Hazardous Gases on Agricultural Operations

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Factsheet

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(replaces OMAF Factsheet 13-025 of the same name)

INTRODUCTION

Hazardous gases on farms can be found in silos, manure storages, anaerobic digesters, grain bins and improperly ventilated barns — structures that provide a confined space in which gases can accumulate to dangerous levels or deprive the air of enough oxygen to sustain life. Plant material stored in a silo ferments, allowing the crop to be stored for a long time. However, the fermentation process uses up oxygen, produces carbon dioxide and, under certain conditions, nitrogen dioxide, as by-products. This results in an environment unsuitable for humans soon after the silo is filled, lasting for up to 2 weeks.

Manure that is stored for a long time undergoes anaerobic decomposition, which produces manure gases. Warm weather and poor ventilation can increase the concentration of these gases. Liquid manure tanks can contain toxic levels of gases or can be devoid of oxygen. High hydrogen sulphide gas levels can also deteriorate exposed concrete above the liquid manure surface.

This Factsheet focuses on dangerous gases found around farm operations and the safety precautions required to protect farm workers.

HYDROGEN SULPHIDE

Hydrogen sulphide (H_2S) is the most dangerous of the manure gases. It is classified as a chemical asphyxiant because it immediately chemically interacts with the blood's hemoglobin to prevent oxygen from being carried to the body's vital organs and tissues. It is produced from the anaerobic decomposition of organic materials such as manure. Its characteristic rotten egg smell is easy to detect at low concentrations, but at higher concentrations, H_2S paralyzes the sense of smell. In high concentrations, hydrogen sulphide causes instant paralysis and death.

Table 1. Hydrogen sulphide effects on humans at various concentrations

H_2S Concentration, PPM	Effect on Humans
4	Easily detectable, moderate odour
10	Eye irritation
27	Unpleasant odour
100	Coughing, eye irritation, loss of sense of smell after 2–15 min. exposure
200–300	Eye inflammation and respiratory tract irritation after 1 hour
500–700	Loss of consciousness and possible death in 30–60 min.
800–1,000	Rapid unconsciousness, cessation of respiration and death
>1,000	Diaphragm paralysis on first breath, rapid asphyxiation

Source: American Society of Agricultural and Biological Engineers, ASABE EP470 Standard, 2005.

Table 1 outlines the effect of hydrogen sulphide at various concentrations. Hydrogen sulphide is heavier than air, therefore it tends to stay just above the surface of the manure. Ventilation systems and wind effects can cause the gas to move up into the barn space towards an exhaust fan or open window. The release of hydrogen sulphide is relatively low when manure remains undisturbed and the outside temperature is low. However, hydrogen sulphide levels can reach dangerous levels in seconds when a tank is agitated, especially if splashing or surface agitation takes place (Figure 1). Extra precautions are required when dealing with an under-floor manure storage (see *Management Suggestions – Manure Storages*). Several deaths have occurred when workers have entered manure storages or the room above one in an attempt to save someone who had been overcome by H_2S.

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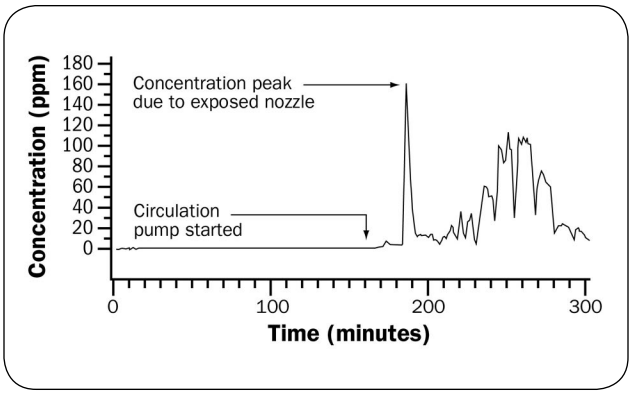

Figure 1. H_2S gas concentration during pit agitation. *Source:* Patni, N.K., and S.P. Clarke, ASAE, 2003.

