Beneficial Management Practices for Mitigating Hazardous Air Emissions from Animal Waste in Wisconsin

December 13, 2010

Acknowledgments

The Wisconsin Department of Natural Resources would like to thank the Agricultural Waste Air Emissions Advisory Group members for their dedication and efforts in collaborating with the Department in the development of beneficial management practices. While the Advisory Group was invaluable in the discussion of animal agriculture and beneficial practices to reduce ammonia and hydrogen sulfide, Department staff primarily authored the report and are responsible for its content.

We would also like to acknowledge other experts who presented to the Advisory Group and were consulted during the process. These include experts from Wisconsin, Minnesota, Iowa, US Environmental Protection Agency and the Wisconsin Agricultural Statistics Service.

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EXECUTIVE SUMMARY

Purpose

On April 17, 2010 the WDNR convened the first in a series of meetings of the Agricultural Waste Air Emissions Advisory Group. The charge given to the Advisory Group was to identify, and recommend to the Department, suitable best management practices (BMPs) for the reduction of emissions of hazardous air pollutants from various types of livestock operations in Wisconsin. For the purposes of this report, the Advisory Group was neither asked to consider rule making nor how the BMPs may be implemented. The Advisory Group focused on two hazardous air contaminants: ammonia and hydrogen sulfide. As part of the development of BMPs specific to ammonia and hydrogen sulfide, the Advisory Group identified air quality co-benefits, and potential impacts to water quality.

This report summarizes both the process used by the Advisory Group as well as recommended beneficial management practices for mitigating hazardous air emissions from animal agriculture. A total of 30 recommended BMPs are the product of nine meetings among the full advisory group and two subgroups, along with additional conference calls, occurring between April and December 2010.

The full Advisory Group used a collaborative process to develop the content of the final report.

BMPs Defined

- In the context of air quality and animal agriculture, BMPs are defined as production methods, technologies and waste management practices used to prevent or control air emissions from livestock facilities.

- The term best management practice was redefined as *beneficial* management practice, not best management practice; because what may be best for one farm may not be best for another. The term “beneficial management practice” also acknowledges that future practices and technologies may provide greater benefits than practices or technologies we describe today as “best.”

Resources Consulted

- Practices were evaluated relying on the most recent and appropriate science available, as well as the collective knowledge, experience, and professional judgment of Advisory Group members.

- Scientific literature was consulted on a global basis and the Advisory Group extracted information applicable to Wisconsin animal agriculture.
- Where available, Wisconsin specific studies, experiences, and current practices were carefully considered.

- Advisory Group meetings included presentations from outside experts and a field visit to the University of Wisconsin Arlington Research Station.

- Department Runoff Management staff participated in the evaluation of practices and potential benefits or disbenefits to water quality. The staff were consulted for their expertise in the area of animal agriculture in Wisconsin as well.

Limitations and Applicability

- The beneficial management practices (BMPs) recommended by the Advisory Group are tailored to Wisconsin animal agriculture and many of the recommendations focus on nitrogen (ammonia), due to the greater volume of available literature, relative to hydrogen sulfide.

- Not every BMP will be appropriate for every animal agricultural operation, nor will every BMP be technically or economically feasible for a given farm. Animal agricultural operations will choose to use a number of individual, or a combination of, practices based on farm-specific features and other factors.

- In some cases, a specific BMP focusing on one air pollutant may actually contribute to an increase in other air emissions or to environmental problems in other media (e.g. ground water or surface water).

- Not all animals and animal production methods associated with waste from agricultural operations were considered with the development of Wisconsin-specific BMPs. Particular focus included dairy and beef operations, poultry layers, poultry broilers (including turkeys) and swine operations.

Additional Facts and Qualifiers

- In general, practices which reduce odor tend to reduce ammonia and/or hydrogen sulfide, but not always.

- Different production methods, animal types, and manure management systems have the potential to create different types and quantities of air emissions. In order to successfully mitigate emissions, different, or a combination of, practices and technologies may be required.

- Many of the BMPs, which prevent or mitigate air emissions, often make common sense. For example, mixed operations that integrate optimal cropping systems with animal production typically retain nitrogen for crops (minimizing ammonia losses), resulting in decreased need for fertilizer nitrogen.

- Successful reduction of ammonia and hydrogen sulfide losses from animal agriculture requires an integrative, whole-farm emissions approach for effective evaluation and selection of practices or technologies.

- While certain practices or technologies may be quite effective for controlling emissions from one part of a farm, it is important to understand the fate of those controlled emissions elsewhere.

- Unhealthy levels of hydrogen sulfide beyond the property boundary of large animal agricultural operations have been little studied in Wisconsin and to date have not been documented as a health hazard associated with dairy operations in Wisconsin.

NR 445 was not developed with the purpose of regulating emissions of hazardous air contaminants associated with agricultural waste or byproducts. The Department believes that using beneficial management practices is the preferred approach to mitigate emissions from these types of sources. Accordingly, the 30 beneficial management practices presented in Section 1 represent the Advisory Group’s collective recommendations as methods that can reduce ammonia and hydrogen sulfide emissions from animal agriculture in Wisconsin.

SECTION 1 - Beneficial Management Practices

The Agricultural Waste Air Emissions Advisory Group was tasked, by Division Administrator Al Shea in April 2010, to identify, evaluate, and recommend suitable management practices for the reduction of emissions of hazardous air pollutants from various types of livestock operations in Wisconsin. The hazardous air pollutants of concern from animal waste are ammonia and hydrogen sulfide. The Advisory Group divided into two technical subgroups, **Bovine** and **Swine & Poultry**, to evaluate a list of more than 90 potential Beneficial Management Practices (BMPs) using a process and criteria set forth by the Department and described in Section 6.

The Advisory Group acknowledges that many Wisconsin farms already employ production methods and practices that minimize air emissions. This report is a means of communicating practices and methods and are summarized in tables below. These tables are organized by farm component and animal species and indicate whether a practice is established or requires demonstration, and whether the practice reduces ammonia, hydrogen sulfide or both. Detailed BMP descriptions are included in the following Appendices:

- Appendix A - ***Animal Nutrition and Feed Management*** practices;
- Appendix B - ***Animal Housing*** practices;
- Appendix C - ***Manure Storage & Treatment*** practices;
- Appendix D - ***Open Lots & Corrals*** practices;
- Appendix E - ***Pasture*** practices;
- Appendix F - ***Land Application*** practices.

