Measuring Air Pollution and Odor at Minnesota Swine Facilities

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Introduction

In 1998, the State of Minnesota identified the need for a Generic Environmental Impact Statement (GEIS) on animal agriculture. The Environmental Quality Board (EQB) was directed by the Legislature to examine the long-term effects of the livestock industry, as it exists and as it is changing, on the economy, environment and way of life of Minnesota and its citizens. Minnesota has always had a very aggressive environmental regulation program and in many areas has been a national pioneer and leader. This paper examines air quality and odor impacts from animal agriculture facilities in Minnesota (EarthTech 2001). The general trends discussed are similar in all Minnesota livestock facilities. This paper focuses on the swine industry, which has shown the most dynamic and controversial changes in the decade 1990 to 2000.

As farm size and animal concentration increase, there is a greater potential for odor and air quality concerns to be raised by members of the local community. Increase in the size and concentration of animal operations does not necessarily mean that more odor and air quality concerns will result. Management practices are essential to controlling and reducing odor and air quality problems regardless of facility size. However, citizens are becoming much more vocal about their environmental concerns, even items that were formerly regarded as minor or normal aspects of farming operations. In some cases activist groups are organizing grass-roots efforts to promote more stringent control of nuisances from livestock animal operations.

Little has been done to date by the United States (US) federal government to address air quality and odor issues from animal agriculture facilities. Consequently, state and local governments have been essentially left on their own to develop programs addressing air quality. This trend toward greater regulation by state governments is occurring despite a lack of definitive information on the sources and quantities of air emissions from animal agricultural operations. These factors have led to substantial variability in the extent and stringency of rules and guidelines in those states that have developed programs.

Air-quality programs

Historically, farming has not been subjected to the level of environmental regulation that is applied to traditional manufacturing industries. However, farms are getting bigger, consolidating and becoming more industrialized. Individual farms are forming business cooperatives, which can lead to finishing and/or processing of livestock at larger central facilities. Continued increase in size and concentration of animal operations is likely to lead to more widespread public concern over health and environmental impacts. To allay concerns, it will be necessary to treat these livestock operations more similar to the environmental regulations already widely applied air emissions at other US industries. Recommended steps in developing a more comprehensive air program for addressing animal agriculture facilities in Minnesota would include the following:

1. Fill data gaps in the demographic feedlot information for a number of heavily agricultural counties.
2. Monitor research efforts nationally and internationally to gain a better understanding of air emissions from swine facilities.
3. Develop a comprehensive statewide emissions inventory of criteria air pollutants, toxic air contaminants, and odorous air pollutants.

4. Enhance the usefulness of the Minnesota Pollution Control Agency's Incident Management System database system by adding fields that would focus on the odor "episode" (location/citizen, duration, frequency) in addition to the odor "source."
5. Conduct additional ambient air monitoring focused on defining the impact of swine facilities, especially to define concentrations of volatile organic compounds downwind of facilities as well as at appropriate "background" locations.
6. Evaluate new facility designs, management practices, and control equipment to determine their cost-effectiveness in preventing or reducing emissions from swine feedlot facilities.
7. Monitor the effectiveness of regulatory and non-regulatory programs in other states, provinces and nations to determine their suitability as models for implementation in Minnesota.
8. Implement flexible incentive programs to provide non-regulatory mechanisms to reduce air emissions and odors.

The major air quality components from feedlots, which are a regulatory concern, are hydrogen sulfide and ammonia. Both of these gases have well-known negative human and public health impacts and established regulatory concentration limits. There is increasing attention directed at an array of other components of feedlot air emission, including particulates, volatile organic compounds and endotoxins. Far less is known about these substances and the health effects. Feedlot odor, in particular, presents very complex challenges for environmental regulation.

Review of the available literature to date on feedlot odor complaints, animal feedlot demographics, and ambient air quality monitoring data were conducted to seek out correlations, relationships, and patterns associated with odor and air quality and animal feedlot operations within the State of Minnesota.

