SUSTAINABLE DAIRY

SCIENCE FOR SUSTAINABLE PRODUCTION

UW Extension
University of Wisconsin-Extension

Horacio Aguirre-Villegas
Biological Systems Engineering,
University of Wisconsin-Madison

Rebecca A. Larson
Biological Systems Engineering,
University of Wisconsin-Madison

Matthew D. Ruark
Soil Science,
University of Wisconsin-Madison

SUSTAINABLE DAIRY PARTNERS

UNIVERSITY OF WISCONSIN-MADISON

CORNELL UNIVERSITY

PENNSYLVANIA STATE UNIVERSITY

UNIVERSITY OF ARKANSAS

UNIVERSITY OF MARYLAND

UNIVERSITY OF MICHIGAN

UNIVERSITY OF WASHINGTON

NORTH CAROLINA AGRICULTURAL AND TECHNICAL STATE UNIVERSITY

INNOVATION CENTER FOR US DAIRY

USDA ARS DAIRY FORAGE RESEARCH CENTER

USDA ARS PASTURE AND WATERSHED MANAGEMENT

USDA ARS NATIONAL LABORATORY FOR AGRICULTURE AND ENVIRONMENT

USDA NATIONAL AGRICULTURE LIBRARY

2017 · sustainabledairy.org

Manure Agitation

Introduction

Agitation of manure during storage is important as it resuspends the settled solids so they can be removed when the storage is periodically emptied. If solids are allowed to build up at the bottom of the storage structure, the effective storage volume can be reduced (Figure 1), especially if sand bedding was collected along with manure from the barn. The settling of solids can also cause stratification of nutrients in the stored manure, which has implications for nutrient management planning. For example, phosphorus can vary more than 300% from top to bottom in manure storages without agitation (Lorimor, Powers, and Sutton 2004).

Agitation of manure during storage reduces nutrient variability and maintains the storage's intended design by removing solids. Despite the advantages, agitation represents an additional cost in manure systems and can release greenhouse gases and other gases that increase odor and pose health risks for people and animals. As a result, it is important to develop a safety plan and to use management strategies that protect the health of people and animals near storage during agitation.

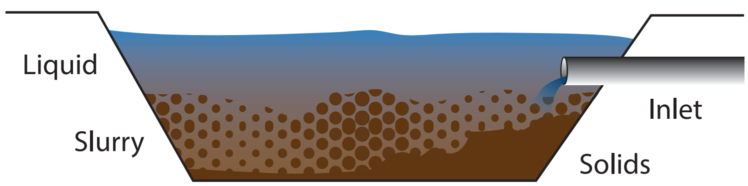

Figure 1. Settlement of solids in the manure storage.

Agitation and Nutrient Management

When manure is not mixed properly, the manure nutrients are inconsistent as the storage is emptied, leading to inconsistent land applications of nutrients. Dou et al. (2001) estimated a nutrient variability of up to 300% on farms where agitation was not conducted. These inconsistencies can lead to both under- and over-application of nutrients. Under-application of manure nutrients can reduce crop yields and over-application can increase nutrient losses, contaminating surface and groundwater.

The high variability of nutrients in stored manure that has not been agitated highlights the need to collect multiple samples just before manure is land-applied for a reliable estimate of nutrient concentrations. However, this sampling process can be costly and time consuming as several samples need to be taken for a reliable estimate. Dou et al. (2001) concluded that at least 40 samples would be required for systems without agitation. However, the variation in nutrient concentration in systems with agitation was only 6%-8%, and producers could reduce sampling to only three to five samples.

Agitation Processes and Equipment

Agitation commonly begins before emptying the storage and continues until the emptying has finished. Aguirre-Villegas and Larson (2017) found an average agitation time of 0.5 minutes per animal unit (AU, 1 AU = 1,000 pounds of animal) per agitation event based on a survey of 143 dairy farms. When analyzing specific farm size groups, this translates to an average of 63 minutes per agitation event for farms with 1-99 cows, 134 min for farms with 100-199 cows, 283 min for farms with 200-999 cows, and 1,215 min for farms with more than 1,000 cows. Agitators are placed near the inlet pipe of the storage structure and are moved around the storage as emptying continues. More agitation may be required when there is a thick crust or solids have settled, particularly near the inlets where more solids may accumulate.

Agitating thousands of gallons of manure can be a challenging process particularly in large storage structures, as some of these structures can reach 20 feet deep and more than 200 feet across. It is therefore critical to have the proper equipment that responds to the specific needs of each farm to achieve high agitation efficiencies. Agitation equipment ranges in price from as low as $10,000 to nearly $200,000 (Sanford 2016). Some common systems available for manure agitation are either driven by tractor power takeoff (PTO) or remotely controlled boats (Figure 2).