Farm Component	Established or Demonstration	Reduces Ammonia (A) or Hydrogen Sulfide (HS)	Dairy	Beef	Swine	Poultry – Broilers & Turkeys	Poultry – Egg Layers
Animal Nutrition and Feed Management							
Animal Nutrition and Feed Management	Established	A & HS	X	X	X	X	X
Silage Storage	Established	A & HS	X	X			

Farm Component	Established or Demonstration	Reduces Ammonia (A) or Hydrogen Sulfide (HS)	Dairy	Beef	Swine	Poultry – Broilers & Turkeys	Poultry – Egg Layers
Animal Housing							
Biofilter	Established	A & HS	X		X	X	X
Composting Manure with Proper C:N Ratio	Established	HS	X	X	X		
Vegetative Environmental Buffers (VEB)	Established	A & HS	X	X	X	X	X
Mechanical Scraping	Established	A & HS	X				
Vegetable oil sprinkling (for swine only)	Established	A & HS			X		
Swine Housing - Wall or Ceiling Ventilation	Established	A & HS			X		
Binding Ammonium - Alum Treatment of Poultry Litter	Established	A				X	
Frequent Cleaning (Removal) of Poultry Litter or Manure	Established	A				X	X
Wet Scrubber/Bio Scrubber	Demonstration		X		X	X	X
Urine-Feces Segregation	Demonstration		X		X		
Chemical or Biological Manure Additives Chemical Additives	Demonstration		X	X	X	X	X
Chimney Exhaust/Air Impaction Methods	Demonstration		X		X	X	X
Poultry Manure Drying	Demonstration	A					X

Farm Component	Established or Demonstration	Reduces Ammonia (A) or Hydrogen Sulfide (HS)	Dairy	Beef	Swine	Poultry – Broilers & Turkeys	Poultry – Egg Layers
Manure Storage & Treatment							
Impermeable Cover	Established	A & HS	X	X	X	X	X
Permeable Geotextile and Bio-covers, including Natural Crust	Established	A & HS	X	X	X	X	X
Biofilter	Established	A or HS	X	X	X	X	X
Composting Manure with Proper C:N Ratio	Established	HS	X	X	X	X	X
Vegetative Environmental Buffers (VEB)	Established	A & HS	X	X	X	X	X
Bottom Filling, Minimizing Surface Agitation	Established	A & HS	X		X		
Covering Solid Manure Storage – (poultry)	Established	A				X	X
Anaerobic Digester	Demonstration		X	X	X		
Wet Scrubber/Bioscrubber	Demonstration		X	X	X	X	X
Wastewater Treatment	Demonstration		X	X	X	X	X
Chemical or Biological Manure Additives	Demonstration		X	X	X	X	X
Manure Solids Separation	Demonstration		X		X		

Farm Component	Established or Demonstration	Reduces Ammonia (A) or Hydrogen Sulfide (HS)	Dairy	Beef	Swine	Poultry – Broilers & Turkeys	Poultry – Egg Layers
Open Lots & Corrals							
Vegetative Environmental Buffers (VEB)	Established	A & HS	X	X			
Open Lot Frequent Cleaning (concrete and earthen surface)	Established	A & HS	X	X			
Feedlane - Durable Surfaces	Established	A & HS	X	X			
Chemical or Biological Manure Additives	Demonstration		X	X			

Farm Component	Established or Demonstration	Reduces Ammonia (A) or Hydrogen Sulfide (HS)	Dairy	Beef	Swine	Poultry – Broilers & Turkeys	Poultry – Egg Layers
Pasture							
Rotational Grazing as Production Method	Established	A & HS	X	X			

Farm Component	Established or Demonstration	Reduces Ammonia (A) or Hydrogen Sulfide (HS)	Dairy	Beef	Swine	Poultry – Broilers & Turkeys	Poultry – Egg Layers
Land Application							
Injection	Established	A & HS	X		X		
Incorporation	Established	A & HS	X	X	X	X	X
Banding	Established	A & HS	X		X		
Other Techniques	Demonstration	A & HS	X	X	X	X	X

Below is the salient information for each beneficial management practice recommended by the Advisory Group to the Department. Each practice includes the following information:

- a description of the recommended practice(s)
- the supporting rationale
- identification of the conventional baseline practice (the practice judged by the Advisory Group to be the most common practice at this time) against which emission reductions, due to the beneficial management practice, are determined
- identification of the affected farm component(s)
- identification of the affected animal operation type
- the stated emission reduction percentage, specific to the farm component, not the whole farm
- other air quality considerations, noting whether the practice reduces, or negatively impacts, volatile organic compounds, particulate matter, greenhouse gasses, or odor, when known
- engineering Operation and Maintenance (O&M) requirements
- methods for confirming that the practice is working, including record keeping and monitoring (note: this is not ambient air monitoring)
- additional considerations and references

SECTION 2 - Background

Purpose/Charge of Advisory Group

The Agricultural Waste Air Emissions Advisory Group was tasked, by Division Administrator Al Shea in April 2010, to identify, evaluate, and recommend suitable management practices for the reduction of emissions of hazardous air pollutants from various types of livestock operations in Wisconsin (Appendix G). The hazardous air pollutants of concern from animal waste are ammonia and hydrogen sulfide.

Advisory Group Members

After consultation with staff from the Wisconsin Department of Agriculture, Trade and Consumer Protection, the WDNR solicited commitments from individuals representing various interests, including: agricultural, state and federal government, Non-Governmental Organizations (NGOs) and academia to serve as NR445 Agricultural Waste Best Management Advisors. Advisory Group members and their Areas of Expertise are listed in the table below.

Name	**Organization**	**Area of Expertise**
Asche, Loren	Day Break Foods & Creekwood Farms	Poultry farming
Breitenmoser, Hans Jr.	Golden Dawn Dairy	Dairy farming
Buelow, Kenn	Holsum Dairy	Dairy farming
Busch, Dennis	Pioneer Farm	Agricultural research
Jacobson, Larry	University of Minnesota – Bioproducts & Biosystems Engineering	Manure management practices research
Meyer Smith, Amber/Peter Taglia*	Clean Wisconsin	Environmental science
Murphy, Pat	Wisconsin Natural Resources Conservation Service	Resource conservation
Pofahl, Bob	Resource Engineering Associates – President	Agricultural and environmental engineering
Powell, J. Mark	USDA ARS & University of Wisconsin	Research environmental impacts of ruminants
Saul, James	James N. Saul, Attorney at Law LLC.	Environmental law
Sponseller, Bart (Chair)	Department of Natural Resources	Air quality
Struss, Steve	Department of Agriculture, Trade & Consumer Protection	Agricultural engineering
Thiboldeaux, Rob	Department of Health Services	Toxicology
Wehler, Mike	Pork Farmer & Wisconsin Pork Association	Pork farming
* Peter Taglia substituted Amber Meyer Smith starting in August 2010, as Ms. Meyer Smith went on maternity leave.		

Sub-group Leaders

Air emissions from animal waste differ from animal species, both in terms of emissions created and strategies to mitigate them. To better address the differences, the Agricultural Waste Advisory Group was divided into two sub-groups: (1) Bovine, led by Dr. J. Mark Powell and (2) Swine/Poultry, led by Dr. Larry Jacobson. From July through September, the Bovine and Swine/Poultry subgroups worked independently to focus on species-specific practices and some practices shared by both sub-groups. The two technical sub-groups (Bovine and Swine & Poultry) evaluated a list of more than 90 potential Beneficial Management Practices (BMPs), using a process and criteria set forth by the Department, described in Section 6.

Introduction to Toxic Air Contaminants of Interest and Animal Agriculture

Wisconsin Rule NR 445, Control of Hazardous Air Pollutants, regulates more than 600 hazardous air contaminants, from all stationary air contaminant sources in the state. At least 25 different toxic air contaminants regulated under NR445 are known to be emitted from agricultural waste, including carcinogens, chronic and acute pollutants. The pollutants include ammonia, hydrogen sulfide, benzene, methane and various aldehydes, alcohols, phenolics, sulfides, amines, and acids.

Of the 25 known toxic pollutants, two are likely emitted from agricultural waste above levels of concern. These pollutants are ammonia (NH_3) and hydrogen sulfide (H_2S).