Emissions data and air dispersion computer models are often used to determine minimum setback distances for various types and sizes of feedlot operations. Ambient air contaminant monitoring data collected at Minnesota Pollution Control Agency (MPCA) stations as well as other MPCA monitoring data that were collected near animal feedlot operations was evaluated to try to determine correlations, patterns and relationships, associated with feedlot characteristics and the results of air contaminant monitoring data. In general, ambient concentrations of air toxics are lower in agricultural areas than in urban areas, but are higher than the concentrations found in "background" areas. Additional air monitoring data would be needed to determine what portion of total ambient concentrations are contributed by swine facilities.

Data from the MPCA odor database and the EQB county demographic feedlot database were reviewed and compared to seek out correlations, relationships, and patterns associated with the two data sets. Comparison of the two data sets yielded no apparent correlations or trends. It is likely that the public response to odor is related to a combination of a number of different factors including increasing feedlot sizes (and animal density), the species of animal housed, weather conditions, building sizes and configurations, manure management practices, public perception, public and personal odor sensitivity. There is also a strong psychological component associated with individual odor perceptions and emotional reactions to the gaseous stimulus.

Air dispersion modeling is a valuable tool in making predictive measurements of air pollutants from a variety of industrial and municipal emission sources. The costs associated with continuous air monitoring of all components of concern at feedlots has always been seen as prohibitively expensive to employ as a routine operational practice. Air modeling of large facilities as a permit prerequisite and intermittent monitoring in response to odor complaints at permitted facilities are normal operating procedures in Minnesota.

Computer models are often used to calculate appropriate setback distances, determine emission quantities and to estimate extent and magnitude of dispersion of these various contaminants. There is a great deal of the debate on the use and accuracy of these various models. Generally, the models are only as good as the quality of the input data. These tools can be valuable when used with an awareness of their basic limitations. Even with excellent input data, meteorological chaos can often confound model predictions.

Emission rates

Another area of difficulty is the problem of precisely quantifying the variance in emission rates of gaseous components at a feedlot facility over time. Emission factors are available for only a small subset of the toxic and odorous air contaminants emitted from swine facility activities. It is likely that the emission factors for hydrogen sulfide and ammonia account for a large portion of the air toxics on a mass basis, uncertainty about emission rates of volatile organic compounds and air toxics make it difficult to assess what portion of the potential risk these compounds represent.

The variability and uncertainty in characterizing emission rates appears to be the greatest limitation for utilizing an air dispersion model to make an accurate predictive measure of air quality impacts. Determining accurate emission factors for animal feedlots is difficult since there are many variables that impact air emissions, including:

1. The time and duration of the air sampling measurements used to derive emission factors.
2. Physical variance in specific facility designs.
3. Differences in management practices.
4. Meteorological conditions.

The potential exists for both localized impacts and long-range pollutant transport and transformation of ammonia, hydrogen sulfide and particulate emissions from animal agricultural operations. These considerations point toward the need for a national or international strategy for addressing these concerns.

Odor complaints

The MPCA feedlot odor complaint database includes the non-confidential information that has been recorded by the MPCA from incoming odor complaints received from June of 1995 to September of 2000. Over this period of time the MPCA has compiled data on feedlot odor complaints using two separate database systems. Data from these two database systems cannot be directly compared, although general trends can be discerned.

A number of non-quantifiable factors play a role in receiving and processing odor complaint incidents. Odor events are often extremely transient in space and time. Odor sensitivity varies from one individual to the next. Some people are quite sensitive to low levels of an odor. Many others are desensitized from constant occupational exposure or suffer from a generalized diminished sense of smell (anosmia). Two individuals can perceive the same odor generated from a facility quite differently, which results in difficulty assessing the severity of the immediate odor episode.

In some instances an odor complaint regarding a feedlot may also go unreported due to a real or imagined fear of retribution or social ostracism. Other personal issues may also potentially come into play resulting in exaggerated or fabricated odor complaints. Odor is an economic externality where the costs and benefits are difficult to quantify.

Many Minnesota farmers, like most in the United States, are very independent and reluctant to release detailed information on their operations to the state or federal government. The conflict between individual rights and social good often creates difficulties in timely environmental management. As part of the comprehensive generic Environmental Impact Statement (GEIS), EQB collected all available feedlot inventory information on facility size, facility location, number and species of animals, and potential for the facility to have public health and/or environmental problems. The quality of data varies widely in different parts of the state.

