SF-00006-01

STATE OF MINNESOTA

Office Memorandum

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DEPARTMENT Pollution Control Agency

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DATE: 12/22/80

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SUBJECT: PROJECT REPORT

Pursuant to Minnesota 1978 Session Laws, Chp. 480, Section 2, Subdivision 1 (4) and Subdivision 5, and your request, please find enclosed one copy of the following report.

UNIVERSITY OF MINNESOTA

Review and analyze the current literature on the production and control of odors from livestock production facilities.

WPA:al

enclosure

*Consultant's Report to P C A
by University of Minn.
Dec 1980*

Livestock Production Odors and Their Control

Methods of livestock production have changed greatly in recent years resulting in new challenges for producers. One problem of growing concern for many producers is over the odors from livestock production facilities and the complaints from neighbors who consider the odors objectionable.

Odor problems are very complex and often have no simple solution. Much is unknown about the gases which cause odors. Many factors which affect their production and release into the air need to be studied. However, with the information available, producers usually can find alternative production and management practices that will reduce odors to non-offensive levels.

Livestock producers and their neighbors must realize that some odors will inevitably be produced and released into the air using current livestock production and waste management practices. Producers must recognize the potential for odor problems and accept the responsibility for keeping odors at non-offensive levels. This may require selecting a remote site for locating confinement facilities and manure storage structures or adopting waste management procedures specifically designed to reduce odor levels. Neighbors must be impartial in their assessment of the offensiveness and frequency of the odors detected. The subjective nature of odors, however, makes this very difficult.

The purpose of this publication is to inform those concerned about odors and odor problems, of the current state-of-the-art of odor control during livestock production and waste handling, storage and disposal. The information on odor phenomena, the sources, and control techniques should help producers and neighbors who are experiencing an odor problem to investigate ways to alleviate the problem. Those concerned about potential odor problems will find ideas for preventing a problem from developing. This information should help livestock producers to operate compatibly within the community without producing odors at offensive levels that disrupt the quality of life of their neighbors.

ODOR MEASUREMENT AND ANALYSIS

Odors are a response to gaseous substances in the air detected by the sense of smell. They can be characterized according to their quality, intensity, and objectionability. The quality describes its similarity to another odor. Intensity specifies the magnitude of the perceived odor sensation. The degree of like or dislike of an odor is described by its objectionability or offensiveness. These characteristics are based on subjective human responses which are biased by a person's attitude, preferences and past experiences as well as what they see and hear.

Though the process of smelling is not thoroughly understood, many facts about odor perception and the substances which produce odors have been observed. Table 1 lists some of these facts which show the problems involved in trying to measure and describe odors. The human nose is the most sensitive odor measuring device known but it is extremely unreliable. Using an odor panel of five or seven specially trained people to measure odors is difficult, time consuming and imprecise.

Measuring the concentrations of individual odorous substances and relating them to an odor level is extremely difficult because of the very low gas concentrations that humans can detect. The odors from livestock production facilities are mixtures of gases, not separate gases. An odor's intensity and objectionability cannot be characterized by measuring the concentrations of the individual gaseous substances in the air.

Odor intensity can be estimated in the field using a Scentometer. The results obtained, however, depend on a person's sense of smell and their perception of smell influenced by what they see.

Table 1. Characteristics of odors and odor perception.

Only gaseous substances are odorous but gases such as oxygen and nitrogen have no odor.
Air movement in the nasal cavity is required for odor perception and sniffing enhances perception.
Exposure to an odor produces a high initial response which declines with continued exposure.
A strong odorant can completely exhaust the capacity to perceive odor in two to three minutes.
Some people have a better developed sense of smell than others.
Some odorants are detectable at concentrations below 1 part per billion.
Individual odorants can interact to produce a more intense and offensive odor.

This inability to measure odor levels accurately and completely makes regulation of odors very difficult. The extent of an odor problem of a livestock production facility cannot be accurately determined because of the inability to measure odors without relying on the subjective response of the human sense of smell.

ODOR SOURCES

Many sources of gaseous substances are found in livestock production facilities. They all contribute to the overall odor. If an odor problem exists, all of the sources need to be evaluated to find out which of the sources are the most important. Then appropriate control techniques can be selected to reduce odor emissions from the major odor sources.

The animals themselves produce some odor. Manure on the animals can also be an important source of odors. Feeds and feed materials can produce objectionable odors. Fermenting silage produces noxious gases and odors which can be offensive if the concentrations are high enough. In some cases, if food processing wastes are used as livestock feed, they can produce particularly offensive odors if allowed to decompose before they are consumed. Special handling may be needed to use food processing wastes as a valuable feed component.

Dead animals allowed to decay can also be an important odor source. Incomplete or improper incineration can produce offensive odors. Appropriate procedures for handling dead animals, used faithfully, can eliminate these odors.

Dust, though not a true odorant, can contribute to an odor problem by helping transport odors. Dust includes fecal material, feed particles, fragments of feathers or hair, microorganisms and other particles. They obtain some of their odor by having odorous gases adhere to their surfaces. When the particles are inhaled some of the gases are released producing an odor sensation. Dust from an open feedlot or in a confinement building can detract from the visual quality of the air. Exposure to high dust levels can lead to increased respiratory problems for the workers and livestock in confinement buildings or feedlots.

