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Development of an Odor Management Plan for South Dakota

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South Dakota State

DEVELOPMENT OF AN ODOR MANAGEMENT PLAN FOR SOUTH DAKOTA

BY

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DEVELOPMENT OF AN ODOR MANAGEMENT PLAN FOR SOUTH DAKOTA

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This thesis is approved as a creditable and independent investigation by a candidate for the Master of Science in Agricultural and Biosystems Engineering degree and is acceptable for meeting all the thesis requirements for this degree. Acceptance of this does not imply that the conclusions reached by the candidates are necessarily the conclusions of the major department.

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ABSTRACT

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Odor from livestock operations is often a nuisance to the neighborhood stakeholders and is one of the major environmental and societal issues associated with livestock industries. An odor management plan is not a requirement during the state permitting process of any livestock operation in South Dakota, but may be required to varying degrees for county level approval. Some neighboring states have developed odor management planning guides or templates which help address odor issues. Adoption of an odor management plan in SD can help address concerns of odor for the continuously expanding livestock industry in this state. Hence, an odor management plan template has been developed in this study to help proactively minimize odor conflicts among livestock operations and neighborhood communities. This template was guided by the existing guides or tools from other states, along with the engagement of different interest groups in SD. Some case studies were analyzed to relate hydrogen sulfide gas with odor annoyances, which could play a role in assessing odor annoyances and in odor management. Our template includes scientific tools to assess odor impacts of an operation. However, voluntary adoption of this OMP template will give producers from SD and surrounding regions an advantage of explaining their positive attitude of reducing odors generated by their operation towards the community.

CHAPTER 1: BACKGROUND

1.1 Introduction

South Dakota hosts a large farming industry with almost 31,000 farm and ranch families (Ag United, 2016). Being 21st in national milk production, 9th in national beef production, and11th in national pork production this state is continuously playing a vital role in the national economy (Ag United, 2016). With the continuously growing and expanding livestock industries, various environmental and societal issues are increasing in South Dakota, including odor (Garcia et al., 2015; Hult, 2015; Jauhola, 2015).

Odors are often the cause of complaints brought against livestock farms. The number of complaints are increasing in several states with the growth in the number of large operations. Several of these verified and non-verified complaints are brought back to planning and zoning boards which leads to a threat of shutting down of some farms (Koba, 2014; Lane, 2016; Markey, 2001; Segall, 2015). It is difficult to detect, measure, and completely remove odor from livestock operations. Due to various tolerance limits and perception levels of neighbors, odor has a possibility to create nuisance to communities. Hence, it has become a challenge to resolve the odor-related issues for the livestock owners.

Various management practices and technologies can help reduce odors and improve the public perception of livestock operations. An odor management plan (OMP) is one proactive approach that helps identify the odor impact, identifies opportunities to minimize the risk, and how to handle complaints. Several university (including Extension) and state agencies have designed OMP guides or templates for mostly voluntary adoption.

Currently South Dakota has no state-level rules regarding odor or air quality. The OMPs are typically not required as part of operating permits, except for some county level requirements (Cortus, 2012; Garcia et al., 2015). For an example, a management plan to control odor and flies is required to permit a Concentrated Animal Feeding Operation (CAFO) of any size by Brookings County Zoning Commission, South Dakota depending on the site specific prevailing wind direction and topography (Brookings County South Dakota, 2017). Union, Spink and some other counties in SD are also required to submit odor control plan depending on size and location of the operation (Spink County, 2002; Union County, 1996).

Odor conflicts have the potential to hinder the growth and expansion of the livestock industry and agricultural economy in South Dakota. Odor management planning could be one proactive step that attempts to minimize odor nuisance in the future for a farm, neighbors and community. Therefore, in this study our goal is to develop an odor management plan for livestock operations in South Dakota.

1.2 Livestock Odor

1.2.1 Definition

Odor is a sensation that can be either pleasurable or offensive. It is a perception resulting from the stimulation of olfactory receptors (ASTM E253-92a, 1992) hence it is difficult to define odor quantitatively as perception varies person to person. Schulte (2000) defined odor as a complicated mixture of chemical compounds, particulates, and aerosols that are difficult to measure and control. O'Neill and Phillips (1992) identified over 168 compounds from livestock wastes and air around them. Most of these compounds are formed by the decomposition of organic material by microorganisms.

Pfost et al. (1999) reported sulfur and nitrogen gases (e.g. hydrogen sulfide and mercaptans, ammonia and amines), volatile organic acids, phenols and alcohols are the common odorous compounds in manure and wastewater. The most objectionable odors result from volatile compounds formed during decomposition of manure in anaerobic conditions. Feedstock, oxygen supply, temperature and pH are the typical factors affecting this microbial activity (Schmidt, 2009). Various odorous compounds create odor when mixed with others which leads to unique odor for every different mixture. For example, odor from swine manure most commonly has a 'rotten egg' smell due to hydrogen sulfide while ammonia is the dominant odorous compound in poultry farms (Anderson-Bereznicki, 2009).