County-specific data was only available for 39 out of 87 counties, from within the State of Minnesota, and included permitted as well as non-permitted feedlots. Each county data set included information on the total number of feedlots and the animal units per feedlot. A number of county data sets included a breakdown of animal units based on species. There was not enough species-specific data available to make comparisons or confirm correlations and trends of demographic data to the MPCA feedlot odor database. Although no strong scientific correlations could be made from the data sets there were a few visible trends of significance within the MPCA odor complaint database.

Nine separate facilities across the State of Minnesota (out of approximately 40,000 total feedlots within Minnesota) were suspected to be responsible for 345 of the 911 feedlot odor complaints logged by the MPCA from 1996 to 2000 (EarthTech 2001). The average number of animal units (AU) housed in each of these feedlots was approximately 967 AU, which is greater than the state average feedlot size of approximately 150 AU. Although these facilities are larger than average, there are approximately 500 other feedlots across the state of similar size with the same species of animals that operate without being suspected of a significant number of feedlot odor compliant incidents. For those not aware of the term, an animal unit is a facility design factor with one animal unit being equal to the waste produced by an animal approximately 1,000 pounds in size.

Of the 911 odor complaints, 597 are suspected to have originated from swine facilities from across the state; approximately 50 percent of the total swine odor complaints were suspected to have originated from only six or seven swine feedlots. Comparatively, there are a large number of swine feedlot of similar size and type of operation across the state that have not been suspected of a significant number of feedlot odor compliant incidents.

The MPCA commented that the only noteworthy similarity amongst all nine of these facilities is that they all operate using earthen manure storage basins (Sullivan, 2001). A state-wide database was not available to determine significance of earthen storage basins in relation to feedlot odor complaints.

Although there is a lack of information to draw any strong scientific conclusions from the available data sets, it is likely that odor sensitivity and complaints are a function of several variables. These variables include:

1. Increasing feedlot sizes (and animal unit density).
2. Species and age of animal housed.
3. Meteorological conditions.
4. Building configurations.
5. Manure management practices.
6. Public perception, and public odor sensitivity

With an increasing concern pertaining to animal feedlot odors, each of these factors should be evaluated on a feedlot-specific basis in order to develop a plan that will minimize public odor episodes, while still allowing for economic growth and stability within the animal agricultural industry.

Hydrogen sulfide

Hydrogen sulfide (H_2S) is released to the atmosphere from natural and anthropogenic sources. Natural sources, including swamps, sea-spray, sulfur springs, and volcanoes, are responsible for about 90 percent of the H_2S in the atmosphere. Certain types of bacteria that are commonly found in animal and human wastes also produce H_2S through the decay of sulfur-containing organic compounds, such as proteins (National Research Council 1979). Other anthropogenic sources include petroleum refineries, kraft paper mills, rayon manufacturing plants, and iron smelters (Beauchamp 1984).

The growing number and size of animal feedlot operations, and increasing H_2S emissions from these sources are of increasing significance to the environment. Gaseous sulfur is oxidized by various chemical or biological reactions into sulfate and eventually sulfuric acid. Sulfuric acid from the atmosphere returns to earth through “acid rain.” Increased acid concentrations in soils and freshwater ecosystems have been shown to have damaging impacts on plant and animal life (European Environmental Agency 2000).

Ambient air concentrations of H_2S vary based on the proximity to various sources. Hydrogen sulfide concentrations have been measured near several animal feedlot operations in Minnesota (MPCA 1999). These measurements were recorded using a Jerome Meter, and were taken at animal feedlots with a variety of animal species, facility sizes, and manure management practices. The measured H_2S concentrations ranged from 0 to 497 ppb, with an average reading of 11.5 ppb and a median value of 5.6 ppb. These values are higher than those measured in unpolluted areas or urban areas, but are significantly less than concentrations reported in industrial areas.

The bulk of the data was collected as non-continuous spot samples using a gold film H_2S monitor (or Jerome Meter). Sampling was performed near facilities that were selected primarily based on community odor complaints, and by pre-selection through a numeric modeling study. Therefore, the feedlots sampled may not represent a “typical” group of feedlots found in the State of Minnesota. The sampling encompassed a large variety of feedlot sizes, animal types, and manure management systems. MPCA collected 435 data points from 137 individual facilities. Each data point represents a single site visit.

