Fertilizer Research Council Final Report

Assessment of Manure Storage Processing and Handling on Nutrient and Solids Content

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Introduction

Storing manure is a common practice for dairy producers within the state of Wisconsin. Manure storage provides producers with the flexibility to apply manure throughout the year as opposed to daily hauling. This can result in operational benefits to the producer (including reducing the time spent on daily hauling and allowing producers to apply manure at times of the year when availability of nutrients is critical for crop growth) as well as environmental benefits as it avoids runoff issues associate with winter spreading and snowmelt. With increasing herd sizes manure storages are becoming more numerous and larger in volume which in turn increases the percent of manure within the state that first undergoes storage prior to being land applied. The increase is partly a function of the requirement of all permitted facilities (1,000 animal units and above, or approximately 800+ dairy cows) to maintain 6 months of storage as well as environmental pressures and requirements from farmstead improvement funding sources to install manure storage systems. Those farms with greater than 200 animals (which are most likely to have manure storage) total approximately 40+% of the dairy cows within the state (NASS, 2007). Many of these facilities (and some smaller facilities) rely on manure storages as part of their manure management system. Data from 2010 has shown greater than 50% of dairy facilities in Wisconsin use some type of manure storage (USEPA 2012), indicating a significant amount of manure is stored before application.

Although storage can result in some benefits, emptying manure from manure storages particularly for manure slurry systems where manure is pumped, can pose significant operational issues. As manure is stored for up to six months or a years' time, a significant amount of stratification occurs within the manure pit. This becomes an operational challenge as significant agitation may be needed to re-suspend the solids in order for the storage to be emptied using a pumping system for land application. Practices concerning agitation equipment, duration of agitation, and other handling techniques vary significantly - all which impact the characteristics of the manure throughout the emptying process. The settling and agitation methods can also significantly affect the distribution of nutrients. This is particularly true for phosphorus as it is commonly sediment bound and susceptible to settling, varying more than 300% in manure in storages which have not been agitated (MWPS 2004). The variability in the manure handling systems can result in drastic changes in manure characteristics over the course of emptying the manure storage facility.

Changes in manure consistency can create problems when trying to adhere to nutrient management plans and achieve known application rates needed for supplemental nutrient applications. With continued efforts to increase nutrient management plans throughout the state it has become evident that many producers who have developed plans may not be achieving their outlined nutrient application rates. Errors in determining the nutrient characteristics of manure are thought to be one source of the discrepancy from planning to practice. Land application of manure relies on accurate manure analysis to achieve the desired application rates as outlined in nutrient management planning. It is unknown how many samples should be conducted when emptying manure to get an accurate representation of nutrient content which can then result in inaccurate application rates. This can result in over or under application of manure and the supplemental fertilizers following manure applications. An over application can result in significant nutrient losses to the environment, whereas an under application can result in significant reductions in crop yield.

Previous work has shown that manure samples are variable in terms of nutrient and solids content (Safley et al. 1985). Others have looked at the necessary samples required to form an accurate composite sample (Dou et al. 2001), and found that agitation was effective in reducing the variability in manure characteristics. However, none of the studies conducted has evaluated neither new agitation practices nor

the effect of treatment processes on manure consistency during storage emptying, nor made recommendations as to the frequency of manure sampling for nutrient management planning.

To account for the change in consistency, this research attempts to better characterize manure characteristics during emptying of manure storages. A brief *Methods and Materials* and *Results* are presented below with the main points of the work. The details of the work can be found in the attached technical papers that are published based on this work.

Holly, M.A. and R.A. Larson. 2017. Effects of Manure Storage Additives on Manure Composition and Greenhouse Gas and Ammonia Emissions. *Transactions of the ASABE*, 60(2): 449-456.

Aguirre-Villegas, H., M.A. Sharara, and R.A. Larson. 2018. Nutrient Variability Following Dairy Manure Storage Agitation. *ASABE Applied Engineering in Agriculture*, In Review.

