Confined Space Manure Storage Hazards

Automated manure and waste water handling is most often accomplished by collecting and storing manure and waste in storages located directly beneath the animals or in a nearby containment structure that may be located either below ground or at ground level.

The use of confinement systems for livestock and dairy production is a well established practice in American agriculture (see figures 1 & 2). Integral to many animal confinement systems is automated feeding and watering of the animals, barn ventilation, and manure and waste water handling. Automated manure and waste water handling is most often accomplished by collecting and storing manure and waste in storages located directly beneath the animals or in a nearby containment structure that may be located either below ground or at ground level. In many cases, the collection system usually involves a smaller below ground pit for pumping the manure to a longer-term storage structure or for pumping the manure directly into a manure spreader. While this method of manure handling is very efficient, it can create a unique set of hazards for both humans and animals. The purpose of this publication is to identify confined space manure storage hazards and methods for reducing risks when entering storages that are empty or nearly empty.

Figure 1. Slotted floors, like this example in a dairy barn, cover a manure storage that may be up to 10 feet deep, usually referred to as deep-pit storage.

Figure 2. Slotted floors are also used extensively in swine facilities.

Manure Storages and Confined Spaces

Most below ground manure storages, above ground tanks and transfer structures (e.g., enclosed gravity flow ways to move manure between storages) meet the definition of a confined space. This means that it: 1) Is large enough and so configured that a worker can enter and perform work; (2) Has limited or restricted means for entry or exit; and (3) Is not designed for continuous human occupancy (OSHA, Confined Space Standard 1910.146). The hazards contained within a confined space manure storage may include a lack of oxygen, toxic and flammable gases, and exposure to drowning. Once a person has entered a confined space manure storage, it is often too late to mitigate the associated hazards. The human senses of smell and sight are not helpful since the gases being generated by the manure are colorless, may be odorless, and are easily masked by other common farm smells. For example, hydrogen sulfide, one of the most dangerous manure gases, has an odor but it is often not detectable above 100 parts per million (PPM) because it deadens the sense of smell. The characteristic colorless and odorless factors and undetected low oxygen levels often fool even the most experienced farmer.

Tragically, fatalities occur when workers enter facilities and are overcome by toxic manure gases or are exposed to an oxygen-deficient atmosphere. Between 1975 and 2004, 65 fatalities were reported across the U.S. when farmers, workers, family members and would-be rescuers unknowingly entered manure storages when dangerous levels of manure gas or a lack of oxygen were present (Beaver and Field, 2007). This report also showed that the rate of deaths per year in manure storages is increasing. Several of the multiple fatality incidents involved immediate family members who lived and worked on the farm. Later reports on the incidents indicated that the initial entry into the storage was to perform work in a manner that was typical on that farm.

Monitoring Gas Levels

Use of a hand-held gas detection monitor prior to and during any entry event is highly recommended. These monitors must be properly calibrated, maintained and used.

Hand-held, portable gas detection monitors are now available that not only provide a reliable digital read-out of the gas levels present but also have multiple warning alarms that activate (see figure 3). Many newer portable gas detectors have the option of measuring multiple gases, including oxygen, and can be borrowed, rented, or purchased.

Figure 3. Hand-held, portable multi-gas monitors measure most of the manure gases and oxygen levels.

Hand-held gas monitor costs generally start at about $250 for a single gas detector and range up to $1,400 for better quality multiple gas monitors. When using these detectors, it is important to periodically recalibrate them according to the owner's manual. Battery-powered units should be checked regularly to ensure they are fully charged.

Monitoring of manure gas levels can also be measured with gas detector tubes. These tubes contain a reactant that changes color based on the gases that are present and their concentration. The drawbacks for this type of gas monitoring are the delayed time in which the gas levels are displayed and the lack of an accurate measurement that can be as much as 25 percent different from the actual gas level. Manure gases, especially hydrogen sulfide, are particularly critical at higher levels and any delay in detecting or accurately measuring these dangerous levels is life-threatening. See publication E 52 *Confined Space Manure Gas Monitoring* for more gas monitoring details.

