A Primer on Livestock Air Quality

What is air quality?

Zhang (2005) defines air quality as the degree of pollution of clean air. Clean air is the air that is free from impurities. Air quality can be determined by measuring the concentration of pollutants in the air. The lower the concentration of airborne pollutants, the better is the air quality. Auvermann (2006) defined air pollutants as compounds or materials that, when suspended in or mixed with air, degrade air quality and impair its utility for any of a wide range of purposes. Emission of pollutants is the release or discharge of a substance into the environment. Generally refers to the release of gases or particulates into the air. Emissions load on the environment in terms of mass per unit time is the product of pollutant concentration and the air flow rate (e.g., load = concentration **x** ventilation rate). Confined Feeding Operations (CFOs) can affect air quality through emissions of gases (ammonia and hydrogen sulfide), particulate matter, volatile organic and odour. Emissions from CFOs come from three primary sources: manure storage facilities, animal housing, and land application of manure. Emissions of pollutants depend on many factors such as temperature, humidity, ventilation rates, wind speed, ventilation rate, housing and manure management systems, and animal characteristics (species, size and density). Effective reduction of overall emissions of air pollutants will most likely include several of control strategies rather than any single one.

Why air quality is important?

Good air quality in livestock facilities can have an impact on the health and well-being of animals and humans. There are many implications and potential impacts of air quality on human and animal health. Extensive research documents acute and chronic respiratory disease and dysfunction among workers animals in swine and poultry buildings from exposure to particulate and gaseous pollutants (AEX-721-07). Pigs continually exposed to hydrogen sulphide concentrations of 20 ppm had reduced feed intake, increased stress and a fear of light (Robertson and Galbraith 1971). Animal production performance is also affected by air quality. Studies conducted in Australia demonstrated that pigs raised in clean environment with better air quality grew faster than pigs living under "normal" commercial. Maintaining good air quality is not only important for the productivity of the animals, but also for the welfare of the animals. Air quality is also a concern to producers as well as rural residents. CFOs livestock air quality may have a regional, national and global impact on the environment.

What are the benefits of improving livestock air quality?

- Improves the health, welfare and production performance of the animals.
- Improves the health and safety of producers and workers.
- Reduces emissions of harmful pollutants to the outside environment which helps reduce nuisance complaints.
- Results in significant energy and economic savings.
- Prolongs the life of building structures

What are the factors affecting livestock air quality?

Generally air quality is affected by weather, livestock facilities and management conditions

(a) Weather: The atmosphere is the agent that transports and disperses pollutants between sources and receptors. Air quality is getting worse during light wind conditions, as pollutants cannot be blown away. For emissions at a given source, a higher wind speed provides the pollutants with a greater air volume within which to disperse.

(b) Livestock facilities and manure management: Building hygiene is one of the most important factors affecting air quality and livestock health (Banhazi *et al.* 2000; Hartung *et al.* 1986; Rantzer and Svendsen 2001). Adopting more innovative management systems is essential for improving air and surface hygiene in both new and existing livestock buildings (Murphy and Cargill 2004)

How we measure air quality?

Air pollutants can be identified and measured using a variety of sensors and techniques. Odour measurement is tricky. It is measured by olfactometry technique.

What are the major air pollutants emitted from CFOs?

More than 160 gaseous compounds are produced and emitted by livestock operations. Of theses gases, ammonia, hydrogen sulphide are most commonly found and extensively researched.

Table 1: List of major air pollutants in livestock buildings (Adapted from NRC 2004)

Emissions	Global, national, and regional	Local (property line or nearest dwelling	Primary effects of concern
Ammonia	Major	Minor	Atmospheric deposition, haze
Hydrogen sulfide	Insignificant	significant	Quality of human life
Particulate matter	Insignificant	significant	Quality of human life
Volatile organic	Insignificant	Minor	Quality of human life
Odour	Insignificant	Major	Quality of human life