The most important source of odors and noxious gases of a livestock production facility is usually the manure. The gaseous by-products of microbial decomposition by bacteria and other microorganisms escape into the air to produce the odor. Manure contains microorganisms, water, and organic matter which provides essential nutrients and energy for microbial growth. This mixture promotes decomposition of the organic material in manure during collection, storage and disposal as long as environmental conditions permit.

Environmental conditions influence the type and quantity of gases produced and released into the air during manure decomposition. Conditions can change during collection and storage which change the odor depending on the type of waste management system used. Some of the factors are: temperature, pH (acidity), moisture content, oxygen content, and the number of days stored.

Manure stored for six months or more, will have a different odor compared to that of fresh manure. Freshly excreted manure has a limited amount of odor which dissipates quickly and is generally regarded as less offensive than the odor from manure allowed to undergo anaerobic or septic decomposition. Prolonged storage permits further decomposition of the manure and an accumulation of gaseous substances in the wastes. This mixture of more and different gases produces the different odor. Minnesota Pollution Control Agency rules state that manure stored for more than one year is not considered domestic fertilizer and may be subject to additional odor control requirements.

Temperature affects the rate of microbial activity. Temperatures below 50°F (10°C) reduce microbial growth while higher temperatures increase microbial activity as well as gas volatility. Volatility is an indication of a compound's ability to vaporize and escape into the air. Temperature effects produce seasonal variations in the production and release of gases from stored manures. Warm summer temperatures, 80-95°F, (27-35°C) enhance microbial activity and gas volatility which often results in greater odors during the summer.

The pH and moisture levels of manure affect microbial activity and gas volatility. At either high or low pH levels microbial activity is inhibited. In dried manure microbial growth is reduced significantly. A dried crust also traps gases and odors in stored manure, preventing their release until the crust is disturbed.

Oxygen levels in manure change the microbial decomposition processes. Maintaining an oxygen concentration of 2 milligrams/liter (mg/L) throughout the stored manure will cause aerobic microorganisms to grow. Aerobic decomposition is different from anaerobic processes which occur in the absence of oxygen. Few odors are released from aerobically stored manures. Small zones of anaerobic activity can produce enough odorous gases to make an aerobic treatment system appear to produce odors.

ODOROUS GASES

Many chemical compounds have been identified as volatiles from livestock manures. A composite list of the compounds from cattle, poultry and swine manure is given in Table 2. The compounds are grouped according to their chemical structure. The large number of compounds shows the complexity of manure decomposition and the wide variety of compounds which can contribute to the odor.

People can detect many volatile substances at very low concentrations. The concentration at which people with a normal sense of smell can identify a compound is called the Population Identification Threshold (PIT). PIT

Table 2. Chemical compounds identified as volatiles from cattle, poultry and swine manure and their population identification threshold concentrations. (* Threshold odor concentration value)

Compound	Odor Threshold ppm
ALCOHOLS	
Methanol	100
Ethanol	10
n-Propanol	0.13
iso-Propanol	28.2
n-Butanol	2.0
sec-Butanol	0.56
iso-Pentanol	---
n-Hexanol	0.09
2-ethoxy-1-Propanol	---
PHENOLIC SUBSTANCES	
Phenol	0.047
p-Cresol	0.001
Ethylphenol	---
ALDEHYDES	
Formaldehyde	1.0
Acetaldehyde	0.21
Propionaldehyde	0.080
n-Butyraldehyde	0.039
iso-Butyraldehyde	0.236
n-Valeraldehyde	---
Capronaldehyde	---
Enanthaldehyde	---
Caprylaldehyde	---
Nonlaldehyde	---
Decylaldehyde	---
Acrylaldehyde	0.21
Benzylaldehyde	0.006*
AROMATIC ORGANICS	
Toluene	2.14
Xylene	0.27
Methylnaphtalene	---
SULFIDES	
Hydrogen sulfide	0.00047
Carbonyl sulfide	---
Carbon disulfide	0.21
Dimethyl sulfide	0.001
Diethyl sulfide	0.0005*
Dimethyl disulfide	0.0056*
Dimethyl trisulfide	0.0012*
Diphenylsulfide	0.0047
Thiophenol	0.0002*
MERCAPTANS	
Methylmercaptan	0.0021
Ethylmercaptan	0.001
n-Propylmercaptan	0.00075*
Allylmercaptan	0.00001*
Benzylmercaptan	0.00003*
Crotylmercaptan	0.00006*
ACIDS	
Acetic	1.0
Propionic	0.034
n-Butyric	0.001
iso-Butyric	---
n-Valeric	0.0006*
iso-Valeric	0.0018*
n-Caproic	0.006*
iso-Caproic	---
Caprylic	0.008*
Enanthic	0.015*
Benzoic	---
Pelargonic	0.00084*
KETONES	
Acetone	100
2-Butanone	10
3-Pentanone	8*
Diacetyl	0.025*
Acetoin	---
2-Octanone	248.*
Acetophenone	0.60
ESTERS	
Methylformate	2000
Ethylformate	---
Methylacetate	0.21*
Propylacetate	0.15
iso-Propylacetate	0.97
iso-Propylpropinate	---
Butylacetate	0.037
iso-Butylacetate	0.50
AMINES	
Ammonia	46.8
Methylamine	0.021
Ethylamine	0.830
n-Propylamine	---
iso-Propylamine	0.95
n-Butylamine	0.24
Pentylamine	---
Dimethylamine	0.047
Trimethylamine	0.00021
Triethylamine	0.28
N-HETEROCYCLES	
Indole	---
Skatole	0.075ppt
Pyridine	0.021
3-Aminopyridine	---
SIMPLE ORGANICS	
Carbon dioxide	odorless
Methane	odorless

