NEWTRIENT EVALUATION SUMMARY

NEW YORK FARM VIABILITY INSTITUTE & NRCS CONSERVATION INNOVATION GRANT:

Nitrogen Fixation Technology by Plasma Injection

Dairy Manure Treatment Innovations – Enhancing Water Quality and Sustainability

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INSIDE

BACKGROUND

Dairy farms generate significant amounts of manure, which must be managed in ways that minimize environmental impacts such as greenhouse gas (GHG) emissions and nutrient runoff and leaching. Traditional manure storage and land application practices often result in the release of methane (CH_4), ammonia (NH_3), and nitrous oxide (N_2O), all of which contribute to air and water quality concerns.

The N2 Applied plasma technology was developed to address these environmental challenges by treating and enriching manure with nitrogen, creating a nitrogen-enriched organic (NEO) liquid. This process is intended to reduce emissions during storage and provide a more stable, nitrogen-rich nutrient fertilizer product, which could reduce the need for synthetic fertilizers.

In 2023, a demonstration unit of the N2 Applied plasma system was deployed at CoBar Dairy in Mount Upton, New York. This evaluation was conducted over several months to assess the system's performance, particularly its ability to reduce GHG and NH_3 emissions from dairy manure. The test compared emissions from untreated slurry and the NEO produced by the system, using both static and flowthrough manure treatment tanks. The study also measured the energy consumption and economic feasibility of the system, evaluated operational challenges and maintenance requirements, and monitored the long-term stability of the NEO product.

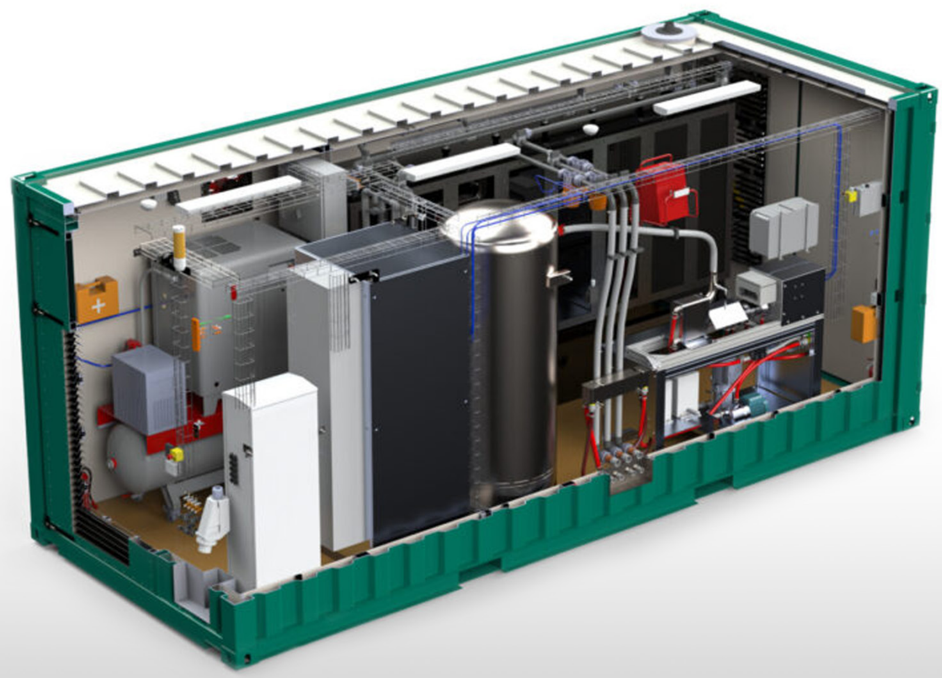
INTRODUCTION

The N2 Applied technology is a cutting-edge manure treatment system designed to elevate and preserve nitrogen levels in manure while simultaneously reducing the emissions of environmentally significant gases, specifically CH_4 and NH_3. This innovative system is housed in a shipping container and utilizes ambient air compression along with a high-voltage plasma torch to convert atmospheric nitrogen (N_2) and oxygen (O_2) gases into reactive nitrogen oxides (NOx). The generated NOx is then absorbed into separated liquid manure through a venturi and recirculation process, reacting with the waste until a targeted pH decrease of typically 5.0 is achieved. From this process, the acidified NEO is produced.