1.2.2 Odor Sources

Odor sources are primarily categorized based on three sources (Casey et al., 2006; Mielcarek and Rzeźnik, 2015):

1) Animal housing (indoor animal housing and open lots animal housing)

2) Manure storage structures

3) Land application of manure

Within a livestock facility, odorous gases are generated mainly from feed materials (food-processing wastes and fermented feeds), fresh manure and stored manure (Sweeten, 1991). Dead animal disposal sites; silage piles, feed centers, any other storage areas of bulk organic matters are all considered secondary sources of odor (Ndegwa and Harrison, 2017; Rappert and Müller, 2005; WSU, 2017). Manure is identified as the most common source of odor, hence any kind of activities (i.e. collection, handling, treatment, transportation) involving manure inside or outside of a barn can produce odor. When manure is applied on land, the field becomes one of the major sources of odor emission (Casey et al., 2006). Animals themselves or vehicles around the facility are also sometimes considered as a source of odor (Anderson-Bereznicki, 2009).

1.2.3 Odor Measurement

Measuring odor is a difficult process as it is subjective (Anderson-Bereznicki, 2009). In the past, several studies have measured odor concentration within and surrounding livestock facilities (Anderson-Bereznicki, 2009; Brewer and Cadwallader, 2004; Capelli et al., 2013; Hobbs et al., 1995; Mills et al., 1963; O'Neill and Phillips, 1992; Zahn et al., 2001; Zhang et al., 2010).

Two general approaches have been used to measure odor: 1) measuring individual gas concentrations; and 2) olfactometry (Kim and Park, 2008; Mielcarek and Rzeźnik, 2015; Nicolai and Pohl, 2005). Measurement of individual odorant gases is done by complex physical and chemical analyses such as gas chromatography or infrared and mass spectroscopy. In measuring gas concentration, calibrated instruments are used to measure relative amount of gas in the air (Kim and Park, 2008; Mielcarek and Rzeźnik, 2015). Olfactometry is a quantitative measurement of odor by human nose(s) and this process needs trained individuals and instrumentation such as an olfactometer (Anderson-Bereznicki, 2009; Kim and Park, 2008). Standardized procedures for olfactometry were established by the American Society of Testing and Materials (ASTM) and the European Committee for Standardization (CEN) in the 1990s (Anderson-Bereznicki, 2009; Nicolai and Pohl, 2005).

Both of these methods have advantages as well as disadvantages. Olfactometry has direct correlation with odor and it uses the most sensitive detector i.e. human nose for many compounds (Brewer and Cadwallader, 2004; Nicolai and Pohl, 2005). Another advantage of olfactometry is, it considers the complete mixture of gases in analysis and hence, all contributing compounds are considered (Nicolai and Pohl, 2005). On the other hand, olfactometry has potential to give biased and highly variable results as it involves the evaluation by one or more persons (Guo et al., 2003; Nicolai and Pohl, 2005). The advantage of using gas concentration in odor detection is, it can quantify individual components of gas. However, the relationship between odor and gas concentration differs from gas to gas and no direct correlation between odor and any identifier gas has been established yet. Hence, gas concentration sometimes does not address odors adequately sensed by the people downwind of a source.

1.2.4 Odor Emission

Once generated by microbial activity, odorants and other gases are released into the atmosphere through physical and chemical processes which depend on the concentration of the gas, temperature, surface wind speed and relative humidity (Guo et al., 2003; Schmidt, 2009). The rate at which odorous gases or particles are released into the ambient air is called emission and it is calculated by multiplying the concentration of the component with the momentary air exchange rate (Casey et al., 2006; Mielcarek and Rzeźnik, 2015).

Odor emission from livestock facilities is a complex process and the amount of emitted odor in several studies is influenced by the measurement methods and rate reporting bases (Akdeniz et al., 2012; Bicudo et al., 2003; Casey et al., 2006). Several ways to report emissions make comparison among studies difficult. Animal units (AU), animal live weight, per animal place, area, volume or weight of manure are some ways to report emission as any standardized methods have not been established (Casey et al., 2006; Jacobson et al., 2005).

1.2.5 Odor Movement

Understanding odor movement helps us understand the impact of odor at varying distances around a source (Mielcarek and Rzeźnik, 2015). Industry and regulatory agencies describe air pollutant movement with dispersion models. Once odor is emitted from various sources/points at a livestock facility, it is dispersed by several factors and ultimately transfers to receptor points (Anderson-Bereznicki, 2009; Schmidt, 2009). In the dispersion process odor is diluted by mixing with the fresh air (Ullery et al., 2003). The responsible factors for the movement of odorous gases are wind speed, relative humidity and atmospheric stability, which affect the duration, concentration and frequency of the gases at the receptor locations (Guo et al., 2003; Schmidt, 2009). Under certain conditions, odor plumes can travel several miles downwind of a source (Hofer, 2009; Schmidt, 2009).