The majority of Jerome Meter readings were taken at swine facilities, followed by dairy and beef facilities. The samples were taken in a variety of locations at varying distances from the sources, with the majority of samples collected within a distance of 1000 feet of the source. This was due to field logistics, such as property boundaries and location accessibility. Three types of confinement systems were studied. The majority of the samples were taken from total confinement type facility, with a small portion of the samples taken near partial confinement and open lot type facilities. Several manure management systems were represented at the examined facilities. Earthen basin and concrete pit manure storage facilities were the two most frequent manure storage types.

The MPCA conducted continuous air monitoring for H_2S at four feedlot facilities found throughout the State of Minnesota. These facilities were selected for monitoring based on odor complaints directed at the facilities. Screening data were collected to determine the facilities’ compliance with the state ambient H_2S standard. The screening data indicated the facilities had the potential to exceed the standard. In each case, the facility owners took action to reduce the hydrogen sulfide and odor emissions at the facility. These actions included enclosing manure flow channels, adjusting the animal feed ingredients, introducing biological additives to the waste storage system, covering the manure storage system, and constructing windbreaks. Not all corrective actions were taken at all the facilities. In many, but not all cases, the facilities were able to demonstrate compliance with the state ambient H_2S standard after the application of corrective actions.

Ammonia

A majority of the atmospheric ammonia (NH_3) emissions are produced and released into the atmosphere by natural processes, primarily through the decay and decomposition of organic matter. Animals used for agriculture purposes are considered to be one of the major contributors to global atmospheric ammonia emissions (Bouwman, 1997). The MPCA has reported that approximately 25 percent of the state-wide ammonia emissions are from animal husbandry. With increasing number and size animal feedlot operations the fate of atmospheric NH_3 emitted from animal feedlot operations is of growing importance because NH_3 is one of the air contaminants that is believed to contribute to water and soil acidification and eutrophication (European Environmental Agency, 2000).

Atmospheric concentrations of ammonia have proven to be higher near intense agricultural activity than in non-industrialized rural settings. From a review of available literature, the range of atmospheric NH_3 concentrations measured near intense feedlot activity was 1.3 to 1,734 milligrams per cubic meter (mg/m^3). The range of published concentrations measured in unpolluted rural areas ranged from 0.2 to 17 mg/m^3 (Environment Canada, 2000). Ammonia is mainly emitted from scattered low-level sources, and is not released into the atmosphere in significant concentrations until the animal waste dries.

A number of studies have demonstrated the increased deposition rates of ammonia within a short range of animal feedlot operations. Research of atmospheric dispersion and deposition of NH_3 in a large dairy area (142,000 dairy cows on 380 dairy farms) in California showed that atmospheric nitrogen concentrations were 23 times greater within the dairy area, with atmospheric nitrogen concentrations of 80 micrograms per cubic meter (μg/m^3) found near the dairy site and 3 to 5 μg/m^3 found at the control site. Analysis of rainfall from both of the sites showed that the rain over the dairy area contained roughly three times more distillable nitrogen than the control area. The rainfall added 1.6 kilograms of nitrogen per hectare (kg N/ha) to soils in the dairy area compared to 0.5 kg N/ha in the control area (Luebs, 1973).

In a two-year study at nine sites in southern Alberta, Canada, the rate of NH_3 soil deposition was studied. Results of the study showed average concentrations of 4 to 6 kg N/ha per year at two background (control) sites. The highest average rates of approximately 66 kg N/ha per year were observed near a beef feedlot. Soil samples were collected at various distances downwind from the beef feedlot. The highest deposition rates were reported close to the feedlot and diminished with increased distance from the feedlot. At a distance of one kilometer from the facility, nitrogen levels were below the average background deposition rate (Environment Canada, 2000).

The study of a lake located two kilometers from a large cattle feedlot (90,000 head) in the United States concluded that atmospheric NH_3 from the feedlots can deposit significant levels of NH_3 in the nearby lakes. The quantity of NH_3 received by the lake studied was enough to raise the total nitrogen content of the lake by 0.6 mg/L over a one-year period. The average difference in atmospheric concentrations of NH_3 between the cattle feedlot and the controls yielded a 20-fold difference. The average deposition of NH_3 in the soil closest to the feedlot was 145.6 kg NH_3/ha per year, and the background site was only 7.8 kg/ha per year (Hutchinson and Viets, 1969).

