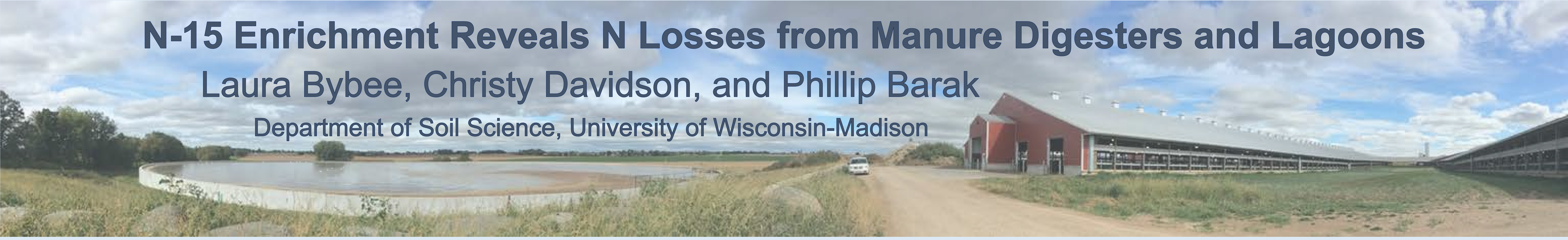

N-15 Enrichment Reveals N Losses from Manure Digesters and Lagoons

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Introduction

Ammonia volatilization has one of the highest isotopic fractionation factors in the N cycle and ammonia loss causes the greatest degree of $\delta^{15}N$ enrichment. When ammonium deprotonates to ammonia and volatilizes from the solution, there is a fractionation factor of 1.034 (Kirshenbaum et al., 1947), leaving the ammonium left behind enriched in ^{15}N. The enrichment signature can be used to track nitrogen losses in manure handling systems. Isotopic analysis may provide a simple, cost-effective method to track nitrogen losses from manure digesters and lagoons compared to mass balance methods.

Objectives

- Model nitrogen losses from manure handling systems using $\delta^{15}N$ enrichment.
- Verify $\delta^{15}N$ changes using a relationship between conserved ions (K, Na, and Cl) and nitrogen measurements in the lagoon feed and lagoon.

Methods

Samples were collected at various points in the manure handling process at ten WI dairy operations chosen from the AgSTAR Database (Fig. 1). The farms had anaerobic digesters and solid-liquid separation before the digester effluent was sent to storage lagoons.

Sites were sampled in the spring and fall at the time of field application, at minimum from pre-digestion manure, separated liquid post-digestion and storage lagoons (Fig. 2). If a dairy operation had an ammonia recovery system samples were collected there as well.

Figure 1. Ten sites from the AgSTAR Database.

Lagoon samples were collected at field application (preferred) or as surface grab samples. Analysis included the following:

- $\delta^{15}N$
- Soluble (P, K, Ca, Mg, S, Na, NH_4-N, Cl)
- Total (P, K, Ca, Mg, S, Na, N)
- pH, EC, Percent Solids

