Confined Space Manure Gas Monitoring

A gas monitor with remote sampling enables measurements to be taken by workers located safely outside the storage facility.

Before entering confined space manure storage, gas detection equipment must be used to determine concentrations of hazardous gases and oxygen levels. This should be done prior to and during entry because extremely toxic gases often accumulate from decomposing manure and safe oxygen levels are often depleted. **A gas monitor with remote sampling enables measurements to be taken by workers located safely outside the storage facility.** These measurements can also be used to establish ventilation times before workers enter the manure storage. The gas and oxygen measurement results would be used with ANSI/ASABE S607, *Ventilating Manure Storages to Reduce Entry Risk*, to establish ventilation times before entry for a specific manure storage facility. Once a worker has entered the facility, gas sensors allow for constant monitoring of the atmosphere while the person is in the storage.

The purpose of this fact sheet is to identify gas detection instruments and information on properly using these devices to reduce risk of entry into confined space manure storages.

Important: As you read through this publication, there are terms that may not be familiar. A list of definitions can be found on the last page of this publication.

Selecting Gas Detection Equipment

Gas detection equipment is very helpful when it is necessary for workers to enter confined space manure storage. The equipment should display reliable measurements of toxic gas levels found in manure storage facilities. This specialized equipment compliments the often limited and compromised human senses because toxic manure gases are colorless and most can't be identified by a characteristic smell.

Figure 1. An example of a handheld, portable gas monitor with probe and hose.

The first decision that must be made is whether to borrow, lease or purchase gas detectors. Borrowing is the least expensive option. The downside of borrowing is being assured that a gas detector is available when needed; that it is properly calibrated; and that it has been well-maintained with a properly functioning sensor. The downside of leasing is having the detection equipment available on a timely basis when it is needed before entering confined space manure storages. Obviously, the downside of buying is the cost associated with the purchase, calibration, and maintenance of the detector and its sensor.

Several questions about gas sensor technology, its sophistication, and available accessories are important to consider when purchasing or leasing gas detection equipment. Most detection equipment also requires maintenance and occasional calibration. Although these functions are not necessarily complicated, leasees and purchasers may want to take advantage of hands-on, or web-based training to ensure they understand how to properly operate the equipment that they will be using. Please refer to Table 1 as a guide for selecting gas detection equipment.

Type	Advantage	Disadvantage	Price Range*
* Prices current as of 9-1-2011			
Gas Detection Badges	Inexpensive Light-weight Easy to wear Mobile (move with worker) Color-change types Show immediate results	One-time use only Lab analysis type takes valuable time Color-change types are not accurate Must be replaced regularly No oxygen monitoring capability	$141 per box of 10 to $195 per box of 50
Gas Detection Tubes	Inexpensive Instant measurement Easy to read	Pump is necessary Tubes may be cross-sensitve to other gas Analysis can take 10 seconds to 15 minutes Single-use only, no oxygen monitoring Reading valid only where sampling occurred Lab analysis may be required Accuracy only +/- 25%	$68 per pack of 10 to $82 per pack of 10 * requires basic pump and hose (approximately $150)
Single- and Multi-gas Monitors	Can be worn by workers Portable and/or handheld Accurate Continous readings Visual and audible alarms Most are durable with longer sensor life span	One gas only on less expensive models More expensive than badges or tubes Must be well-maintained and calibrated Users may need training Sample draw pumps add to cost H 2 S range may be too narrow (0-100 ppm)	$250 - $700 single gas $400 - $1,400 multi-gas
Fixed Systems	Very accurate Data logging capabilities Advanced alarm systems Distance monitoring up to 1000 feet ≥ 2% calib. drift/month	Most expensive option Sensors prone to deterioration in manure storage environments Owners/users will need training	$2,000 - $4,000 + Wireless sensor network systems add significant costs.

Table 1. Guidelines for Selecting and Using Gas Detection Equipment

There are two types of gas detection equipment available: permanently installed (fixed), and portable.

Fixed Gas Detectors

Fixed gas detectors are usually more expensive and less practical for use in confined space manure storage. The corrosive conditions in confined space manure storage are very hard on the electrochemical circuitry, sensors, and wiring systems with the only alternative being wireless sensor networks that can significantly increase the fixed detection system costs.

Fixed gas detection systems are not commonly found on farms and ranches with confined space manure storage in the United States.

Gas Detection Badges

This type of detection equipment is worn by employees to track their exposure to contaminant gases as they work. The two types of detection badges are color-change indicators usually designed for a single gas, and badges that are sent to a laboratory for analysis after being worn by workers. Neither type are recommended for confined space manure storage because of imprecise gas measurements and the length of time it takes to get reliable results from a laboratory. Gas detection badges do not monitor for oxygen levels.

