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HAZARDOUS GASES

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(Replaces OMAFRA Factsheet *Hazardous Gases*, Order No. 99-001, Printed November 2006)

INTRODUCTION

Hazardous gases on farms are found in silos, manure storages, grain bins, and barns. These structures provide a confined space in which certain gases may accumulate to dangerous levels.

When plant material is stored in a silo, fermentation takes place, a process that allows the crop to be stored for a long period of time. However, the fermentation process uses up oxygen and produces carbon dioxide and nitrogen dioxide as byproducts. This can lead to an environment which is unsuitable for humans soon after the silo is filled.

When manure is stored for a long period of time, it undergoes anaerobic decomposition. During this process, manure gases are produced. Warm weather and poor ventilation can increase the concentration of these gases. Liquid manure tanks therefore can produce toxic levels of gases, or result in a lack of oxygen. Agitating manure in a liquid storage also results in a rapid increase in the release of manure gases. In addition to the human risks, high gas levels can deteriorate exposed concrete above the liquid manure surface. Explosions have taken place when methane gas was allowed to accumulate in an enclosed space. Clause 78, Part VIII in Ontario Regulation 267/03 created under the *Nutrient Management Act*, 2002, requires all new liquid manure storages provide some form of ventilation to prevent the accumulation and or intensification of corrosive, noxious or explosive gases.

Silo and manure storages contain a variety of gases. These gases may be classified as irritants or asphyxiants. Irritants cause inflammation and irritation to the respiratory system tissues. Asphyxiants are gases that displace oxygen from the air (simple asphyxiants), or combine with the blood's hemoglobin (chemical asphyxiants). This Factsheet focuses on dangerous gases which can be found around farms and safety precautions which will help protect farm workers from these silent killers. For information on health problems related to respirable dust, refer to OMAFRA Factsheet, *Farm Workers Health Problems Related to Air Quality inside Livestock Barns*, Order No. 93-003.

HYDROGEN SULPHIDE

Hydrogen sulphide, H_2S, is the most dangerous manure gas. It is classified as a chemical asphyxiant because it immediately chemically interacts with the blood's hemoglobin to block 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 it paralyses the sense of smell. This can give someone a false sense of security when exposed to hydrogen sulphide. In high concentrations, hydrogen sulphide causes instant paralysis and death.

TABLE 1. Hydrogen Sulphide Effects on Humans at Various Concentrations

Hydrogen Sulphide Concentration, PPM	Effect on Humans
0.005	Barely detectable
4	Easily detectable, moderate odour
10	Eye irritation
27	Unpleasant odour
100	Coughing, eye irritation, loss 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 – 1000	Rapid unconsciousness, cessation of respiration and death
1000	Diaphragm paralysis on first breath, rapid asphyxiation

Source: American Society of Agricultural Engineering Standards, 2003)

Table 1 outlines the effect of hydrogen sulphide at various concentrations. Hydrogen sulphide is heavier than air; therefore, it tends to be located just above the

surface of the manure. 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 very quickly when a tank is agitated, especially if splashing or surface agitation takes place (see 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 a manure storage or the room above one in an attempt to save someone who had been overcome by H_2S.

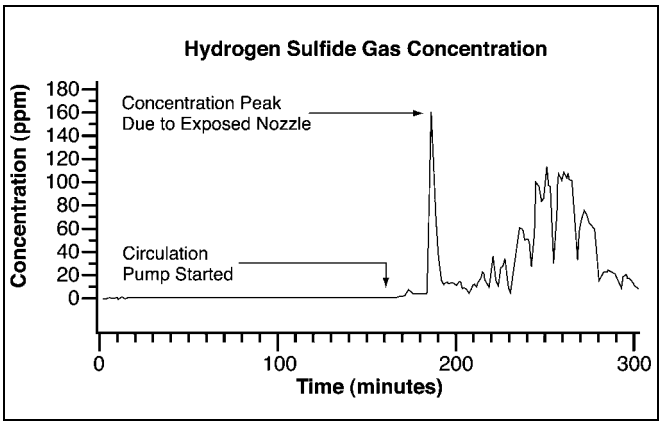

FIGURE 1. H_2S concentration during pit agitation. (Patni, N. K. and S. P. Clarke, Ontario Swine Research Review, 1990)

METHANE

Methane, CH_4, is a colourless and odourless gas. This combustible gas is generated by anaerobic digestion of organic material and if stored can be used as a fuel source for internal combustion engines. It is lighter than air, therefore, tends to rise from the manure storage. Methane is non-toxic and is unlikely to be a concern in well-ventilated livestock buildings. In covered and in-barn storages, methane can become trapped and the concentration can reach dangerously explosive levels.

In 1996, an Ontario farmer sat down at his office desk after doing the morning feeding and proceeded to light a cigarette. The office, washroom, feed room, and connecting hallway were constructed on top of a concrete covered manure storage that was located between two parallel swine barns. The tank was almost filled to capacity and due to be pumped out. The shower facility had not been actively used for several years and likely did not have any water in the drain trap, causing methane to escape into the office for some time. The spark ignited the methane gas that had accumulated in the office area causing an explosion and small fire. Although the office was destroyed, fortunately the farmer managed to escape with second degree burns to his hands.