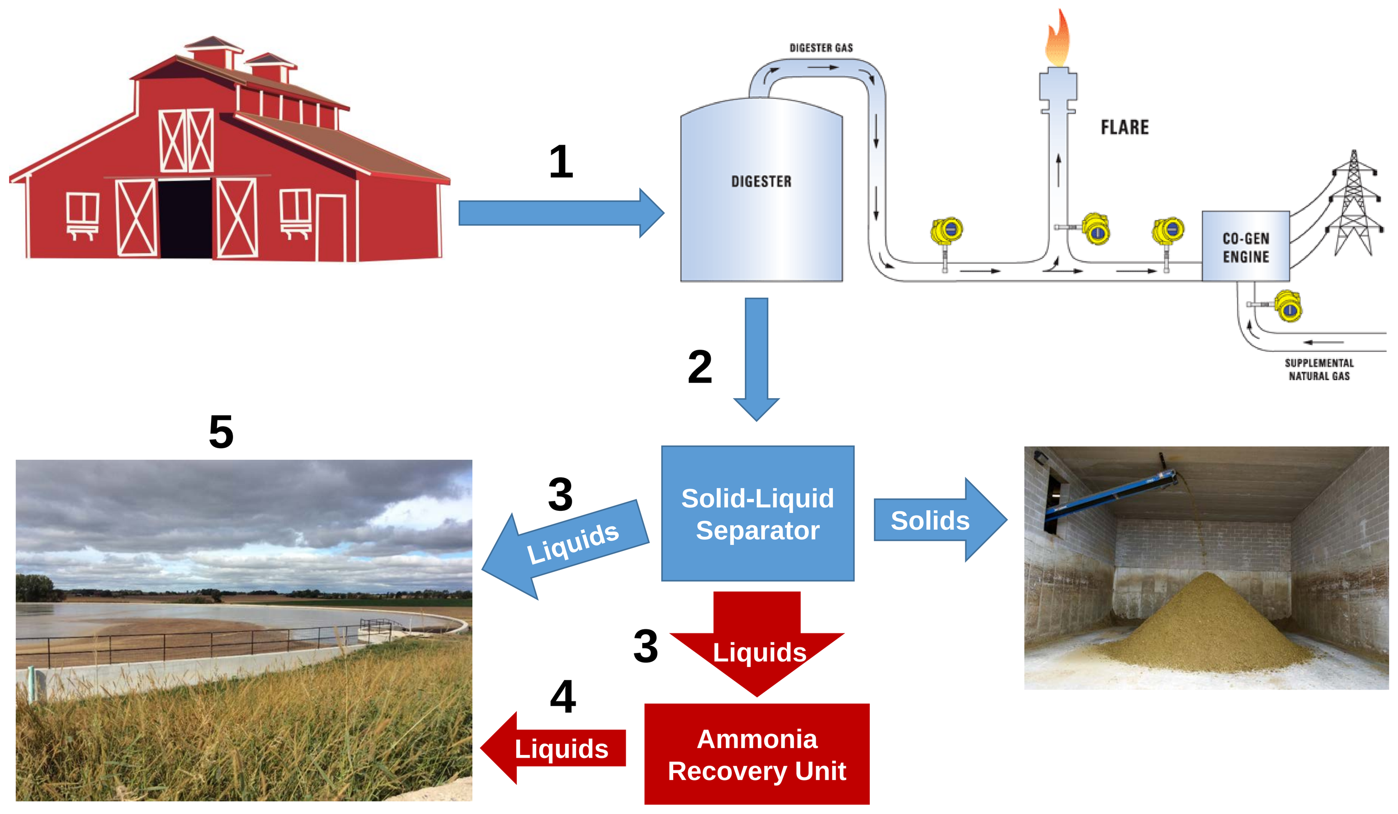

Figure 2. Schematic of manure handling systems with an anaerobic digester. Arrow 1 is pre-digestion manure, 2 is digestate, 3 is separated liquid, 4 is liquid exiting an ammonia recovery system and 5 is a storage lagoon. Not all systems have an ammonia recovery unit.

Results

Measurements of $\delta^{15}N$ at various points in the manure handling system show that there is significant enrichment occurring in the barn and after storage in lagoons (Fig. 3). Samples collected in the fall are more enriched in ^{15}N than in the spring. The $\delta^{15}N$ values from pre-digestion manure, digestate and separated liquid overlap and indicate that significant nitrogen loss did not occur during anaerobic digestion.

