1.14	1.16	0.047	0.04	0.004	0.03
Manure Liquid Pre LWR Screen	Average	4.24	2.87	0.216	0.10	0.027	0.13
	Max	5.99	3.92	0.263	0.14	0.035	0.18
	Min	2.70	1.87	0.148	0.07	0.019	0.08
	Std. Dev.	0.73	0.57	0.031	0.01	0.004	0.03
Manure Liquid Post LWR Screen & Polymer	Average	1.48	0.95	0.137	0.09	0.008	0.12
	Max	2.63	1.75	0.184	0.12	0.015	0.17
	Min	0.97	0.60	0.083	0.01	0.002	0.06
	Std. Dev.	0.36	0.23	0.029	0.02	0.003	0.03
Manure Liquid Post LWR Screw Press	Average	2.14	1.44	0.154	0.09	0.013	0.12
	Max	3.41	2.42	0.215	0.12	0.026	0.16
	Min	1.02	0.74	0.083	0.07	0.004	0.07
	Std. Dev.	0.64	0.45	0.039	0.01	0.005	0.03
Manure Solids Post LWR Screw Press	Average	21.67	16.13	0.858	0.18	0.171	0.15
	Max	28.49	21.81	1.022	0.32	0.204	0.26
	Min	18.06	13.27	0.684	0.10	0.132	0.10
	Std. Dev.	2.26	1.82	0.088	0.05	0.019	0.03

FIGURE 4: SEPARATION INDEX (SI) FOR TOTAL SOLIDS (TS), VOLATILE SOLIDS (VS), TOTAL KJELDAHL NITROGEN (TKN), TOTAL AMMONIUM NITROGEN (TAN), TOTAL PHOSPHORUS (TP), AND TOTAL POTASSIUM (TK).