1. Ammonia

1.1 Introduction

Ammonia is emitted from manure in livestock buildings, manure storage facilities and during manure application to soils. Ammonia in livestock facilities results primarily from the breakdown of urea (present in urine) by the enzyme urease (excreted in feces). In poultry, urease is excreted with uric acid. Livestock operations are a major contributor of ammonia emissions. Ammonia is produced inside livestock buildings, in open feedlots, in manure storage facilities, during manure handling and treatment and when manure is applied to soils. The major sources for atmospheric emissions of ammonia in Alberta in order of output are: agricultural activities (animal feedlot operations and other activities), biomass burning (including forest fires), fertilizer plants, fossil fuel combustion, and accidental releases. Gaseous ammonia is a very important basic compound in the atmosphere. It reacts readily with acidic substances or sulphur dioxide to form ammonium salts that occur predominantly in the fine particle (size< 2.5 μm) fraction. A small amount of gaseous ammonia is converted to nitric oxide.

Typical ammonia levels in well-ventilated, environmentally regulated buildings are 10 - 20 ppm with liquid manure systems and 50 ppm where manure and urine are deposited on solid floors. Levels can exceed 50 ppm with lower winter ventilation rates and reach 100 - 200 ppm in poorly ventilated buildings. High levels of ammonia are found particularly in solid manure systems. Ammonia is lighter than air and can be easily removed from livestock buildings by proper ventilation. The current Alberta Environment (AENV) 1-hour Ambient Air Quality Objective for ammonia is 1,400 $\mu g/m^3$ (2,000 ppb) and is based on odour detection.

Table 1 Summary of effects in humans following acute ammonia exposure

Air Concentration (mg/m^3)[a]	Exposure Period	Effects Reported
3480	30 min	Death
350	1 d, 30 min	Nasal and throat irritation, increased minute volume
70	6 hr/d	Transient irritation of eyes, nose and throat
56	1 d, 2 hr/d	Coughing, eyes, nose and throat irritation
35	1 d, 2 hr/d	No adverse effect
35	6 wk, 5 d/wk,	No adverse respiratory effects or eye irritation
10	2 d, 5 hr/d (8 days apart)	Inflammatory response, acute respiratory symptoms and an increase in bronchial responsiveness
0.5 – 37 (3.5 average)		Odour threshold
12 - 14		Odour complaint level

Table 2 Summary of chronic effects in humans following inhalation exposure to ammonia

Air Concentration (mg/m^3)[a]	Exposure Period	Effects Reported
> 50	> 1 yr	Reduction in pulmonary function of exposed workers (cough, phlegm, wheeze or dyspnea)
8	9.7 yr	3% decline in Forced expiratory volumes (FEV) measured pre- and post-shift
6	12.2 yr	No adverse effects on lung function
5	10.7 yr	2% decline in FEV measured pre- and post-shift
1.7	15.1 yr	No significant association between ammonia exposure and measured bronchial responsiveness
0.12 to 0.16	> 6 mo	Significant increase in the incidence of reported acute respiratory disease in school children
0.12 to 0.16	> 6 mo	No increase in the reported incidence of acute respiratory disease in school children

[a] Conversion factor and assumptions used: $mg/m^3 \times 24.45/MW = ppm$; MW = 17.03, air at 25°C and 101.3 kPa

Province	Standard/Regulation (ppm)	Standard/Regulation $\mu g/m^3$	Averaging time	Uses	Agency
Alberta	2.000 ppm	1400 $\mu g/m^3$	1 hour	Ambient Air Quality Objective	Alberta Environment
Ontario	5.142 ppm	3600 $\mu g/m^3$	30 min	POI interim standard	Ontario MOE
	0.143 ppm	100 $\mu g/m^3$	24 hours	Ambient air quality criterion (AAQC)	
Manitoba	2.000 ppm	1400 $\mu g/m^3$	1 hour	Maximum acceptable level concentration	Manitoba Conservation

Table 2.2 Ambient Ammonia Standards and regulation in Canada

1.2 Why control ammonia emissions?

Ammonia emissions decrease the nutrient value of manure and represent a significant loss of fertilizers. It has a negative impact on the environment such as soil acidification and eurotification surface water. Ammonia that lost to the atmosphere combines with nitric acid to form aerosol nitrate, which contributes significantly to total particulate matter. These particles have serious impacts on human health and cause visibility impairment.