Gas Detector Tubes

Gas detector tubes measure toxic gas concentrations with a material (reagent) that is sensitive to specific toxic gases (Figure 2). These gas detector tubes are used only one time and each tube detects only one toxic gas. In order to use detector tubes, air from the testing environment is pulled through the tube with a pump and the reagent in the tube changes color to indicate the level of contaminant gas concentration. There are drawbacks to using gas detector tubes. This method of sampling is designed to identify contaminant gases and their **approximate** concentrations, which can be +/-25% of the observed reading. In addition, tubes that are near their expiration dates, or shelf life, can be less accurate than “fresh” tubes. Storing detector tubes under refrigeration preserves the freshness of the detector tubes and prolongs their life. Gas detector tubes do not monitor for oxygen levels.

Electronic Single- and Multi-Gas Monitors

Electronic gas monitoring equipment uses sensitive electro-chemical technology to measure contaminant gas concentrations and oxygen levels. These monitors are either worn by workers or are handheld, portable devices (Figure 3). Handheld gas monitors can be purchased with a small air pump and several feet of hose that allows for attached probes to be inserted into a potentially contaminated environment without a person actually entering the manure storage facility.

There are many manufacturers of portable gas monitors in a price range from $250 to over $1,400. Many are programmed for monitoring manure gases and to detect oxygen depletion. Purchasers or leasees should ensure that the multi-gas detectors they are considering have the capability for detecting hydrogen sulfide and methane, and also oxygen deficient environments within the 0-30% by volume range.

Note: All electronic sensors have both a normal and over-range readings and alarm. For example with hydrogen sulfide, the normal range alarm sounds when concentrations exceed the TLV of 10 ppm. The over-range alarm will sound on some detectors when hydrogen sulfide concentrations are at, or exceed 100 ppm. If the over-range alarm sounds, all one knows is that concentrations are at, or exceed 100 ppm. An over-range alarm means the person should immediately leave the area. Short-term over-exposure to extreme gas concentrations is not likely to result in sensor "burn out". Continuous over-range exposure to extreme gas concentrations may damage sensors and require replacement.

Measuring Contaminant Manure Gas Levels

Prior to entering a confined space manure storage facility, manure gas and oxygen levels must be measured. These measurements are also used to determine ventilation times and rates necessary to remove toxic gases and replenish oxygen prior to worker entry. Plastic tubing with an air pump should always be used to sample air from locations inside the pit with all workers staying outside the facility. When sampling, the plastic tube with a probe should first be lowered into the facility a few inches above the manure surface, using care so that the end of the detector tubing does not touch the manure. Gas measurements should be taken several times in different locations before a worker plans to enter the facility. Finally, raise the tube and monitor gas concentrations approximately 12 inches from the top of the storage to check for high concentrations of lighter than air gases, such as methane. Measurements should be taken continually for the entire time that any worker is in the facility. Note: Any manure disturbance, including walking in or agitating the manure, will release additional trapped gases and may increase contaminant gas concentrations.

To safely remove toxic gases and ensure proper oxygen levels, adequate ventilation should be turned on prior to and during all manure storage entry events. Gas concentration measurements must be taken prior to and during manure pit entry! See publication E 51 Confined Space Manure Storage Hazards for information on manure gases and oxygen levels required for safe human and livestock occupancy. More information on ventilating manure storages can be found in E 53, Confined Space Manure Storage Ventilation Systems. When a worker is preparing to enter confined space manure storage, procedures described in publication E 54, Confined Space Manure Storage Emergencies should be followed.

Calibrating Gas Detection Equipment

Workers cannot rely on their sense of smell to alert them to odorless or colorless gas hazards. This requires the use of gas monitors or detectors prior to workers entering an area with the potential for contaminant gases. But having and using gas detection and monitoring equipment is only part of the process. Making sure that it is properly calibrated and adequately maintained ensures accurate measurement of the toxic gases that may be present. Calibration refers to an instrument's measuring accuracy relative to a known concentration gas (OSHA, 2004). See Calibration — Best Practices chart on the next page.

Maintaining Gas Detection Equipment

Maintenance of gas detection equipment is important to preserve the accuracy and life of the device. Electronic devices should be fully charged or have fresh replacement batteries readily available. They should be stored clean, dry, and dust-free in a protective storage container. **Warning:** Electronic sensors have a limited life span. Most manufacturers provide a sensor warranty statement in the literature that accompanies the detector. Sensors on detectors used in the demanding and corrosive environments found in manure storages may require additional calibration or replacement to ensure reliability of the manure gas and oxygen measurements that are being detected. Calibration should always follow the manufacturer's recommendations and schedules in the owner's manual.