Hydrogen sulphide gas is a major concern for agricultural biogas systems. It can be present in many structures related to the production and consumption of biogas and can contain other hazardous gases. For management options of hydrogen sulphide in agricultural biogas systems, consult the OMAF Factsheet, *Hydrogen Sulphide in Agricultural Biogas Systems*.

METHANE

Methane (CH_4) is a colourless, odourless, non-toxic but combustible gas, generated by anaerobic digestion of organic material. If stored and managed properly, it can be used as a fuel source for internal combustion engines or cleaned and injected in the natural gas grid. It is lighter than air and therefore tends to rise from the manure storage. In well-ventilated livestock buildings, methane is unlikely to cause problems, however, in covered and in-barn storages, methane can become trapped, and the concentration can reach dangerously explosive levels.

Agitating manure in a liquid storage results in a rapid increase in the release of manure gases and methane. If allowed to accumulate in an enclosed space, methane gas can cause explosions. Improperly designed plumbing pipes in staff rooms can also accumulate explosive levels of methane. For example, floor drains must be equipped with water traps to prevent migration of methane from the manure storage back into the staff room.

Clause 78, Part VIII, in Ontario Regulation 267/03, created under the *Nutrient Management Act, 2002,* requires that all new liquid manure storages provide some form of ventilation to prevent the accumulation and/or intensification of corrosive, noxious or explosive gases.

The American Society of Agricultural and Biological Engineers provides guidance for the management of hazardous gases with two published standards:

- *Manure Storage Safety,* ASABE EP470 JAN1992 (R2005)
- *Ventilating Manure Storages to Reduce Entry Risk,* ANSI/ASABE S607 OCT2010

Both standards offer management options to minimize the risks — asphyxiation, poisoning and explosions — to humans and livestock exposed to manure gases when entering confined-space manure storages and to minimize the potential for drowning at manure storage sites.

A series of incidents in North America involving fires in hog barns caused by dangerous levels of methane have been a major concern lately. For more information on the causes and management practices of fires in hog barns, review the OMAF Factsheet, *Methane Gas in Hog Barns*.

AMMONIA

Ammonia (NH_3), a colourless gas with a characteristically pungent odour, is produced by the decomposition of nitrogen compounds in animal manures. Classified as an irritant, this gas is lighter than air and can predispose livestock to various respiratory diseases if they are exposed to a significant level for an extended period of time.

Ammonia irritates the eyes at levels in the range of 20–50 PPM, depending on the sensitivity of the person or animal. This gas is likely to be found mainly in swine, poultry and rabbit buildings, however, it can also be a problem in manure composting operations. As a guideline, if livestock or humans develop irritated eyes, improve the ventilation in the building.

CARBON DIOXIDE

Carbon dioxide (CO_2) is colourless and odourless. It is, in part, the product of respiration of both plant material and animals, and is found naturally in the atmosphere. Open-flame, non-vented space heaters will also contribute carbon dioxide to the surrounding air space, as one of the products of combustion. CO_2 is heavier than air and, like hydrogen sulphide, will tend to accumulate just above the animal pen

floor, surface of manure in a manure tank or silage surface in a silo. The main danger with carbon dioxide is that it can create an oxygen deficiency, resulting in asphyxiation or suffocation. Properly ventilated livestock buildings do not generally contain dangerous levels of CO_2, however, lethal concentrations can be found in sealed silos, liquid manure storages and grain storages.

As part of the ensiling process, living plant material quickly uses up available oxygen and dies. During this respiration process, oxygen is converted to water and CO_2. Carbon dioxide displaces the oxygen in a sealed silo, making this environment unsuitable for humans without an external air supply.

