Hydrogen Sulfide in Manure Handling Systems: Health and Safety Issues

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Introduction

Hydrogen sulfide is a poisonous, acidic gas that can kill in a matter of seconds. It is especially dangerous in confined spaces with little or no ventilation, where it can render victims unconscious in an instant. Life-threatening conditions are unpredictable and may occur in areas that were entered many times previously without incident. Consider the tragedy below that happened on a New York dairy farm.

Case Study

On a summer day several years ago in upstate New York, two dairymen prepared to repair a gate valve in an open manure holding tank. After emptying the tank, which was 10-12 ft. deep, the first man climbed down. It was a fateful decision. He plugged the 12-inch transfer pipe with rags and wood to hold back manure from the main storage. Backpressure inside the pipe blew out the rags, and manure instantly began filling the holding tank, along with a cloud of gas. The man in the tank immediately tried to climb out, but collapsed down into the liquid manure. The other man, standing above on the floor at the opening of the tank, immediately bent down to try to grab hold of the victim and pull him out. He was also instantly overcome by the gas and fell down into the holding tank. Both of the men were now unconscious in the rapidly filling tank. A third person, standing nearby, also started to lose consciousness. A fourth person, who had witnessed the accident from outside the room, ran in and pulled him to safety. He called the rescue squad. The third person survived but was severely disabled. The first two men did not. The purpose of this fact sheet is to explain the danger of hydrogen sulfide and how tragedies like this one can be prevented.

How Hydrogen Sulfide is Formed

Hydrogen sulfide is a by-product of manure decomposition under “anaerobic” conditions, which means in the absence of oxygen. Manure storage pits, reception pits, and above-grade manure storage tanks are examples of manure handling systems in which hydrogen sulfide may be produced and accumulate. “Biogas” produced by anaerobic digesters also contains hydrogen sulfide.

Upright manure storage tank

Anaerobic digester

Confined space in a manure reception pit

Properties of Hydrogen Sulfide

Hydrogen sulfide is heavier than air, which is why it accumulates in low, confined spaces. It is also very water-soluble, which allows it to dissolve rapidly in eye moisture and in the respiratory tract. Other properties of hydrogen sulfide are shown in the table below. The specific gravity of 1.19 means that hydrogen sulfide is 1.19 times heavier than air, which is why it collects in lower, confined spaces, making them especially difficult to purge with ambient air.

Properties of Hydrogen Sulfide	
Chemical formula	H_2S
Odor at low concentrations	Rotten eggs
Odor at higher concentrations	Odorless!
Boiling point	- 76.6°F
Specific gravity	1.19

Source: American Industrial Hygiene Association

Hazards and Physiological Effects

Hydrogen sulfide burns the lining of the lungs in just a few breaths. Exposure to concentrations of 1,000 parts per million (ppm) or more can lead to death from respiratory paralysis with little advance warning. Survivors have permanent lung damage. The table below describes the effects of exposure to increasing concentrations of hydrogen sulfide on adult humans. By comparison, the concentration of hydrogen

Physiological Responses to Hydrogen Sulfide (Adult Human)	
Effect on Humans	**Concentration in Parts Per Million**
Odor barely detectable	0.005
Easily detectable, moderate odor	4
Eye irritation	10
Unpleasant odor	27
Coughing, eye irritation, loss of smell after 2-15 min. exposure	100
Eye inflammation and respiratory tract irritation after 1 hour	200-300
Loss of consciousness and possible death in 30-60 min.	500-700
Rapid unconsciousness, cessation of respiration and death	800-1,000
Diaphragm paralysis on first breath, rapid asphyxiation	1,000

Source: ASABE Standard EP470 FEB03 Manure Storage Safety, Table 1.

sulfide in biogas produced from the anaerobic digestion of manure is typically 2,000 – 4,000 parts per million (ppm), making it extremely poisonous if inhaled directly. Note that hydrogen sulfide can quickly

deaden the sense of smell at 100 ppm, so do not assume the gas is gone if it can no longer be smelled after a few minutes! According to American Conference of Governmental Industrial Hygienists guidelines, for a standard 40-hour work week, the threshold limit value for exposure to humans during an eight-hour day is 10 ppm of hydrogen sulfide (time-weighted average).