levels for many of the gases from livestock manure are listed in Table 2. Several compounds which do not have a known PIT have the Threshold Odor Concentration (TOC) listed instead. The TOC is the concentration at which the compound can be detected, but not identified, and is usually lower than the PIT. The values listed indicate that very little gas is needed to produce a detectable odor. At these levels it is very difficult to measure the gas concentrations of the gases present.

A mixture of gases which make up an odor can interact. This interaction can either increase or decrease the odor intensity and objectionability. This can cause gases at levels below their threshold odor concentration to produce an odor that can be detected.

HEALTH AND SAFETY

Several of the odorants and noxious gases from livestock manures can be hazardous. They can present a real threat to animal and human health and property when permitted to accumulate to dangerous concentrations in confined areas. These areas include enclosed confinement buildings which are poorly ventilated and covered manure storage tanks. Even though these gases are generated in nearly every instance where manure is decomposing, they do not pose a threat in open or properly ventilated areas or in the exhaust air from ventilation systems. This threat to health and safety affects only the animals and those who contact these gases during the course of routine work. Effects from this type of contact are considered an occupational issue and not an environmental issue.

There are certain conditions when gas concentrations in confinement buildings with manure storage pits below slatted floors can reach toxic levels. Fatalities among animals have occurred when the ventilation system has failed in a tight building or when the manure in the pit was vigorously agitated and precautions were not taken to exhaust the gases released from the manure. Human deaths have resulted when people have entered a manure storage pit without ventilating it and without having an auxiliary air supply. In one case a death occurred when the ventilation system was shut off while a worker steam cleaned the building interior and pens. The exact cause of death in each of these instances has been difficult to determine. Death may have resulted from oxygen deficiency (by the gases physically displacing the air) or from actual physiological toxicity. The physiological effects of short term exposure to four common gases - ammonia, carbon dioxide, hydrogen sulfide and methane - at very high concentrations are given in Table 3.

Little is known about the effect of repeated exposure of workers to the toxic gases. The thirty-two gases listed in Table 4 are the gases from livestock manures which have exposure limits set by the National Institute for Occupational Safety and Health. The threshold limits are the maximum average concentration that a worker can be exposed to during an eight hour day without some adverse physical effect. Ammonia and hydrogen sulfide concentrations measured in several commercial swine confinement buildings were all below the exposure limits set. Ammonia concentrations ranged between 6 ppm and 35 ppm. The hydrogen sulfide concentrations ranged from 0.12 to 0.85 ppm.

Research has been conducted to measure the effect of gases at various concentrations on livestock production. Lambs exposed to high levels of ammonia (75 ppm) showed lower growth rates and exhibited severe coughing and sneezing and profuse nasal discharge. Pigs exposed to ammonia at levels between 50 - 150 ppm had similar effects. In another study pigs exposed to mixtures of ammonia between 50 - 75 ppm, dust at 10 and 300 mg/m^3, and hydrogen sulfide at 2 and 8.5 ppm showed that the rate of gain and the respiratory tract structure were not directly affected. However, in other studies the incidence and severity of chronic pneumonia increased. Ammonia and dust

Table 3. Physiological effects of important gases produced in the anaerobic decomposition of manure.

	Concentration ppm	Exposure period min.	Physiological Effect
Ammonia			IRRITANT
	400		Irritation of throat
	700		Irritation of eyes
	1700		Coughing and frothing
	3000	30	Asphyxiation
	5000	40	Could be fatal
Carbon dioxide			ASPHYXIANT
	20,000		
	30,000		Increased breathing
	40,000		Drowsiness, headaches
	60,000	30	Heavy asphyxiating breathing
	300,000	30	Could be fatal
Hydrogen sulfide			POISON
	100		Irritation of eyes and nose
	200	60	Headaches, dizziness
	500	30	Nausea, excitement, insomnia
	1000		Unconsciousness, death
Methane			ASPHYXIANT
	500,000		Headaches, non-toxic

Table 4. Threshold limit values set by the National Institution of Occupational Safety and Health for some volatiles from livestock manures.

Compound	Threshold limits ppm	Compound	Threshold limits ppm
Carbon dioxide	5000	Ammonia	50
Hydrogen sulfide	20	Methylamine	10
Carbon disulfide	20	Ethylamine	10
Methylmercaptan	10	Dimethylamine	10
Ethylmeraptan	10	iso-Propylamine	5
Mathanol	200	Triethylamine	25
Ethanol	1000	n-Butylamine	5
n-Butanol	100	Methylformate	100
sec-Butanol	150	Ethylformate	100
iso-Propanol	400	Methylacetate	200
p-cresol	5	n-Propylacetate	200
Phenol	5	iso-Propylacetate	250
Pyridine	5	Butylacetate	150
Toluene	200	iso-Butylacetate	150
Xylene	100	Acetone	1000
Acetaldehyde	200	2-Butanone	200

from poultry litter can cause increased incidents of respiratory disease in turkeys. The maximum allowable concentrations of dust, ammonia and other gases has not been clearly established because of the influence of many other factors but reduced production and increased respiratory diseases can occur at high concentrations.

