NEWTRIENT EVALUATION SUMMARY

CONSERVATION INNOVATION GRANT (CIG):

BioFiltro Biodynamic Aerobic (BIDA®) System Vermifiltration Technology

Dairy Manure Treatment Innovations – Enhancing Water Quality and Sustainability

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INSIDE

BACKGROUND

The efficient utilization of dairy manure, a valuable agricultural by-product traditionally used to fertilize crops and maintain cattle well-being, presents a pressing challenge for farmers. Exploring optimal export avenues and on-farm management strategies is essential. Currently, there is a need for balance in manure management to prevent potential overapplication of manure nutrients onto fields, which could contribute to increased nitrate levels in local groundwater aquifers. To address this multifaceted issue, innovative solutions are imperative. Farmers require novel approaches to manure management that enhance water quality, preserve water resources, ensure compliance with regulatory standards, and support economic viability, necessitating a strategic reevaluation of current practices.

In response to this need, vermifiltration technology has emerged as a valuable alternative, providing a decentralized and environmentally friendly approach to wastewater treatment. At the forefront of this innovation is Royal Dairy, a sustainable dairy farm in Grant County, Washington. With a herd of approximately 6,000 milking cows, the farm faced the challenge of managing significant volumes of liquid manure. Recognizing the need for a sustainable solution, Austin Allred, the owner of Royal Dairy, implemented a pioneering wastewater treatment system in collaboration with BioFiltro, a leading bioremediation company. This system, known as the Biodynamic Aerobic (BIDA®) System, utilizes composting worm beds to efficiently remove excess nutrients from liquid manure while generating valuable worm casting compost.

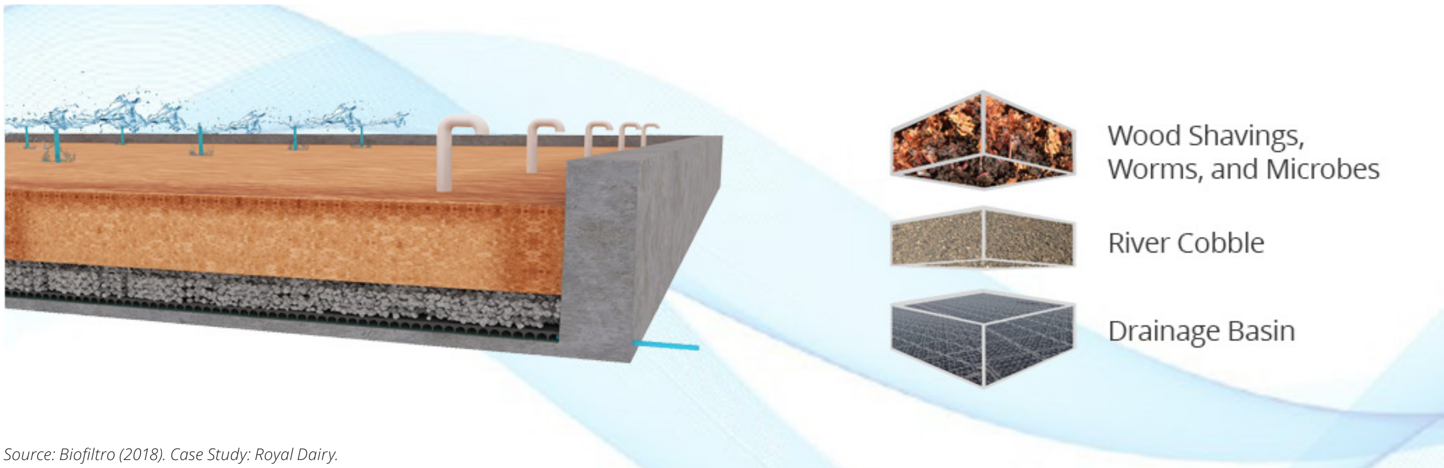
This study examined the efficiency of the vermifiltration system at Royal Dairy, analyzing its nutrient reduction capabilities in detail. By monitoring the system's performance over several months and under varying conditions, this evaluation aimed to provide valuable insights into the potential of vermifiltration as a sustainable solution for managing wastewater in large-scale agricultural operations. Through sampling and analysis, this study sheds light on the practicality and effectiveness of vermifiltration pertaining to the dairy industry.