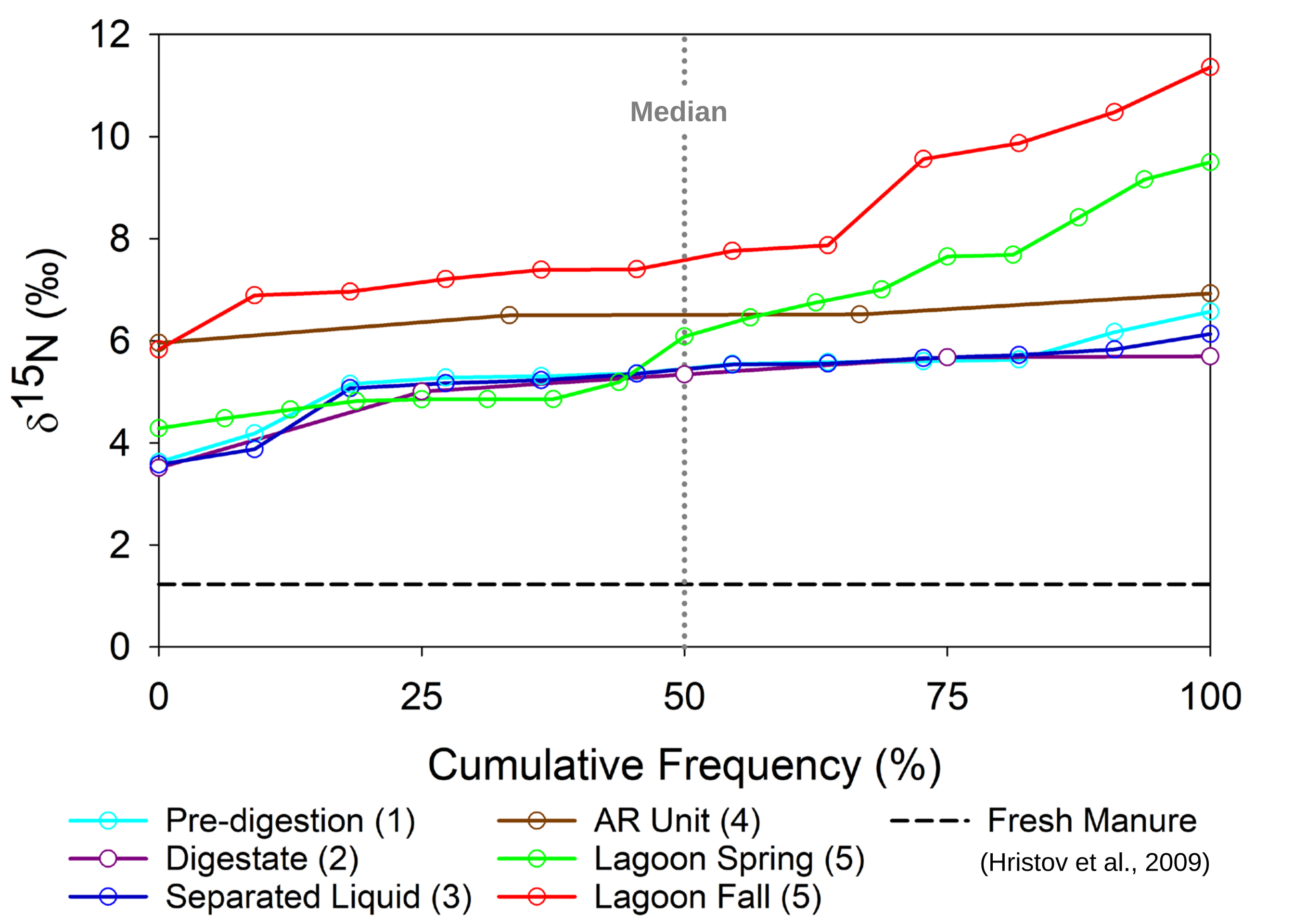

Figure 3. Cumulative frequency plot of $\delta^{15}N$ enrichment in dairy digester systems, all sites.

Pre-digestion manure and post-digestion separated liquid at Site III (Fig. 4) have enrichment similar to their medians from all sites (Fig. 3). The $\delta^{15}N$ enrichment at Site III also indicates that nitrogen loss occurred during storage. Lagoons show enrichment both seasonally and by series (lagoon 1 overflows into lagoon 2).