Ammonia

Ammonia (NH_3) is an atmospheric pollutant of concern that readily reacts with acids and precursor pollutants in the atmosphere to form particulate ammonium sulfates [NH_4HSO_4 and $(NH_4)_2SO_4$], and ammonium nitrate (NH_4NO_3), which are contributors to ambient fine particulates (PM2.5) and regional haze, as well as to soil and water acidification.

Ammonia is generated from animal waste and is released from barns, lagoons and from land application. Based on a statewide 2005 inventory, agricultural livestock operations accounted for 84 percent of estimated ammonia emissions.

Most ammonia is produced when the urea contained in urine comes in contact with the urease enzyme contained in feces (also on barn floors and in soil). Much smaller amounts of ammonia are produced during the decomposition of feces. Nitrogen occurs as both unabsorbed nutrients in animal feces and as either urea (mammals) or uric acid (poultry) in urine. The potential for ammonia emissions exists wherever manure is present, and ammonia will be emitted from confinement buildings, open lots, stockpiles, anaerobic lagoons, and land application from both wet and dry manure handling systems.

The volatilization of ammonia from any manure management operation will be highly variable depending on total ammonia concentration, temperature, pH, and storage time. Ammonia is highly soluble in water, but can also readily volatilize from water solution to enter the air. However, when the pH of an ammonia solution is acidic, ammonia exists in the form of ammonium ion (NH_4^+), which is much less volatile than ammonia (NH_3). High pH and high temperature favor a higher concentration of ammonia and, thus, greater ammonia emissions. The pH of manures handled as solids can be in the range of 7.5 to 8.5, which results in fairly rapid ammonia volatilization.

Manure handled as liquids or semi-solids tends to have lower pH. However, there may be little difference in annual ammonia emissions between solid and liquid manure handling systems, if liquid manure is stored over extended periods of time prior to land application. Limited research in Wisconsin found that ammonia emissions from tie-stall barns (the most common housing type on dairy farms with small to medium-sized herds) are usually lower than those from freestall barns.

Ammonia emissions are not constant throughout the year, but demonstrate seasonal, even daily, variability. The degree of seasonal variation depends on the geographic region, animal sector, and type of animal production practices used. For example, high temperature increases ammonia volatilization. Precipitation and humidity can either increase or decrease emissions depending on how manure is managed. Higher wind speeds can increase emissions from open manure storage facilities. The population of animals on a farm also varies throughout the year, thereby changing ammonia emissions from housing and manure storage facilities.

The Midwest Regional Planning Organization (MRPO) has been collecting and analyzing data on ambient ammonia concentrations in order to evaluate the potential impacts of ammonia emission reductions on levels of ambient PM2.5 and regional haze. The MRPO found that reducing ammonia emissions would be an effective strategy to reduce PM2.5 concentrations and improve visibility in the Great Lakes region.

Human Health Effects - Ammonia

Ammonia is listed as a toxic air contaminant in chapter NR 445 because it can cause adverse health effects at ambient concentrations. Ammonia's toxicity is based upon its caustic properties. At low concentrations, ammonia is irritating to wet tissues of the lungs, airways, and eyes. At sufficiently high concentrations, ammonia begins to dissolve those tissues, causing more severe damage.

Ammonia Toxicity Progression

Property	Concentration in Air (ppm)
Detectable Odor	0.04-53
Eye, Nose Irritation	50-100
Strong Cough	50-100
Airway Dysfunction	150
Lethal in 30 Minutes	2,500-4,500
Lethal Immediately	5,000-10,000

Few monitoring studies have been completed in Wisconsin, to date, which document ambient ammonia concentration change with respect to distance and time from a source.

A secondary effect of ammonia is the impact of increased nitrogen deposition from airborne ammonia, ammonium sulfates, and ammonium nitrates. This has been documented in studies in Delaware, North Carolina, Idaho and the Netherlands. Effects include increased soil acidification, plant nitrogen fortification, and a tendency within the ecosystem towards degraded plant communities.

Ammonia is a state hazardous air pollutant under Ch. NR 445, Wis. Adm. Code. Wisconsin has an ambient air quality standard for ammonia of 418 $\mu g/m^3$ averaged over a 24-hour period. Agricultural wastes are currently exempt from the requirements of NR 445 [current language calls for this exemption to expire after July 31, 2011 – see s. NR 445.08(6)(d)] and associated permitting requirements of Chs. 406 and 407, Wis. Adm. Code. Ch. NR 438, Wis. Adm. Code, contains reporting requirements, when emissions exceed 2,097 lb/yr of ammonia. The Clean Air Act lists ammonia in section 112.

Hydrogen Sulfide

Hydrogen sulfide is a product of the anaerobic decomposition of sulfur-containing organic matter (primarily manure). It is a colorless gas that is heavier than air, highly soluble in water, with odor and health implications. Although the molecular weight of hydrogen sulfide (H_2S) is more than O_2 or N_2, it is good to remember that gas laws ultimately dictate the equilibrium behavior of a gas. In the case of hydrogen sulfide, its slightly higher density, combined with being slowly released from the aqueous phase, result in it initially lying low. Hydrogen sulfide will eventually mix thoroughly in an enclosed space at equilibrium. Liquid manure storage pits (inside buildings) or basins (near barns) are the primary sources of hydrogen sulfide in animal production. Significant quantities of hydrogen sulfide can be released during agitation of stored liquid manure or during the flushing of animal housing.

Unhealthy levels of hydrogen sulfide beyond the property boundary of large animal agricultural operations have been little studied in Wisconsin and to date have not been documented as a health hazard associated with dairy operations in Wisconsin. Problems with hydrogen sulfide have been documented in 2008 in Minnesota, where air emissions from the Excel Dairy in Thief River Falls were deemed a public health hazard. Note, Minnesota has a different hydrogen sulfide standard than Wisconsin.

Hydrogen sulfide is a state hazardous air pollutant under Ch. NR 445, Wis. Adm. Code. Wisconsin has an ambient air quality standard for H_2S which is 335 $\mu g/m^3$ averaged over a 24-hour period. Minnesota has established air quality standards for H_2S that are more restrictive than Wisconsin's. Minnesota's ambient air quality standards for H_2S are 30 ppb no more than twice in 5 days, averaged over 30-minute periods, and with no more than 50 ppb occurring in any two 30-minute periods over those same 5 days.

Until July 31, 2011, there are exemptions for agricultural waste from the requirements of NR 445 and associated permitting requirements of Chs. 406 and 407, Wis. Adm. Code. Ch. NR 438, Wis. Adm. Code, contains reporting requirements when emissions exceed 3,279 lb/yr of H_2S.

Human Health Effects: Hydrogen Sulfide

The toxic mechanism of hydrogen sulfide is similar to cyanide, though much less potent. Of the several ways in which hydrogen sulfide can affect us, the most dangerous is when H_2S is concentrated enough (perhaps more than 600 ppm) to cause respiratory paralysis through the nervous system, leading to collapse and loss of consciousness while in a dangerous air environment such as a sewer or enclosed manure pit.

Hydrogen Sulfide Toxicity Progression

Property	Concentration in Air (ppm)
Offensive odor, headache (chronic exposure)	0.3
Very Offensive (chronic)	3-5
Asthmatics affected (acute)	2
Olfactory paralysis (acute)	150
Central Nervous System Depression/Loss of Consciousness	>500
Lung Paralysis, Collapse, Death	600-1,000

Air Emission Health Effects

Air emissions, including hydrogen sulfide, ammonia and organic dust, can have a detrimental effect on respiratory health. Even when using beneficial management systems and mitigation techniques, some airborne contaminants may be generated. Concentrations of airborne contaminants may build up inside livestock buildings that result in animal and human health concerns. Most concerns are associated with chronic or long-term exposure. However, some human and animal health concerns or safety hazards can result from acute or short-term exposures.