This treatment process effectively lowers the pH, which inhibits the microbial generation of CH_4 and promotes the formation of ammonium (NH_4^+) over the more volatile NH_3. Consequently, this technology mitigates emissions that are harmful to both air quality and surrounding water systems while enhancing the efficiency of nutrient utilization in manure.

The N2 Applied technology holds unique potential for enhancing dairy manure management and may be particularly beneficial for small farms. While this system has been trialed in Europe, its evaluation on U.S. dairy farms had not previously been conducted, making this study at CoBar Dairy a significant step in assessing its applicability and effectiveness in North American agriculture.

FIGURE 1: N2 APPLIED SYSTEM DIAGRAM



Source: **https://n2applied.com/the-technology/**

THE PROCESS

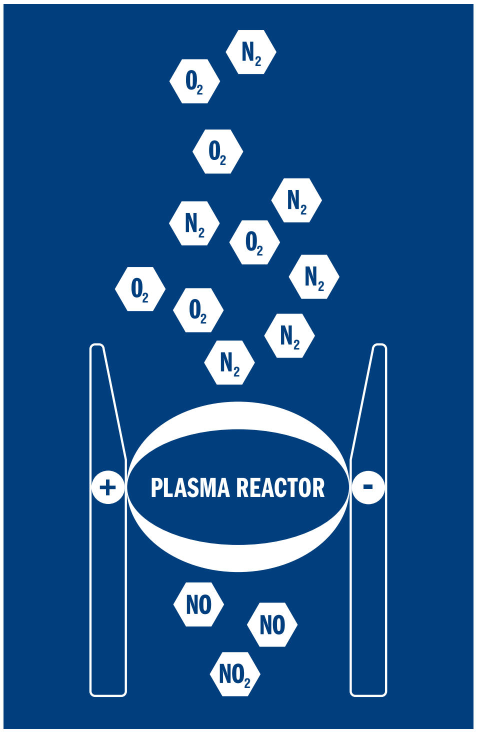
The N2 Applied technology operates in two primary phases: plasma generation and absorption.

Phase 1: Plasma Generation – In this initial step, electricity is utilized to dissociate N_2 and O_2 molecules found in the atmosphere. This process results in the formation of reactive nitrogen gas from the atomic nitrogen (N) and oxygen (O) recombining to form NOx.

Phase 2: Absorption – The reactive nitrogen gas, NOx, is then absorbed into the liquid component of organic materials, such as livestock slurry or biogas digestate, forming an acidic solution. This interaction converts the nitrogen into a form that is readily available for plant uptake. This NOx is mixed with the manure effluent until the desired acidic (pH) set point is reached.

The introduction of reactive nitrogen enhances the organic material by enriching it with nitrogen that plants can readily use, while also stabilizing ammonium nitrogen to minimize losses. Furthermore, by suppressing microbial activity, the plasma treatment effectively prevents the generation of CH_4 – a potent greenhouse gas. This ensures that both organic carbon and nitrogen remain intact during storage, allowing them to be utilized in the field, where they contribute to building long-term soil health and fertility (N2 Applied, 2024).