AMMONIA

Ammonia, NH_3, is a colourless gas and has a characteristically pungent odour. It is produced by the decomposition of animal manures. This gas is classified as an irritant. It is lighter than air and can pre-dispose livestock to various respiratory diseases if exposed to a significant gas 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 tends to be a concern mainly in swine and poultry buildings however, it can also be a problem in manure composting operations. As a guideline, if eye irritation occurs, the ventilation in the building should be improved.

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. All open flame, non-vented, space heaters will also contribute carbon dioxide to the surrounding air space as one of the products of combustion. It 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 and can result in asphyxiation or suffocation. Well-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 (NO_2)

Nitrogen dioxide is a dangerous chemical asphyxiant and is 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. It has a characteristic bleach-like odour and may be visible as a reddish-brown haze. It is heavier than air; therefore, it will tend to be located 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.

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 (see Table 2). Although threshold limit values have not been established for animals, many researchers have suggested that animal responses are likely similar to humans.

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)	1000
Carbon Dioxide (CO_2)	5000
Nitrogen Dioxide (NO_2)	3
Nitric Oxide (NO)	25
Oxides of Nitrogen (NO_x)	3

(Source: American Conference of Government Industrial Hygienists)

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 reasonable gas detection tubes and hand held monitors commercially available from safety and scientific supply stores. A box of 10 gas detector tubes is less than $100 and hand held monitors start at about $250.

All of these gases can be measured 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. These tubes are also available as passive dositubes which react slowly when exposed to the environment containing the gas of interest and yield an average gas concentration over time. Depending on the gas, a passive dositube would be exposed to the environment being checked for several hours to as much as 48 hours.

Hand held monitors (see Figure 2) are now available for not only measuring these gases, but they are also equipped to sound an alarm when a dangerous gas level is detected. In fact, safety consultants are recommending the monitoring units with alarm only and no digital readout so that the person is not inclined to take the extra time to check the actual gas level before making a hasty exit.

FIGURE 2. Example of commercially available monitor for hydrogen sulphide gas. (Source: Agviro Inc.)

MANAGEMENT SUGGESTIONS

Manure Storages

- Ensure covered manure storages are ventilated by some means to prevent the accumulation of all hazardous gases.

- Post a "Danger, Deadly Gases" warning sign in a visible location near each pump out station. These signs are available from the Ontario Farm Safety Association.

- Before agitating and emptying an under floor liquid manure storage, remove all livestock, if possible. If it is not possible to remove the livestock, extra precautions must be taken.

- 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 very

quickly when splashing or surface agitation takes place (see *Figure 1*).

- 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. Secondly, 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. Finally, 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/s (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 and 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 (see Figure 2). Gas monitors can be obtained from safety equipment suppliers for less than $250. In addition, there are consultants in Ontario who offer hydrogen sulphide awareness training.

- Always maintain at least one foot of freeboard between the manure surface and the bottom of the slats to prevent animals from routinely breathing hydrogen sulphide and carbon dioxide.

- When flushing gutters, provide maximum ventilation. Do not enter the barn during and immediately following flushing. If gas detection equipment is available, monitor gas levels in the barn.

- Ideally, all pump-out openings should be located outside the building to eliminate the danger of working in a confined area, and be protected by a safety railing when in use.

- 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 smoking in the barn or near a manure storage facility.

- Manure storages should only be entered by trained personnel equipped with suitable self-contained breathing apparatus. Never assume that gas levels are safe at any time.

- 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 ammonia, hydrogen sulphide or carbon dioxide, consult your physician immediately.

- Inspect the safety fence periodically to ensure there are no openings and that warning signs are still in place.

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, 3 men lost their lives during an attempted repair of a manure tanker and 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.

- Newer liquid tankers are equipped with safety hatches to prevent unauthorized entry. However, there are a large number of older units in use across Ontario that do not have a safety hatch. These tankers should be retrofitted 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.

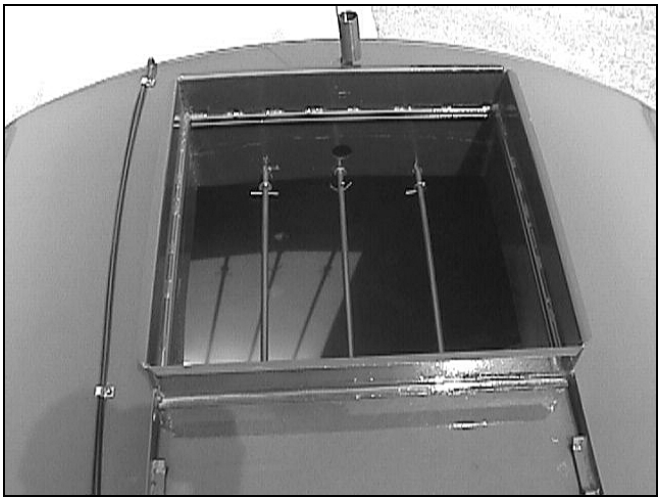

FIGURE 3. Safety hatch for liquid manure tanker.