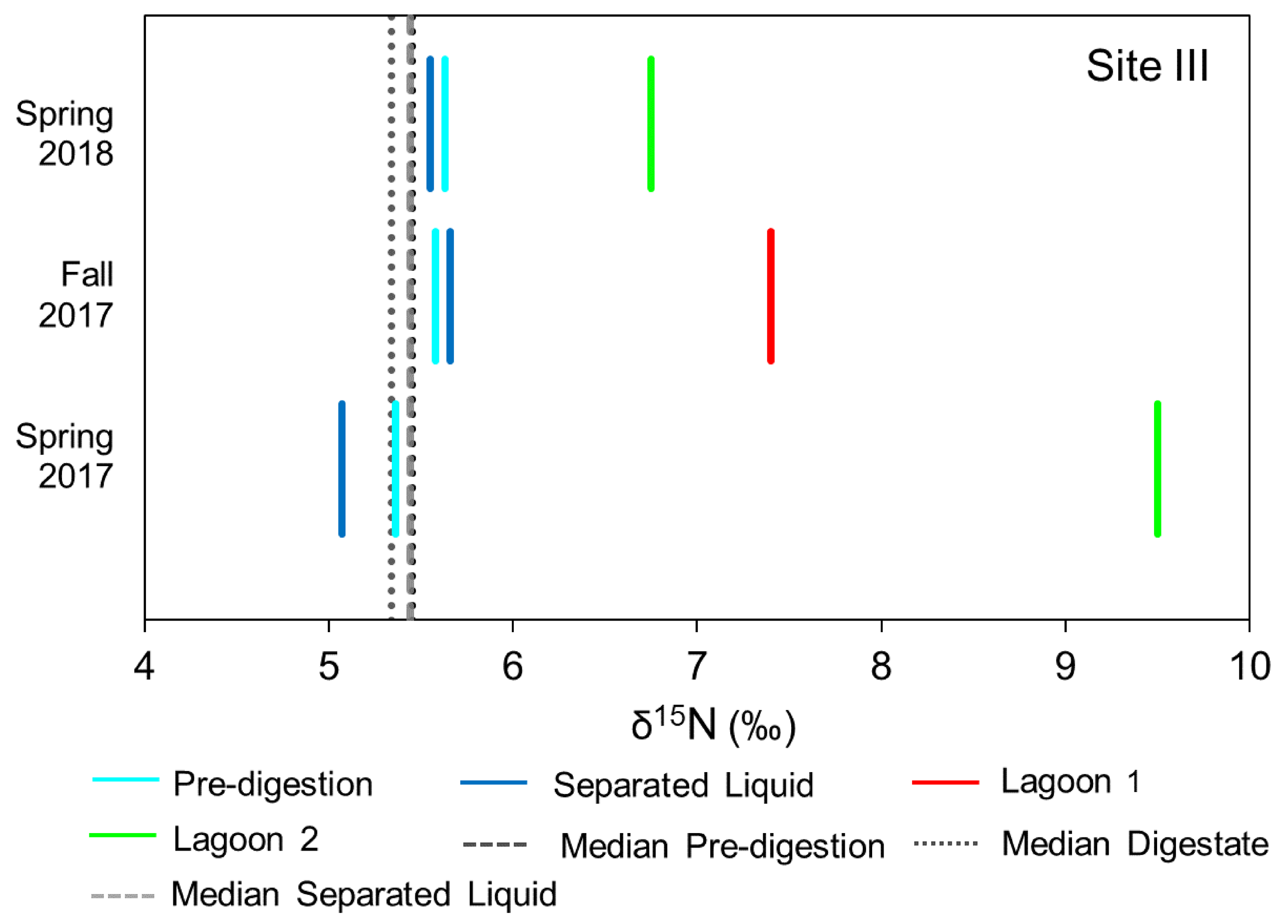

Figure 4. Seasonal measurements of $\delta^{15}N$ enrichment at Site III.

Work by Li et al., 2012 explored the relationship between the change in ^{15}N enrichment using lab solutions of ammonium sulfate and established a temperature relationship for fractionation (Fig. 5). As temperature increases, ammonia is more likely to volatilize and the fractionation factor of ammonia decreases. Using this relationship on our data medians, N lost from pre-digestion manure was ~9% (loss in the barn) and N lost during storage was ~11% in the spring (after winter storage) and ~15.5% in the fall (after summer storage) (Fig. 5).

Results (Cont.)