[1]Air Liquide, Gas Encyclopaedia. 2010. [2]Fulhage, C. D. 1993. [3]Density of air = 1.23 kg/m³@15°C	
Hydrogen Sulfide (H_2S)	
Odor	Rotten egg odor below 100 ppm
Color	Colorless
Density	1.45 kg/m³@15°C (heavier than air) (3)
PPM	**Health Effects/Precautions**
10	Allowable exposure limit for humans for 8 hours (OSHA PEL)
100	Immediately Dangerous to Life and Health (IDLH)/deadens sense of smell
500	Nausea, excitement, insomnia
1,000	Unconsciousness, death
Carbon Dioxide (CO_2)	
Odor	Odorless
Color	Colorless
Density	1.87 kg/m³@15°C (heavier than air) (3)
PPM	**Health Effects/Precautions**
5,000	Allowable exposure limit for humans for 8 hours (OSHA PEL)
40,000	Immediately Dangerous to Life and Health (IDLH)
250,000	Death in a few hours
Ammonia (NH_3)	
Odor	Sharp, pungent, irritating
Color	Colorless
Density	0.73 kg/m³@15°C (lighter than air) (3)
PPM	**Health Effects/Precautions**
50	Allowable exposure limit for humans for 8 hours (OSHA PEL)
300	Immediately Dangerous to Life and Health (IDLH)
3,000	Asphyxiating
5,000	Could be fatal
Methane (CH_4)	
Odor	Odorless
Color	Colorless
Density	0.68 kg/m³@15°C (lighter than air)
PPM	**Health Effects/Precautions**
1,000	Allowable exposure limit for humans for 8 hours (OSHA PEL)
50,000	Lower Explosive Level (LEL)/no open flame or welding nearby
500,000	Headache, Asphyxiating

Table 1. Listing of manure gas properties and characteristics (1,2).

Mechanical Ventilation Systems

A specially designed positive pressure mechanical forced air ventilation system is needed to reduce risks when entering most confined space manure storages. This type of ventilation system forces air into the storage to replenish oxygen levels and mitigate a buildup of dangerous levels of manure gas. Forcing fresh air through a fan into the storage reduces possible fire or damage from exposing electric fan motors to manure gases—as might happen with an exhaust type system. Fans of various capacities can be used; however, it is recommended that the ventilation fan should be capable of moving a volume of air equal to at least 0.5 times the volume of the empty manure facility every minute. The fan can be permanently installed or portable. It is recommended that new manure storages be designed with permanently installed positive pressure ventilation systems. All ventilation systems should be connected to a standby power system to maintain ventilation in the event of a loss of electrical power during an entry event. The standby power system must be regularly maintained and tested. Recommendations and methods to calculate fan sizes and ventilation times can be found in ANSI/ASABE Standard S607, *Ventilating Manure Storages to Reduce Entry Risk* and E 53, *Confined Space Manure Storage Ventilation Systems*. Details for obtaining both publications are found at Manure Pit Safety homepage.

The ventilation system should run prior to entry for the time specified in ANSI/ASABE S607 and for the duration of the entry event. **Never** enter a manure storage when the manure is being agitated or while emptying it.

Ventilation efficiency is improved and ventilation time prior to entry is reduced when intake air is ducted from a fresh air source that is not contaminated by manure gases exhausted from the storage. Ventilation system ducting should be cleaned as needed to remove dust and other material. To

prevent the fan from being clogged, it is recommended that the fan guard be removed periodically to clean the fan housing and blades. All fan guards should be reinstalled before activating the fan following the cleaning.

All confined space manure storages located away from but interconnected to animal living quarters, should use gas traps in transfer pipes to prevent gases from flowing back into the animal housing area.

Legal Considerations

Federal OSHA:

The Occupational Safety and Health Act (OSHA) is the primary regulation that governs occupational safety and health in the U.S. OSHA has a standard that governs entry into confined spaces (Standard 1910.146), but production agriculture has been specifically exempted from this standard.

One may think there is no reason for a farmer to be concerned about his or her confined space manure storage and the OSHA regulation, but this is not completely accurate. If a farm operator employs 11 or more hired workers and is inspected for any reason, OSHA can use its "general duty clause" to cite the employer for violation of easily recognized best safety practices. The OSHA general duty clause says that an employer must provide a place of employment free of recognized hazards. The hazards of manure storages are well-documented. Allowing a hired worker to enter a manure storage without an adequate supply of contaminant-free air, without a safety harness with a lifeline attached to a rescue lifting device, or without using atmospheric testing devices, violates best safety practices for entering manure storages.

State OSHA:

Several states have their own state Occupational Safety and Health standard. One provision in federal OSHA is that if a state adopts a state OSHA plan it has to be at least as strict as the federal regulation. This means that in states with their own OSHA plan, farm operations may not have the same exemptions from standards or enforcement of standards as exists in states where only federal OSHA is in effect. Farmers should know if their state has a state OSHA plan and how those regulations may differ from federal OSHA regulations.

Agricultural Child Labor Regulations:

The U.S. Department of Labor's Hazardous Occupations in Agriculture (AgHO) regulations relate to employment restrictions of youth in hazardous occupations in agriculture. These employment restrictions do not apply to youths employed on farms owned or operated by their parents or legal guardian (US Department of Labor, 2004). But for all other youths employed on a farm, the regulations prohibit working in, around, or with a number of potentially hazardous farm work activities unless exempted by special training such as training that exists for tractors and some machinery. There is no training exemption for working in manure storages; therefore, all youth under the age of 16 who are not the children or legally adopted children of the farm operator, are completely prohibited from working inside confined space manure storages. Not all states adhere to the AgHO regulations. Many states have their own regulations governing child labor that may be different from the AgHO. Check out your state regulations to be sure you understand what is and is not allowed in your state.