FIGURE 2: N2 APPLIED PLASMA TECHNOLOGY



Source: **https://n2applied.com/the-technology/**

METHODOLOGY

During the 2023 growing season, Cornell University led a pilot research-scale study at CoBar Dairy utilizing the N2 Applied demonstration unit (model MK 4.4) operated by ProStar Energy. The N2 Applied unit was initiated on May 15, 2023, and dairy manure was scraped multiple times daily into a below-grade circular concrete storage structure. A lift pump transferred the manure to a screw press solid-liquid separation system, from which the separated liquids were treated in the N2 Applied unit. Approximately 20 gallons of separated manure liquids were processed in a sequential batch until the pH fell below a setpoint, initially set at 5.5 and later adjusted to 5.0 on August 16, 2023. When operational, the N2 Applied unit treated slurry to produce approximately 25-55 gallons of NEO each hour. During the first continuous runtime (May 15 - June 23), about 15,000 gallons of NEO were generated. In the second continuous runtime (August 7 - September 17), around 20,000 gallons were produced. Early in the study, production rates reached 1,055 gallons/day, but later averaged 534 gallons/day—roughly equivalent to the manure from 30 lactating cows per day. This was significantly lower than the expected processing capacity of 200 cows per day, likely due to challenges with solid-liquid separation and manure buffering capacity. It should be noted that the demonstration unit was designed using European electrical systems, which may have contributed to some of the capacity issues. The resulting NEO was pumped out for farm crop usage, while the separated solids served as soil amendments.

To simulate long-term manure storage, on May 20, 2023, two vertical cylindrical polytanks (1,100 gallons) were filled with approximately 800 gallons each of NEO and untreated separated manure liquids. Airflow across the surface of these tanks was maintained to align with industry recommendations (VERA, 2018). Two horizontal steel flowthrough tanks (11,000 gallons) received NEO and slurry at comparable production rates, with overflows directing slurry to long-term storage while NEO overflowed into a collection tote.

Manure sampling began on May 24, 2023, and was conducted three times a week through September 2023. Samples included raw manure, separated liquids, NEO effluent, and slurry, which were transported to A & L Great Lakes Laboratories for analysis of pH, total solids, nitrogen fractions, phosphorus, and potassium. Air emissions were monitored starting May 22, 2023, using gas analyzers to measure concentrations of CH_4, NH_3, NOx, O_2, carbon dioxide (CO_2), and hydrogen sulfide (H_2S).

Key sampling events included the large NEO tank filling on June 16, 2023, and the large slurry tank filling on June 22, 2023. The N2 Applied unit was turned off due to manure shortages on June 23, 2023, and restarted on June 30, 2023. However, the large NEO tank foamed and destabilized on July 2, 2023, likely as a result of the emission of nitrogenous gases. The unit was restarted at a pH of 4.5 on August 7, 2023, and adjustments were made to reach a pH of 5.0 on August 16, 2023. The large tanks were full by August 25, 2023. The study concluded when the N2 Applied unit foamed out of the exhaust vent and was turned off on September 17, 2023.

Temperature loggers recorded data in the filled small static and large flowthrough tanks hourly, which generally tracked ambient temperatures but were usually warmer. Energy usage for the N2 Applied unit was tracked through a newly installed three-phase utility service, with total electricity consumption monitored via utility meters to ensure accurate reporting of power requirements for the system, considering the discrepancies of power consumption between Europe and the U.S.

DISCUSSION OF RESULTS

This study provides valuable insights into the application of N2 Applied technology for dairy manure management. This comprehensive analysis evaluated the efficiency of the N2 Applied unit in producing NEO and its impact on nutrient reduction from liquid manure.

Key Benefits of N2 Applied Technology

Enhanced Nutrient Profiles: The N2 Applied technology significantly enhances the nutrient profile of dairy manure, particularly increasing its nitrogen content. During the treatment process, total nitrogen in the NEO increased by approximately 57% in static tanks and 45% in large tanks, primarily due to elevated nitrate levels. This transformation from trace amounts to 0.17% nitrate in NEO allows for better nutrient availability when applied to crops, promoting healthier soil, improved plant growth, and decreased risk for nutrient runoff and leaching into waterways. Figures 3 and 4 illustrate these changes in nitrogen content, emphasizing the technology's effectiveness in nutrient enrichment.