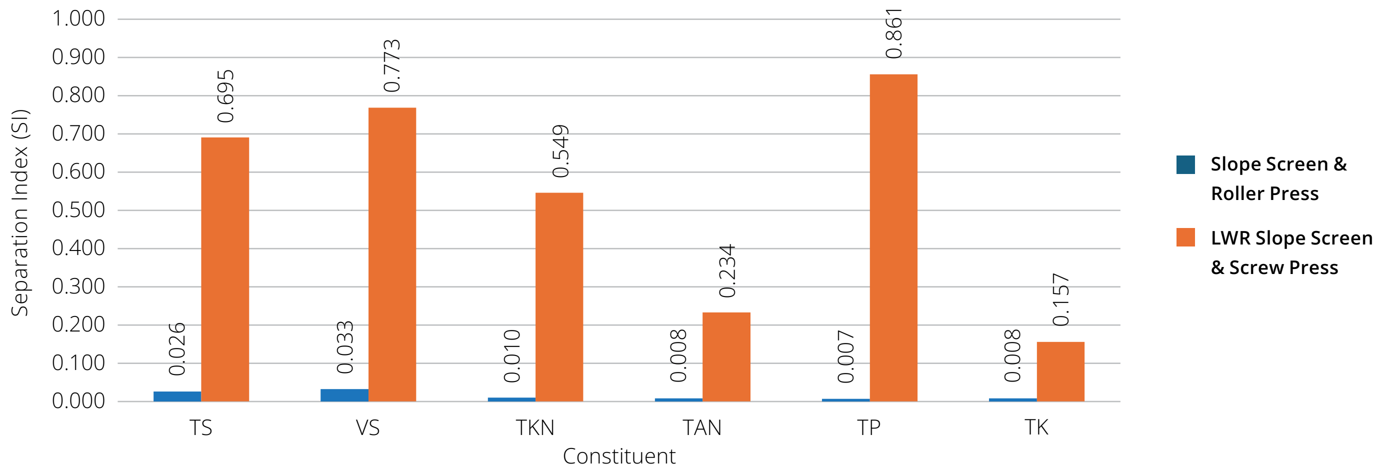
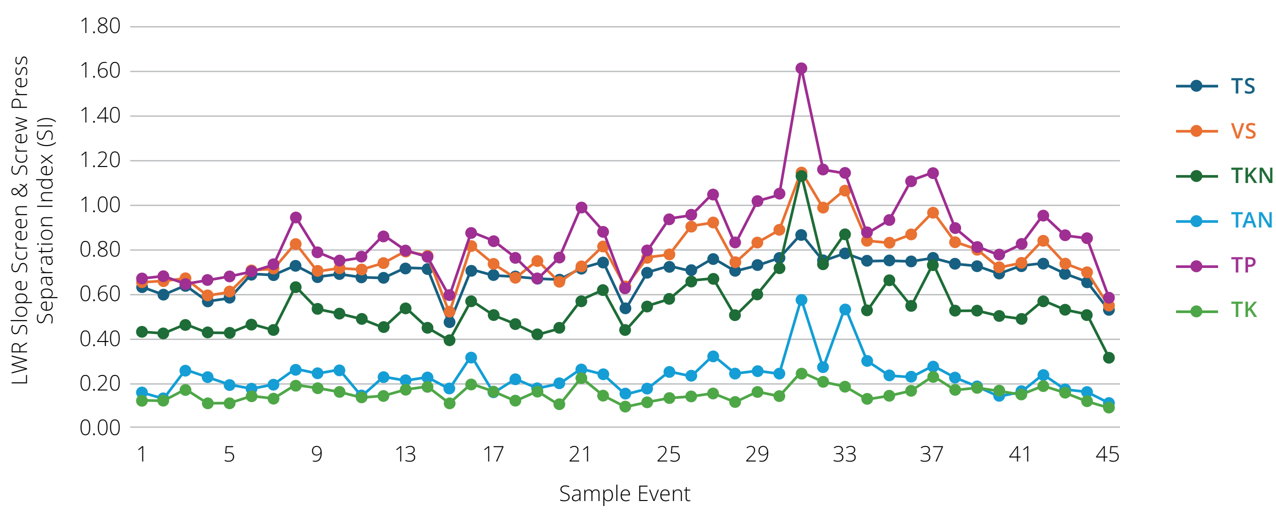
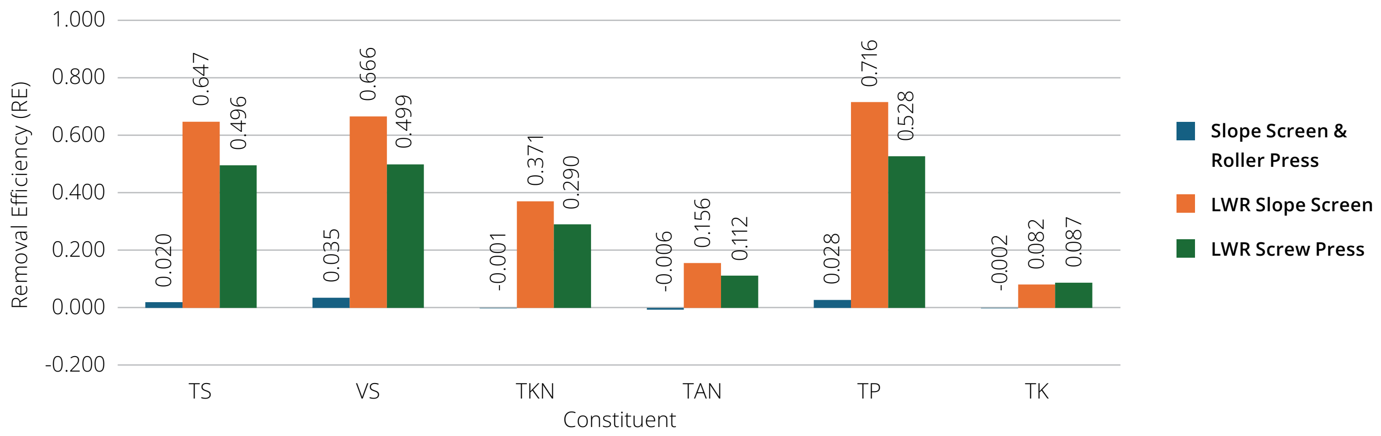


FIGURE 5: SEPARATION INDEX (SI) OVER TIME FOR TOTAL SOLIDS (TS, TOP), VOLATILE SOLIDS (VS), TOTAL KJELDAHL NITROGEN (TKN), TOTAL AMMONIUM NITROGEN (TAN), TOTAL PHOSPHORUS (TP), AND TOTAL POTASSIUM (TK, BOTTOM) FOR THE LWR SLOPE SCREEN AND SCREW PRESS.