The gases in livestock confinement buildings corrode metal and electrical equipment reducing their useful life. Several manure gases are combustible and explosive. Gas concentrations within combustible limits have not been measured in a confinement building, but explosions in confinement buildings have been reported and attributed to manure gases.

ODOR CONTROL

Odors are a normal part of any livestock production facility and do not necessarily constitute a problem. An odor problem exists when offensive levels of odor from a livestock facility are allowed to migrate to neighbors' property. Failure to take corrective action can result in complaints which occasionally can lead to legal action seeking either monetary damages or a court imposed injunction to close the facility. The consequences of letting odors develop into a problem can be very expensive.

Odor control is an inexact science. The principles, however, are relatively few and straightforward. For an odor to be detected, odorous compounds must be (a) formed, (b) released to the atmosphere, and (c) transported across property lines. Inhibiting any one of the steps will diminish the odor and eliminate the odor problem. Many factors including the design and management of the facilities influence the odors often making odor control practices specific to each problem site. Using the basic principles of odor generation and transport and fundamental odor control concepts, several general management practices and artificial measures can be considered which should provide some reduction in odors. The severity of the odor problem and the effectiveness of the odor control practices implemented will determine if the odor problem will be eliminated or whether further action will be needed.

The first step in preventing an odor problem is being aware of the potential for a problem. Information from the Agricultural Extension Service and the Soil Conservation Service can help in the planning of new facilities or expansions. In some instances a professional engineer is needed to identify problems and to design facilities. Anticipating a problem can allow the facilities to be designed properly and operated so that odor production and emissions will be kept at non-offensive levels. Once an odor problem has developed a great deal of time, effort and money may be needed to change the production facilities and management practices to control the problem.

Site Selection and Facility Design

Site selection and facility design can be important considerations to reduce odors and the potential for odor problems. Locating confinement buildings, feedlots and manure storage facilities away from residences, communities, schools, businesses and recreational areas reduces the number of people likely to detect and object to the odors from the facilities. Livestock production facilities should be located as far as possible from neighbors' residences. No general minimum separation distances have been established for livestock facilities. Midwest Plan Service recommends at least 0.5 mile between an anaerobic lagoon and a residence. The buffer zone separating odor sources from people allows odorants to disperse into the air. Separation does not insure that odors will disperse to non-offensive levels. Local topography, hills, and valleys can reduce the rate of odor dispersion so that objectionable levels can travel long distances before abating.

Wind speed and direction can be important in odor control. High winds disperse odors very quickly diluting them to non-offensive levels. Calm winds can transport odors several miles before dispersing them to unobjectionable levels. Hot humid days with little wind let objectionable odors travel great distances. The prevailing wind direction can be included in the evaluation of a proposed site. However, most locations have winds from several directions throughout the year so that locating downwind of neighbors is not sufficient to insure acceptability year round. Wind direction and velocity, however, can be extremely important in helping prevent odor complaints during land application of stored wastes.

Drainage and orientation are important site considerations. Locations should be selected that provide adequate controlled drainage for runoff from open feedlots. Drainage around buildings should be designed to keep clean runoff water out of open lots and manure storage facilities. This will reduce the volume of manure to be stored and help keep lots dry. Unsurfaced lots should have slopes between four (4) and six (6) percent while concrete feedlots should have slopes between two (2) and four (4) percent. Concrete surfaced lots provide improved drainage and are more convenient for manure removal. Mud, odor and fly problems are, therefore, reduced significantly. Open southern exposures provide sunlight to assist in drying manure surfaces which reduces microbial activity.

Zoning is also an important site selection consideration which can help alleviate potential odor problems. State and county land use regulations should be reviewed before selecting the final location of a facility. If an area is zoned for agricultural purposes livestock production would be within the limits of approved land uses for the area. However, in many areas, communities and cities have control of agriculturally zoned lands which fall within a specified distance of their perimeter. Some counties also have special regulations regarding large confinement livestock operations. Nonfarm residences which locate in agriculturally zoned areas may have to accept normal livestock production odors.

Zoning can also be used to keep the number of neighbors at a minimum and to reduce the probability of odor complaints. In some areas, producers are applying for zoning restrictions which will specify a strict agricultural type of use to discourage residential development or at least reduce the probability of legal action from those who do establish residences in these zones. Areas which have the possibility of urban development probably should be avoided as a site for new or expanding livestock production facilities.

Manure Storage and Treatment

Manure storage and treatment facilities often are major sources of odor. To reduce the odors either the formation or the release of the odorous gases into the air must be restricted. This can be accomplished in various ways depending on the type of storage facilities and the management practices being used.

Livestock manure can be handled either aerobically or anaerobically. Aerobically treated manure has the advantage of producing less odors. However, the operating costs and the cost of equipment make aerobic systems very expensive. They also require more careful management to operate. Aerobic systems also lose more nutrients than anaerobic systems thereby reducing the fertilizer value.

Livestock wastes with 20% or more solids can be handled as a solid. Dairy manure with a lot of bedding is commonly handled as a solid waste. Manure that builds up in confinement cattle feedlots can also be handled as a solid. Odor control of solid manure is achieved by either promoting drying or composting.