FIGURE 3: TOTAL N IN NEO AND SLURRY IN STATIC TANKS

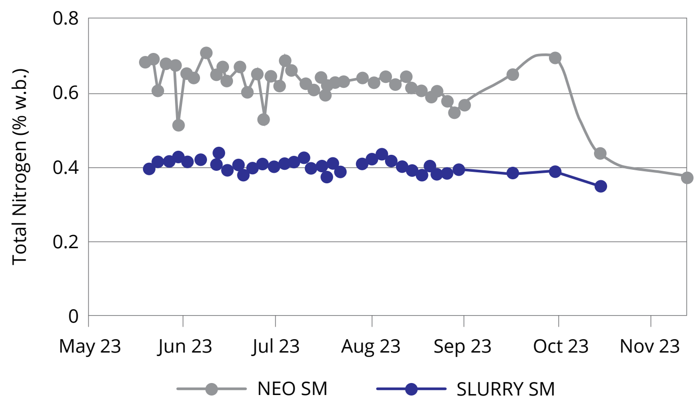
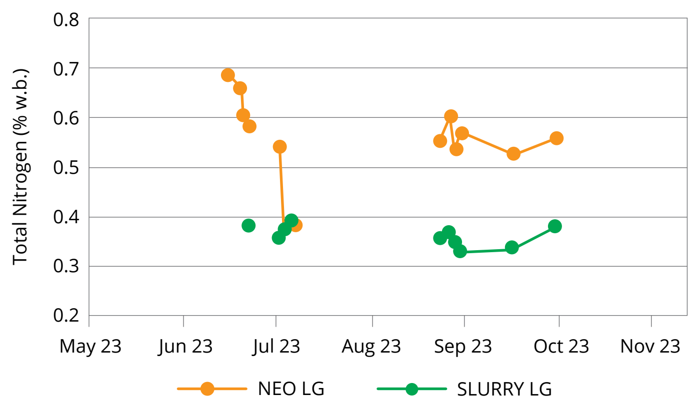


FIGURE 4: TOTAL N IN NEO AND SLURRY FLOWTHROUGH TANKS



Chemical Stability: One of the critical benefits of the N2 Applied process is its ability to dramatically reduce the pH of manure from 6.70 to as low as 5.03. Throughout the study, a consistent pH differential was maintained, ensuring the stability of the NEO produced. Figures 5 and 6 show the pH levels over time, highlighting the treatment's effectiveness in pH management and nutrient stability. A consistent 5.5 or lower pH was maintained in the static manure tanks throughout the study, although a rapid pH rise was observed in October and November, while the flowthrough tanks showed a stable pH between inflows and outflows, except for a sudden increase in the large (LG) NEO tank in late June. The physical properties of the manure slurry, such as moisture and solids content, remain largely unchanged, ensuring that the slurry's handling characteristics are maintained (Table 1).