INTRODUCTION

In recent years, vermifiltration has emerged as a promising technology for wastewater treatment, particularly in various agricultural settings. This innovative approach utilizes composting worm beds to filter wastewater, reducing its nutrient load significantly, and operates with minimal energy requirements (Arora and Saraswat, 2021). The process (Figure 1) involves applying influent wastewater via a sprinkler system, evenly over beds of high carbon source organic material, inhabited by earthworms, microbes, castings, and compost products. These organisms metabolize organic matter and nutrients from the influent, transforming it into a nutrient-rich soil amendment. Effluent is removed from the beds through a drainage basin located at their base and stored in a holding pond until reuse. Vermifiltration has gained attention for its efficacy in municipal, domestic, and industrial wastewater treatment, and more recently, in livestock farming contexts such as swine and dairy farms.

The vermifiltration process at Royal Dairy involves several stages, from the initial mechanical separation of solids to the final nutrient reduction in the BIDA beds. The technology's efficacy lies in the symbiotic relationship between earthworms, microbes, and the influent wastewater. As the wastewater passes through the vermifiltration beds, organic matter and nutrients are digested and transformed, leading to a significant reduction in nutrient content. This process not only yields nutrient-reduced water suitable for efficient and sustainable irrigation but also produces high-quality worm casting compost, providing circularity to the farm.

FIGURE 1: BIDA® SYSTEM DIAGRAM



Source: Biofiltro (2018). Case Study: Royal Dairy.

Treatment System at Royal Dairy

The wastewater treatment system at Royal Dairy involves multiple stages, including mechanical separation and vermifiltration (Figure 2). Initially, raw manure from the free stalls is flushed with water and directed to primary holding pits. From there, the manure wastewater is pumped through the first set of 40-mil slope screens (Screen System I) to remove larger solids. It then moves to a secondary holding pit and travels through a sand lane to a second set of 40-mil slope screens (Screen System II) for further separation. The clarified wastewater is stored in a 7-million gallon holding pond before entering the BIDA Equalization Tank (BIDA Inflow). Within the BIDA Equalization Tank, manure wastewater is stabilized to create a more optimal, uniform influent for the BIDA system. An automated system monitors the wastewater, releasing it via sprinkler to the BIDA bed irrigation system. In the BIDA beds, the water undergoes treatment for approximately four hours, where filter media and biota reduce excess nutrients and solids. The treated water drains to the bottom of the bed and is pumped into a 30-million-gallon pond (BIDA Outflow) for future use.

The Royal Dairy BIDA system comprises seven 46,000 ft^2 concrete beds and utilizes 500 worms/ft^2. This system can effectively reduce excess nutrients and solids in 200,000 gallons of manure wastewater per day by up to 70% and 90%, respectively, as estimated by Royal Dairy (Allred, 2019).

FIGURE 2: ROYAL DAIRY FARM WASTEWATER FLOW

METHODOLOGY

Central Washington University (CWU) conducted a 15-week monitoring trial of the Royal Dairy BIDA system from August 15 to December 23, 2022. Liquid manure and compost samples were collected three times weekly from various points in the system. Liquid manure samples were taken at five locations, where they were then mixed and stored in 16-oz. bottles. Solid compost samples were collected using a pitchfork and placed in plastic bags.

During the study, operational changes occurred, impacting the study's duration and sampling locations. Flow interruptions in the BIDA system due to freezing temperatures led to adjustments in sampling procedures, requiring the collection of BIDA Outflow samples from an underground mixing pit. This pit contained effluent from two out of seven system beds, and the collected samples were stagnant and had been sitting in the pit. BIDA system overloading incidents led to a shutdown from September 10-13, and maintenance on the 7-million-gallon lagoon that feeds the BIDA's equalization tank occurred from October 26 to November 11. Consequently, the study was extended by three weeks to achieve a full 15 weeks of sampling, concluding with final samples taken on December 23, 2022.