Research suggests that deposition of NH_3 is to be of environmental and ecological significance and concern. Deposition of atmospheric NH_3 is believed to contribute to acidification and eutrophication of water and soil. Acidification has shown potential to damage to freshwater systems, forest soils and natural ecosystems. Defoliation and reduced vitality of trees, declining fish stocks and deceased diversity in acid-sensitive lakes, rivers, and streams are all evidence of the effects of acidification. Eutrophication of sensitive bodies of water can potentially result in losses of fish diversity and amenity (European Environmental Agency, 2000).

The potential exists for both localized and long-range transport issues to arise relative to ammonia, hydrogen sulfide, and particulate from animal agricultural operations. The extent of their occurrence in Minnesota is dependent upon differing factors. Relative to localized impacts, while coarse particulate generated from feed, litter and manure handling may not routinely transport beyond facility boundaries in high concentrations, certain conditions can result in transport of particulates to distant off-site receptors. Conditions of low relative humidity and strong winds can create an atmosphere where significant transport of particulate matter could occur. These conditions can occur with some frequency during late fall and winter in Minnesota leading to concerns for localized impacts from hydrogen sulfide and ammonia during this period.

Warm, stagnant air with high relative humidity can result in less dispersion of these pollutants and potentially result in nuisance odors or respiratory irritation to neighbors of animal operations. These conditions occur during the summer months in Minnesota. Although much additional study that should be carried out to better define the factors affecting emissions from feedlots, the seasonal variation in the environmental transport and fate aspects of these pollutants point toward the need for detailed and targeted control measures. We must consider not just how emissions are generated, but when they are generated as well.

The long-range transport issue is related to the persistence and reactivity of hydrogen sulfide and ammonia, and their ability to contribute to the formation of fine particulate matter. The sulfate and nitrate particulate that can form from hydrogen sulfide and ammonia emissions can have impacts on a more regional scale. Because air sheds, unlike watersheds, do not have well-defined boundaries, emissions generated in one part of the state can result in ambient impacts in other regions, possibly even other states. Although the extent of the contribution of animal agricultural operations on regional air quality is not fully understood, it has been estimated that a significant percentage of atmospheric nitrate particulate is of animal agricultural origin.

These considerations point toward the need for a broad, national and international strategy for addressing these concerns. The long-range issues are analogous to recent concerns with acid deposition, global warming and the issue of ozone depletion, which has led the United States. EPA to recently require additional reduction measures on combustion sources in 20 Midwestern and Southeastern states known to generate pollution that impacts the Northeast US and Eastern Canada. For this reason, it is recommended that any policies generated from this GEIS process should include a formal request to the US and Canadian federal governments to increase their activities relative to regulation of trans-boundary issues affecting animal operations. We should also ask both governments to fund additional studies of the global impacts of feedlot operations. Ultimately regional, national, and international control and reduction measures will be required.

With only a limited amount of information available for estimating emissions for a number of the major air pollutants, more extensive research is still needed in order to gain a stronger understanding of the rate and quantities of emissions for a number of gaseous components emitted from feedlot operations. Accurate estimates of emissions will enable us to better determine the compliance status of feedlot operations with State, Provincial and Federal air quality standards. A number of general trends were seen in the data including:

1. NH_3 and H_2S make a large percentage of the total amount of air pollutants emitted feedlot operations and are likely to be of most environmental significance.
2. Cattle/Dairy facilities in general have higher PM, PM10, and NH_3 emission rates per animal unit then swine facilities.
3. A large percentage of total facility emissions are emitted during the handling and spreading of manure.