Pollutant	Sources	Health Effects
Particulate Matter (3 sizes - Total Suspended Particulate (TSP); Particulate Matter up to 10 micrometers (PM10); and Particulate Matter up to 2.5 micrometers (PM2.5)	Grain & Feed storage and handling; animals; wind blown dust	Larger particles of TSP are mostly associated with physical soiling and considered a nuisance while PM10 and PM2.5 are associated with increased respiratory symptoms such as exacerbation of bronchitis and asthma
Hydrogen Sulfide and other sulfur compounds.	Animal manures	Offensive odor at low concentrations. High concentrations cause nervous system depression including temporary respiratory paralysis which may lead to loss of consciousness and death. Intensity of odor is not a good indicator of danger, due to rapid olfactory fatigue.
Ammonia	Animal manures and urine	Ammonia may be associated with increased respiratory symptoms. Ammonia also contributes to PM2.5 concentrations and resulting health effects of fine-particle pollution.
Volatile Organic Compounds	Animals, feeds and waste treatment	This is a general class of chemicals. There are many volatile chemicals given off, many of which have odors and some of which may have effects on the respiratory system, although no one chemical has been strongly associated with symptoms off property as a result of actual exposures. Compounds include volatile fatty acids (butyric and caproic acid), that have a distinct and offensive odor. In addition to health effects of individual compounds, VOCs participate in atmospheric reactions to create ozone, which is a respiratory irritant.

As noted previously, ammonia emissions can contribute to secondary formation of fine particulates (with regional impact), through complex chemical reactions taking place over several hours. It has been estimated that animal agricultural operations in the upper Midwest contribute as much as 20% of the ambient PM2.5 in winter.

Other Known Pollutants and Odors Generated from Animal Waste

Particulate matter and fugitive dust emissions

Wisconsin defines particulate or particulate matter as any airborne finely divided solid or liquid material with an aerodynamic diameter smaller than 100 µm (micrometers). In general, particles are identified according to their aerodynamic diameter, as either PM10 (particles with an aerodynamic diameter smaller than 10 µm), or PM2.5 (aerodynamic diameter smaller than 2.5 µm). Even low concentrations of air pollutants have been related to a range of adverse health effects. Fine particulate matter (PM2.5) is considered more dangerous since, when inhaled, PM2.5, though tiny, are mixtures of reactive chemicals. They are small enough to reach the deepest part of the lungs, where the smallest particles can enter the blood and cause inflammation in the lungs and heart.

The tiny particles classified as PM2.5 are primarily formed by reactions in the atmosphere, or may be emitted directly to the atmosphere during combustion. Key precursor pollutants include, ammonia (principally from agricultural operations), SO_2 (principally from coal burning), NOx (principally from combustion processes) and organic carbon. The nature and sources of organic carbon vary widely and include combustion as well as secondary formation. Together, ammonium nitrate and ammonium sulfate represent about 60% of the total mass of PM2.5.

On average, organic carbon represents about 30% of the mass of PM2.5. Black carbon and crustal material together are about 10% of the mass of PM2.5. Some times called coarse particles, the particles in the PM10 size range are generally created by mechanical action such as crushing, grinding or wind-blown dust.

Greenhouse gases

Agriculture, in general, and livestock operations in particular, are anthropogenic sources of greenhouse gas emissions. The primary GHGs associated with animal agriculture include methane (CH_4) and nitrous oxide (N_2O). The July 2008 report of the Wisconsin Governor’s Task Force on Global Warming reports that the agriculture sector is responsible for 9% of 2003 state greenhouse gas emissions. The Governor’s Task Force report includes several recommended policies for the agriculture sector to reduce GHG emissions. Among the recommendations to reduce emissions are: nutrient and manure management changes (*i.e.* to reduce nitrous oxides and methane); and the production, capture and combustion of animal methane. While enteric emissions appear to be the majority of GHG emitted by livestock, GHG associated with manure management can be significant.

While GHGs are not presently regulated in Wisconsin, the EPA has finalized a rule (40 CFR part 98, subpart JJ) which contains reporting requirements for GHGs (for animal agricultural sources emitting over 25,000 metric tons annually of carbon dioxide equivalents from manure management activities).

Volatile Organic Compounds & Methanol

Volatile organic compounds (VOCs), which contribute to odor and air quality problems, have been identified and associated with CAFOs. Research in the U.S. has focused primarily on dairy CAFOs. VOCs are associated with both enteric fermentation and with fresh and stored manure. Researchers have identified 82 VOCs coming from a lactating cow open stall and 73 coming from a slurry lagoon. These compounds include: alcohols, aldehydes, ketones, esters, aromatic hydrocarbons, halogenated hydrocarbons, terpenes, other hydrocarbons, amines, other nitrogen containing compounds, and sulfur-containing compounds. It appears that the alcohols, methanol (MeOH) and ethanol (EtOH), are the majority of VOCs generated on dairy animal agricultural operations. Both of these alcohols are produced in the rumen (the enteric process) and in the fresh waste, primarily by gram-positive bacteria including *Streptococcus bovis* and *Ruminococcus albus*. To the Department's knowledge, no state has made a regulatory decision based on methanol emissions, nor has the EPA published or cited information to suggest this pollutant could exceed 10 tons/year (the trigger for developing a MACT (maximum achievable control technology) under s. 112(d), or determining a case-by-case MACT under s. 112(g)(2) of the Clean Air Act).

VOCs are defined in s. NR 400.02(162), Wis. Adm. Code as "any organic compound which participate in atmospheric photochemical reactions" excluding a number of compounds determined to have negligible photochemical reactivity, such as methane. VOCs are a criteria pollutant, and have permitting thresholds and general control requirements in Chs. NR 405, 406, 407, 408, 419 and 424, Wis. Adm. Code. Methanol is a federal hazardous air pollutant with emission limitations covered under section 112(b) of the Clean Air Act. Any stationary source which emits, or has the potential to emit, 10 tons per year of methanol would be a "major source" under the Clean Air Act.

Odors

Odors from CAFOs are primarily generated from the breakdown of feed in the gut of animals and in the manure after excretion. Feed, particularly silage under certain conditions, can also be a significant odor source. While there are numerous odorous compounds associated with manure, odors result from a combination of dozens, if not hundreds, of airborne compounds. These compounds can act synergistically to produce an odor that is actually more intense than would be expected from the sum of the individual compounds present.

Most of the odorous compounds that are emitted from animal production operations are byproducts of anaerobic decomposition/transformation of livestock (and poultry which DATCP defines as being livestock) wastes by microorganisms. Animal wastes include manure (feces and urine), spilled feed and water, bedding materials (*i.e.* straw, sunflower hulls, wood shavings), wash water, and other wastes. DATCP (and NRCS standards) define manure as containing all these things (feces, urine, bedding, spilled water, etc.) This highly organic mixture includes carbohydrates, fats, proteins, and other nutrients that are readily degradable by microorganisms under a wide variety of suitable environments. The by-products of microbial transformations depend, in major part, on whether it is done aerobically (*i.e.* with oxygen) or anaerobically (*i.e.* without oxygen). Microbial transformations done under aerobic conditions generally produce fewer odorous by-products than those done under anaerobic conditions. Compounds such as alcohols and acids may have strong odors too. Moisture content and temperature affect the rate of microbial decomposition.