NITROGEN DIOXIDE

Nitrogen dioxide (NO_2) is a dangerous chemical asphyxiant produced as a result of chemical reactions that take place almost immediately after plant material is placed into a silo. Even short-term exposure can result in sudden death. NO_2 has a characteristic bleach-like odour and may be visible as a reddish-brown haze. It is heavier than air, so it will tend to stay just above the silage surface. It may also flow down silo chutes and into feed rooms.

Weather conditions and cultural practices will affect the amount of nitrates in plant material, which in turn will set the stage for the production of NO_2 in the silo. For example, a dry period during the growing season followed by abundant rainfall will encourage a corn crop to take up high levels of dissolved nitrates. If the corn is harvested before the nitrates can be converted to proteins, nitrous oxide (N_2O) and nitric oxide (NO) are produced. Unstable NO combines with oxygen to form deadly nitrogen dioxide.

When inhaled, NO_2 dissolves in the moisture on the internal lung surface to produce a strong acid called nitric acid. Nitric acid burns the lung tissues, which is followed by massive bleeding and death. Repeated exposure to lower concentrations of NO_2 will cause chronic respiratory problems, including shortness of breath, coughing and fluid in the lungs.

Table 2. Threshold limit values (time weighted average) for maximum gas concentrations in humans

Gas	Threshold Limit Value, PPM
Hydrogen sulphide (H_2S)	10
Ammonia (NH_3)	25
Methane (CH_4)	1,000
Carbon dioxide (CO_2)	5,000
Nitrogen dioxide (NO_2)	3

Source: ASABE EP470 Standard, 2005.

SAFE GAS LEVELS

The American Conference of Government Industrial Hygienists has established maximum safe gas concentrations, or threshold limit values, for an 8-hour work day and 40-hour work week for humans (Table 2). Although threshold limit values have not been established for animals, many researchers have suggested that animal responses are likely similar to humans.

GAS DETECTION MONITORS

All of these hazardous gases can be measured with appropriate test equipment. Although much of the equipment is expensive and requires periodic re-calibration, there are some very reasonably priced gas detection tubes and handheld monitors commercially available from safety and scientific supply stores.

The most economical approach is to monitor gases with reactor tubes in which the gas changes the colour of a reactant and gives a good estimate of its concentration. These reactor tubes can be used with a calibrated pump to draw a measured sample of gas through the tube and obtain the result within a few minutes. However, to take an air sample, the person operating the pump must be present in the confined space, exposing himself to the potentially hazardous atmosphere.

These tubes are also available as passive dositubes that react slowly when exposed to the environment containing the gas of interest and yield an average gas concentration over time. Depending on the gas, the required exposure time would vary from several hours to as much as 2 days.

Figure 2. Example of handheld multi-gas detector used to monitor concentration of oxygen, hydrogen sulphide and explosive gas (% LEL — Lower Explosive Limit) available at safety supply stores.

Commercial handheld monitors available from safety and scientific supply stores can also measure hazardous gases (Figure 2). Handheld detectors monitor environmental gases constantly, are compact in size and sound an alarm when a dangerous gas level is detected. They can be equipped with a sampling hose and pump used to monitor the atmosphere of a confined space outside harm's way. When purchasing a gas monitor, note whether the unit can be calibrated at the farm or has to be serviced. Certain units will stop working if the calibration has expired.

Operating the calibrating equipment requires minimal training. The monitors cost from $250–$400 for one gas; multi-gas monitors equipped with a pump may cost up to $1,000. An alternative to purchasing the equipment is to rent the unit (for a week or two) and the appropriate personal protective equipment from a specialized safety supply store. Specialized stores provide training services with rental equipment or are in contact with local training providers. The key is to plan ahead if the farming operation requires personal protective equipment.