Silos

- Post a "Danger, Deadly Gases" warning sign in a visible location near the silo. These signs are available from the Ontario Farm Safety Association.

- Do not allow children or visitors near the silo for 3 weeks after filling.

- Provide sufficient feed room ventilation to exhaust any silo gas which might have spilled from the silo.

- Check with your local fire department to see if pressure-demand remote breathing apparatus is part of their emergency equipment. Scuba equipment is not suitable because often the air tank is too big for climbing the silo chute or the outside ladder-cage.

- During filling, adjust the distributor as needed to level silage. Do not level 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.

- 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.

- 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 (see *Figures4* 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.

- In the event that someone collapses inside a silo, begin ventilating with the forage blower immediately as explained in item #8 above, and contact your local fire department. A fresh air supply is critical for both the victim and rescuers.

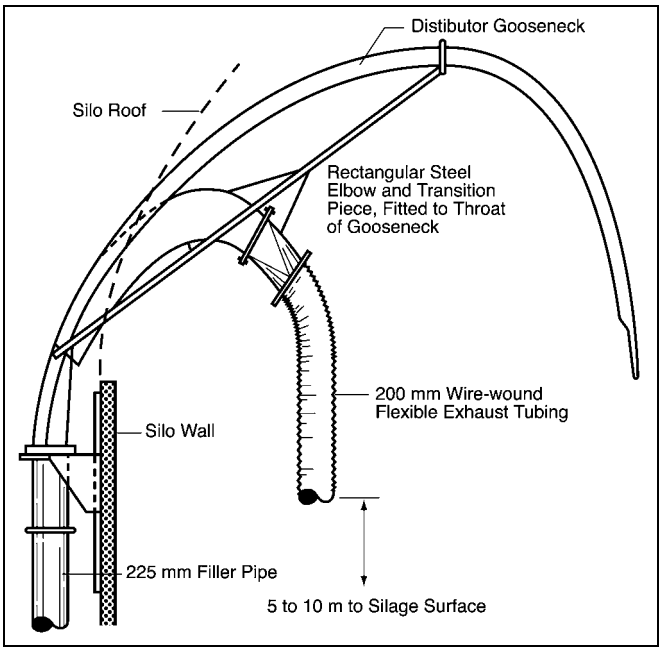

FIGURE 4. Suggested ventilation adapter for rotary distributors.

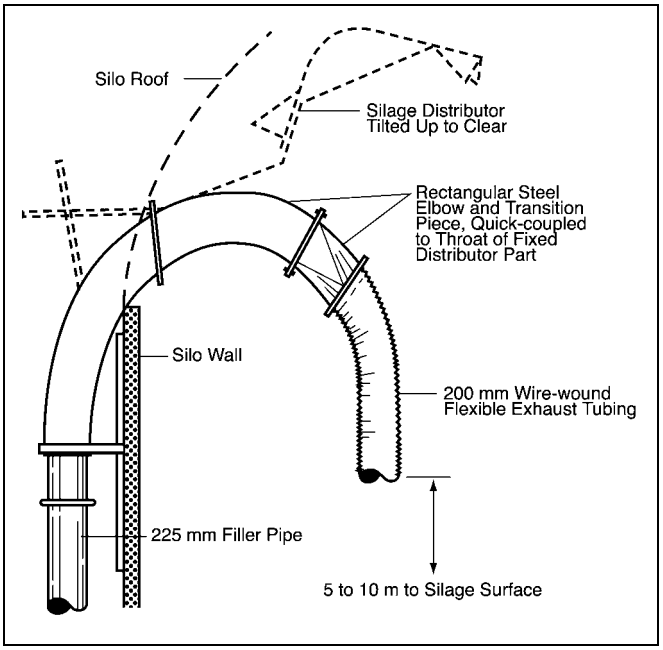

FIGURE 5. Suggested ventilation adapter for fin-type distributors.

CONCLUSION

Never assume that the environment inside a silo or manure storage is adequate. 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 safety person in view of your work. Follow the management suggestions outlined in this factsheet and post clearly visible warning signs to warn others to stay away.

Additional Information

OMAFRA Factsheet, *Farm Workers Health Problems Related to Air Quality inside Livestock Barns*, Order No. 93-003

OMAFRA Factsheet, *Constructing Hydraulically Secure Liquid Nutrient Storage Facilities*, Order No.06-035

Nutrient Management Act, 2002 (NMA), Ontario Regulation 267/03 as amended

Canada Plan Service Leaflet M-8710 Manure Gas, www.cps.gov.on.ca

Canada Plan Service Leaflet M-9707, www.cps.gov.on.ca

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FOR YOUR NOTES

Do you know about Ontario's new *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.gov.on.ca* or visit *www.omafra.gov.on.ca*.

Factsheets are continually being updated so please ensure that you have the most recent version.

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