FIGURE 5: PH OF NEO AND SLURRY IN STATIC TANKS

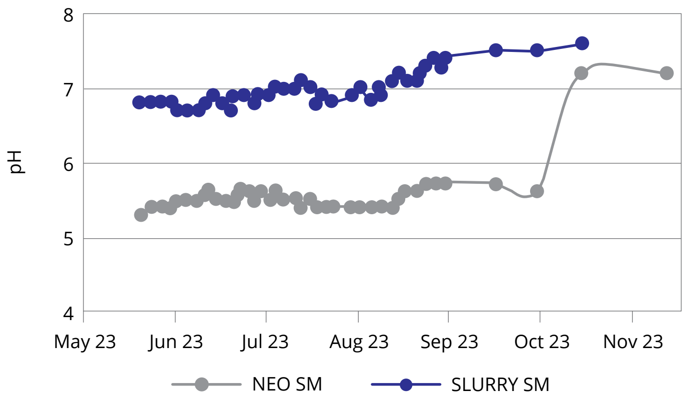


FIGURE 6: PH OF NEO AND SLURRY IN FLOWTHROUGH TANKS

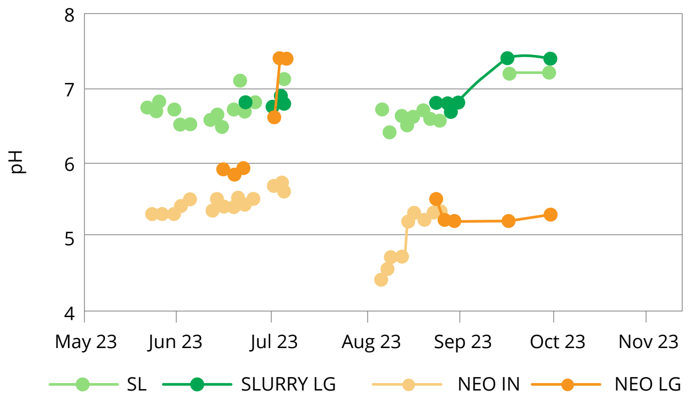


TABLE 1: AVERAGE ± STANDARD DEVIATION PERCENTAGES

Average ± standard deviation percentage (wet basis) of moisture content, total solids, total *Kjeldahl* nitrogen (TKN), ammonium nitrogen (NH_4-N), organic nitrogen (Org-N), nitrate nitrogen (NO_3-N), total nitrogen (TN), phosphorus (P), potassium (K), and pH for each sample from May 20 to Sept 17. n = number of samples.

Sample	n	Moisture	Solids	TKN	NH_4-N	Org-N	NO_3-N	TN	P	K	pH
Raw manure	25	90.71±1.25	9.29 ± 1.25	0.36±0.03	0.16±0.03	0.20±0.03	0.000±0.000	0.36±0.03	0.06±0.00	0.27±0.02	6.67±0.21
Separated manure liquids	27	94.31±0.58	5.69±0.58	0.37±0.04	0.18±0.03	0.20±0.03	0.001±0.003	0.37±0.04	0.06±0.01	0.27±0.02	6.70 ± 0.18
NEO, N2 Applied unit outflow	27	94.15±0.59	5.85±0.59	0.46±0.04	0.16 ±0.01	0.30± 0.04	0.166±0.044	0.63±0.06	0.06±0.01	0.28±0.03	5.26±0.32
Slurry, lg. flowthrough tank outflow	9	94.13±0.78	5.87±0.78	0.36±0.02	0.19±0.02	0.17±0.01	0.002±0.004	0.36±0.02	0.05±0.01	0.28±0.03	6.86±0.21
NEO, lg. flowthrough tank outflow	12	94.07±0.69	5.93±0.69	0.44±0.05	0.16±0.02	0.28±0.04	0.115±0.059	0.55±0.09	0.05±0.01	0.28±0.01	5.93±0.80
Slurry, sm. static tank	40	94.21±0.28	5.79±0.28	0.40±0.02	0.23±0.01	0.17±0.02	0.002±0.007	0.40±0.02	0.06±0.01	0.30±0.01	6.96±0.21
NEO, sm. static tank	40	93.41±0.20	6.59±0.20	0.48±0.03	0.17±0.01	0.32±0.03	0.143±0.041	0.63±0.04	0.06±0.00	0.30±0.01	5.49±0.12

Emissions Reduction: The N2 Applied technology dramatically reduces NH_3 emissions, with levels from NEO tanks averaging less than 10 ppm, compared to an average of 67 ppm from static slurry tanks. This reduction contributes to improved air quality and minimizes the potential for environmental contamination.

Furthermore, the technology also showed lower levels of CH_4 emissions from NEO tanks, averaging no more than 3 ppm, while slurry emissions frequently exceeded 1,000 ppm. Figures 7 and 8 detail these findings, underscoring the environmental benefits of using N2 Applied in dairy manure management.