1.2.6 Odor Impact

Odor is mostly considered as an inconvenience which sometimes creates nuisance and brings complaints against livestock operations (PSU, 2002; Schauberger et al., 2001; Starmer, 2017; Von Essen and Auvermann, 2005; Watts and Sweeten, 1995). Odor problems are mostly associated with the neighborhoods of agricultural operations (Horton et al., 2009; Palmquist et al., 1997; PSU, 2002; Wing et al., 2008). For the non-farming community, odors may be considered as a nuisance while producers or farmers may consider odors an unavoidable consequence of their livelihood (PSU, 2002).

Several researchers conducted studies to assess human health risks associated with livestock odor. O'Connor et al. (2010) summarized a weak relationship between exposure of communities living near animal feeding operations that house animals for food production on any scale and some self-reported diseases (respiratory, gastrointestinal and mental health) from several studies from North America, European Union, United Kingdom and Scandinavia. Schiffman et al. (1995) reported a significant negative impact of swine odor on the mood (i.e. more tension; more depression; more anger; less vigor; more fatigue and more confusion) of experimental subjects (persons living near hog operation) than on the controlled subjects. Schiffman (1998) also reported odor potential to affect mood and memory, besides eye, nose, and throat irritation; drowsiness also occurs due to odor as per the complaints. Odor may lower the normal quality of life, as the residents near hog or cattle operation could not open their windows or go outside even in nice weather (Wing and Wolf, 2000). Also, odor from livestock operations has a potential to reduce the adjacent property values and aesthetics (Hamed et al., 1999; Rappert and Müller, 2005; Taff et al., 1996) as well as downgrading rural economy (Starmer, 2014).

1.2.7 Odor Impact Estimation Tools

Odor impact on the surrounding communities depends on several variables such as emitted odor from the source, distance, weather condition, odor sensitivity and tolerance of the neighbors, which makes determination of proper setback distances a difficult task. Various odor impact estimation tools exist to provide site-specific estimates of odor impact. These tools evaluate the potential impact of odor from new and expanded animal production facilities depending on air dispersion models and the actual odor emission data from the corresponding sites (Jacobson et al., 2005; Stowell et al., 2005).

The South Dakota Odor Footprint Tool (SDOFT), Purdue Odor Setback Model (POSM), Nebraska Odor Footprint Tool (NOFT) and Odor from Feedlot Setback Estimation Tool (OFFSET) are some examples of odor impact estimation tools. These tools were established using several sets of odor emission data obtained by extensive research work. The OFFSET tool is based on the use of an air dispersion model (INPUFF-2) and actual odor emission data from 280 animal buildings and 85 farms in Minnesota, which includes cattle, poultry and swine. Odor concentration was analyzed by olfactometry and then was multiplied by ventilation rate to obtain emission rates (Jacobson et al., 2005). The SDOFT and NOFT used the same principal and emission data and a different dispersion model (AERMOD). In NOFT, the validation of the model was done for a swine facility in Nebraska (Stowell et al., 2006). In POSM tool, emission data from two commercial swine facilities in Indiana were used primarily and odor concentration was analyzed by olfactometry (Anderson-Bereznicki, 2009; Lim et al., 2001). Later, emission data from one dairy in Indiana were added in the model (Anderson-Bereznicki, 2009).

Although these four tools are similar in estimating odorous emission and predicting odor impact or annoyance free distances, they have some differences in their input factors and air dispersion models. Table 1.1 lists some differences in calculating odor impacts by these tools.

Table 1.1. Comparison of odor setback/odor footprint estimation tools

Calculation Type	Factors	SDOFT	NOFT	OFFSET	POSM
Odor emission	Species	Beef, Dairy, Swine	Dairy, Swine, Poultry	Beef, Dairy, Swine, Poultry	Beef, Dairy, Swine, Poultry
	Emitting area options	Rectangular	Rectangular and circular	Rectangular	Rectangular and circular
Odor dispersion	Dispersion model	AERMOD	AERMOD	INPUFF 2	Austrian and German model
	Terrain	Flat only	Flat and others	Flat only	Flat and others
	Meteorological data	Built-in historical data for three regions in South Dakota	Built-in historical data for eight regions in Nebraska	Built-in historical data for Minnesota	Wind frequency data can be manually entered
Outcomes	Setback	Setback distances from the operation at different odor annoyance-free level in four directions (NE, SE, SW,N W)	Setback distances from the operation at different odor annoyance-free level in four directions (NE, SE, SW, N W) for two different sets of odor management	Odor annoyance-free distance for various sources from the operation regardless of wind direction	Individual setback distance for various sources within an operation in eight wind directions (N, NE, E, SE, S, SW, W, NW)

All these tools estimate odor impact from livestock and poultry facilities to the surrounding community depending on various factors. There are some downfalls to these models. The OFFSET and SDOFT do not consider the effects of topography and assumes flat terrain while POSM and NOFT consider different topographical features in calculating setback distances. Site specific odor emission data and meteorological data restrict the use of all four of these tools nationally/internationally. The NOFT is not ready to use for beef feedlots and SDOFT cannot calculate odor emission from poultry operations; POSM and OFFSET considers both of them. The OFFSET model does not calculate setback distances in various wind directions while the other three models can.