A large number of volatile compounds have been identified as by-products of animal waste decomposition. The compounds are often listed in groups based on their chemical structure. Some of the principal odorous compounds, individual and as groups, are: ammonia, amines, hydrogen sulfide, volatile fatty acids, indoles, skatoles, phenols, mercaptans, alcohols, and carbonyls. Carbon dioxide and methane are odorless.

Wisconsin Administrative Code requires all sources of air emissions to regulate objectionable odors (s. NR 429.03, Wis. Adm. Code). This rule establishes general limitations on objectionable odor, defines the tests for what constitutes objectionable odor, and sets abatement or control requirements.

Background on ch. NR 445

Hazardous air contaminants from agricultural waste are regulated under ch. NR 445. This rule establishes ambient air standards for specific contaminants in the ambient air. The acceptable 24-hour average ambient concentrations for ammonia and hydrogen sulfide, the two primary contaminants associated with agricultural waste, are 418 and 335 micrograms per cubic meter, respectively. Ch. NR 445 was intended for stationary industrial point sources of hazardous air contaminants, which can be controlled using "end-of-pipe" technologies, unlike agriculture. As a result, it was determined that agricultural waste beneficial management practices (BMPs as outlined in Section 1 of this report) are the preferred means for complying with NR 445.

History of Exemptions/Delayed Compliance

The primary effort is to establish beneficial management practices (BMPs) that control hazardous air emissions from agricultural waste. Future changes to the NR445 may address scope, timeframe for review, submittal and approval, testing, record keeping, and reporting requirements related to BMPs approved by the Department.

Revisions to ch. NR 445, made in July 2004, provided a 36 month exemption until June 2007 for sources of hazardous contaminants from agricultural waste. After June 2007, new sources were to have complied upon start-up of operations, and existing sources had an additional 12 months to comply. The July 2004 revisions allowed use of best management practices, as approved by the Department, as a means of compliance for these sources.

Also published in July 2004 were revisions to the air permit requirements of chs. NR 406 and 407, providing a parallel 36 month air permit exemption for sources of hazardous emissions from agricultural waste from July 2004 to July 2007.

The end of the 36 month exemption period was established to coincide with the anticipated completion of studies at the state and federal levels. It was anticipated these studies would provide air emission data to support rule applicability determinations, and information about the efficacy of beneficial management practices to support the evaluation and establishment of BMPs. Information about these studies is provided below.

Revisions to ch. NR 445, effective August 1, 2008, extended the exemption period, for a second time, through July 31, 2011.

State Study

The Department engaged in a cooperative project to evaluate air emissions and certain BMPs for the control of hazardous air emissions from the handling of agricultural waste. The project included ambient air monitoring for hydrogen sulfide and ammonia, as well as odor evaluation near several dairy and livestock operations, installation of grant-funded improvements, and ambient air monitoring to evaluate the effectiveness of BMPs to control hydrogen sulfide, ammonia and odor. The final Dairy and Livestock Air Emissions/Odor report was published in September 2009 and can be found in Appendix L. Air emissions from landspreading of agricultural waste were not included in this study.

Federal Study

In the late 1990s, as noted in an August 2005 press release, US EPA realized that it did not have sufficient air emissions data to implement federal Clean Air Act requirements for animal feeding operations. To resolve the situation, US EPA began discussions with animal feeding operation owners in 2001. These discussions led to a January 31, 2005 EPA Federal Register notice offering individual animal feeding operations an opportunity to voluntarily sign a consent agreement committing them to participate in a nationwide air emission monitoring study and establishing a timeline for them to achieve compliance with federal air permit, air emission control, and air emission reporting requirements. In return, EPA provided limited amnesty from enforcement action during the term of the agreement.

Data collection was completed in mid-2009; final data was reported to US EPA during the summer of 2010. Within 18 months of the National Air Emissions Monitoring Study completion, US EPA is expected to evaluate the data and publish air emission-estimating methods for animal feeding operations. Given the multiple study delays, it is unclear at this time when US EPA will complete emissions estimating methodologies.

The intention of the NAEMS study was to measure base line emissions from livestock operations, not to evaluate emission reductions after BMPs were installed at the participating farms. Air emissions from landspreading of agricultural waste were not included in this study.

The study time frame of NAEMS and subsequent emission-estimating methodologies do not meet Wisconsin's legal obligation to develop BMPs, which benefit air quality.

Existing Federal Regulations

Under the federal Clean Air Act, new and existing major stationary sources of federally regulated criteria air pollutant emissions are subject to federal air permit requirements. Included are permit requirements under the federal "Prevention of Significant Deterioration (PSD)" and "Non-Attainment Area" New Source Review programs, along with the applicable requirements for "Best Available Control Technology", and "Lowest Achievable Emission Rate" technology and offsets, respectively. Emissions associated with animal feeding operations (AFOs) are not, categorically, exempt from these requirements.

Under Section 112(b) of the federal Clean Air Act, hazardous air pollutants are regulated through National Emission Standards for Hazardous Air Pollutants (NESHAPs) established by industry sector. No such standards have been established specifically for AFOs. Ammonia and hydrogen sulfide, two air pollutants associated with AFOs, are not regulated as federal hazardous air pollutants under section 112(b).

The Department is not aware of any new or proposed federal regulations pertaining to hazardous air pollutant emissions from animal feeding operations.

Existing State Regulations

The federal air permit requirements described above are incorporated into state air permit rules in chs. NR 405, 406, and 407. In addition, chs. NR 406 and 407 include air permit requirements for minor sources. Emissions associated with animal feeding operations are not categorically exempt from these requirements. However, the revisions to chs. NR 406 and 407 published in July 2004 established an exemption period ending in July 2007 for sources of hazardous air contaminant emissions from agricultural waste. The exemption period was extended again in February 2008 for chs. NR 406 and 407.

As noted above, chapter NR 445 establishes acceptable ambient air concentrations for ammonia and hydrogen sulfide, two pollutants associated with agricultural waste from animal feeding operations. These concentrations are 418 and 335 micrograms per cubic meter, respectively, on a 24-hour average basis.

Similar to federal reporting requirements, state reporting requirements include the air spill reporting requirements in ch. NR 445 and the annual air emission reporting requirements of ch. NR 438. Air emissions from animal feeding operations are not categorically exempt from these reporting requirements.

Wisconsin's Livestock Siting Law (ATCP 51)

The Livestock Facility Siting Law consists of a state statute (s. 93.90) and rule (ATCP 51) that establish state standards and procedures local governments must follow if they choose to require conditional use or other permits for siting new and expanded livestock operations. The siting statute affects local ordinances that require conditional use or other similar permits, but does not affect other ordinances such as shoreland and floodplain zoning. The statute limits the exclusion of livestock facilities from agricultural zoning districts. It also created the Livestock Facility Siting Review Board to hear appeals concerning local permit decisions.

The Siting Law is implemented by local governments. Provisions of the law can be incorporated into local ordinance at any time. ATCP 51 became effective on May 1, 2006 and existing ordinances had to adopt the new state standards by November 1, 2006 to be enforceable, or to keep a permit threshold lower than 500 animal units. Local governments must use the application worksheets in the rule to determine if a proposed facility meets these standards: Property line and road setbacks, Management and training plans, Odor management, Nutrient management, Manure storage facilities, and Runoff management.