Particulate matter

From a global perspective, particulate matter (PM) emissions result from both natural and anthropogenic sources. Natural sources include volcanoes, wind-blown soil, sea spray, and natural combustion sources, such as forest fires. There are many and varied anthropogenic sources of particulate matter, including agricultural activities. Unlike hydrogen sulfide and ammonia, particulate matter is not a distinct chemical entity. Its chemical make-up can vary considerably depending on the specific source of emissions. Size is also a very important factor in characterizing particulate matter. Small (or fine) particulate matter generally consists of sulfate, ammonium, and hydrogen ions; elemental carbon, secondary organic compounds and some primary organic compounds. Larger (or coarse) particulates generally consist of crustal materials, such as calcium, aluminum, silicon, magnesium and iron, as well as some organic materials such as pollen and plant and animal debris. Small particulates generally are more of a problem than the large because these are able to be transported through the atmosphere much longer distances and can pass deeper into human and animal respiratory systems than large particulates.

Among animal related operations, particulate matter emissions have not historically been considered a major problem. Of greater concern has been the occupational exposure to workers from indoor dust levels that can exist within animal confinement buildings. However, sources of outdoor emissions of particulates do occur at animal feeding operations. The most significant of these sources include wind-blown dusts from feed or dried manure and litter handling. In addition to their potential to produce direct effects as particulate matter, emissions from these sources could potentially contain endotoxins which could strongly affect asthmatics and other sensitive individuals. Other sources of particulate matter of environmental significance at animal operations are sulfate and nitrate particulate matter of which hydrogen sulfide and ammonia are precursors.

Annual-average PM10 concentrations in Minnesota during the last 10 years have ranged from 18 $\mu g/m^3$ to 27 $\mu g/m^3$ in urban areas and 5 $\mu g/m^3$ to 15 $\mu g/m^3$ in rural areas. Twenty-four-hour average PM10 concentrations in Minnesota during the last 10 years have ranged from 38 $\mu g/m^3$ to 58 $\mu g/m^3$ in urban areas and 10 $\mu g/m^3$ to 15 $\mu g/m^3$ in rural areas. None of the PM10 monitoring conducted by the MPCA to date has been associated with animal agriculture facilities. With regard to areas around animal agricultural facilities, a majority of the particulate matter measured around them is coarse particulate, greater than 10 µm. In a study of cattle feedlots in Texas measured 24-hour upwind and downwind dust concentrations (total suspended particulate) and by subtracting the two values, determined the impact of the feedlots on ambient concentrations. The levels averaged 412 $\mu g/m^3$, well above the ambient standard for PM10 of 150 $\mu g/m^3$. However, when strictly PM10 was monitored results were much lower, averaging only 19 to 40 percent of the total particulate concentrations, indicating that much of the particulate generated by feedlots is coarse particulate (Sweeten et al., 1988). The MPCA Feedlot Air Quality Work Group has conducted screening-level sampling for hydrogen sulfide emissions around feedlot facilities to determine compliance with the state hydrogen sulfide ambient air standard (Sullivan 1999).

Historically, regulation of animal agricultural operations began with the water quality program and efforts to control non-point source pollution. These regulatory programs were strictly targeted at addressing water quality concerns. In the early 1990's, animal agricultural operations began to become larger, more concentrated, and more industrialized. With the increase in these types of facilities, odor problems became more prevalent. More and more members of the public began to complain to state and local regulatory agencies about the nuisance created by these larger operations. By the late 1990s some regulatory agencies began to respond to the increase in public concern by enhancing either components of existing programs or establishing brand new programs to address odor concerns from animal agricultural operations.

Often, the level of political activism that comes out dictates the extent of a program either in favor of or against additional regulation. These states represent extremes. Most states we examined have some level of odor prevention or control in their regulatory structure. In many cases, these provisions have been established within the pre-existing water quality regulatory programs.

Minnesota's current approach for addressing odors and air quality issues has two main components. First, the state has a two-component Ambient Air Quality Standard for hydrogen sulfide. The standards are:

1. 50 parts per billion (70 $\mu g/m^3$) as a ½-hour average, not to be exceeded over two times per year; and
2. 30 parts per billion (42 $\mu g/m^3$) as a ½-hour average, not to be exceeded more than two times in any five consecutive days.

This standard applies to all areas of the state. Minnesota's new animal agricultural regulations do not establish any control measures to specifically address hydrogen sulfide. Historically, exceedances of the standard that could be traced to a specific source would be addressed in the air quality permitting or enforcement processes.