However, the usage of these tools helps estimate odor annoyance free distances from a livestock operation which could be an important consideration in odor management activity.

1.3 Odor Management Plan

Odor management involves more than just the installation of any gas treatment system (Schlegelmilch et al., 2005). There already exists some OMP developed for several states in North America (Minnesota, Michigan, Alberta, Nebraska, Washington etc.), which were mostly developed as voluntary practices by researchers from those places.

1.3.1 Definition

An OMP is a systematic inventory and assessment of potential odor sources, which identifies effective control strategies to reduce odor from these potential sources, and then establishes protocols to implement control strategies (Atia, 2007; Koelsch, 2002; May, 2012; WSU, 2017). This document helps reduce nuisance conflict and reflects the intent of a producer to be a good neighbor (Schmidt et al., 2001).

Considering the potential audience, an odor management plan (OMP) is an opportunity to document and demonstrate odor management actions by a producer. The effectiveness of an OMP could be enhanced if it is designed and written with the consideration of explaining odor and production practices and management to a larger audience (i.e., neighbors, zoning offices, etc.).

1.3.2 General Components of an OMP

An OMP is a step by step approach towards odor management. The general components of existing OMPs are as follows:

1. Potential odor source identification

This part involves a thorough inventory of all the potential odor sources in a livestock operation. Nuisance odors are generated from various sources from an operation. Typically brief descriptions, including physical features and management activities, of each odor source are listed in this section. Some OMP templates use maps to indicate the odor source and odor receptor’s location. Several approaches (e.g. manual worksheet, excel sheet) are used to identify odor sources in an operation.

2. Assessment of odor impact of the potential sources

The second part involves the assessment of odor impact of all the individual odor sources. This risk assessment is followed by giving a rank to each source because some odor sources emit more intense odor per unit area than other sources. Several techniques have been used to assess the impacts in the various OMPs qualitatively or qualitatively. Quantitative assessment involves odor impact estimation tools. In qualitative assessments, factors to consider in determining potential rankings of odor sources include proximity of the sources to public areas or neighbors, dilution of odors caused through the mixing of odors with ambient air, and meteorological conditions.

3. Identification of effective control strategies

This part mostly involves listing odor control technologies of each odor source with the implementation criteria. Generally, three types of odor control technologies are included: those that reduce the odor generation, those that decrease the odor emission and those that increase dilution of odors.

4. Development of protocol for responding to complaints or issues

One of the most important elements of an OMP is the response protocol to address odor complaints. It is also necessary to monitor the effectiveness of any incorporated technology. Measures to avoid odor complaints, building relationships with community members, monitoring odor events, establishing acceptable intensity and frequency standards, and evaluating control technologies are mostly included in an odor management plan to promptly respond in an effective manner whenever odor issues arise.

1.4 Research Objectives

Total removal of odor is impossible, but better management practices can help reduce the risk of odor conflict around a livestock operation. Some counties require OMPs, but there is little guidance as to what needs to be included in an OMP. Hence, our goal is to develop an odor management plan template for livestock operations in South Dakota. The subsequent chapters describe the various approaches to tailor the development of a SD OMP that can be used as a communication tool to document and describe odor management practices on a farm:

- Chapter 2 provides a review of the development process of existing odor management plans to enhance our own process;
- Chapter 3 details a needs assessment meeting;
- Chapter 4 uses various case studies to relate the occurrence of simulated odor nuisance with measured hydrogen sulfide concentrations at various distances around livestock operations based on weather conditions, distance and topography;
- Chapter 5 is the development of an odor management planning template for South Dakota; and
- Chapter 6 provides general discussions on lessons learned from this research project.

CHAPTER 2: REVIEW OF THE DEVELPOMENT PROCESS OF PREVIOUSLY ESTABLISHED ODOR MANAGEMENT PLANS

2.1 Introduction

Livestock production facilities emit odor which sometimes brings nuisance among community members. The growth in the number of large operations across the country has increased the number of complaints regarding odor (Pfost et al., 1999). South Dakota is an important stakeholder in the country's agriculture industry with a significant number of livestock operations (Ag United, 2016; SDDA, 2014). However, South Dakota has several environmental challenges including odor (Garcia et al., 2015; Hult, 2015; Jauhola, 2015).

Odor management planning is a proactive step that is designed to minimize odor nuisance in the future for a farm, neighbors and community. Although an odor management plan for livestock operations, regardless of size, is not required everywhere during the permitting process of livestock operations, researchers from several states in North America and Europe have developed voluntary odor management plans to help guide livestock operations on odor related issues. Only seven states in USA require operations to submit an odor management, abatement or control plan for Confined Animal Feeding Operations (CAFO), which is often restricted to operations of certain sizes and specification (Charles, 2016). Before starting an odor management plan (OMP) development for South Dakota, various established OMPs from multiple states were reviewed and input sought from the developers regarding creation, use and adoption of the OMPs through a questionnaire. This chapter examines the strengths, weaknesses and outcomes of existing OMPs to guide development of a similar type of plan in South Dakota and states where currently no odor management planning templates exists.