Ammonia poses a threat to both the animals and agricultural workers in livestock facilities. It is a significant respiratory hazard for workers who experience long-term exposure to this gas in constant average values greater than 25 ppm. In addition to respiratory effects, ammonia can cause skin and eye irritation and displace oxygen in the bloodstream. Long-term exposure to ammonia can cause pneumonia.

The main objective of this fact sheet is to help producers and farm mangers reduce ammonia emissions from livestock housing and manure storage facilities. By reducing ammonia emissions, producers will meet environmental criteria, prevent loss of significant portion of nutrients and improve health and safety of animals and workers. Although there is no a direct relationship between ammonia emissions and odour, practices to reduce ammonia emissions can have a corresponding effect on odour generation. Ammonia emissions control during manure application will be presented in a separate factsheet.

1.3 Ammonia Control Technologies and Best Management Practices

A whole spectrum of suppressive, inhibitive, capture and control technologies and best management practices (BMPs) are available for the elimination and or reduction of ammonia emissions from livestock operations. Ammonia is emitted from manure in livestock buildings, manure storage facilities and during manure application to soils; therefore several technologies or best management practices are needed to control ammonia emitted from CFO operations. To date, there no technology or best management practice emerges as a clear choice for the industry due, in part, to associated cost (real and perceived) of implementation and long-term operation of the technology. The technology to completely prevent and remove ammonia either does not exist or is prohibitively expensive to install and/or manage. The efficacy of a particular technology or BMP depends on three factors; efficiency, applicability and cost. Producers are advised to implement efficient but less costly technologies and BMPs.

1.3.1 Suppression methods

1.3.1.1 Impermeable covers

Rigid impermeable covers include concrete or wood lids placed on the top of liquid storage units, and lightweight roofs made of fiberglass, etc. Rigid covers are usually more expensive than other types of covers, but they usually last longer (10 to 15 years, depending on the material (Bicudo 1999). Impermeable covers are capable of reducing 80-95% ammonia emissions from manure storage facilities.

1.3.1.2 Permeable cover

Permeable covers, or biocovers, act as biofilters on the top of manure storage areas. They physically limit the emissions of ammonia and other gases from the surface of storage lagoons, and create a biologically active zone where the emitted ammonia and other gases will be aerobically decomposed by microorganisms. Permeable covers and biocovers include chopped barley, wheat, oats, or brome straw (8-12 inches thick). Effectiveness of ammonia emissions control is lower than with impermeable covers. They are cost effective but they require replacement over time and they are vulnerable to extreme weather conditions. For more information on permeable and impermeable manure storage covers refer to fact sheet 925-D (*Covers for Manure Storage Units: http://agbiopubs.sdstate. edu/articles/FS925-D.pdf)*

1.3.1.3 Acidification

Research in Europe proved that acidification of manure, just before application, reduced ammonia volatilization depending on the degree of acidification and the application technique. A new technology has been developed in Denmark where sulphuric acid is added to slurry and the acidified slurry is returned to the livestock building (Eriksen and Sørensen, 2006). It has been documented that NH_3 volatilization is reduced by 50-80% by this technique. Because acidification is a suppression technique, the potential exists for ammonia to be volatilized from downstream processes (e.g., storage or land application) if the pH increases above 4.5.Using acidifying agents to suppress the ammonia emissions from manure may favour the conditions for the release of more hydrogen sulphide to the environment. The costs of the chemical additives vary widely, and they can be cost prohibitive for smaller operations.

1.3.2 Inhibition Methods

1.3.2.1 Manure management in barns

(1) Ammonia emissions from liquid manure surface is proportional to its surface area, Therefore decreasing manure surface area by changing the shape and dimensions of manure pit will reduce ammonia emissions from the barn.

(2) The type floor area exposed to manure in animal housing facilities can have a significant impact on the emissions rate of NH_3. Emissions of NH_3 from the solid part of the floor can be reduced by using an inclined or convex, smoothly finished surface.

(3) Decreasing of the length of the time manure remained in the livestock building is an important factor in reducing ammonia emissions. This can be achieved by frequent removal of manure from livestock buildings or pens and daily flushing of manure from barn alleys.

(4) Using ventilation techniques that create low air velocities around surfaces exposed to manure will also help reduce ammonia emissions. Air speeds across manure-covered surfaces should be minimized since the amount of ammonia gas given off by manure is increased with air speed (Heber *et al*. 1996).