FIGURE 7: NH_3 FROM NEO AND SLURRY STATIC TANKS

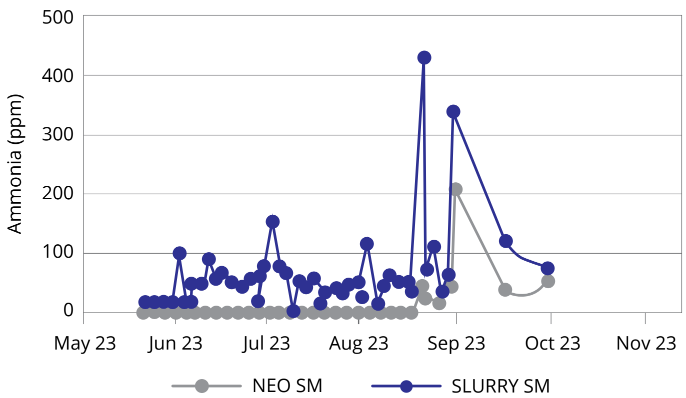
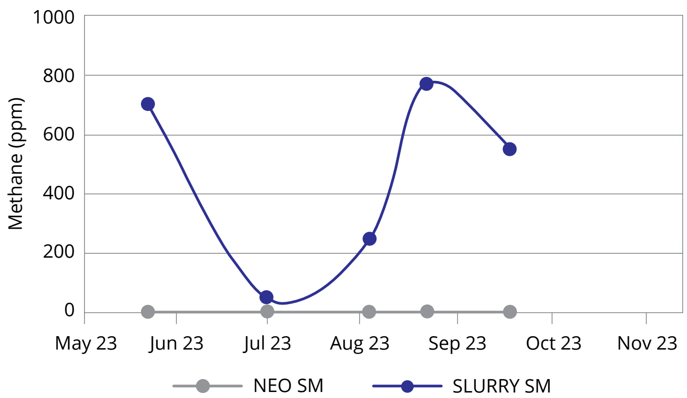
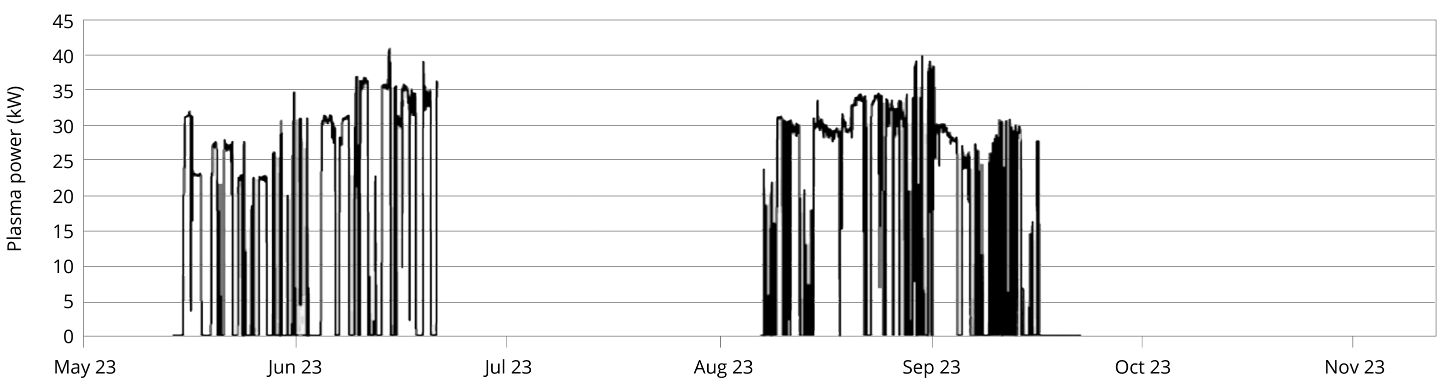


FIGURE 8: CH_4 FROM NEO AND SLURRY STATIC TANKS



Energy Efficiency and Economic Viability: The N2 Applied technology demonstrates operational efficiency with an electricity consumption rate of 1.25 kWh per gallon of NEO produced. With projected annual electricity costs of the demonstration unit to be approximately $26,840 for continuous operation, the system presents a potentially feasible economic model for dairy farms. The anticipated efficiency improvements in newer models, described by the technology provider, may further reduce operational costs. Figure 9 provides insight into the power usage patterns, reinforcing the economic viability of adopting this technology in manure management.