Methods and Materials

For this project we conducted two separate experiments. The first was an agitation experiment in which we assessed the nutrient content of manure on 16 farms during agitation and emptying of a manure storage. The second project investigated the impact of numerous additives for manure storage systems to assess the impact to total solids degradation and emissions release.

Agitation

To assess agitation practices, 16 farms were sampled as manure was agitated and removed from storage systems. Each farm collected ~20 samples throughout the emptying of their pit during which agitation practices and volume emptied were recorded. Samples were then analyzed to determine changes in total solids (TS), total nitrogen (TN), ammonium (NH4-N), and total phosphorus (TP).

Additives

Two separate studies were conducted to assess the impact of additives (MTM^{TM}, Pro-Act, aeration, Pro-Act and aeration, and biochar) on 1. gaseous emissions of NH_3, CH_4, CO_2, and N_2O and 2. Manure characteristics. Manure was collected from a USDA dairy farm in south central Wisconsin and stored in a controlled environment while emissions or manure characteristics were measured base don the study design.

Key Results

Agitation

The mean values range from 2.45% to 15.28% for TS, 0.17% to 0.53% for TKN, 0.01% o 0.33 for TAN, 0.02 to 0.06 for TP, and 0.11% to 0.31% for TK. This wide range is mostly attributed to the between-farms variability in manure nutrient content. The within-farm variability was also important and explained most of the variation in TS content. In general, samples with higher TS content showed more variability and TKN, TAN, and TP contents were more uniform than TS. A bootstrap analysis showed that 1-13 samples for TKN, 1-15 for TAN, and 3 to 7 for TP are needed to be between 10% of the experimental mean. results show that 9-11 samples are sufficient to achieve significant reductions in the difference with the experimental mean.

Additives

Biochar was the only manure treatment to impact manure characteristics, with significantly more ammoniacal nitrogen (TAN) on day 14 than the control ($p < 0.012$) in the manure composition study. MTM increased CO2 emissions, with significantly higher emissions on days 7 and 14 during the gaseous emissions study. Overall, no treatments were able to reduce manure solids or nitrogen emissions for these manure storage conditions.

Publications (Please click on the document to read)

Agitation

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NUTRIENT VARIABILITY FOLLOWING DAIRY MANURE STORAGE AGITATION

Journal:	*American Society of Agricultural and Biological Engineers*
Manuscript ID	NRES-12796-2018
Journal Name:	Applied Engineering in Agriculture
Manuscript Type:	Technical Note or Research Brief
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Keywords:	Manure agitation, Dairy manure, nutrients, Sample size, Nutrient variability
Abstract:	High nutrient variability in manure implies less certainty of the actual nutrients being land-applied, which suggests more frequent sampling to improve accuracy. Agitation of manure during storage is a common practice to resuspend solids providing a more uniform nutrient consistency for application. This study explores the effect of agitation on dairy farms to estimate the variation in manure solids and nutrient concentrations and the number of samples needed for accurate nutrient application rates. A total of 16 dairy facilities across Wisconsin were sampled in the study. Samples were taking during agitation and analyzed for total solids (TS), total Kjeldahl N (TKN), total ammoniacal nitrogen (TAN), total P (TP), total potassium (TK), and microminerals. The mean values range from 2.45% to 15.28% for TS, 0.17% to 0.53% for TKN, 0.01% o 0.33 for TAN, 0.02 to 0.06 for TP, and 0.11% to 0.31% for TK. This wide range is mostly attributed to the between-farms variability in manure nutrient content. The within-farm variability was also important and explained most of the variation in TS content. In general, samples with higher TS content showed more variability and TKN, TAN, and TP contents were more uniform than TS. A bootstrap analysis showed that 1-13 samples for TKN, 1-15 for TAN, and 3 to 7 for TP are needed to be between 10% of the experimental mean. results show that 9-11 samples are sufficient to achieve significant reductions in the difference with the experimental mean.