2.2 Methodology

2.2.1 Questionnaire Survey

The developers of existing odor management planning templates and guides were identified from internet searches and personal contacts. We asked questions about different aspects of the OMP development process to the persons who were directly involved in the planning process. We personally contacted and emailed a questionnaire with all open-ended questions to these personnel following their consent (Appendix A). Odor management plan developers from Minnesota, Michigan, Nebraska and Pennsylvania participated in this survey.

The questionnaire topics were as follows:

1) Development
2) User
3) Marketing process
4) Template
5) Evaluation

2.3 Results and Discussions

The summary of the responses for the OMP development topics are described in the following sections.

2.3.1 Development

The participants were asked if there was any kind of request to develop an OMP or not. There were no specific requests or demands prior to development of an OMP in any state except Pennsylvania. In Pennsylvania, the thought for odor management law and regulations came from an air quality workgroup like United States Environmental Protection Agency (U.S. EPA) who were working to set up an agricultural air quality.

We wanted to know if the OMP was required by the state or not. An odor management plan is a mandatory requirement for Concentrated Animal Feeding Operations (CAFO) and Concentrated Animal Operations (CAO) in Pennsylvania and Nebraska. The developers from other states produced these guides voluntarily for the betterment of the livestock industry in their state.

We wanted to know if there was any exchange program before or during the development of an OMP. During development of the OMPs, there was little exchange between producers, neighbors or policy makers collectively. Only Pennsylvania had some discussions with different agricultural, environmental associations and township supervisors.

2.3.2 User

We wanted to know the target user of an OMP and hence asked if the OMP was built state-specifically or for more of a region. The OMPs from Michigan, Pennsylvania and Nebraska were developed for their own states. Michigan developed a template that could be used in other places. The Pennsylvania OMP incorporates a site index tool to measure the odor impact around an operation there and depending on the score from this tool, the odor best management practices need to be identified. No OMP was established for individual animal species.

2.3.3 Marketing Process

In response to a question “how OMP was marketed?” we found the Minnesota OMP had no marketing at all. In the other three states, there was not extensive marketing for the OMP guides aside from extension news updates and some presentations. During the development process, Pennsylvania met with various agricultural and environmental groups to discuss the program and to seek input. Most of these tools and guides are readily available online.

We wanted to know if there was any training program on OMP. Some training was offered by the Extension, college, and/or commission staffs in Pennsylvania, Nebraska and Michigan. The training was typically designed for CAFO managers, consultants and farmers who were regulated under specific certification programs by the state. As a special step to make specific interest groups aware, Nebraska shared the OMP program with a stakeholder advisory committee. Pennsylvania met with their state association of township supervisors.

2.3.4 Template

The developers were asked if they followed any existing template. Except for Nebraska, all the other template developers were guided and inspired by some existing template for either odor management or nutrient management. None of the templates set an expiration date although all of them encouraged update or review depending on demands. Odor monitoring was suggested by Michigan and Minnesota.

2.3.5 Evaluation

The use, evaluation and impact of the OMP templates was not tracked anywhere. The states (Pennsylvania and Nebraska) who required OMP for specific operations had some records of usage. Michigan received feedback after implementation to make the OMP less extensive. Pennsylvania mentioned of bringing some changes into an operation after implementation and these changes were then evaluated by certified plan writers or commission staffs.

The OMP developers were asked if they have to develop an OMP template again what they would do differently. Except for Michigan, all the other three agreed to bring changes if it needs to be. The changes they would brought was to make an easier and more user friendly one along with the guidance.

2.4 Recommendations

The feedback from previous OMP developers identifies some opportunities in the future development of OMP templates and guides:

- A voluntary odor management plan can help address odor issues even when not required by rules or legislation
- Exchange programs between producers, neighbors or policy makers during development stage could reduce user frustration (i.e. length) after implementation
- Quantitative estimation or adoption of quantitative estimation tools of odor risks gives a science base in an OMP
- Some news release or marketing about the ideas of an OMP helps educate the people who are involved in odor issues
- Evaluation of an OMP upon implementation would be helpful in assessing the impact of an odor management plan on odor issue

2.5 Summary

Content and format-wise, most odor management planning guides are similar. The feedback from developers of existing OMPs suggest there has been a lack of collaboration during development of existing OMPs, and little incorporation of odor impact estimation tools. An odor management plan was mostly marketed through some sort of publications, extension news release or training programs although it is not a mandatory requirement for livestock operations everywhere. Evaluation of a developed OMP were not done mostly by the users. However, the previous developers would develop an easier, user friendly one if they were to develop a new one.