ATCP 51 covers new and expanded livestock facilities over 500 animal units (AU) in size in local jurisdictions that have a permit requirement (unless the local government grandfathered a lower threshold prior to Nov. 1, 2006). An expansion is an increase in the maximum number of "animal units" kept for at least 90 days in any 12-month period. An expansion may or may not involve the construction or alteration of livestock structures. A change in livestock structures does not trigger a local siting permit requirement, unless accompanied by an increase in "animal units" that triggers the permit requirement (local building codes may apply, however).

Currently existing facilities may initially expand "animal units" by up to 20% without triggering a permit requirement (even if the expanded facility is more than 500 AU). For example:

- A 490 AU facility may expand to 588 AU without a permit, even if the local permit threshold is 500 AU

- A 600 AU facility may expand to 720 AU without a permit

- A 490 AU facility expanding to 750 AU (more than 20%) will need a permit

- A 600 AU facility expanding to 1000 AU (more than 20%) will need a permit

Certain facilities covered by the Siting Law must comply with an odor standard that uses a predictive model to determine acceptable odor levels from the farm structures. The Siting Law does not provide authority to monitor and regulate air emissions.

Odor is a very real and often highly charged issue for farmers, neighbors and local government in terms of health risks, both perceived and real, and nuisance law suits. In fact, often times the issue of air emissions and odors are talked about as being one-in-the-same. However, it is important to note that not all hazardous air emissions have odors, just as not all odor-causing agents are hazardous air contaminants. Differentiating between hazardous air emissions and odors is important, both in terms of practices used to mitigate each, and the effectiveness of those practices.

The odor standard set forth in the siting rule creates a more uniform approach to the regulation of odor associated with livestock operations. The intent of the standard is to simplify existing local approval processes for both livestock operators and local governments.

DATCP utilizes a predictive model to estimate odor from manure storage, animal housing and open lots. The model has several features. For example, the model:

- requires practices if a proposed facility does not have adequate separation distance from neighbors

- provides a range of practices to choose from (including low cost options to manage odor)

- protects future expansions by fixing the closest neighbor at the time of the original application

- is a one-time determination that does not allow for continuous odor monitoring for enforcement purposes

ATCP 51 also provides exemptions to the odor standard for certain facilities. Exemptions are provided when:

- an expansion will contain fewer than 1,000 AU

- a new facility will result in fewer than 500 AU

- all of the livestock structures associated with a facility will be located at least 2,500 feet from the nearest affected neighbor.

Producers have the option to voluntarily complete and comply with the odor standard even when exempt.

In 2009, The Department of Agriculture, Trade and Consumer Protection underwent a four-year review of ATCP 51, as provided for in the siting statute. The review began with four listening sessions and the department's presentation of an evaluation report to the DATCP Board (Appendix M). As a result of the four-year review, DATCP convened an expert technical committee to evaluate if the current requirements of the siting standards provide for responsible growth of an operation while correctly balancing environmental and other considerations such as public health and safety.

The scope of this committee is limited to assessing if the existing livestock facility siting standards appropriately address changing manure and odor management technologies and practices. The committee is not evaluating broader policy areas such as the social acceptance of large livestock farms, animal husbandry practices, or other related issues.

The technical expert committee is comprised of public and private sector experts knowledgeable in the areas of permitting livestock operations, odors, nutrient management, runoff management, agricultural engineering, land use planning and public health.

By December 31, 2010 the committee will develop recommendations to clarify how the standards could address the lessons learned over the past four years while continuing to meet the objectives of the siting law. The recommendations will be provided to the Board of Agriculture, Trade and Consumer Protection.

SECTION 3 – Wisconsin Animal Agriculture Profile

Wisconsin is known as the Dairy State. According to USDA National Agricultural Statistics Service, in 2007, there were 1,247,000 dairy cows on 14,400 farms state-wide. As of October 1, 2010, Wisconsin had 12,567 licensed milk cow herds with dairy cows numbering 1,260,000.

Livestock agriculture in Wisconsin is diverse and spans many animal species. In 2007, there were approximately 2,127,000 heifers, calves and other cattle in inventory, including approximately 400,000 beef cattle sold. Nearly 1,000,000 hogs and pigs were sold and almost 5 million chickens laying eggs (layers) were in inventory. Over 46 million chickens were raised and sold for meat (broilers), and nearly 7.4 million turkeys were sold.

Since 1995, the number of livestock operations has decreased for most animal species, including dairy cows, cattle, and hogs. The number of beef cows and sheep has remained about the same during this period. The goat inventory has increased dramatically and is still small relative to the primary livestock operations in Wisconsin.

Consolidated information is lacking with respect to how most of Wisconsin's animals are produced and how their manure is managed, with the exception of larger animal agricultural operations (concentrated animal feeding operations – CAFOs permitted by the DNR's water quality program). Larger dairy (and swine) operations manage manure in liquid systems with manure scraped or flushed to manure storage facilities. Most swine finishing operations (and some dairies) store manure in deep pits below slatted floors of the animal housing.

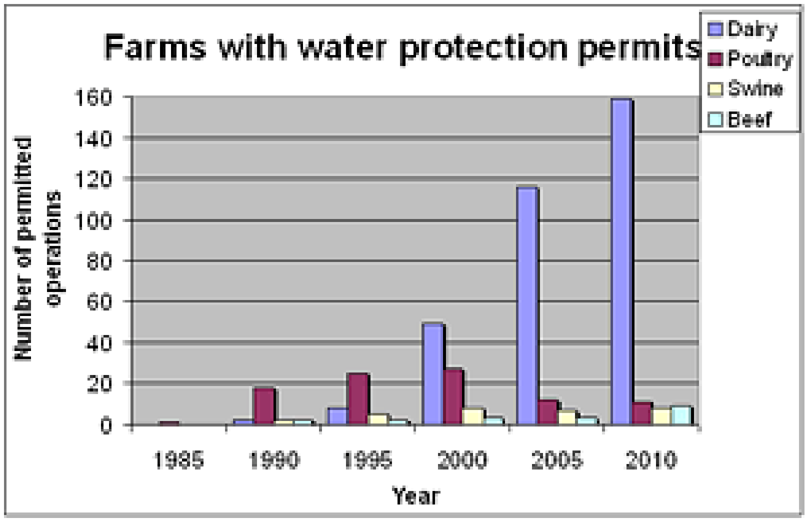
Most CAFO-sized egg laying operations in Wisconsin include cage and belt systems, although high rise housing is still common in the industry. There are no CAFO-sized broiler operations, but it can be inferred that most broilers are raised in poultry houses with litter systems (similar to turkeys).

Farms with greater than 1000 "animal units" must apply for a WPDES CAFO permit. s. NR 243.05, Wis. Adm. Code provides these "equivalency numbers" below.