MANAGEMENT SUGGESTIONS

Manure Storages

- Ensure covered manure storages are ventilated by some means to prevent the accumulation of all hazardous gases.
- Always maintain at least 0.3 m (1 ft) of freeboard between the manure surface and the bottom of the slats to prevent animals from routinely breathing hydrogen sulphide and carbon dioxide.
- Post a "Danger, Deadly Gases" warning sign in a visible location near each pump-out station.
- Do not agitate the liquid manure in storage unless absolutely necessary. If agitation is necessary, keep the agitator below the liquid surface and do not direct the stream of agitated manure towards a post or wall. Research has shown that gas levels will increase to lethal levels in seconds when splashing or surface agitation takes place (Figure 1). Remove all livestock, if possible, before agitating and emptying. Monitor gas levels in the barn.
- If the barn has under-floor (pit) ventilation and the porosity of the slatted floor is such that an air velocity through the slats of at least 0.10 m/sec (20 ft/min.) can be obtained, use the pit ventilation system. Ensure that any openings such as pump-out ports are sealed off. For the pump-out port, this might require the use of a piece of plywood or flexible skirt to fit around the tractor-driven pump. This will maximize the amount of air being drawn from the room down through the slats. If gas detection equipment is available, monitor gas levels in the barn.
- If the barn does not have under-floor ventilation, or if conditions are such that an air velocity down through the slats of at least 0.10 m/sec (20 ft/min.) cannot be obtained, provide maximum room ventilation. Be aware that there exists a greater risk when there is no under-floor ventilation. Do not enter the barn during or immediately following pumping or agitation. If gas detection equipment is available, monitor gas levels in the barn.
- It is highly recommended that a hydrogen sulphide gas monitor with an alarm be used to monitor gas levels in the barn, whenever this type of storage is agitated or emptied (Figure 2). In addition, consider taking hydrogen sulphide awareness training, available from consultants in Ontario.
- When flushing gutters, provide maximum ventilation. Do not enter the barn during or immediately following flushing. If gas detection

equipment is available, monitor gas levels in the barn.
- Ideally, locate all pump-out openings outside the building to eliminate the danger of working in a confined area. Surround them with a safety railing.
- Do not attempt to rescue an animal if it collapses during pumping or agitation. Turn off the pump, provide maximum ventilation and wait a reasonable time before entering the barn. Again, if gas detection equipment is available, ensure a safe concentration level prior to entering.
- Avoid any source of ignition, such as smoking, in the barn or near a manure storage facility. Avoid operating welding equipment in confined spaces without testing and monitoring the atmosphere and providing constant ventilation.
- Covered manure storages, even when empty, should only be entered by trained personnel equipped with suitable self-contained breathing apparatus. Never assume that gas levels are safe.
- If a rescue becomes necessary, call your local fire department. Do not attempt a rescue on your own.
- If you suspect that you have been exposed to high levels of manure gas, consult your physician or the anti-poison centre immediately.
- Inspect the safety fence periodically to ensure there are no openings and that warning signs are still in place.
- Ensure that modifications to the ventilation system or any reconfiguration of the livestock building do not affect the venting of hazardous gases in under-barn manure storages. Consult an agricultural engineer when making structural or ventilation modifications where an under-barn manure storage is present.

Liquid Manure Tankers

- Never assume a tanker is safe to enter, even when empty. Hydrogen sulphide, which is heavier than air, will collect at the bottom of the tanker and remain there, even though there is an opening at the top. In August 2000, three men lost their lives during an attempted repair of a manure tanker and the subsequent rescue effort. Never enter a liquid manure tanker unless you are equipped with suitable self-contained breathing apparatus.
- When working around liquid manure storages and tankers, farm workers can protect themselves by wearing a pocket-sized hydrogen sulphide monitor that will sound an alarm when dangerous gas levels are reached.

Figure 3. Safety hatch for liquid manure tanker.

- Newer liquid tankers are equipped with safety hatches to prevent unauthorized entry. However, a large number of older units in use across Ontario do not have a safety hatch. Retrofit these tankers with a safety hatch on the top opening to prevent unauthorized entry. These safety hatches can be purchased from a number of farm equipment dealers or can be custom made. Figure 3 shows an example safety hatch.