(5) Keeping buildings and the animals clean and dry is essential for reducing ammonia emissions.

(6) Separation manure from urine may slow the rate of reactions that lead to ammonia generation and may help minimize ammonia volatilization. Most systems employ a separator or a belt conveyor whereby feces, containing urease, are captured on the belt and urine is stored below. As much as 80 % reduction in ammonia emissions is expected from using this system but the practice has not yet been commercially implemented. However, several urine/feces segregation systems are in the developmental phase at this time (Power 2004).

(7) Manure pH has an important effect on the NH_3 release as a lower pH value results in less NH_3 being emitted. As pH increases above 7.0, the concentration of ammonia increases as does the rate of ammonia volatilization. The pH of manures handled as solids can be in the range of 7.5 to 8.5, which results in rapid ammonia volatilization. Manure handled as liquids or semi-solids tend to have lower pH.

(8) Many producers will add a layer of water in the bottom of the slurry pits prior to manure collection in order to reduce initial ammonia emissions from the slurry pit (Lim et al., 2004)

1.3.2.2 Diet manipulation

Nitrogen fed in excess of requirements of animals is simply excreted in urine and feces. Matching feed to the nutritional requirements of animals reduces nitrogen excretion without affecting productivity. Production can be significantly affected if protein levels are reduced too far. Research found that ammonia emissions could be reduced in dairy cows by 20% to 30% by manipulating dietary crude protein types and levels. Feeding a reduced crude protein, amino acid–supplemented diet is also an effective tool for reducing ammonia emissions from growing-finishing swine housing. Phase feeding is a commonly used practice for meeting livestock nutrient needs without exceeding them. Producers should consult with extension personnel or certified livestock nutritionists for more information on diet manipulation. No cost information for diet manipulation was found in the literature review. However, dietary manipulation has the potential of reducing feed costs.

1.3.3 Capture and Control Methods

1.3.3.1 Filtration and biofilteration

Biofilters usually consist of ventilation and fan that exhausts air from the building through ducts into plenum below the biofilter media. The air passes through the biofilter media where the microorganisms treat it before it emitted into the atmosphere. Theoretically biofiltration is an effective method for reducing the emissions of ammonia from livestock buildings. It was proved elsewhere that biofilters are efficient in removing ammonia from livestock buildings but not under Alberta conditions.

1.3.3.2 Bioscrubbing

The concept of bioscrubbing is similar to biofiltration. Both rely on microbial degradation of NH_3. The difference between bioscrubbing and biofiltration is that the bioscrubber is housed in a closed tower containing water. When ammonia passes through the tower, it will be captured and absorbed by water, then oxidized by the microorganisms. High reduction of ammonia emissions by scrubbing has been reported in numerous research publications but cost and applicability to Alberta situations have not been proved yet.

Ammonia stripping is a process for the removal of ammonia from manure. The manure is first made alkaline to favor the NH_3 form, and then aerated so that exchange between the water and the atmosphere is encouraged. Stripping towers are often used, with the waste trickling downward as air is forced upward through the tower. Ammonia (a weak base) reacts with water (a weak acid) to form ammonium hydroxide. In ammonia stripping, lime or caustic is added to the wastewater until the pH reaches 10.8 to 11.5.

1.3.3.3 Landscaping

Trees, shrubs and other vegetative barriers planted around livestock buildings have the potential of reducing ammonia emissions. Trees and shrubs act as biofilters for odorous compounds that are attached to fine particles. They also offer visual protection for livestock building. A demonstration site on the Delmarva Peninsula has shown a 67% reduction in ammonia levels downwind of the vegetative filter belt planted on commercial broiler farms.

2. Hydrogen sulphide

2.1 Introduction

Hydrogen sulfide is a toxic gas and has potential to cause health problems if the concentration becomes too high. Hydrogen sulphide in livestock buildings is mainly present in shallow barn gutters, underground, in outdoor holding storage tanks, or in earthen manure storage facilities. Hydrogen sulphide is heavier than air, soluble in water, and can accumulate in underground pits and unventilated areas of livestock buildings. The current Alberta Environment 1-hour Ambient Air Quality Objective for Hydrogen sulphide is 14 µg/m^3 (10 ppb) based on odour perception and the 24-hour Ambient Air Quality is 4 µg/m^3 (3 ppb). In Alberta, the threshold limit value (TLV) eight-hour time weighted average (TWA) exposure limit for H_2S is 10 ppm (Alberta Human Resources and Employment 2003).