Number of Animals Equivalent to 1,000 Animal Units ANIMAL TYPE	EQUIVALENCY NUMBERS
DAIRY CATTLE	
Milking and Dry Cows	700
Heifers (800 lbs to 1,200 lbs)	910
Heifers (400 lbs to 800 lbs)	1,670
Calves (up to 400 lbs)	5,000
BEEF CATTLE	
Steers or Cows (600 lbs to market)	1,000
Calves (under 600 lbs)	2,000
Bulls	700
HOGS	
Pigs (55 lbs to market)	2,500
Pigs (up to 55 lbs)	10,000
Sows	2,500
Boars	2,000
SHEEP	
Sheep (per animal)	10,000
HORSES	
Horses (per animal)	500
TURKEYS	
Turkeys (per bird)	55,000
DUCKS	
Ducks - Wet Lot (per bird)	5,000
Ducks - Dry Lot (per bird)	100,000
CHICKENS	
Layers (per bird)*	100,000
Broilers (per bird)* **	200,000
* Layers or Broilers - liquid manure system	30,000
** Broilers - continuous overflow watering	100,000

From WDNR Runoff Management Program

The numbers of CAFO permits issued from 1985 to 2010 in Wisconsin is presented in the following figure. Water quality-permitted dairy operations have increased exponentially, and because of the importance of the dairy sector to Wisconsin's economy, a brief discussion of the dairy sector follows.



From WDNR Runoff Management Program

The vast majority of CAFO-sized farms are dairies (more than 80% of permitted farms as of 2010) primarily located in the northeast and west central regions of Wisconsin. CAFO-sized laying operations are located in the south central region of Wisconsin, while CAFO-sized swine operations are located in the west and south central regions. CAFO-permitted turkey operations (a single integrator with one permit for multiple locations) are located in Wisconsin's northern region. Most broiler operations (not covered by water quality permits) are located in the west central region.

According to a 2007 report published by the University of Wisconsin-Madison/University of Wisconsin-Cooperative Extension, dairy farming in Wisconsin has undergone significant structural changes in the past two decades. Major changes in the size distribution of Wisconsin dairy farms have occurred, led by the recent rapid growth in number of herds over 200 cows and the steady decline in the number of herds under 50 cows. In addition, as many as five distinctive dairy farming systems have emerged from the moderate-scale, semi-confinement approach, which was predominant until the 1990s; large-scale confinement; medium-large scale confinement; management-intensive rotational grazing; organic and Amish.

Wisconsin's beef industry is diverse, according to a 2008 University of Wisconsin publication. It includes traditional cow-calf operations in which brood cows are maintained on pasture and their calves are often weaned and sold, stocker operations that usually raise lightweight cattle primarily on pasture, operations that feed cattle in feedlots, operations that raise cattle for breeding purposes (seedstock producers), and farms where young cattle are taught to eat out of a bunk before heading to a feedlot (background operations).

A 2009 USDA report states that production of hogs to be slaughtered for pork involves four phases:

1. breeding and gestation (breeding females and their maintenance during gestation)

2. farrowing (birth of baby pigs until weaning)

3. nursery (care of pigs immediately after weaning until about 30-80 pounds)

4. finishing (feeding hogs from 30-80 pounds to a slaughter weight of 225-300 pounds).

Hog producers are commonly classified according to the number of production phases conducted on the operation:

- farrow-to-finish (all four phases)
- farrow-to-feeder pig (phases 1, 2, and 3)
- feeder pig-to-finish (phase 4)
- wean-to-feeder pig (phase 3)
- farrow-to-wean (phases 1 and 2)

According to an Iowa State report on the Wisconsin Pork Industry 2008, total hog marketings in the Wisconsin have increased in recent years but the number of farms raising hogs has continued to decline. Since 1999, the number of farms with hogs decreased from 3,300 to 2,200 farms. Meanwhile, the average inventory of hogs has increased from 173 to 200 per farm. Fifty-eight percent of the hogs are on farms with less than a 2,000 head inventory. Twenty-six percent of the inventory is on farms with 2,000 to 5,000 head, and 16 percent are on farms with more than 5,000 hogs.

SECTION 4 - Successful Air Quality Impacts Mitigation

Successful reduction of ammonia and hydrogen sulfide losses from animal agriculture requires an integrative, whole-farm emissions approach for effective evaluation and selection of practices or technologies. Reduced loss from one farm component is easily negated by increases in another, if all components are not equally well managed. Stated another way, while certain practices or technologies may be quite effective at controlling emissions from one farm component, one must consider the fate of those controlled emissions elsewhere on the farm.

There are practices and technologies which prevent or reduce the formation of ammonia or hydrogen sulfide. For example, the benefits of not over-feeding nitrogen to animals through dietary and nutrition practices are reductions in nitrogen excretion (and, hence, ammonia) which will be realized throughout all farm components (e.g., animal housing, manure management systems including manure storage, and land application).

Technologies which capture and treat air (e.g., biofilters) can also significantly reduce air emissions (both ammonia and hydrogen sulfide) from any mechanically ventilated space. Production methods and practices which keep manure in an aerobic state will greatly reduce the emissions of hydrogen sulfide.

Many practices or technologies are useful for capturing and controlling emissions, but the fate of those captured emissions must be considered for effective overall reductions. For example, while an impermeable cover is one of the most effective ways of controlling emissions from manure storage facilities, liquid manure still has potential to release contaminants during subsequent land application activity.

SECTION 5 - Beneficial Management Practice Development

A number of sources were used to gather information on practices and technologies to reduce emissions of ammonia and hydrogen sulfide from animal agriculture. This information was summarized in two draft tables and accompanying explanation of these practices was presented to the Advisory Group at their June 8, 2010 meeting (Appendix J). Technical feasibility and cost information was provided in the draft table, where available.

The draft tables were a compilation of practices and technologies found in the literature and contained approximately 93 practices. Sources included:

- the Wisconsin ATCP 51 rule
- work done in the states of Minnesota, Iowa, California (primarily from the San Joaquin Valley Air Pollution Control District), Idaho, and Oregon
- the Livestock and Poultry Environmental Learning Center; and
- a number of journal articles

The draft tables of practices included all animal species together, although there were some specific practices for swine or poultry. The tables were not organized by how manure is handled, such as slurry/liquid or dry, nor did it presuppose, or restrict, practices or technologies for specific production methods and manure handling systems.

The draft tables were divided into the following six farm component categories:

- animal nutrition and feed management,
- housing
- manure storage and treatment,
- open lots/corrals,
- pasture systems, and
- land application.

Many practices or technologies were found to be effective for more than one species and housing choice. For example, biofilters could work on cross-ventilated dairy housing (although ventilation rates may be large), deep pit swine and any number of tunnel-ventilated poultry broiler or layer operations. The primary rationale for inclusion in the draft tables was whether there were reductions in hydrogen sulfide or ammonia. There were some practices or technologies included which disperse ammonia and hydrogen sulfide through a variety of installed practices like air dams, vegetative or other windbreaks. These practices may have more than a dispersive benefit, as there may be co-benefits of particulate matter reduction and potential capture/treatment of ammonia, hydrogen sulfide or other air pollutants. In some cases, practices or technologies for controlling odor, particulate matter (PM), volatile organic compounds (VOCs), or greenhouse gases (GHGs) have been included for completeness. Where control reductions were provided by sources, the ranges were given.

The original practices and technologies presented to the Advisory Group were based on ATCP 51 (odor control practices) and work done on the air quality portion of the Environmental Assessment for the WPDES General Permit for dairy operations. In some cases, practices or technologies presented to the Advisory Group appeared to provide some reductions for one or more air pollutants while it was unclear exactly what control reductions would be appropriate. Also, the percent reductions provided with the original list of practices or technologies were emissions from the farm component category and not a whole-farm percent reduction. Section 6 outlines the assessment process for the 90-plus original practices and technologies presented to the Advisory Group.