Figure 2. Types of agitators: a) pump, b) propeller (source: Dan Bolinger, Michigan State University), and c) boat (source: Kevin Erb, University of Wisconsin-Extension).

Tractor-driven systems include high-capacity pumps, inclined shaft propeller-type agitators, inclined-shaft centrifugal agitators and chopper-agitator pumps. To be effective, these tractor-driven agitation devices should be able to move manure in the center and edges of the manure storage well enough to suspend the solids that concentrate in these areas. It is recommended to operate the agitation equipment every 100 feet, which is the average reaching distance for this type of equipment (Fulhage and Pfost 2000).

Figure 3. Erosion of an earthen manure storage (source: USDA-NRCS).

The agitator should be kept above the bottom liner of the storage (Fulhage 1994) and not pointed directly at the liner to reduce the chances of eroding an earthen liner (Figure 3) or tearing a plastic liner. Tears can occur when a rock or other debris in the manure is propelled at high speed into the liner by the agitation equipment, or when the agitation equipment causes the liner to rub against the subsurface, particularly if the subsurface stone has jagged edges. Concrete ramps and pads, big enough to hold the agitation equipment, are recommended in non-concrete storages to reduce damage to the storage liner when positioning and operating the agitator. Lack of an engineered ramp can result in the collapse of the manure storage side walls when agitation equipment is lowered into the storage. Remote-controlled agitation systems, or agitation boats, are practical for large storage structures as they can move freely over the surface, reaching the center of the storage and other difficult to reach areas with traditional agitation systems (Andersen 2015).

Deep pit or under-barn storages should be designed with numerous agitation access points to prevent solids buildup. When limited access points exist in these types of systems, pumps that simultaneously agitate and pump are recommended. Continuous ventilation in the barn and storage head space is extremely important to disperse gases. It is also recommended to remove people and animals from the building during agitation to avoid exposure to dangerous gases. This applies to all storage systems but especially to those that are enclosed.

Efficiency and system capabilities are both important factors when selecting agitation equipment. For example, manure propeller agitators can turn manure over at rates of up to 33,000 gallons per minute (gal/min), whereas pumps or boats have turnover rates of only 3,000-5,000 gal/min (Sanford 2016). Therefore, multiple agitation units running simultaneously may be needed to achieve similar agitation times compared to propeller agitators. While they may not achieve the same rates of manure flow, boats have the advantage of freely targeting the center of the storage with no problems. Manure agitation systems should meet the demands of each particular operation.

Release of Gases from Manure Agitation

Gases that have human health and climate implications form during manure storage and are released during agitation. These gases include hydrogen sulfide, ammonia, methane, carbon dioxide, and nitrous oxide among others. Hydrogen sulfide poses the greatest concern as it has health implications at very low levels and can lead to loss of consciousness, respiratory distress, and death at concentrations higher than 500 ppm (ATSDR 2016). Hydrogen sulfide has a rotten egg smell at low concentrations, but it can paralyze the nerves of the nose at fairly low concentrations, making it even more dangerous as people can no longer perceive the gas and may assume the risk is gone. Ammonia can irritate the eyes and respiratory tract at low concentrations, and carbon dioxide and methane can lead to asphyxia if they displace enough oxygen. Methane presents additional concerns as it is an odorless flammable gas that is difficult to detect.

The emission of methane, carbon dioxide, and nitrous oxide has direct implications on climate change. Ammonia can lead to formation of particulate matter, can be redeposited in waterways or other undesirable areas, and can be converted, leading to indirect emission of nitrous oxide. However, there is limited literature exploring the release of these emissions during and after agitation.

Vanderzaag et al. (2010) found that emissions of carbon dioxide and methane increased during agitation events, but quickly returned to normal and even decreased after agitation. This made the overall increase in emissions negligible when analyzing the total duration of manure storage. This same study found that agitation did not have any effect on nitrous oxide emissions from manure storage. However, agitation increased ammonia emissions compared to undisturbed manure, with higher emissions when manure was covered with straw.

More research is needed to reach definite conclusions on the release of gases from manure agitation and to recommend practices to reduce these emissions during agitation. However, some general practices can be adopted by dairy farmers to reduce these emissions. One way to reduce agitation emissions would be to impact the processes that lead to gas production in the first place. For example, anaerobic digestion decomposes the majority of volatile compounds (i.e. the carbon compounds that are easily degraded) that are responsible for methane emissions. As a result, methane emissions during liquid manure storage and agitation are reduced compared to undigested manure. Solid-liquid separation also reduces greenhouse gas emissions. After separation, some of the degradable carbon is separated into the solid stream, reducing the potential to emit methane during liquid storage and subsequent agitation. In addition, removing total solids via separation and therefore in the stored liquid manure avoids the formation of a natural crust on top of the storage. Because destroying this crust during agitation produces emissions of nitrous oxide, eliminating the crust altogether would theoretically reduce the emission of these gases during agitation.