Samples were transported to A&L Great Lakes Laboratories for analysis, following recommended methods of manure analysis. Various tests, including pH, moisture content, solids percentage, macro and micro-nutrient concentrations, and organic matter, were conducted on liquid manure and solid compost samples. Statistical analyses were performed using R software and XLSTAT. Methods included identifying outliers, normality tests, non-parametric tests for differences between sampling locations, and trend analyses. Efficiency was evaluated in terms of nutrient load, converting concentrations to lb./day using manure density and 24-hour flow data. The study focused on characterizing the wastewater pathway and evaluating the BIDA system's efficiency, providing valuable data for understanding its performance in nutrient reduction.

DISCUSSION OF RESULTS

The study conducted at Royal Dairy in central Washington provides valuable insights into the application of vermifiltration technology. This comprehensive analysis evaluated the efficiency of a full-scale vermifiltration system in reducing nutrient loads from liquid manure.

Key Benefits of Vermifiltration

Performance: Although operational variability took place during the study, the effectiveness of the BIDA system in reducing nutrients is evident through substantial decreases in several measured parameters, as the liquid manure progresses from the BIDA Inflow to the BIDA Outflow. Notable reductions in organic carbon (OC), Total *Kjeldahl* Nitrogen (TKN), ammonia-nitrogen (NH_4), phosphorus (P), and calcium (Ca) were documented throughout the BIDA system (Table 1); however, other nutrients such as potassium (K) and sodium (Na) did not experience reductions. Despite the limitations of percent change calculations, which do not consider influent concentration and system usage, they offer a comprehensive overview of nutrient reductions, ranging from 45% to 67% across various elements. These findings underscore the pivotal role of the BIDA system in efficiently diminishing nutrient loads, contributing to a more sustainable wastewater treatment process at Royal Dairy. In humid climates, it is advisable to cover the BIDA system to prevent potential issues such as excess moisture and leaching through the bed.

TABLE 1: CONCENTRATIONS FOR SELECTED NUTRIENTS FOR BIDA INFLOW AND OUTFLOW AND PERCENT CHANGE

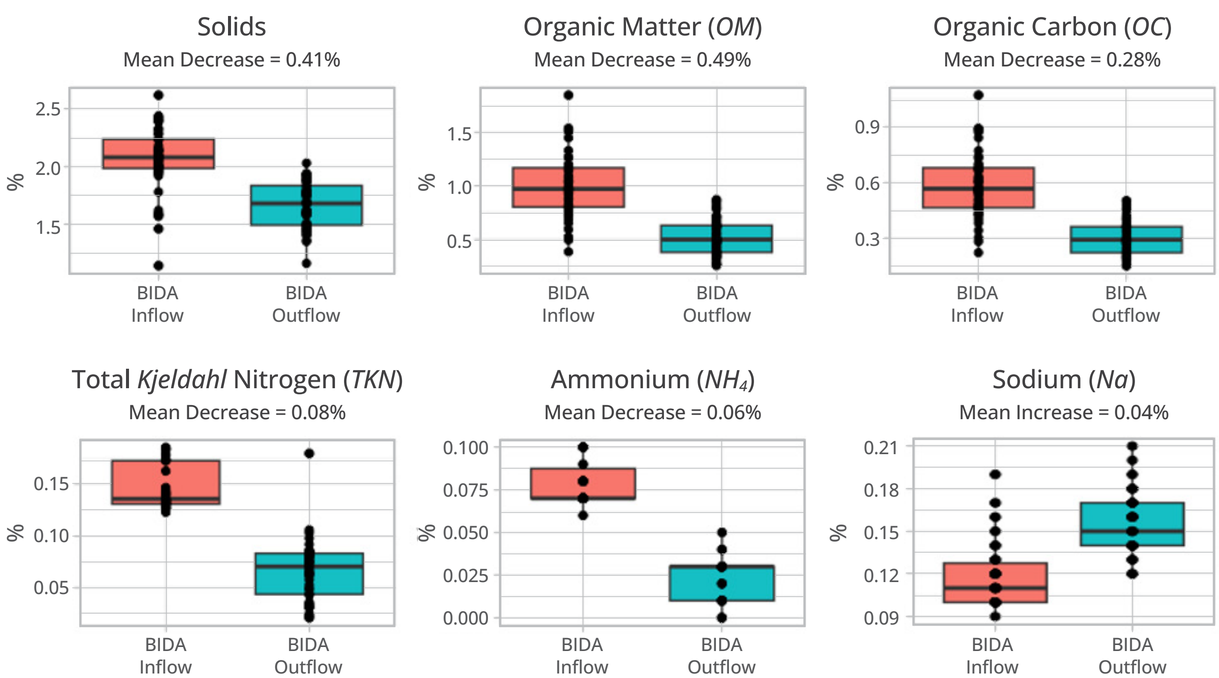
	BIDA INFLUENT			BIDA EFFLUENT			CHANGE (IN-OUT)	
Parameter	Median wt %	Ave wt %	Std Dev wt %	Median wt %	Ave wt %	Std Dev wt %	Ave %	Std Dev %
Organic Carbon	0.57	0.59	0.15	0.29	0.31	0.09	45	19
Total *Kjeldahl* Nitrogen	0.14	0.15	0.02	0.075	0.07	0.03	51	18
Ammonia-Nitrogen	0.07	0.08	0.01	0.03	0.02	0.01	67	14
Phosphorus	0.02	0.02	0.003	0.011	0.01	0.004	46	25
Potassium	0.169	0.17	0.02	0.17	0.17	0.04	-2	25
Calcium	0.06	0.06	0.01	0.03	0.02	0.01	56	28
Sodium	0.11	0.12	0.02	0.15	0.16	0.02	-30	29