2.2 Characteristics

Hydrogen sulphide is heavier than air, soluble in water, and can accumulate in underground pits and unventilated areas of livestock buildings. It has a rotten-egg odour and it can be easily detected at low concentrations (well below one part per million in air).

Table 2.1 Hydrogen sulphide and health hazards.

Concentration	Health response
0.01 - 0.7	Least Detectable Odour
3 - 5	Offensive Odour
10	Eye Irritation
20	Irritation Mucous Membranes and Lungs
50 - 100	Irritation of Respiratory Tract
150	Nose Nerve Paralysis
200	Headache, Dizziness
500 - 600	Nausea, Excitement, Unconsciousness
700 - 2000	Fatal

Table 2.2 Hydrogen sulphide ambient standards in Canada

Province	Standard/Reg ppb (µg/m^3)	Averaging time	Uses	Agency
Alberta	**10 (14**) 3 **(4)**	1 hour 24 hour	Ambient Air Quality Objective	Alberta Environment
Ontario	9.1 (**13)**	10 min	Proposed Ambient Air Quality Criterion (AAQC) 2006	Ontario MOE
	7 **(10)**	30 min	Proposed Point of Impingement (POI) standard (2006)	
	4.9 **(7)**	24 hours	Proposed Ambient Air Quality Criterion (AAQC) (2006)	
Manitoba	1000 **(1400)** 10.5 **(15)** 3.5 **(5)** 0.7 **(1)**	1 hour 1 hour 24 hour 1 hour	Maximum acceptable level concentration Maximum Acceptable Level Concentration Guideline Maximum Acceptable Level Concentration Guideline Maximum Desirable Level Concentration Guideline	Manitoba Conservation
Saskatchewan	10.5 **(15)** 3.5 **(5)**	1 hour 24 hour	Air Quality Objectives Air Quality Objectives	
British Columbia	(5.25 –9.8 **(7.5-14)** 19.6 –31.5 **(28-45)** 29.4-31.5 **(42-45)** 2.8 **(4)** 4.2 –5.25 (**6-7.5)** 5.25-5.6 **(7.5-8)**	1 hour 1 hour 1 hour 24 hour 24 hour 24 hour	Maximum Desirable Criterion Maximum Acceptable Criterion Maximum Tolerable Criterion Maximum Desirable Criterion Maximum Acceptable Criterion Maximum Tolerable Criterion	
New Brunswick	10.5 **(15)** 3.5 **(5)**	1 hour 24 hour	Air Quality Objectives Air Quality Objectives	

The American Conference of Governmental Industrial Hygienists (ACGIH) defined Threshold Limit Value (TLV) as an estimate of the average safe airborne concentration of a substance, which represents conditions under which it is believed that nearly all workers may be repeatedly exposed to day after day without adverse effect.
Threshold Limit Value (TLV) for hydrogen sulphide in Alberta: is 5 ppm and 15 minutes TLV is 10 ppm.

Table 2.3 Provincial Hydrogen Sulphide Occupational health and safety limits

Province	**8-hour average ppm (mg/m^3)**	**15-minute average ppm (mg/m^3)**
Alberta	5 **(7**)	10 **(14)**
BC	10 **(14)**	14 **(19.6)**
Ontario	10 (**14)**	14 **(19.6**)
Saskatchewan	14 **(19.6)**	21 **(29.4)**

2.3 Hydrogen sulphide detection

Hydrogen sulphide is an extremely poisonous gas, so appropriate detection equipment should be available in livestock buildings, specifically during manure agitation and pumping. There is a variety of detection equipment such as Gas Detector Tubes, Continuous Monitors**,** Personal Monitors and Portable Monitors. Some of these monitors are simple to use and some of them need some training to calibrate and use. Use a gas detector tube with an extension hose to avoid the possibility of breathing highly toxic hydrogen sulphide. The detector tube must be specific for the gas to be measured (hydrogen sulphide). While reaching through a window or other opening, place the detector tube near floor level and use the vacuum pump to draw air into the tube. Remove the detector tube and read the gas concentration (NASD).