Solid manure can be collected and stored in stacks until it is applied to the land. Structures for stacks should be designed and located so that urine, snowmelt and rain can be drained away to promote drying on the stack surface. A dry surface crust will help retain odorous gases generated within the stack. This will control the odors until the crust is disturbed during field application when other odor controlling methods may be needed. If a stack is not drained and becomes water logged, manure handling is more difficult and fly and odor problems can develop.

Manure packs are a solid waste system where manure is allowed to build up where it is deposited in confinement buildings or on open lots. Odors are kept to a minimum by keeping the pack dry. In buildings bedding can be added while on open lots drainage must be provided. Periodic collection and field application is required to dispose of the accumulated manure.

Composting is an aerobic treatment for solid wastes which reduces odor. It is done by storing solid wastes in long windrows four to five feet in height and turning them twice weekly the first 30 days. The windrows are turned to maintain aerobic conditions in the windrow. The wastes must have the proper moisture content and nutrient composition for complete composting. Well composted wastes have a slightly musty smell. Special management is needed for operating a composting system and the labor and land requirements are quite high.

Liquid waste handling systems can include various storage components such as earthen storage pits, concrete pits, tanks, lagoons and runoff settling basins and retention ponds. Liquid wastes contain less than 15% solids and can be pumped or allowed to flow like a liquid. Each component listed can be a source of very offensive odors if not designed and managed properly.

Earthen pits, concrete pits and above ground tanks are designed to provide storage to allow flexibility in scheduling field application. Their capacity is determined by number of animals and the number of days of storage planned. These structures are emptied with a pump after the slurry has been well agitated. Depending on weather conditions, equipment and the volume of wastes, agitation and field application can take a week or more to complete.

These storage structures can be sources of very offensive odors. Odors can be reduced by covering the wastes to prevent their release into the air. A crust of dried manure, a plastic liner or cover or an artificial organic mat can be used. Dairy and beef wastes usually develop a crust naturally which reduces odors. Swine and poultry wastes do not form a crust. Various relatively expensive plastic or vinyl products are available commercially for lining and covering manure pits. The deteriorating effects of the ultraviolet rays of the sun and weather should be considered when selecting a product. Covering concrete pits also reduces the odors effectively. Artificial organic covers are a relatively new concept still being developed. The mat is constructed each spring by spreading either chopped straw, rice hulls, wood chips or other similar material over the stored wastes. Normal microbial action decomposes the mat which then needs to be reconstructed.

Above ground storage structures sometimes appear to be less odorous than pits. The degradation processes and odor production are the same. Apparently the chimney effect of above ground structures, which causes the odor to be released ten or more feet in the air, helps disperse the odors enough for them to seem less odorous. The effect may not be significant enough to warrant the extra cost of an above ground storage structure to try to reduce an odor problem.

Anaerobic and aerobic lagoons are waste treatment systems. They are designed to treat fresh wastes and provide storage. In Minnesota lagoons need to be several times larger than storage facilities to accommodate the treatment. Lagoons should be started 1/3 to 1/2 full of water in the spring to allow microorganisms to become well established. Periodically lagoons need to be partially emptied to remove sludge and liquid. This should be done in the spring so that wastes that have accummulated during the winter are removed. A certain volume of lagoon liquid must be retained to insure an adequate microbial population to re-establish treatment.

Treatment is accomplished by loading the lagoon (adding fresh manure) at the same rate that the microorganisms can decompose the manure. This reduces the number of odorous compounds produced. Daily loading is recommended to better match manure addition and its decomposition. A lagoon can become very odorous if it is overloaded. This causes incomplete decomposition and makes the lagoon act as a storage facility. Overloading occurs when there are sharp changes in animal numbers or when a production facility expands without a corresponding expansion of the lagoon.

Lagoons can also develop odors during spring turnover. Odors result when wastes which have accummulated during the cold winter weather, when microbial activity was very low, begin to be decomposed. This causes the microorganisms capacity to decompose wastes to be temporarily overloaded. Mixing caused by warm surface waters replacing cooler waters at the bottom of the lagoon increases the odor problem. Spring turnover can last two to four weeks depending on weather conditions. Sometimes those odors can be reduced if the lagoon contents are mixed with a large pump as soon as the ice cover melts and temperatures rise above 45°F (7°C).

Lagoons can be either aerobic or anaerobic. Aerobic lagoons produce very little odor because the by-products of aerobic decomposition are carbon dioxide and water which are odorless. Odors result when small anaerobic zones develop or when the lagoon is under-aerated. Aerobic conditions exist as long as the lagoon maintains an oxygen concentration of 1-2 mg/L. This requires either a very large amount of land for shallow lagoons, a maximum of 5 ft (1.5 m) deep, or the use of mechanical aerators. Mechanical aerators must be run 24 hours a day to maintain aerobic conditions. The size and number of aerators needed depends on the amount of waste to be treated. Energy costs make aeration a relatively expensive treatment alternative.

Anaerobic lagoons are designed matching the loading rate to the rate of anaerobic decomposition. They can be built 20 ft (6 m) deep, depending on local groundwater conditions, which reduces the amount of land required. Anaerobic lagoons cannot be totally odor-free. They can be very odorous if overloaded and during spring turnover in which case other odor control practices must be used.