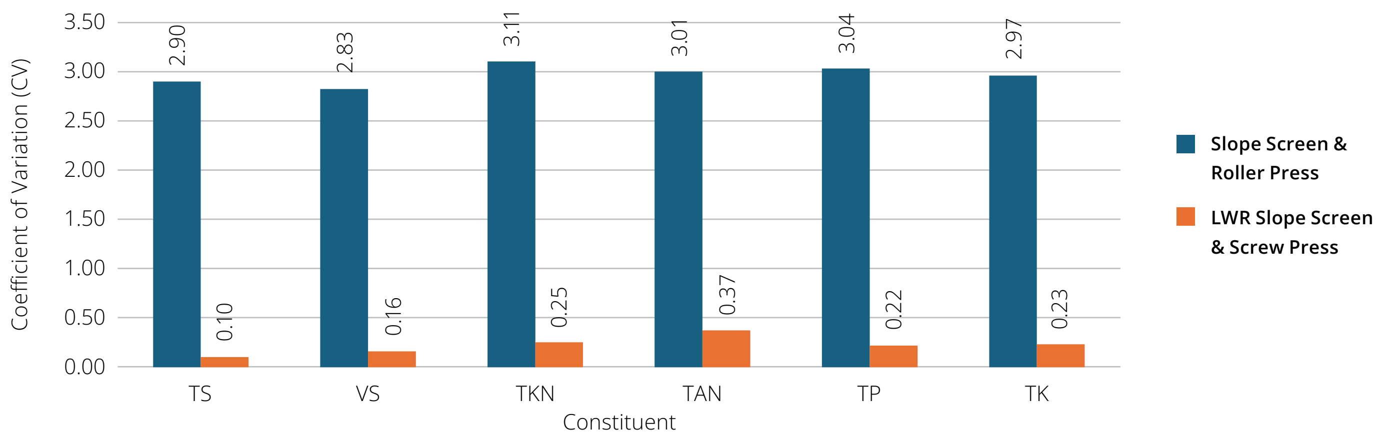
Enhanced Phosphorus Removal: Phosphorus removal was notably enhanced by the LWR "First Wave" system, with an average P concentration in the separated solids of 0.171%, compared to only 0.033% in solids from the roller press (Table 1). The system also exhibited high RE for P across its components (Figure 6), which is particularly important for farms managing phosphorus-sensitive soils. This enhanced P separation provides the farm with greater flexibility to meet nutrient management goals and reduces the risk of P buildup in fields and excess P runoff, thereby supporting sustainable land application practices and healthy soils. It should be noted that although the screw press provided drier solids, the mechanical action also broke some of the solids' flocculations allowing a portion of the nutrients to re-enter the liquid stream.

FIGURE 6: REMOVAL EFFICIENCY (RE) FOR TOTAL SOLIDS (TS), VOLATILE SOLIDS (VS), TOTAL KJELDAHL NITROGEN (TKN), TOTAL AMMONIUM NITROGEN (TAN), TOTAL PHOSPHORUS (TP), AND TOTAL POTASSIUM (TK) FOR THE SLOPE SCREEN & ROLLER PRESS, LWR SLOPE SCREEN, AND THE LWR SCREW PRESS.



Supports GHG Mitigation Through Volatile Solids Reduction: While improved separation of total and volatile solids contributes to better manure handling, the reduction in VS specifically plays a key role in lowering methane generation during manure storage. The LWR "First Wave" system achieved higher removal efficiency for VS compared to the slope screen and roller press (Figures 4, 6, and 7), supporting its potential contribution to GHG mitigation efforts. This environmental benefit adds value for farms seeking to lower their environmental footprint or participate in future carbon credit programs.

FIGURE 7: COEFFICIENT OF VARIATION (CV) FOR THE SEPARATION INDEX FOR TOTAL SOLIDS (TS), VOLATILE SOLIDS (VS), TOTAL KJELDAHL NITROGEN (TKN), TOTAL AMMONIUM NITROGEN (TAN), TOTAL PHOSPHORUS (TP), AND TOTAL POTASSIUM (TK).



Consistent and Reliable Performance: Finally, the LWR "First Wave" system delivered more consistent and stable separation performance over the 49-week sampling period than the roller press system. The coefficient of variation (CV) for the SI values was lower in the LWR "First Wave" system compared to the roller press system (Figure 7), indicating more reliable nutrient partitioning in daily operations. Such consistency is crucial for farms requiring predictable nutrient outputs to effectively plan storage, application, and meet regulatory environmental compliance.

Evaluation Key Challenges and Issues

High Operational and Maintenance Requirements: One of the primary challenges observed with the LWR "First Wave" system was the need for frequent and consistent maintenance to sustain its performance. As indicated by the variability in the SI values across the 45 sampling events (Figures 5 and 8), the system's effectiveness is sensitive to changes in operational conditions, including screen cleanliness, polymer dosing consistency, and equipment wear. Daily attention is required to manage the slope screens and presses, which may present a labor and logistical burden for farms without sufficient personnel or automation systems. Without regular cleaning and adjustments, separation efficiency can decline, leading to greater nutrient carryover into the liquid stream.