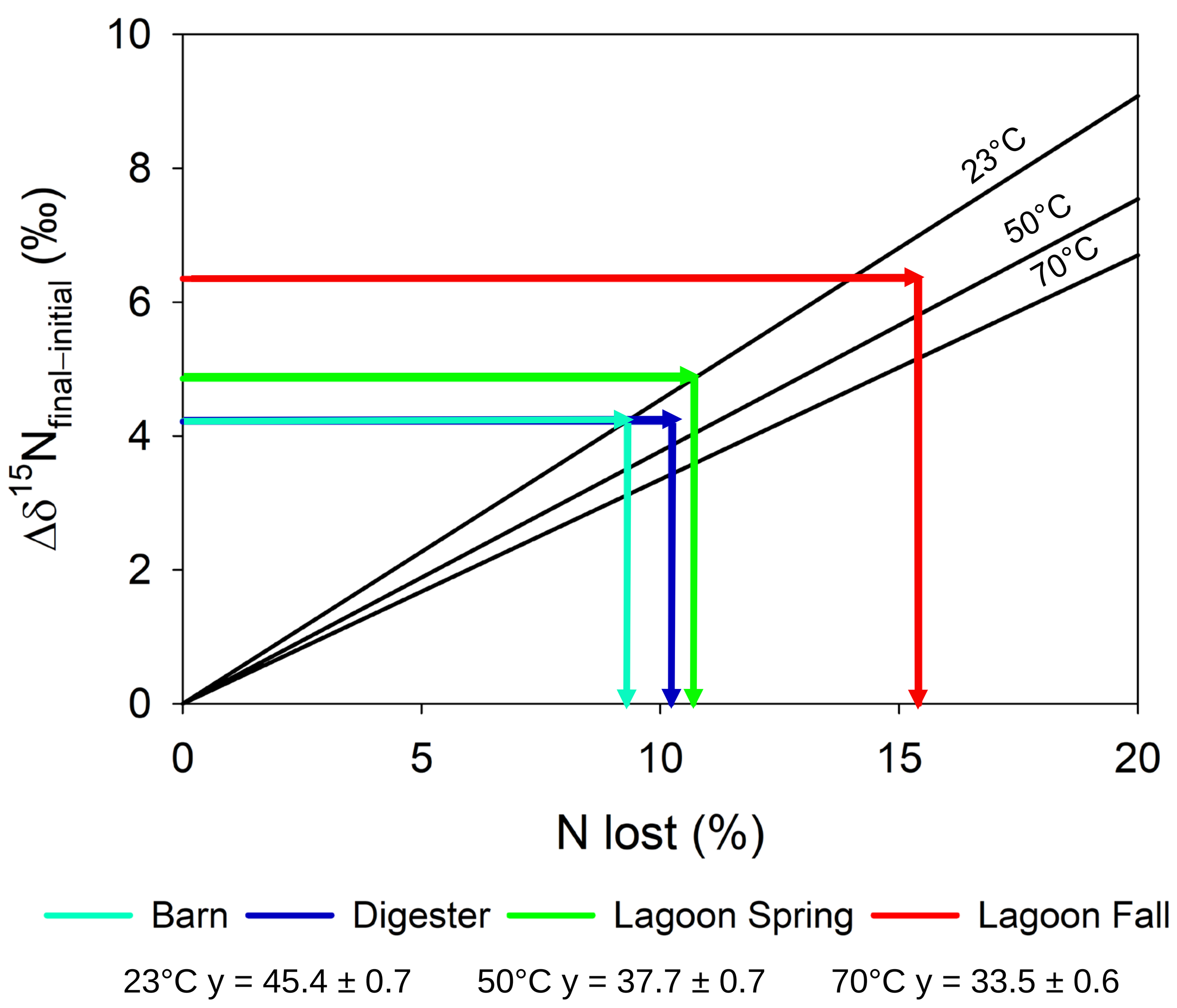

Figure 5. Predicted cumulative N lost using median values from pre-digestion, separated liquid post-digestion and lagoons, spring and fall, compared to fresh manure, calculated using equations from Li et al., 2012.

The amount of nitrogen lost can be calculated by comparing the molarity of conserved ions such as potassium, sodium and chloride that will not undergo any changes in quantity from the source to the lagoon using the equation below.

$$N_{Lost} = N_{Source} - N_{Lagoon}\frac{M_{ion\ source}}{M_{ion\ lagoon}}$$

Analysis is ongoing to compare N loss by ^{15}N enrichment and conserved ions.

Conclusions

Significant nitrogen loss occurs both in the barn and during long-term storage in lagoons. Losses can be tracked using $\delta^{15}N$ enrichment.

The next step is to validate that $\delta^{15}N$ measurements are a good proxy for nitrogen loss by calculating the total nitrogen lost. This value would then be plotted against the change in ^{15}N and compared to the experiment by Li et al, 2012.

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