Lagoons must be designed and managed properly or they can produce extremely offensive odors. Anaerobic lagoons are less expensive to build and operate but they cannot control odors completely. Aerobic lagoons are more expensive to build and operate, but they can control odors effectively.

An anaerobic digestor can be used to control odors from liquid livestock wastes as well as to provide usable low energy gas. A digestor is a complex treatment system that includes a tank in which conditions are controlled to enhance methane production. Special equipment and plumbing is needed for pumping and mixing the wastes and for gas collection. The digestion reduces the amount of organic matter by only 50 percent so the digestor effluent needs to be treated further to prevent odors. Special management and constant monitoring are required to insure that a digestor will function properly. The special equipment and extensive plumbing demand continual maintenance.

Runoff settling basins and retention ponds are used together to control runoff from feedlots, exercise lots and in some cases, open pastures. They are used to prevent the runoff from entering streams and public waters. A settling basin removes the solids in the runoff water before it reaches the retention pond where it is stored. To be effective, the solids need to be removed from the settling basin before the next rainfall event with runoff occurs. Retention ponds can become odorous if too many solids are allowed to enter the pond. A retention pond may have to be emptied if solids and odors become a problem.

Removal and Field Application

Manure removal and field application can be a major odor releasing process. Agitation of pits releases many gases retained in normally still manure. In confinement buildings extra ventilation is needed to prevent toxic levels of these gases from accumulating. Odors emitted during agitation and spreading are temporary and diminish within a few hours after finishing.

Special consideration during land application can reduce odors and lessen the probability of odor complaints. Table 5 lists some recommendations. Subsurface injection or surface spreading followed by incorporation into the soil provide the most direct methods of reducing the amount of odor released from the manure. Irrigation, which is a faster method of land application, does not permit any control of the odors in the manure other than weather considerations and incorporation.

On humid warm days with little wind, odors tend to travel much farther before dispersing. Days with winds greater than 5 mph and rising air temperatures should be selected for manure spreading because the air turbulence helps disperse odors quickly. Watching wind direction so that the application site used is always downwind of nearby sensitive neighbors can help reduce odor complaints.

Table 5. Recommendations for odor control during land application.

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1. Avoid spreading near residences, highways, parks or other places where people gather. Schedule spreading when the wind will blow odors away from such areas.

2. Spread early in the day when air is warming and rising to help disperse odors. Also, odors from manure spread mid to late afternoon do not have an adequate amount of time to disperse before evening.

3. Avoid spreading just prior to or on weekends and holidays or other special occasions when people are likely to visit neighbors, parks, or normally unpopulated areas.

4. Inject all liquid wastes directly into the soil and incorporate surface spread or irrigated wastes as soon as possible after spreading.

5. Apply manure uniformly and in a thin layer to promote drying and to prevent fly propagation.

6. Use weather information when scheduling land application. Spread on days when the wind speed exceeds 5 mph in a direction away from neighbors.

Good Housekeeping

Good housekeeping involves managing important odor sources to eliminate their contribution to the odor problem and to improve the appearance of the production facilities. Odors are a subjective response which is influenced by past experiences and preferences and by what is seen as well as what is smelled. Operators with well maintained and attractive facilities who have maintained a cooperative public attitude may not be subjected to serious odor complaints.

Landscaping around feedlots, manure storage facilities and confinement buildings can improve runoff control as well as the appearance of the facilities. Trees can effectively hide odor sources from sight and help disperse odors in the wind by creating more air turbulence.

Keeping animals clean and lots scraped, prevent them from becoming important odor sources. Manure allowed to accumulate on lots can retain water, turn anaerobic and become very odorous. Frequent collection and subsequent disposal or storage keeps lot surfaces dry and aerobic.

Prompt handling and disposal of dead animals within 24 hours can eliminate a severe potential odor source. Burial, removal for rendering or incineration are acceptable alternatives. Incineration done incompletely or improperly can produce extremely offensive odors.

Chemical and Biological Additives

Various commercial odor control products are available on the market. Research studies have indicated these products are generally not effective in reducing odor levels. Under specialized conditions some products have been helpful when used during disposal. The cost is highly variable and often considered too expensive. It is important that a trial be conducted with the chemical being considered to make certain that it operates satisfactorily before purchasing large quantities.

Additives can be classified as one of four types. Masking agents have a stronger odor, hopefully more pleasant than the odor being masked. Counteractants interact with the odors trying to produce a less objectionable odor. Enzymes or biological products try to alter or accelerate manure decomposition, but an excessive amount is usually needed to affect the microbial activity in manure. Disinfectants attempt to stop microbial activity to prevent the formation of odorous gases.

Controlling the pH of stored manure can affect the gas production and release. Adding lime to maintain a high pH will reduce microbial activity and retain hydrogen sulfide in the manure. Adding an acid to maintain a low pH level also reduces microbial activity but retains ammonia rather than hydrogen sulfide. The amount of acid or base needed and the limited odor control make it an unattractive alternative.

An untested practice being tried by swine producers with concrete pits has been to turn the pit into an anaerobic digester. This is done by emptying the pit and adding anaerobic sludge from a local municipal waste treatment plant. The sludge provides a seed of anaerobic microorganisms for digesting the manure. The amount of sludge added is dependent on the amount of manure added to the pit each day. The pit then acts as an anaerobic digester producing less odorous gases. Effects of Minnesota winters are unknown and research is still being conducted.