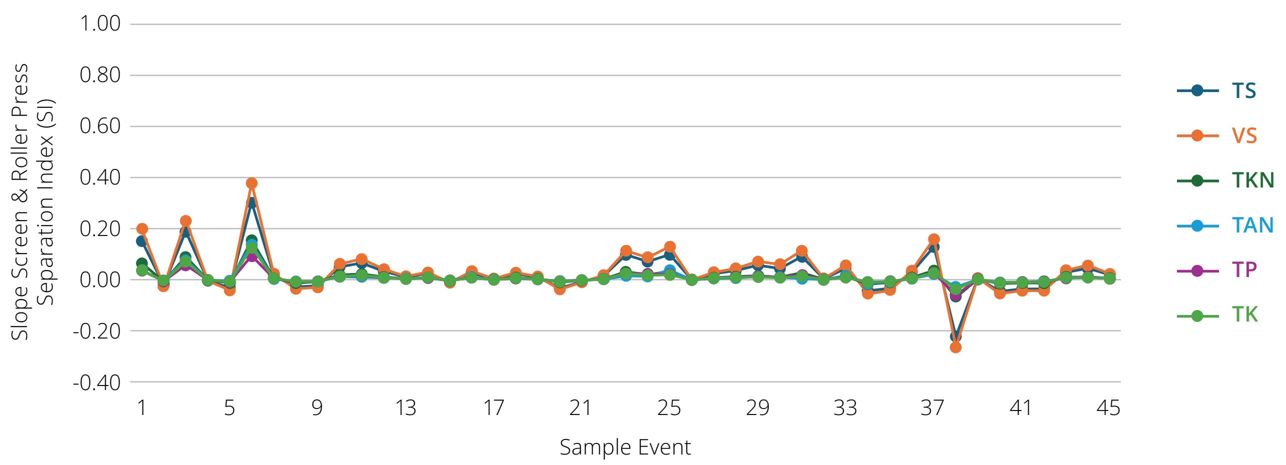
Limited Recovery of Dissolved Nutrients: While the LWR "First Wave" system demonstrated strong performance in separating TS, VS, and TP—with high SI and RE values shown in Figures 4 and 6—it was significantly less effective at recovering dissolved nutrients, particularly TAN and total potassium (TK). Table 1 illustrates that average TAN and TK concentrations in the liquid fraction post-screw press remained relatively high (0.09% and 0.12%, respectively), underscoring that these nutrients are not effectively partitioned into the solids. As a result, further treatment or careful nutrient management planning is required to handle these nutrients during land application. The system's inability to significantly concentrate TAN and TK in the solid fraction (Figures 4 and 6) may limit its utility for producers seeking to minimize nutrient loads in effluent destined for surface application or storage.

Performance Sensitivity to Manure Characteristics: The effectiveness of both the initial slope screen/roller press and the LWR "First Wave" system is highly dependent on the characteristics of the influent manure. For instance, the dilute nature of the manure stream (~4% TS, Table 1) limits the initial system's ability to efficiently separate constituents, leading to low SI values for the first separation step (Figure 8). This challenge highlights the importance of upstream water management and suggests that systems like the LWR "First Wave" perform best when used in tandem with manure pre-treatment processes that can optimize solids content.

IMPLICATIONS

The findings from this study underscore the potential of the LWR "First Wave" system to improve manure management through more effective separation of solids and enhanced nutrient concentration in the recovered materials. The system demonstrated strong performance in removing TS, VS, TKN, and TP compared to the conventional slope screen and roller press, indicating that the integration of chemical treatment with mechanical separation can yield more consistent and effective results under real-world conditions.

FIGURE 8: SEPARATION INDEX (SI) OVER TIME FOR TOTAL SOLIDS (TS, TOP), VOLATILE SOLIDS (VS), TOTAL KJELDAHL NITROGEN (TKN), TOTAL AMMONIUM NITROGEN (TAN), TOTAL PHOSPHORUS (TP), AND TOTAL POTASSIUM (TK, BOTTOM) FOR THE SLOPE SCREEN AND ROLLER PRESS.



By shifting more TP and TKN into the solid fraction, the LWR system creates a denser, more transportable product that can be managed off-site or used in accordance with the farm's nutrient management plan. This provides a practical strategy for reducing nutrient loading on phosphorus-saturated fields, expanding land application options, and improving the nutrient balance of effluent retained in storage lagoons. Additionally, by reducing VS content, the system may also contribute to lower methane emissions and reduced odor potential from storage.

However, the system was less effective at recovering TAN and TK, which remained in the liquid fraction. This limitation points to the need for complementary strategies to better manage dissolved nutrients—particularly in regions with regulatory or environmental sensitivities. The consistent daily oversight and maintenance required to ensure system performance also present operational considerations and labor limitations for producers evaluating its adoption.

Future research should focus on validating nutrient recovery performance across a broader range of farm conditions and seasons, assessing the long-term agronomic performance of separated solids and liquids when applied to fields, and exploring opportunities for recovering TAN and TK from the liquid stream. Studies that quantify the environmental benefits—such as reductions in GHG emissions or improved water quality—will also help further evaluate the full value proposition of the LWR "First Wave" system. With continued optimization and research, LWR offers a promising tool for modernizing manure management while supporting both environmental and operational goals on dairy farms.

For additional information on the vendor, environmental impacts, financial implications, and polymer-enhanced separation technology, visit the LWR Vendor Snapshot on the **Newtrient website**.

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NEWTRIENT™

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

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