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EFFECTS OF MANURE STORAGE ADDITIVES ON MANURE COMPOSITION AND GREENHOUSE GAS AND AMMONIA EMISSIONS

M. A. Holly, R. A. Larson

ABSTRACT. *Storage of dairy manure slurry allows flexibility in the timing of land application of manure to reduce environmental impacts related to water quality. However, manure storage can increase greenhouse gas (GHG) and ammonia (NH_3) emissions and cause operational issues due to the buildup of slurry solids. To combat these negative consequences, stored manure was treated with manure additives, i.e., More than Manure (MTM), Pro-Act Biotech (Pro-Act), and biochar, to quantify their effects on manure solids, nitrogen losses, and GHG emissions in two separate trails. Gaseous emissions were studied over a 48-day manure storage period with treatments of MTM, Pro-Act, aeration and Pro-Act, aeration alone, and biochar. Manure characteristics were further examined in a 28-day manure storage study with treatments of MTM at the supplier-recommended rate, MTM at 25× the recommended rate, aeration and Pro-Act at the supplier-recommended rate, aeration and Pro-Act at 10× the recommended rate, aeration alone, and two additional Pro-Act treatments without aeration, one at the recommended rate and one at 10× that rate. Biochar was the only manure treatment to impact manure characteristics, with significantly more ammoniacal nitrogen (TAN) on day 14 than the control ($p < 0.012$) in the manure composition study. Biochar did not reduce NH_3 emissions from the control, likely due to the 10 cm natural crust on the control. MTM increased CO_2 emissions, with significantly higher emissions on days 7 and 14 during the gaseous emissions study. Overall, no treatments were able to reduce manure solids or nitrogen emissions for these manure storage conditions.*

Keywords. *Dairy manure, Greenhouse gas emissions, Manure additives, Manure management, Solids reduction.*

Dairy manure storages are responsible for considerable emissions of greenhouse gases (GHG) and ammonia (NH_3) (Amon et al., 2006). Chemical and microbial additives have the potential to mitigate nitrogen losses and may reduce manure solids during storage. Producers are interested in reducing manure solids to avoid operational issues during pumping, transport, and land application. More than Manure (MTM) is a chemical additive that aims to reduce manure nitrogen losses from leaching, volatilization, and denitrification while also reducing manure solids (Berg, 2012). The active ingredient in MTM is a mixture of maleic-itaconic copolymer partial calcium salt and itaconic copolymer partial ammonium salt. It is thought that the copolymers can bind to the nickel (Ni^{2+}) contained in manure, decreasing its availability for urease metalloenzymes, delaying urea hydrolysis, and thereby reducing NH_3 emissions (Connell et al., 2011). However, a study by Sun et al. (2014a) found no significant effects on NH_3 when manure received MTM during storage. It is currently unknown how MTM effects GHG emissions from manure storages. Solids destruction could increase emissions of CO_2 or CH_4 and should be quantified to determine recommendations for incorporating this additive.

Pro-Act Biotech (Pro-Act) is a microbial manure treatment additive that is intended to reduce odor and solids. The microbes are applied in an attempt to develop three distinct treatment layers within a manure storage system. The bottom layer is intended to support anaerobic microbes to degrade carbon, the middle layer is intended to support facultative microbes that can reduce the gases produced by the anaerobes, and aerobes in the top layer further reduce gaseous emissions that pass through the facultative microbes (Pro-Act, 2011). The anaerobic microbes are intended to stimulate methanogenesis and degrade solids at the bottom of a manure storage (Pro-Act, 2011). To maintain conditions that support the aerobic microorganisms in the top layer, it is necessary to aerate the surface of the manure storage, which is also thought to reduce odor and CH_4. Additionally, N is more available to plants when organic N in the manure is converted into inorganic ammoniacal nitrogen by the added microbes (Jensen, 2013). The performance of this potential treatment additive has not been quantified, which is critical to its application.

Manure storage covers are an alternative to chemical and microbial treatments by providing a physical barrier to reduce gaseous emissions and odors. Permeable covers, such as straw, clay, and sawdust, can disrupt gas fluxes from the

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