Feed additives or altering rations to affect odor production has also been tried. Various additives such as sagebrush, peppermint oil, charcoal, yeast and calcium bentonite have been tried. The mixed results obtained have limited their development.

Air Pollution Equipment

Air pollution equipment such as electrostatic precipitators, filters and scrubbers can be used to reduce odor emissions. They are used on confinement buildings to remove dust and odorants from the exhausted ventilation.

Electrostatic precipitators place an electrical charge on the dust particles. They then can be collected on a plate of the opposite charge. Odorous gases are unaffected and not collected. Filters collect dust by entrapping it on some type of filter media. Filters can clog quickly depending on the dust level in the building and need to be either thrown away or cleaned. Various disposable filters have been tried. Scrubbers entrap dust and odorous gases using a liquid. Freezing is an important problem to be considered before selecting a scrubber. Electrostatic precipitators, filters and scrubbers all involve specially designed equipment and modifications in the conventional ventilation systems. Their operation requires regular maintenance and proper disposal of the collected odorous material.

The "Extra Mile"

Producers can use the fact that odors are a subjective response to help reduce odor complaints by maintaining a public image of concern, responsibility and productivity. By being aware of odors and by developing good communication and relations with neighbors, odor problems can usually be kept from developing into a community problem.

Producers need to be constantly aware of an concerned about potentially odorous situations that can develop either as a normal part of the operation or as a result of expansion. Anticipating a problem can usually prevent it from developing.

Communication between producer and neighbors experiencing objectionable odor levels is essential for identifying the odor source and determining the extent of the problem. Neighbors should report objectionable odors to producers indicating the source and objectionability. Properly defining the problem can often indicate the best solution. Informing neighbors of odor control efforts and times when odors can be expected helps them understand the producer's situation.

Good neighbor relations are always a good idea but where odors are a potential problem they can be good for business, too. Some odor complaints are based upon ill feelings between a producer and neighbor. Producers with odor problems sometimes have to make an extra effort to compensate for objectionable odors released.

Summary

Odors are a normal part of livestock production and waste management. Producers must control them so that they are not a public nuisance. The best ways to minimize odors are:

1. Locate facilities away from populated areas.
2. Contact neighbors - if an odor problem exists, do something about it.
3. Keep animals, buildings and feedlots clean.
4. Treat and utilize collected wastes properly.
5. Cover storage facilities.
6. Dispose of dead animals quickly.
7. Landscape to shield facilities and to improve their appearance.
8. Be a good neighbor.

CASE STUDIES

There are many different types of odor problems and concerns. In some instances the concern is about the future prospect of odors from a proposed livestock facility or the expansion of an existing facility. In other cases objectionable odors are regularly detected by neighbors. There are cases where an odor problem develops and the producer acts promptly to control the odors to everyone's satisfaction. Some cases are settled legally in court and others remain unresolved indefinitely.

Two case studies developed from interviews illustrate some typical odor problems. Included are the circumstances that led to a problem, and the steps taken by the producers to alleviate it. The neighbors' reactions and the effects of the odors on their lives are also presented.

Swine Confinement Case Study 1

This swine farm is located on 360 acres near a southern Minnesota community. Though the farm has been in the family many years, the hog operation was first begun in the early 70's. It started as a finishing operation, with a farrowing unit being added later in the mid 70's. Further expansion has increased the current capacity to over 600 sows. Currently half of the pigs farrowed are sold as feeder pigs. Plans for increasing the finishing operation to accommodate the feeder pigs being sold are being developed.

The confinement buildings are either partially or fully slatted with pits below them. Manure flows from them to an earthen storage pit after trickling over stand pipes in the pits which keeps 2-4 ft of manure in the pits.

The pit has a capacity of over 350,000 ft^3 when it is completely filled. The producer currently pumps it down as far as possible twice a year, once in the spring and again in the fall. The manure is irrigated onto cropland of continuous corn using a traveling gun.

Manure was irrigated the first time during the summer when the farrowing unit was added. The producer received complaints about the odor from neighbors up to several miles away. The producer felt that inexperience with irrigation of manure contributed to the odors. To help reduce odors the manure irrigation is scheduled in spring and the fall when temperatures are lower. Days are selected when winds are from the northwest away from neighbors nearest to the disposal site. Occasionally the producer still receives complaints during the disposal but reported that none are received during the rest of the year. The owner was concerned about odors yet and willing to try new waste management techniques to control odors.

Several neighbors living around the hog operation complained during interviews that odors from the facility were still a problem. Two located about a half mile to the northwest of the buildings and the lagoon are just across the road from the disposal field. They complained that they smelled odors from the lagoon whenever they were downwind of it. Hot humid days were especially bad. They also said that odors were still bad during disposal. One complained about the traveling gun getting within 200 feet of his home. On one occasion drift had gotten manure on a neighbor's car as it travelled on the gravel road past the field. A neighbor about a mile south, did not notice odors except occasionally during disposal. They did not complain to the owner directly because they felt previous complaining had been fruitless.