CHAPTER 3: INITIAL NEEDS ASSESSMENT FOR AN ODOR MANAGEMENT PLAN BY A FOCUS GROUP

3.1 Introduction

There are no state specific air quality or odor regulations for livestock operations in South Dakota. Some county level odor rules may exist in terms of setback distances (Cortus, 2012). The growing concerns about livestock odor on the surrounding community has not been provided any consistent solution yet. Development of an odor management planning template would proactively guide livestock producers in minimizing odor impacts as well as complaints. Besides, keeping an OMP template could give a positive opening to help communicate with anyone about odor management practices. It was deemed an important task to assess the needs of building a template for SD prior to developing an odor management plan (OMP).

Our goal was to assess the needs of citizens who are frequently dealing with livestock odor i.e. the people who are living in the vicinity of livestock operations, livestock producers, and local county officials. A meeting with an existing taskforce of people including producers, neighbors and local officials was used to assess the needs when developing an odor management plan. The discussion also identified information and processes needed in an odor management plan template to provide accountability.

3.2 Methodology

3.2.1 Question Development

A series of questions were developed prior to the meeting. The questions were divided into three parts.

The first part was an "ice breaker" for the meeting with some quick multiple-choice questions. Five multiple choice questions were built to find the participant's level of experience about odor management planning and general opinions about odor.

The second part aimed to figure out the necessity of having an odor management plan, what could or should be the components of a plan, and how to encourage adoption of the odor management planning process. Six individual questions were developed.

The final part was the evaluation of the meeting. There were some open ended questions where participants could provide additional comments about the topics that were not discussed in the short time span of the face-to-face meeting.

3.2.2 Meeting Details

The meeting was held at the South Eastern Council of Government office on 10 March, 2017, in Sioux Falls, SD. Total time of the discussion was approximately 90 minutes. The focus group of 7 persons consisted mostly of urban planners, agricultural development groups and private citizens. This group was an existing group who regularly met to discuss model regulations for concentrated animal feeding operations. A communication specialist helped host the discussion to keep the discussion focused on the topics of interest. Participants, who could not attend directly, participated over the phone. The ice-breaker part was operated with "clicker" technology (Turning Technologies, Youngstown, OH). The conversation notes were recorded by two observers.

3.2.3 IRB Exemption

The survey and process were deemed exempt by the South Dakota State University Institutional Review Board (IRB-1703008-EXM).

3.2.4 Analysis Method

The results of multiple choice questions are presented as the proportion of participants responding to the various options. Open-ended discussion based questions were recorded by two observers. We matched the notes from the two observers and used Word Cloud software (Microsoft, 2018) to identify the frequently used words in the discussion. “Word cloud is a graphical representation of word frequency that give greater prominence to words that appear more frequently in a source of text” (BetterEvaluation, 2017).

3.3 Results and Discussion

3.3.1 Part 1

During the ice-breaker, the survey questions captured the following characteristics and experiences of the focus group participants.

- 86% were from local or state government and 14% were producers
- 42% of the participants confirmed their involvement with odor management planning before; 29% of the total participants were involved somewhat in odor management planning before while 29% never had any involvement
- All of the participants agreed that odor is not removable but manageable
- 57% of the participants described odor management planning as a mediocre approach with community acceptance while the rest of them thought it is a proactive solution to eliminate odor issues in a community
- 86% felt that owner, neighbor and county officials together should be involved in odor management planning for a specific operation. Only 14%

of the participants thought county officials (solely) should be involved in odor management planning

This feedback in Part 1 of the meeting told us this group of participants had considerable experience with odor management planning, primarily from a county planning and zoning perspective.

3.3.2 Part 2

For each open-ended question in the second part of this meeting, a word cloud is presented and discussed.

Question 1: What elements should be included in an odor management plan? (Figure 3.1)

Figure 3.1. Elements of an odor management plan from the view of participants of the meeting

Operation types, manure management, nutrition, mitigation technologies, vegetation, visibility, climates were words most frequently used to describe the elements that participants wanted to see as part of an odor management plan (Figure 3.1). These elements are consistent with elements of established odor management plans from Michigan, Minnesota, Washington, Pennsylvania and Nebraska (discussed in Chapters 1 and 2).

Question 2: Which tools, techniques, or processes would be acceptable in an odor management plan for? (Figure 3.2)