Even though there are numerous exemptions and restrictions from federal regulations that govern occupational safety and health, farm owners and operators should remember that any farm operation can be vulnerable to civil lawsuits resulting from incidents associated with confined space entry. The long-standing recognition of the dangers of entering confined spaces, along with the widely published best practices for reducing risks when entering such spaces, provides ample standing for lawsuits once one or more persons die from unsafely entering a manure storage.

Planned Entry into A Confined Space Manure Storage

Entering a confined space manure storage will always entail some level of risk and should be avoided if possible. One way to avoid entering the storage is to remove the agitator pump and service it outside the storage rather than leaving it in place to service. If you must enter a storage, there are several actions you can take to reduce entry risks. These actions are applicable for entering storages that are currently being used or that may have been empty and not used for months or years:

1. Test from outside the storage for contaminant gas and oxygen levels before entry (see figure 4). The person entering the storage should be able to observe all pre-entry testing of the storage for hazardous gases and oxygen level.

2. Ventilate the manure storage with a positive ventilation system prior to and during the entry event. Use ANSI/ASABE S607 for guidance about ventilation capacity and ventilation time prior to and during entry.

3. The person entering should wear an adjustable body harness with a lifeline attached to a combined rescue

and retrieval system. This person should also wear or carry a portable gas and oxygen monitor to protect against rapidly changing conditions.

4. A second person should be available and stationed at the entrance to the storage. This person should have the capability of using the rescue and retrieval system to lift the person out of the storage in case of emergency.

5. This second person should maintain either visual or verbal contact with the person in the storage. This person must also be mentally and emotionally strong enough to not enter the storage in case of emergency.

Figure 4. Always remain outside the manure storage facility when taking initial gas measurements.

Additional suggestions to reduce risks associated with manure storages include posting danger signs at all entrances to the storage, informing family members, employees, contractors and visitors about the dangers of confined space manure storages, and preparing a written confined space entry procedure. All of these recommended actions and suggestions are consistent with OSHA's permit-required confined space entry procedures. Type in, "OSHA confined space standard" in your web browser for more details on these procedures.

Additional details on monitoring for potentially hazardous atmospheres in manure storages can be reviewed in publication E 52 *Confined Space Manure Gas Monitoring*. More information about ventilating manure storages to reduce entry risk can be found in publication E 53, *Confined Space Manure Storage Ventilation Systems*. Finally, more information on protocols for entering manure storages is found in publication E 54, *Confined Space Manure Storage Emergencies*. It is also recommended to consult with industrial hygiene consulting services that advertise expertise in confined space entry procedures. They can be found in the yellow pages or through a web search.

References

- American Society of Agricultural and Biological Engineers (ASABE). 2010. ANSI/ASABE S607: Ventilating manure storages to reduce entry risk. St. Joseph, MI.: American Society of Agricultural and Biological Engineers.
- Beaver RL and Field WE. 2007. Summary of documented fatalities in livestock manure storage and handling facilities. Journal of Agromedicine 12(2): 3-23.
- Fulhage CD. 1993. Gases and odors from swine waste. Agricultural Publication G01880, Department of Agricultural Engineering, University of Missouri-Columbus, Columbus, MO.
- Gas Encyclopaedia, Air Liquide, Paris, France. 2010.
- Hill DE, Murphy DJ, Steel JS and Manbeck HB. 2011. Confined space manure storage emergencies. E 54. The Pennsylvania State University, College of Agricultural Sciences, Department of Agricultural and Biological Engineering, University Park, PA. 4 pp.
- Manbeck HB, Murphy DJ, Steel JS. 2011. Confined space manure storage ventilation systems. E 53. The Pennsylvania State University, College of Agricultural Sciences, Department of Agricultural and Biological Engineering, University Park, PA. 7 pp.
- Occupational Safety and Health Administration (OSHA). 2002. Application of the permit-required confined spaces (PRCS), 29 CFR 1910.146. Washington, D.C.: OSHA.
- Steel JS, Murphy DJ, Manbeck HB. 2011. Confined space manure gas monitoring. E 52. The Pennsylvania State University, College of Agricultural Sciences, Department of Agricultural and Biological Engineering, University Park, PA. 5 pp.
- US Department of Labor. 2004. Child Labor Requirements in Agricultural Occupations Under the Fair Labor standards Act. WH-1295. US Department of Labor, Employment standards Administration, Wage and Hour Division, Washington, DC.

Prepared by Joel S. Steel, Senior Research Associate, Dennis J. Murphy, Professor, and Harvey B. Manbeck, Professor Emeritus

1 st Edition, 9/11

Contact Information

Dennis J. Murphy
Nationwide Insurance Professor and Extension Safety Specialist
djm13@psu.edu
814-865-7157

extension.psu.edu

Penn State College of Agricultural Sciences research and extension programs are funded in part by Pennsylvania counties, the Commonwealth of Pennsylvania, and the U.S. Department of Agriculture.

Code: E-51