Silos

- Post a "Danger, Deadly Gases" warning sign in a visible location near the silo.
- Do not allow children or visitors near the silo for 3 weeks after filling.
- Provide sufficient feed room ventilation to exhaust any silo gas that might have spilled down from the silo.
- Check with your local fire department to see if pressure-demand remote breathing apparatus is part of their emergency equipment. Self-contained breathing apparatus (i.e., scuba) equipment is not suitable because of the air tank. It is sometimes too big for climbing the silo chute or the outside ladder-cage or too small to contain enough reserve air to rescue someone.
- During filling, adjust the distributor as needed to level the silage. Do not level the material by hand.
- If it is necessary to enter the silo when filling is complete, do so immediately following the last load, on the same day. Remember to leave the blower running while inside.

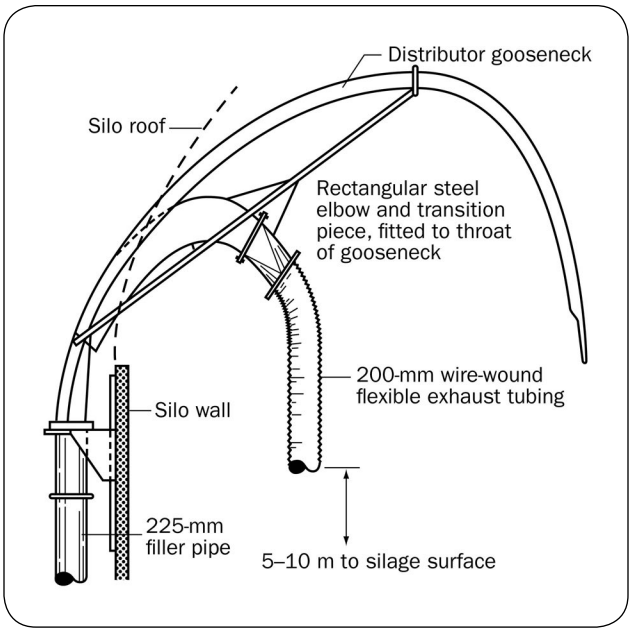

Figure 4. Suggested ventilation adapter for rotary distributors.

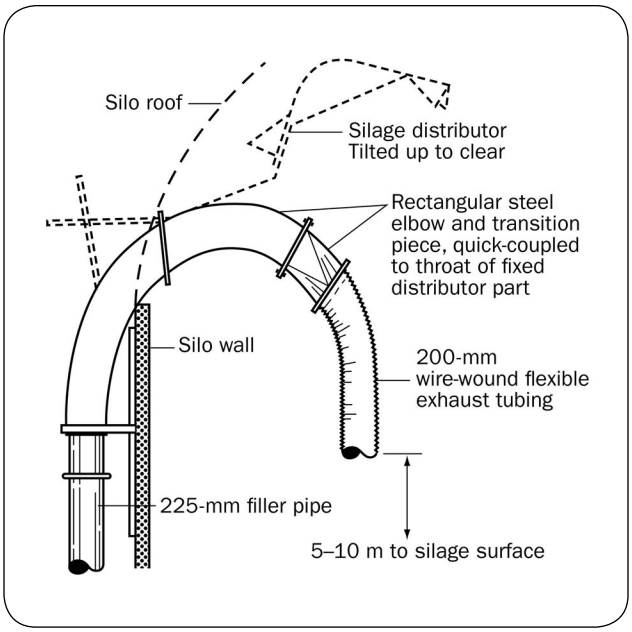

Figure 5. Suggested ventilation adapter for fin-type distributors.