Calibration — Best Practices

- Calibration should be done regularly with certified standard gas concentrations. This will update the instrument's reference point and ensure that the unit will continue to produce reliable readings. Always confirm that the certified calibration gas has not passed its expiration date.
- Calibration should always be based upon the manufacturer's recommendations. Never calibrate with certified standard gas concentrations that are in excess (over-range) for the targeted gases and vapors.
- Calibrate detectors under environmental conditions that are the same as, or similar to, actual field conditions. This means that detectors should be calibrated in an environment (temperature, humidity) similar to where the equipment is to be used.
- Calibration should always be done with gas detection equipment that has been properly stored. If the unit comes with a carrying or storage case, the detector should always be stored safety and securely in that case. Replace storage cases that are damaged or lost.
- Calibration activities should be carefully documented. Written records should be maintained for the life of each gas detection unit. This allows for quicker identification of equipment that has been prone to excessive repairs and/or erratic readings.
- Calibration of gas detection equipment is an important procedure. Sites where gas detection accuracy with immediate results is needed should consider providing worker training on the proper methods of calibration.
- Calibration of detectors may be impossible if they have been exposed to extreme atmospheric and physical abuse (having been dropped or submerged) conditions. At this point, calibration is impossible and sensors may need to be replaced and/or the unit serviced by qualified personnel.
- Calibration can be difficult for detectors as the unit ages. This is the result of a gradual degradation of sensors, resulting in "calibration drift", and it could mean that the unit or gas sensors will need to be replaced. Aging may be more of a problem with less expensive gas detection equipment using older detection technology and circuitry.

Once the decision has been made to purchase or lease a gas detection device, it is important to use it prior to and during every entry into a manure storage facility. All of these recommendations and suggestions may seem expensive, complicated or time consuming, but one breath of highly toxic manure gas can be fatal. These fatal incidents are preventable, so always use gas detection equipment to identify high concentrations of contaminant manure gases and oxygen deficient atmospheres before a person enters any confined space manure storage.

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Definitions

(sources include: OSHA, NIOSH, and ACGIH)

Alarm – An audible, vibratory and/or visual warning indicating the presence of a dangerous level of a toxic gas/vapor.

Calibration – A procedure used to adjust a detection instrument to accurately measure levels of specific gases or vapors.

Explosion – An uncontrolled chemical reaction that produces a large amount of heat and gas. Methane, a known manure gas, is very explosive in small concentrations when an ignition source is present.

Fixed installation – A type of gas detection that is permanently installed in a confined space to measure toxic gases and oxygen levels. Fixed gas detection in manure storage is not common due to corrosion and the high costs associated with fixed gas instruments.

Gas detection equipment – A combination of electrochemical components integrated as a gas detection system.

Gas monitor – See definition for gas detection equipment.

IDLH – An acronym for Immediately Dangerous to Life and Health. The IDLH for hydrogen sulfide is 50 ppm.

LEL – An acronym for Lower Explosive Limit. It refers to the smallest amount of a gas that will support a flame when mixed with air and ignited.

Manure gas – A term that includes any of the four contaminant gases of hydrogen sulfide, methane, carbon dioxide, and ammonia that are generated by decomposing organic matter in confined space manure storages.

Oxygen depletion – A term that describes the decline in oxygen content of the atmosphere. Normal atmospheric oxygen content of the air is 20.9 percent. When it declines to less than 19.5 percent, people begin to feel health effects.

Portable gas monitor – Gas detection equipment that is light-weight and can either be handheld or worn on work clothing.

PPM – An acronym for parts-per-million. It is used to describe the amount of a substance relative to one million total parts of air in a specific environment.

Sample draw – The amount of gas or vapor that is sampled in a specific environment to indicate visually or chemically their concentration.

TLV – An acronym for the threshold limit value of a gas or vapor usually expressed in ppm. The TLV for hydrogen sulfide is 10 ppm. This is also the PEL (permissible exposure limit) for hydrogen sulfide.

TWA – An acronym that refers to time-weighted average for an 8-hour work day and a 40-hour work week during which workers are exposed to a contaminant gas at the worksite. The maximum allowable level of contaminant gas exposure is the predetermined TLV defined above and can be found for each gas as determined by the American Conference of Government and Industrial Hygienists (ACGIH).

Toxic gas/vapor – Refers to contaminant gases associated with manure stored under anaerobic conditions.

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