SECTION 6 - Process for Evaluating Practices

The Agricultural Waste BMP Advisory Group met publicly to evaluate the technical aspects of beneficial management practices (BMPs) for reducing ammonia and/or hydrogen sulfide emissions from livestock. The evaluation of practices was based on scientific literature as well as the collective knowledge and expertise of the Advisory Group members.

The process for selecting BMPs was iterative and collaborative. Initially, the Department provided the Advisory Group with over 90 potential beneficial practices to evaluate. For each practice, the Group determined whether the practice could apply to bovine (dairy and beef cattle), or swine and poultry (broilers, turkeys & layers). The Group also identified the farm component in which the practice could be applied (i.e., nutrition or feed management, housing, manure storage and treatment, open lots and corrals, or land application). The Group recognized key differences among the animal species being addressed by the practices and the Department decided, for purposes of evaluating the technical aspects of the practices, to divide the Advisory Group into two subgroups, Bovine (dairy and beef) and Swine & Poultry.

The Department developed an evaluation approach consisting of three rounds of review, referred to in this report as Rounds 1, 2 and 3. Each round of review critically evaluated the practices under consideration.

Round 1

In Round 1, the initial screening stage, subgroups evaluated each practice for its ability to reduce ammonia and hydrogen sulfide, the primary hazardous air pollutants of concern. Each practice was also evaluated for other air quality impacts (volatile organic compounds (VOCs), particulate matter (PM), odors, and greenhouse gases (GHGs). Each practice was considered for its ability to reduce emissions, and an evaluation of other air quality impacts considered benefits and disbenefits associated with that practice.

The evaluation process utilized a ranking system. For ammonia and hydrogen sulfide, each practice was assigned a score of 0, 3, 6, and 9. Zero equates to no or very minimal emission reduction or a possible increase, and 9 equates to a significant control (i.e., 90% control or greater). Other air quality impacts were considered in aggregate, where information was available in scientific literature, or professional experience and knowledge was available, and were assigned scores of -9 to +9. The Subgroups evaluated the practices for volatile organic compounds, particulate matter, odors, and greenhouse gases, where information was available. The scores for ammonia, hydrogen sulfide and other air quality benefits were considered in aggregate. However, a practice was removed entirely from future consideration if:

- the practice provided no emission reduction benefit for ammonia and/or hydrogen sulfide
- the practice created an air quality disbenefit
- insufficient information was available about air emission reductions
- the practice was already considered a standard practice on farms, or
- the practice was considered to be impractical to implement

A table summarizing Round 1 findings is located in Appendix I. The Wisconsin Poultry Producers' Odor/Air Emissions Reduction Best Management Practices (BMPs) document (Appendix N) from 2001 was reviewed by the Swine & Poultry Subgroup and relevant practices were incorporated into this Advisory Group's recommendations.

Round 2

The Round 2 evaluation focused on identifying methods for verifying emission reductions, the ability to verify the practices, as well as evaluating water quality impacts both to ground and surface waters.

The ability to verify a practice was ranked using the following scale:

- practice not verifiable = 0,
- practice difficult to verify = +3 or
- practice easy to verify = +6.

Various methods for verification were identified. In some cases, the subgroups noted that it may be necessary to use more than one means of verification to verify emission reductions. The methods for verification include:

- direct measurement via air sampling and analysis at an emission source
- indirect measurement by sampling and analyzing manure, milk, or other materials for nitrogen or sulfur content
- required maintenance procedures specific to the BMP
- record keeping
- visual inspection

The potential practices were evaluated for ground and surface water impacts separately. Each practice was then evaluated to determine if implementation would result in negative impacts (-3, -2, -1), little, if any, impact (0), or positive impacts (1, 2, 3) on water quality.

The cumulative ranking of each practice was considered and the subgroups decided collectively whether a practice should be removed from consideration or continue to be evaluated in a third round. A table summarizing Round 2 findings is located in Appendix I.

Round 3

In the final stage, Round 3, Subgroups drafted language to describe the practices and, where possible, companion practices were identified. Companion practices are described as practices or technologies which are needed in conjunction with one or more other practices or technologies to achieve a system-wide emission reduction, preventing the transfer of pollutant emissions from one farm component to another.

Group members were asked to develop practice descriptions in Round 3. Instructions were provided to Advisory Group members that descriptions be clear and succinct, yet comprehensive. The group was to consider existing Wisconsin rules and/or literature references, where available and appropriate, (such as ATCP 51), which describe a practice; but they could expand or depart from existing descriptions, as necessary, to focus on ammonia and/or hydrogen sulfide.

Group members were asked to include the following key elements when developing a practice description.

1. the farm component to which the practice will be applied i.e., nutrition and feed management, animal housing, manure storage and treatment, open lots and corrals, pasture systems, or land application

2. the livestock animal type to which the practice applies (dairy, beef, swine, layers, broilers, turkeys, etc.)

3. the conventional baseline practice (the practice judged by the Advisory Group to be the most common practice at this time) against which emission reductions, due to the beneficial management practice, are to be evaluated

4. the specific air toxic that the practice effectively reduces (ammonia, hydrogen sulfide, or both)

5. the air emission reduction range (percentage) relative to the farm component that the practice affects

6. whether the practice alone can achieve the stated air emission reduction(s), when considering all farm components

7. the necessary engineering design, operation, and maintenance specifications, based on good engineering practices (GEP) that describe the practice sufficiently for an engineer, consultant, and farmer to understand. GEP must ensure that the technology is described in a fashion that enables the verification of operation and maintenance. (For certain management practices, this may not apply.)

8. the means of confirming BMP implementation
    - record keeping
    - required maintenance procedures specific to the BMP
    - visual inspection
    - common direct measurements e.g., temperature, BOD measurement
    - common indirect measurements e.g., sampling and analyzing manure, milk, or other materials for their nitrogen or sulfur content.

At public meetings and on conference calls, the Subgroups evaluated the descriptions and made revisions in order to more clearly identify the practices as well as their emission reduction capability. Members decided whether to combine practices under a single practice (e.g., chemical and biological additives were combined into one practice description, except litter treatment with alum) or whether certain practices should be divided into separate description documents for clarity (e.g., land application of manure was divided into three separate categories, injection, incorporation, and banding). The group also determined whether a practice should be designated as established or as a demonstration management practice.

- Established - These practices are well researched, considered to be practical, and there exists quantitative data on their emission reduction ability. They are on the current list of recommended practices.

- Demonstration - Practices or technologies that require a review of the individual design and integration with the farming operation to demonstrate certainty of emission reductions. They are on the list of recommended practices.

BMPs Evaluation Process

During the evaluation process, the Advisory Group recognized that practices and technologies will continue to be developed for mitigating air emissions from animal operations and that a mechanism for recognizing new practices or technologies should be created. For organizational purposes, the Advisory Group refers to these future practices as “emerging.”

- Emerging or Undescribed – Beneficial Management Practices that are new or promising, but field scale research and commercial demonstration is presently limited. This also serves as a mechanism for demonstrating any beneficial practice not specifically described in either the established or demonstration categories.

During the last two meetings, the group reviewed and commented on draft final description language. Comments were reviewed and incorporated into the description language for this report. The beneficial management practices included in the report comprise practices recommended by the Advisory Group to the Department of Natural Resources as practices that reduce either ammonia and/or hydrogen sulfide emissions from animal agricultural operations.