2.4 Options to reduce hydrogen sulphide emissions from livestock buildings

- Modifying swine diets to balance rations reduce hydrogen sulphide emissions.
- Frequent removal of manure from static pits significantly reduces hydrogen sulphide.
- Physical, chemical and biological treatment of stored manure such as manure additives and oil sprinkling.
- Biofiltration is an effective method for reducing the emissions of hydrogen sulphide.

2.5 How to protect yourself from hydrogen sulphide exposure

- Provide strong ventilation during agitation and pumping. The building interior should be off limits to people. If possible, stock should be removed from the facilities (Farm Safety Association).
- Keep the agitator below the liquid surface. Gas will be released in greater volumes if vigorous surface agitation occurs.
- If possible, lower the level of liquid manure in the storage facility before commencing agitation. This will further reduce the possibility of gas being forced above floor level.

- Never allow the manure pit to fill completely. Allow one to two feet of air space to accommodate concentrations of gas.
- Do not enter a manure storage pit without full respiratory protection. Wear Self-Contained Breathing Apparatus (SCBA) where high concentrations exist or supply air-breathing apparatus.

3 Particulate Matter (Dust)

3.1 Introduction

Particulate Matter (PM) is an unusual air pollutant in that it is defined by its physical morphology rather than chemical identity. PM is categorized by aerodynamic diameter, which is the size of a spherical particle that behaves the same as the actual particle (most PM is highly irregular in shape). The most common classifications are PM_{10} (coarse PM), which includes particles smaller than 10 µm in aerodynamic diameter, and $PM_{2.5}$ (fine or respirable PM), which includes particles smaller than 2.5 µm in diameter.

Dust from swine barns originates from feed, bedding material, manure and the animals themselves. Many of the respirable dust particles are odorous because of their fecal origin. The factors determining the amount of dust in confinement includes animal activity, temperature, relative humidity, and ventilation rate, stocking density and feeding methods.

3.2 Factors affecting dust emissions

3.2.1 Temperature

Takai (1992) conducted a study in which he found that a significant correlation exited between inside temperature and respirable dust concentration. In another study he found a negative correlation between outside temperature and the dust concentration. The significance of the temperature on the dust concentration seems to be a reflection of a level of the activity of animals rather than the relative humidity of the air. Predicala et al. (2001) reported that and the respirable dust in swine buildings was influenced by the temperature difference between inside and outside air.

3.2.2 Relative humidity

The effect of relative humidity on the dust level is related more or less to the influence of the temperature. Humidity has two effects on airborne dust. It affects dust generation and it affects the viability of airborne microbial contaminants. The absorption of water vapor by dust particles in humid air produces heavier particles, which settle more rapidly, thus lowering aerial dust concentration. The humid air also increases the moister content of the dry manure or and settle dust, so that less dust become airborne. Heber et al. (1988) found that both the number and net mass concentration of the total dust is affected by relative humidity.

3.2.3 Animal Activity

Animal activity plays an important role in dust concentration inside livestock buildings. Takai (1992) animal activity is a major factor causing high dust concentration. Smith

(1993) reported that during certain periods of the day the animal activity can be a least as important as the ventilation rate determining the aerial concentration of irrespirable and respirable dust.

3.3 Livestock producers and workers are at risk for respiratory diseases

3.3.1 Bronchitis

Symptoms include cough, phlegm, tightness of chest, shortness of breath, wheeze.

3.3.2 Chronic Farmer Lung Disease

May occur with repeated dust exposures although it is possible to develop it after only one attack. Symptoms include chronic coughing, increasing and severe shortness of breath with slight exertion, weakness and body aches, and occasional fever.

3.3.3 Occupational Asthma

Symptoms include tightness of chest, shortness of breath and wheeze.

3.3.4 Organic Dust Toxic Syndrome (ODTS)

About one-third of swine producers have had one or more episodes of (ODTS). Symptoms include fever episodes, headaches, muscle aches, flu-like illness and shortness of breath.