- Oxygen-limiting silos are a special case and should never be entered. If it becomes absolutely necessary to enter such a silo, it is essential that an external air supply be worn and back-up emergency safety measures are in place. Consult publication I33 *Alert: Atmospheric Hazards Associated with Oxygen-Limited Structures (Silos) on Farms,* by the Ministry of Labour, for suggested precautions.
- A top unloader can ventilate a silo effectively. However, if it becomes necessary to service a defective unloader, assume that gases are present. To expel gases before entering, run the forage blower with the chute doors closed and the roof vent open. If the head space is greater than 5 m (15 ft), attach a tube adapter to the blower pipe (Figures 4 and 5). For a 7.2-m (24-ft) diameter silo with 5–10 m (15–30 ft) of head space, let the blower run for 30 min. For larger diameter silos or silos with a deeper head space, increase the ventilation time. Leave the forage blower running while in the silo.
- If someone collapses inside a silo, begin ventilating with the forage blower immediately, as explained above, and contact your local fire department. A fresh air supply is critical for both the victim and rescuers. Never attempt to rescue someone yourself. This has been attempted many times and, without the proper equipment and training, has resulted in many incidents of multiple fatalities.

Agricultural Biogas Systems

Consult the OMAF Factsheet, *Hydrogen Sulphide in Agricultural Biogas Systems*, for detailed management options for the various structures that store organic materials or produce and are in contact with biogas.

Farm Labour Concerns and Hazardous Gases

Since 2006, the Ontario *Occupational Health and Safety Act* applies, with some limitations and conditions, to all farming operations that have paid workers, under O. Reg. 414/05, Farming Operations. It does not apply to a farming operation operated by a self-employed person who does not have paid workers.

A recent hazard alert, I33 *Alert: Atmospheric Hazards Associated with Oxygen-Limited Structures (Silos) on Farms* was published by the Ministry of Labour following a recent fatality in Eastern Ontario involving an unplanned entry in an oxygen-limited atmosphere. The worker was overcome immediately after entering a silo by the hazardous atmosphere. The hazard alert lists relevant legislative requirements for employers and employees and suggested precautions for entry in oxygen-limiting structures, such as training, supervision, work procedures, signage, atmospheric monitoring, PPE (personal protective equipment) and mechanical ventilation. In general, the employer shall take every precaution reasonable for the protection of a worker.

For a more complete overview of legislative requirements and suggested practices, consult the *Occupational Health and Safety Guidelines for Farming Operations,* published by the Ministry of Labour, www.ontario.ca/labour (Ministry of Labour Health and Safety Contact Centre, 1-877-202-0008).

CONCLUSION

Never assume that the environment inside a silo or manure storage is safe. Do not enter a liquid manure tank or recently filled silo, under any circumstances, without a pressure-demand remote breathing apparatus. These confined spaces often contain lethal concentrations of hazardous gases. Always have a lifeline attached, with a responsible, trained and competent safety person in view of your work. Follow the management suggestions outlined in this Factsheet and the legislative requirements of the *Occupational Health and Safety Act.* Post clearly visible warning signs to warn others to stay away.

This Factsheet provides basic awareness information on hazardous gases found on agricultural operations. This document does not intend to provide assurance of compliance with occupational health and safety regulations in Ontario. To receive local assistance for compliance with the *Occupational Health and Safety Act,* call Workplace Safety Prevention Services (formerly known as Farm Safety Association), toll-free at 1-800-361-8855, if you are located in Ontario.

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This Factsheet was revised by Terrence Sauvé, Farmstead Optimization and Safety Engineer, OMAF, and originally written by Luc Brunet, Engineer, OMAF.

Do you know about Ontario's *Nutrient Management Act*?

The provincial *Nutrient Management Act* (NMA) and the Regulation 267/03, as amended, regulates the storage, handling and application of nutrients that could be applied to agricultural crop land. The objective is to protect Ontario's surface and groundwater resources.

Please consult the regulation and protocols for the specific legal details. This Factsheet is not meant to provide legal advice. Consult your lawyer if you have questions about your legal obligations.

For more information on the NMA, call the Nutrient Management Information Line at 1-866-242-4460, e-mail nman.omafra@ontario.ca or visit www.ontario.ca/omaf.

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