a. **Producers**
b. **Neighbors**
c. **Local officials**

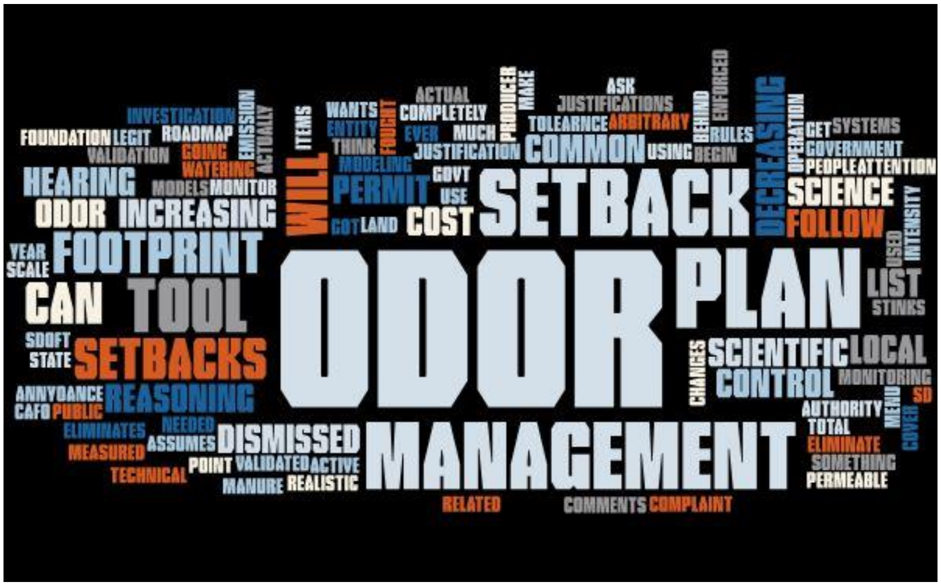


Figure 3.2. Acceptable tools, techniques and process for an OMP

There are some tools and techniques, which could estimate risk of odor of the operation or could be used to estimate setback distances. Most participants mentioned science-based tools, if any. Nevertheless, participants wondered if these tools were validated or not. The word cloud shown in Figure 2 infers participants expected tools to estimate setbacks to give odor management planning scientific support. The South Dakota Odor Footprint Tool was one example of a science-based tool mentioned in the conversation. One concern regarding this OMP template was clarifying its usage, otherwise public will assume an OMP is going to eliminate odor completely.

Question 3: How do you determine when to add/list available or proposed mitigation technologies of an operation to a plan? (Figure 3.3)

Figure 3.3. Content that helps to identify when mitigation technologies needs to be added on plan

From the conversation and word cloud in Figure 3.3, it is clear that adding/listing of available or proposed mitigation technologies of an operation needs to be considerate of neighbors. One of the participants suggested adding mitigation technologies to a plan to appease the neighbor. One another participant said “whenever odor reaches anyone’s vicinity, mitigation technologies are needed to be added to a plan.”

Question 4: As an element of the plan, we would like your opinion on how to handle complaints (as needed) locally. If a complaint arises, what do you see as a first step and by whom? (Figure 3.4)

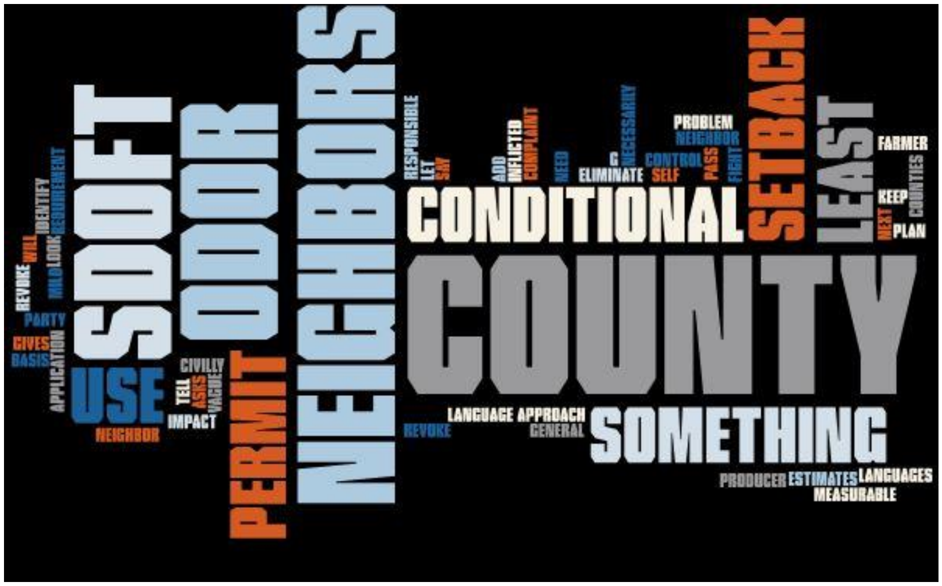


Figure 3.4. Components and first step to handle complaints

Many participants thought the county should be given the first priority at handling a problem, likely reflective of the fact that the majority of the participants were county officials (Figure 3.4). However, some comments indicated that participants wanted the county to be kept out totally, concerned that neighbors would think the county is the only responsible party to eliminate odor. Some of the participants felt the neighbor should approach the farmer directly to eliminate the issue by mutual understanding. In this graph, there are some other words more highlighted even though they were not addressed the questions directly because of some diverse discussion points (e.g. SDOFT, setback etc.)

Question 5: How can operators stay engaged with their neighbors? What are some suggestions for a healthy relationship between a livestock operation and its neighbors? (Figure 3.5)

Figure 3.5. Participant's responses regarding suggestions to build healthy relationships between livestock operation and neighbors

The participants suggested livestock operators can stay engaged with their neighbors without irritating them by reaching out to the neighbors regularly, even if the operation is within setbacks (Figure 3.5). Both parties should try to be good neighbors. If there is any upcoming public hearing, producers could talk to the neighbors to clarify questions or concerns before the hearing or public process.