3.4 Dust and odour

Gases and odorants adhere to dust particles and it has been indicated that removal of dust in animal production facilities can reduce the odour in the air by 65-75% (Hammond and Smith 1981; Hartung 1985.Hartung, 1986; Hoff *et al.*, 1997). Hartung found that at least 60 compounds from different groupings were identified in dust from animal houses Hartung (1986). Furthermore, previous research has indicated that dust can transport and amplify the odor (Takai *et al*., 1998; Hammond *et al*., 1979). Bottcher *et al.* (2001) reported that odorants can exit in much higher concentration in dust particles than equalivant volumes of air. Thus inhalation of odorous dust and deposition of dust particles in mucus overlaying the olfactory mucus are likely responsible for some odour related complains by swine farmer neighbours. Bottcher *et al.* (2000) reported that odours attached to airborne particulate might increase the persistence of the odour as it dispersed away from the source. Hangartner (1990) indicated that filtering dust from the exhaust air reduced VOC–odor emissions from swine buildings by up to 65%.

3.5 Dust Control Methods for Livestock Buildings

The control of dust in intensive livestock buildings is important to reduce nuisance and dust respiratory hazards and also to prevent heat recovery or heating and cooling equipment and buildings from being fouled by dust. Dust hazards can be reduced in four ways:

- by minimizing the occurrence of fine particles,
- by preventing these particles from forming dust clouds,
- by removing airborne dust using air cleaning devices, and
- by workers using dust masks.

3.5.1 Feeding

Proper and timely maintenance of feeders, augers, and other feed handling equipment is required for proper dust control. Addition of oil to dry swine rations significantly reduces the amount of dust in a building.

3.5.2 Ventilation

The major method of controlling dust and air contamination in enclosed livestock facilities is by mechanical ventilation. A well-designed and maintained ventilation system will help control levels of dust inside swine buildings. Air flow by ventilation has capabilities to remove aerosol from livestock building especially during the warm weather when the ventilation rates are very high, but Wang et al. (1999) found that ventilation system has a direct effect on the dust spatial distribution in swine buildings, but increasing the ventilation rate does not effectively reduce the overall dust level because the dust production rate increased with an increase of ventilation rate.

3.5.2 Air Misting

Maghirang et al. (1995) concluded that oil/water spraying is a promising technique for dust control in livestock buildings. Van't Klooster et al. (1993) and Gustafasson (1994) reported that spaying small droplets of water into the air would result in a significant reduction in airborne dust emission in swine buildings.

3.5.3 Fibrous Filter

Fibrous filters are considered suitable for removing respirable aerosol from livestock facilities. The mechanism of capturing the dust and aerosol particles by interception and internal impact on filter materials. Some fibrous filters are capable of removing aerosol less than 1 micron. The removal efficiencies of fibrous filters vary. Some fibrous filters have removal efficiencies up to 99% (Veenhuizen, 1989). Carpenter and Fryer (1990) suggested that fibrous filters could be used effectively in swine and dairy housing, but the cost of frequent cleaning and maintenance are very high because the filter are subjected to rapid clogging in dusty environment.

3.5.4 Ionization

Air ionization systems to accelerate and remove dust from livestock buildings have been investigated by a number of researchers (Veenhuizen and Bundy, 1990; Atia. 1991, Atia 1995, Tanaka and Zhang, 1996).

3.5.5 Wet Collectors

Wet scrubber using water to capture dust particle are very efficient in removing dust particles from air, however its use is not recommended in livestock building due to the needs for handling large amount of air in livestock buildings (Dawson, 1990).

3.5.6 Oil Sprinkling

Mnakell et al. (1995) reported that airborne total dust concentration generated from swine feed may be markedly reduced by adding 1% soybean oil. Jacobson *et al*. (1998) reported that daily sprinkling 0.5 ml/ ft^2 of vegetable oil to swine barn could reduce the dust concentration by 40-50%. Sprinkling a small quantity of canola oil in growerfinisher sections on the horizontal surfaces (on floor and pigs) reduced respirable and inhalable dust by 71 and 76%, respectively (Zhang *et al*., 1996). Paszek et al. (2001) reported that the average percent reduction by sprinkling vegetable oil for respirable, inhalable and total dust for all measurements equaled 65.3 %, 78.8 % and 58.8 %, respectively.