FIGURE 9: MACHINE-REPORTED PLASMA TORCH DC POWER DRAW



Evaluation Key Issues and Challenges

Regular Maintenance: The N2 Applied unit requires regular maintenance to ensure optimal performance. One critical component is the plasma torch, which uses significant power to create a plasma of compressed ambient air injected into the manure. The torch's copper core degrades with use and needs refurbishment every 12 to 14 days. This process involves stopping the unit, refurbishing or replacing the copper core, and restarting the unit, which incurs downtime and maintenance costs. Additionally, the unit uses defoamer to manage foaming events, with approximately 15 gallons used over six months. Faults in the foam indication sensor led to increased defoamer usage, occurring twice during this study, and required consistency checks. The mixing towers within the unit also need periodic cleaning to remove solids build-up, especially after long periods of inactivity. This involves disassembling, power washing, drying, and reassembling the components.

Integration and System Compatibility: Integrating the European-designed N2 Applied unit with the U.S. farm system posed several challenges. The unbalanced loads and the need for voltage and frequency conversion led to faults and system errors. The farm also lacked the necessary infrastructure, requiring the setup of pumps, separators, and conveyance systems. Many of the components chosen were undersized or improperly installed, causing pump cavitation, clogs, and manure supply issues. These integration challenges highlighted the importance of system-level compatibility for successful manure treatment.

Operational Stability: Operational stability was another key issue, particularly with the destabilization of the NEO. Inconsistent operation and potential comingling of untreated slurry led to denitrification in the large flowthrough NEO tank, causing a rapid pH increase and foaming. Seasonal temperature changes may have also contributed to this instability. Additionally, the unit experienced overheating issues, particularly in the control panel, due to heat generated by the air compressor and transformers. Ventilation improvements performed during the study, such as installing vents and exhaust fans, were necessary to prevent downtime.

Controls and Sensors: The N2 Applied unit faced several issues with controls and sensors. Initial software problems prevented remote monitoring and control, requiring a new internet service provider. Sensor faults, particularly with the foam level indicator, led to operational disruptions and required replacements. The foam level sensor was sensitive to substantial ambient temperature changes, causing foam to overflow from the unit's exhaust during overnight temperature drops. Furthermore, the original air compressor was inadequate and needed replacement, and valve issues with the compressed air supply required repairs. These challenges underscored the need for reliable controls and high-quality components to ensure smooth operation.

IMPLICATIONS

Key findings indicate that the N2 Applied technology effectively enriches nitrogen in manure and reduces NH_3 and CH_4 emissions during the summer months. However, long-term stability, especially in colder months, remains unassessed, with late-trial NH_3 emissions suggesting potential stability issues. Operational challenges and intermittent use hindered a full evaluation of the unit's efficacy and economic viability. Continuous operation of the new, commercial Gen 0 unit is needed to accurately assess treatment effects, production rates, and costs. Initial estimates suggest the system may be cost-prohibitive without substantial carbon credit incentives, though improved efficiencies in the Gen 0 unit are expected. Additionally, both the N2 Applied unit and NEO storage are potential sources of NOx emissions, requiring careful monitoring. Agronomic trials and field emissions monitoring are necessary to ensure NEO can enhance crop yield and quality without increasing emissions of NH_3, N_2O, or other pollutants. Despite these challenges, the N2 Applied technology shows significant promise for sustainable manure and nutrient management with further optimization and continuous operation trials.

For additional information on the vendor, environmental impacts, financial implications, and N2 Applied technology visit the N2 Applied Vendor Snapshot on the **Newtrient website**.

REFERENCES

N2 Applied (2024) **https://n2applied.com/the-technology/**

VERA (2018) VERA Test Protocol: Covers and other Mitigation Technologies for Reduction of Gaseous Emissions from Stored Manure. Version 3:2018-07

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

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