Reduction in Nutrients: The vermifiltration system emerged as a pivotal component of the wastewater treatment process, demonstrating substantial nutrient reduction capabilities. Statistical analyses reveal significant decreases in organic carbon (OC), Total *Kjeldahl* Nitrogen (TKN), ammonia-nitrogen (NH_4), phosphorus (P), and calcium (Ca) as the liquid manure traverses from the BIDA Inflow to the BIDA Outflow. However, it's crucial to consider that there is a notable increase in sodium (Na) of approximately 30%, which contrasts with the reductions observed in other vital nutrients. Notably, the BIDA system's impact on nitrogen reduction is substantial, with TKN showing a 51% average decrease.

By effectively minimizing total nitrogen concentrations, the treated effluent becomes more suitable for reuse on the dairy, specifically for irrigation and flush water. This reuse aligns with sustainable water management practices, allowing the dairy to optimize its water resources, protect water quality, and promote a closed-loop system.

Furthermore, the benefits of reducing total nutrients in the effluent extend beyond the immediate operational considerations of the dairy. The treated water, now containing lower nutrient loads, contributes to the protection and preservation of local waterways, ensuring environmentally responsible management of nutrients in a way that is supportive of the overall health of the surrounding aquatic environment. This dual-purpose achievement—enhancing on-site water reuse while safeguarding downstream water quality—reflects a comprehensive and sustainable approach to dairy wastewater management.

FIGURE 3: BOX PLOTS SHOWING CHANGE IN NUTRIENT CONCENTRATIONS ACROSS BIDA SYSTEM



Reduction in Solids: Beyond its capacity for nutrient reduction, the BIDA system demonstrates notable efficacy in attenuating solid content within the liquid manure. The system achieves a notable decrease in solids from 41,000 lbs./day at the first set of screens to 27,000 lbs./day upon exiting the BIDA system, reflecting a reduction of 14,000 lbs./day or a 34% reduction in solid content (Table 2). This decrease encompasses the contribution of the BIDA beds, where a specific reduction of 5,800 lbs./day occurs.

Solid separation is an essential pre-treatment that simultaneously generates valuable fiber, providing the option to utilize it on the dairy as bedding, compost, or fertilizer or market it for sale. Without this preliminary step, the sprinklers are prone to clogging, leading to an uneven application of lagoon water onto the filter surface, highlighting the importance of effective solids removal for the optimal functioning of the treatment process. Additionally, an excess of solids in the effluent may accumulate in the BIDA bed, potentially diminishing the inflow into the bed by sealing or "blinding" the surface. This could result in anaerobic conditions and significantly impair the overall performance of the system. The combined efforts of these treatment components underscore the efficacy of Royal Dairy's system approach to mitigating solids and emphasize the specific contributions of each stage in the overall reduction process.