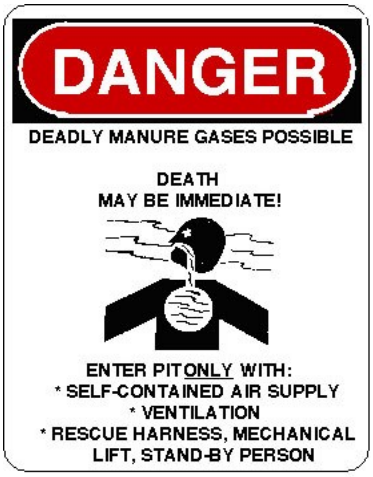
Steps to Prevent Accidents

Before entering a manure storage or any confined space which contains or contained manure:

1. Provide continuous, powered ventilation for *at least* 15 min. with an explosion-proof blower and hose to turn over the air before and during entry. A positive-pressure ventilation system is preferred as it greatly reduces the chance of explosion.
2. Test the atmosphere inside to confirm that there is adequate oxygen, and that hydrogen sulfide levels do not exceed 10 ppm. Note that in some confined spaces, hydrogen sulfide levels may remain high regardless of how much the area is ventilated.
3. Wear a Self-Contained Breathing Apparatus (SCBA) or a supplied-air respirator. Air-purifying respirators (those with cartridges) and disposable dust masks will not protect you from large amounts of hydrogen sulfide because the gas can not be filtered! Safe operation of SCBAs requires custom fitting, testing and training.
4. Locate a secure, structural point of attachment, or rescue pole, with rope within reach of the manure storage.
5. Wear a harness or safety belt with a lifeline secured outside of the manure storage.
6. When entering any confined space, such as a manure pit, a coworker should always be stationed outside of the pit opening in case of emergency. Never enter a manure storage or confined space alone! A coworker outside the storage area should maintain constant contact with the person inside. The coworker should be able to lift the person inside to safety with mechanical equipment (winch, hoist, or pulley) in the case of an emergency.

If irritation of the respiratory tract is experienced, leave the storage area immediately and seek fresh air. Supply bottled oxygen if available, and consult a physician.

Warning signs should be placed at all openings to manure storage systems. Warn visitors about the hazards around manure storage systems. The farm is legally responsible for everyone's safety when they are on the property.



Signs are available from: U.S. Municipal Supply, Inc. 800-331-3812 www.usmuni.com
Gemplers 800-382-8473 http://www.gemplers.com/ Grainger 888-361-8649 http://www.grainger.com

Safe Management of Liquid Manure Systems (especially below-floor and transfer pits)

Agitation of stored manure can lead to sudden, large releases of hydrogen sulfide gas. The following precautions will reduce the risks of release and exposure:

1. Keep people away during periods of agitation!
2. Provide strong, continuous ventilation during periods of pumping and agitation.
3. Do not allow the pit to fill completely. Reserve one to two feet of air space above the surface to hold gas concentrations, as opposed to letting the concentrated gas escape within the barn.
4. If air space has not been maintained, then lower the level of manure before agitating.
5. Agitate below the surface of the liquid. (Some studies suggest that more gas is released by surface agitation.)
6. In-barn, below-grade storages require sufficient ventilation rates to ensure health for workers and animals. Do not agitate manure pits with insufficient ventilation. With natural ventilation systems, curtains need to be fully open, even on a cold day, with adequate winds moving air through the barn to ensure removal of released gases. When agitating in-barn storage, barn ventilation rates in summer should be one-room air-volume exchange per minute, and one-room air-volume exchange every two minutes all other times of the year for mechanically ventilated barns.

Safety Design Considerations

The following should be considered to design safe manure handling systems:

1. Incorporate safety factors into all new designs as a requirement. Plan for the safe dispersion of all manure gases.
2. Locate pit pump-out openings outside of the building.
3. Separate manure storage from the livestock housing.
4. Install gas traps in liquid manure and graywater building pipes to prevent backflow of gas.
5. Smaller pit compartments may reduce sedimentation and the need for agitation.
6. Fence in all open manure storages with locked gates that are 5 ft. or less in height above the adjacent grade.

Ventilating and Monitoring Equipment

For further information on ventilation, see ASABE Standard EP470 FEB03, “Manure Storage Safety”, section 4, “Controlling manure gases with ventilation”. Ventilation and monitoring equipment are available from a number of merchants, such as Gemplers http://www.gemplers.com/ and Grainger www.grainger.com .

Personal Protective Equipment

The National Institute for Occupational Safety and Health has information on respirators at http://www.cdc.gov/niosh/npptl/topics/respirators/ , including a searchable list of certified equipment at http://www.cdc.gov/niosh/npptl/topics/respirators/CEL/default.html . Information on air packs and safety equipment is also available from the New York Center for Agricultural Medicine and Health at 800-343-7527(www.nycamh.com). Gemplers and Grainger also carry personal protective equipment.

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