Recently, the Minnesota Department of Health proposed an acute Inhalation Health Risk Value (HRV) for hydrogen sulfide of 80 $\mu g/m^3$ as a one-hour average (Bloomgren 2001). HRVs represent concentrations of chemicals emitted to air that are unlikely to pose a significant risk of harmful effects to humans. The HRVs are publicly reviewed, health-based criteria. In the case of hydrogen sulfide, the State Ambient Air Quality Standards actually provide a greater margin of protection than the HRV.

Air Emission Plan

In addition to the hydrogen sulfide standard, Minnesota's new water quality regulations require facilities with a capacity to house more than 1000 animal units to include an Air Emission Plan in their water quality permit application. The plan must include:

1. Methods and practices that will be used to minimize air emissions.
2. Measures to be used to mitigate air emissions in the event of an exceedance of the state ambient hydrogen sulfide standard.

3. A complaint response protocol describing the procedures the owner will use to respond to complaints directed at the facility, including:
    a. A list of each potential odor source at the facility.
    b. A determination of the odor sources most likely to generate significant amounts of odors.
    c. A list of anticipated odor control strategies for addressing each of the significant odor sources.

Regardless of the specifics of any program approach, certain general aspects are common. These include ambient standards, applicability, prevention or control requirements, compliance monitoring/tracking and enforcement. Historically in air quality programs, technology and work practice standards are designed to ensure that the ambient standards are met. There are currently national ambient standards for particulate matter, sulfur dioxide, oxides of nitrogen, ozone, lead and carbon monoxide. These standards apply throughout the entire United States. Some states have also developed stricter standards or ambient standards for additional pollutants.

Minnesota has established an ambient air quality standard for hydrogen sulfide, even though the federal government has not promulgated an ambient standard for this gas ambient standards for odor are less common. Several of the more recent programs addressing animal agricultural facilities have incorporated ambient odor standards. While in some ways more comprehensive, the Minnesota program for addressing air quality and odors from animal agricultural operations is typical of other recently developed programs in the following respects. It utilizes existing authorities for issuing water quality permits as a mechanism for requiring air quality measures, while at the same time recognizing the need for additional measures to address the increased potential for air quality and odor concerns at animal agricultural facilities. The main component of the Minnesota odor management procedure is the development of a plan that each facility must develop on a case-by-case basis and utilize to minimize odor emissions.

The ultimate success of this program approach in addressing concerns over odors and air quality has yet to be determined (Coleman, 2001). It is currently still in the initial stages of implementing new regulations and have only recently begun to evaluate the effect of new regulations on odor concerns. Follow-up evaluation of this program over the next several years should yield valuable information on the long-term effectiveness. While Minnesota’s program for addressing air quality and odor concerns is not extremely stringent, it shouldn’t be concluded that it will not be as effective in minimizing odor and air quality concerns. It should provide the MPCA with sufficient flexibility to fit the specific control measures required at a particular facility to the specific aspects of the operation and the level of local concern and complaint regarding odors at the facility.

Generally, one of the early phases of any environmental regulatory effort is the collection and analysis of data on the levels of environmental release generated by an industry category. The purpose of this phase is to identify whether additional regulation of an industry is warranted, and if so, to identify what aspects of the industry and to what level the regulations should focus. Relative to air quality and the animal agricultural industry, there is much data that still needs to be gathered to better characterize the sources of air emissions and their ultimate impact on air quality. While more prescriptive air emission control measures may prove to be warranted for various aspects of animal agricultural operations, these measures will have to be based on sufficient background data.

Beyond strict regulatory programs, flexible incentive programs can also provide mechanisms for emission reduction in the animal agricultural industry. These programs are not designed to establish specific regulatory standards such as emission or ambient air limits, but instead provide incentive for facilities to reduce emissions by providing financial benefits or more flexible operation if emissions are reduced. These programs are also discussed in greater detail in a very recent USEPA report on using economic incentives for protecting the environment (USEPA, 2001).

The trends in the animal agricultural industry have been identified and discussed in numerous sections of the Literature Summaries for the GEIS (Jacobson, 1999). A great deal of additional research information is available by looking at the Minnesota Planning's website for feedlots (http://www.mnplan.state.mn.us/eqb/geis/index.html)

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