Neighbors described the odor as an unusual smell, different from fresh hog manure and very offensive. To avoid the odors they close their windows and stay inside, running the air-conditioner. Neighbors complained that clothes cannot be dried outside and they cannot enjoy the out-of-doors when odors are bad.

Many of the neighbors feel the lagoon has been an odor source since it was started. They think it has gotten worse as the owner has expanded the swine operation. Several feel the owner is not doing enough about the odors. They are concerned about further expansion feeling that the current odor problems should be fixed before adding to them.

This swine facility has an odor problem because of past mistakes during irrigation and because neighbors still consider odors from the facility objectionable. To solve this problem communication between the owner and neighbor needs to be established. The producer needs to question neighbors to find out that a problem exists. Then alternative solutions can be investigated and implemented. Currently the producer does not have any new plans for reducing odor emissions from the facilities. Neighbors are trying to change zoning laws for the future, while the present problem remains unresolved to their satisfaction.

Dairy Operation - Case Study 2

This 90 cow dairy operation is located in east central Minnesota in a beautifully wooded area with several residences nearby. The herd has not been expanded in the past fifteen years. A liquid manure system was installed in the late 60's when the present barn was built.

The manure in the free stall barn is scraped into manure pits twice each day using a cable driven scraper. The manure is stored in two 2800 ft^3 pits under the barn. The limited amount of storage means that the pits must be emptied each month. The pits are agitated and the manure removed and spread on available cropland using a 3000 gal tanker truck. During the summer, 7-10 acres of cropland are set aside for manure application. An exercise lot is scraped each week or sooner if rain is predicted. The producer does not like the manure on the lot to become rain soaked and sloppy.

The first odor complaints were received after the liquid manure system was put into operation. They came from a resort restaurant about two miles away and some nearby neighbors. To control the odors the owner began trying various chemical and biological additives. The additives were considered ineffective and so an aeration system was installed in the pits. The aeration system eliminated the odor complaints entirely.

At the present time the aeration system is not being used because of cost and because changes in the disposal practices are providing adequate odor control. The original tank wagon surface spread the manure spraying it widely as the wagon moved across the field. The producer felt that this was contributing to the release of the odors. The tanker now being used spreads manure in a swath the width of the tanker. Less pit agitation is used now, to minimize the release of the odors. Disposal is scheduled so that manure is not spread on either Friday, Saturday or Sunday. These practices combine to keep odors at acceptable levels.

Neighbors feel that there is no odor problem with this dairy operation at the present time. A neighbor one quarter mile east of the farmstead does not notice any odors from the buildings and exercise lots. Only occasionally, if the wind is right, do they detect odors during disposal. Another neighbor about 400 feet from a disposal site doesn't notice the odor often. Both mentioned that if odors are detected they are gone within a day and are not objectionable. Neighbors mentioned that they never had to move indoors or close windows as a result of any odors.

This producer currently does not have an odor problem. Prompt action to control odors when they were objectionable, using various appropriate techniques selected by the producer, has eliminated the problem. Good neighbor relations have also helped in this case. Neighbors commented favorably on the owner's involvement in and concern for the community. Recently neighbors have asked for some of the manure to be spread on their gardens and lawns for fertilizer. This the owner does readily at no charge. The producer's ability to control odors from livestock production has kept this operation compatibile within the community.

Reference Materials

Information on the design and operation of livestock waste management facilities can be obtained in the following two Midwest Plan Service publications. They are available through the Agricultural Extension Service for a nominal fee.

MWPS-18, Livestock Waste Facilities Handbook

MWPS-19, Livestock Waste Management With Pollution Control

Information and recommendations for farmstead planning is available in another Midwest Plan Service publication.

MWPS-2, Farmstead Planning Handbook

POLICY

1. Submission and review of priority lists. A class deviation has been granted from 40 CFR 35.562 and 35.563 for FY 79 setting June 15, 1978, as the date for submission of the preliminary list, and August 15, 1978, for the final list. Also, a class deviation has been granted from 40 CFR 35.915(a)(1)(iv) and 35.915(c)(2) waiving portions of the information requirements of the new regulation and restriction of consideration of geographical region as a priority rating criteria during FY '79. No priority list is to be accepted as final by the Region until all remaining required and available information has been received for each project and the public participation requirements have been met. Upon receipt of the draft list the Region should immediately enter the information into the Regional Construction Grants Management Information System (RCGMIS) for subsequent review and analysis. The Regional Administrator will review the final State project priority list within 30 days of submission to ensure compliance with the approved State priority system and this policy memorandum. All questionable projects (relating to eligibility and enforceable requirements) must be identified during this 30 day period. The final list is to be generated from RCGMIS and the list in RCGMIS will be considered as the official list for funding and management purposes.

2. Definitions:

- State project priority list - an ordered listing of projects for which Federal assistance is expected during the five-year planning period starting with the beginning of the next fiscal year based on and drawn from the Needs Survey inventory.

- Fundable list - that portion of the State project priority list which contains projects scheduled for award during the first year of the five-year planning period, not to exceed the total funds expected to be available during the year less all applicable reserves. Note that this definition of the fundable list is changed from that set forth in PRM #77-7. The fundable portion of the list no longer relates only to the amount of available funds but rather to the first year (fundable year) of the five-year list. It is conceivable that the fundable list will not contain enough projects to use all available funds because the allotment period of some of the currently available funds extends well beyond the fundable year.