4.0 Volatile organic compounds (VOCs)

A Volatile Organic Compound (VOC) is an organic compound that participates in atmospheric photochemical reactions. VOCs contain at least one carbon atom (excluding carbon dioxide and carbon monoxide), have a vapour pressure of 0.01 kPa or greater at 25^{o}C and vaporize easily at room temperature. They include fatty acids, nitrogen heterocycles, amines, alcohols, aliphatics, aldehydes, ethers, *p*-cresol, mercaptans, hydrocarbons, and halocarbons.

There are a large number of VOCs that have been identified in manures. These are generated by the partial breakdown of feed materials that takes place in an animal's digestive tract by anaerobic bacteria. Many of the resultant compounds are highly odorous, the most important of these being Volatile Fatty Acids (VFAs), indolics, phenolics and sulphur compounds. VOCs are a precursor to ozone, which is also associated

5.0 Odours

Sources of odours on the farm can include compost, manure, commercial fertilizers, silage, decomposing **organic matter**, livestock mortalities and household wastewaters. Odours differ depending on the source and the receiver's response to the smells themselves. Most of the odours from the above mentioned sources are a result of ammonia (NH_3) and hydrogen sulphide (H_2S) gas levels.

Odour is generally considered a **nuisance** rather than a health risk to neighbours because of the degree of dilution and dispersion that occurs within short distances from the odour source. Here the discussion includes human response to odour, which is unique for each person and extremely variable, and the environmental factors of the site, which can be managed to reduce the environmental risk to air quality.

It is difficult to evaluate odour and its effects for the following reasons:

- Odour from manure is made up of about 160 compounds. Humans have varied responses to these compounds.
- The proportion and characteristics of odour contributed by each of the primary sources (barns, storages and land application) are not well understood. Research is underway to characterize odours released from each of these sources.
- Odour intensity and offensiveness varies between individuals.
- The combination of different odours can have positive and negative effects on intensity and offensiveness. These effects are not easily predicted.

However, there are management practices that can control odour within reasonable limits. Odour mitigation practices should focus on reducing the nuisance to neighbours, by minimizing the frequency, intensity, duration and offensiveness of odours.

While research and development are underway to find solutions for odours, the following factors should be considered:

- To date, no technology emerges as a clear choice for the industry because of costs (real and perceived) associated with implementation and long term operation of the technology.
- The technology to completely prevent and remove odour either does not exist or is prohibitively expensive to install and/or manage.
- Many odour control technology studies have focused on mitigation of odour at a particular location of the operation or reducing emissions from a single source.
- Effective odour control strategy for a livestock operation may require using more than one technology or management practice.
- More research is needed to further evaluate the effectiveness of some of the odour control technologies that have been tested.

5.0 Livestock Air Quality Extension and Technology Transfer

One of core business goals of Alberta Agriculture and Food is to enhance rural sustainability and to improve environmental stewardship. AF realizes that environmental degradation, particularly of water and air, can occur from excessive use or improper handling or application of nutrients. AF is working on developing technologies and evaluating management practices in areas of manure and nutrient management. AF is working on minimizing the impact of agricultural operations on environment by developing information, technologies, tools and processes that supports environmentally friendly crop and livestock operations.

5.1 Livestock air quality Resources for Producers in Alberta

Robins the web site that contains news articles, upcoming events, fact sheets, and research papers related to air quality, as well as contact information for air quality experts.
http://www1.agric.gov.ab.ca/$Department/deptdocs.nsf/all/epw10940

5.2 Clean Air Strategic alliance (CASA)

The Clean Air Strategic Alliance (CASA) is a non-profit association composed of stakeholders from three sectors – government, industry and non-government organizations such as health and environmental groups. All CASA groups and teams, including the board of directors, make decisions and recommendations by consensus. These recommendations are likely to be more innovative and longer lasting than those reached through traditional negotiation processes. CASA’s vision is that the air will be odourless, tasteless, look clear and have no measurable short-or long-term adverse effects on people, animals or the environment.

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