Evaluation Key Issues and Challenges

Operational Variability: The operational dynamics of the BIDA system displayed inconsistency during the study period, marked by fluctuating flow rates and two extended shutdowns, one lasting nearly a month. Irrigation patterns across the BIDA beds were irregular, with certain beds receiving more frequent irrigation than others. Moreover, the study observed substantial changes in temperature and humidity, transitioning from unseasonably warm conditions with low humidity in early fall to freezing temperatures and higher humidity in December. These dynamic environmental shifts likely played a role in the observed variability in BIDA system efficiency.

Operational adjustments were necessitated throughout the study, impacting both its duration and specific sampling locations. Interruptions in the flow through the BIDA system and lagoon maintenance prompted the field researcher to collect samples from an underground mixing pit. These samples, stagnant and residing in the pit for some time, posed challenges. Overloading incidents and dairy lagoon maintenance further extended the study by three weeks to ensure a comprehensive 15-week sampling period.

Inconsistent Nitrogen Removal Efficiency: The efficiency of the BIDA system in nitrogen removal displayed significant variability, ranging from approximately 30% to 80%.

TABLE 2: TOTAL MASS PER DAY OF SOLIDS AND NUTRIENTS ALONG WASTEWATER TREATMENT PATH

	TOTAL SOLIDS (1000 lbs./day)			ORGANIC MATTER (1000 lbs./day)			TOTAL KJELDAHL NITROGEN (1000 lbs./day)		
	Median	Ave	Std Dev	Median	Ave	Std Dev	Median	Ave	Std Dev
Screen I Inflow	41	41	23	20	23	14	2.5	2.4	1.4
Screen I Outflow	41	38	21	20	20	11	2.5	2.3	1.4
Screen II Outflow	38	36	17	19	19	9	2.6	2.5	1.3
BIDA Inflow	35	33	15	24	16	8	3.3	2.3	1.0
BIDA Outflow	27	27	14	8	9	6	1.1	1.2	0.7

A correlation between Total *Kjeldahl* Nitrogen (TKN) reduction and humidity, coupled with wetting and drying events, underscored the sensitivity of the vermiculture bed's nutrient uptake to moisture conditions in the compost material. Notably, the higher nitrogen removal efficiency observed immediately after a brief shutdown in September suggested the potential impact of the drying process during that period.

Sodium Concentration in Wastewater Treatment: The analysis revealed a notable increase in sodium (Na) concentration within the liquid manure along the wastewater treatment flow path. This rise is likely attributed to a combination of evaporation and the absence of biological uptake of sodium. Interestingly, a significant reduction in sodium concentration was observed across the inclined screens, indicating the potential retention of sodium in the filter bed. Subsequently, samples collected from a holding tank for BIDA effluent exhibited anomalously high Na concentrations. These findings raise questions about the mechanisms of sodium accumulation within the BIDA beds and its release during effluent application, warranting further investigation into the source and dynamics of sodium in the wastewater treatment process.

IMPLICATIONS

Key findings underscored the substantial role of the vermifiltration system in reducing solids and nutrients at Royal Dairy. However, operational inconsistencies, varying weather conditions, and anomalies in nutrient concentrations posed challenges to consistent efficiency.

To further explore and refine these insights, future studies could delve into seasonal trends in nutrient reduction, examining their correlation with weather conditions, particularly humidity. Additionally, a comparative analysis of efficiency and irrigation patterns, incorporating periodic short-term shutdowns for bed drying, could provide deeper insights. Measures of biological uptake, emissions from BIDA beds, and a detailed examination of compost composition, particularly sodium accumulation, could contribute to a more comprehensive understanding of nutrient fluxes. Lastly, investigating worm density and soil health over time and across seasons, coupled with a comparison to BIDA efficiency, would offer valuable insights into the interplay between biological factors and system performance.
For additional information on the vendor, environmental impacts, financial implications, and BioFiltro vermifiltration technology, visit the BioFiltro Vendor Snapshot on the **Newtrient website**.

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

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