The addition of covers to manure storages has shown to reduce ammonia emissions during storage but could also make the agitation and emptying process operationally difficult. Moreover, the agitation equipment could damage the cover.

Finally, using additives or strong acids, or separating urine from feces reduces hydrogen sulfide and ammonia emissions during storage (Andersen et al. 2014). The impact of all of these practices has not been studied directly during agitation, but the principle that they limit the factors contributing to the emission of gaseous compounds could also apply for agitation.

References

Aguirre-Villegas, Horacio A., and Rebecca A. Larson. 2017. "Evaluating Greenhouse Gas Emissions from Dairy Manure Management Practices Using Survey Data and Lifecycle Tools." *Journal of Cleaner Production* 143: Elsevier Ltd: 169–79. doi:10.1016/j.jclepro.2016.12.133

Andersen, Daniel. 2015. "Manure Agitation – What Is a Manure Agitation Boat?" Ames, Iowa: Iowa State University Extension and Outreach. http://themanurescoop.blogspot.com/2015/01/manure-agitation-what-is-agitation-boat.html

Andersen, Daniel S., Jay D. Harmon, Steven J. Hoff, and Angela Rieack-Hinz. 2014. "Manure Storage and Handling - Manure Additives." Air Management Practices Assessment Tool (AMPAT). Ames, Iowa: Iowa State University Extension and Outreach. http://www.agronext.iastate.edu/ampat/storagehandling/additives/homepage.html

ATSDR, Agency for Toxic Substances and Disease Registry. 2016. "Toxicological Profile for Hydrogen Sulfide and Carbonyl Sulfide." Atlanta, Georgia: Agency for Toxic Substances and Disease Registry. https://www.atsdr.cdc.gov/toxprofiles/tp.asp?id=389&tid=67

Dou, Zhengxia, David T. Galligan, R. D. Allshouse, John D. Toth, Charles F. Ramberg, and James D. Ferguson. " 2001. Manure Sampling for Nutrient Analysis: Variability and Sampling Efficacy." *Journal of Environmental Quality* 30: 1432–37. doi:10.2134/jeq2001.3041432x

Fulhage, Charles D. 1994. "Solids Removal from Livestock Manure Lagoons." Columbia, Missouri: University of Missouri Extension. http://extension.missouri.edu/p/WQ324

Fulhage, Charles D., and Donald L. Pfost. 2000. "Earthen Pits (Basins) for Liquid Livestock Manure." Columbia, Missouri: University of Missouri Extension. http://extension.missouri.edu/p/EQ388

Lorimor, Jeff, Wendy Powers, and Al Sutton. 2004. "Manure Characteristics." *Manure Management Systems Series, Edition 2*. Ames, Iowa: Midwest Plan Service, Iowa State University

Sanford, Jeremy. 2016. "Manure Agitation Equipment Options: Answering the Million-Gallon Question." *Progressive Dairyman:* Jerome, Idaho. http://www.progressivedairy.com/topics/manure/manure-agitation-equipment-options-answering-the-million-gallon-question

Vanderzaag, Andrew C., Rob J. Gordon, Rob C. Jamieson, David L. Burton, and Glenn W. Stratton. 2010. "Effects of Winter Storage Conditions and Subsequent Agitation on Gaseous Emissions from Liquid Dairy Manure." *Canadian Journal of Soil Science* 90 (1): 229–39

Acknowledgement

This material is based upon work that is supported by the National Institute of Food and Agriculture, U.S. Department of Agriculture, under award number 2013-68002-20525. Any opinions, findings, conclusions or recommendations expressed in this publication are those of the author(s) and do not necessarily reflect the view of the U.S. Department of Agriculture.

Authors: Horacio Aguirre-Villegas, assistant scientist, Biological Systems Engineering, Rebecca A. Larson, assistant professor, Biological Systems Engineering, and Matthew D. Ruark, associate professor, Soil Science, University of Wisconsin-Madison. Cooperative Extension publications are subject to peer review.

Reviewers: Zong Liu, Biological and Agricultural Engineering, Texas A&M University; Mahmoud A. Sharara, Biological Systems Engineering, University of Wisconsin-Madison; and Scott L. Gunderson, Manitowoc County, University of Wisconsin-Extension.

Graphic design: Elizabeth Rossi, University of Wisconsin Environmental Resources Center.

This publication is available from your county UW-Extension office (counties.uwex.edu) or from Cooperative Extension Publishing. To order, call toll-free 1-877-947-7827 or visit our website at learningstore.uwex.edu.

United States Department of Agriculture

National Institute of Food and Agriculture

Publication Numbers: UWEX A4131-03
GWQ 075