Question 6: How do we encourage adoption of an odor management plan with or without a template? (Figure 3.6)

Figure 3.6. The elements that could help to encourage adoption of an OMP

An odor management plan could better be adopted if it is science based and has clarity (Figure 3.6). The usage of techniques and tools could help adaption of an OMP. A template would be nice for adoption as per the audiences.

3.3.3 Part 3

From the evaluation part, we found the participants were satisfied mostly to completely about the meeting and the environment. From the additional open-ended comments provided, the participants emphasized the necessity of identification of tools more than process.

3.4 Summary and Recommendations

According to the conversation and comments given by the participants, we can say that an odor management plan for South Dakota's livestock operations has potential and the following elements should be considered as elements of an OMP:

1. Inventory of an operation (size and type of operation, animal size and type, animal nutrition, manure management, vegetative buffers, weather condition)

2. A science based tool to estimate odor potential
3. Odor mitigation technologies
4. Protocol for complaint response

The open discussion helped shape recommendations for developing an odor management plan for South Dakota. The following recommendations we prepared based on the participants discussion:

1. An odor management plan has to be science-based
2. An odor management plan could better be appreciated if it has more clarity
3. An odor management plan would be better accepted if it reflects the views of various groups who are frequently involved with odor i.e. producer, neighbor and county officials
4. An odor management plan has to specify its approach towards addressing odor issues; if not, people would think an odor management plan is designed to eliminate odor completely from an operation.
5. Odor issues could be better managed if there is a good social relationship among neighbors and producers.

CHAPTER 4: CASE STUDIES OF AIR QUALITY MONITORING AND ODOR IMPACT SIMULATION AROUND LIVESTOCK OPERATIONS

4.1 Introduction

Odor is one of the various air quality issues associated with livestock operations. Several different gases emanate from livestock operations and poultry facilities, which produce odor at various concentrations and/or chemical compositions (Bunton et al., 2007). Air quality around livestock operations can be degraded once the concentrations of emitted pollutants from operations exceed the desirable levels (Ni 2015). There are no federal regulations that specifically address odor from livestock operations, but some states and/or counties have enacted laws to address odor plans, measurements, permits, location or setback requirements, nuisance actions and other protocols (Charles, 2016; Guo et al., 2000).

The standard procedure for quantifying odor concentration is complex (Anderson-Bereznicki, 2009) and an expensive procedure that relies on human panelists (Guo et al., 2000). Several approaches including dynamic olfactometry, dispersion modelling, and public participation and surveys have been used to assess the odor impact on the surrounding area (Chemel et al., 2012; Ranzato et al., 2012; Sironi et al., 2010). Establishing a reliable indicator gas to quantify and characterize odor around livestock farms could be one solution to resolve the complexity of measuring odor nuisance and has been the focus of much research (Akdeniz et al., 2012; Barth et al., 1974; Guo et al., 2000; Lu et al., 2011; Lunn and Van De Vyver, 1977; Ostojic et al., 2000; Qamaruz-

Zaman and Milke, 2012; Riskowski et al., 1991; Zhu and Jacobson, 1999; Zhu et al., 1999).

Among various identified compounds of odor, H_2S has a very low threshold and is comparatively easy to detect with available instrumentation. Barth et al. (1974) identified H_2S as the second best among three odorants (volatile organic acids, H_2S and NH_3) for stored manure. Guo et al. (2000) indicated H_2S as a good odor indicator for some animal facilities with a coefficient of determination of 0.569 for air samples collected from various sources on 80 different farms including swine, cattle and poultry facilities; odor was analyzed by eight trained panelists with a dynamic olfactometer and compared to H_2S measurements by a Jerome Hydrogen Sulfide Analyzer (Model 631-X, Arizona Instrument, Phoenix, AZ, USA) (Guo et al., 2000). Akdeniz et al. (2012) examined a significant correlation between H_2S concentration and odor from two free stall dairies (coefficient of determination = 0.30 and 0.21 respectively), a swine finishing site (coefficient of determination= 0.61), and at a farrowing site with a 0.10 coefficient of determination. Some researchers found little or no correlation between odor and H_2S concentration (Hobbs et al., 1999; Williams, 1984).

Several techniques and instruments exist to measure H_2S concentration. Single Point Monitors (SPMs) use colorimetry to measure gas concentration based on the change of reflection upon the exposure of some tape to the target gas (Bicudo et al., 2003; Liang et al., 2004; Schmidt et al., 2002). The Jerome meter uses gold film sensing technology to detect the mass of H_2S which is proportional to an increase in electrical resistance of a thin gold film at the presence of H_2S (Koelsch et al., 2004; Rahman and

Newman, 2012). Several other scientists used an H_2S/SO_2 analyzer that uses fluorescence technology to detect H_2S concentration (Joo et al., 2015).

Hydrogen sulfide concentration and emission from animal buildings from several studies showed a wide variation due to several factors (Bicudo et al., 2002; Heber et al., 2006; Koziel et al., 2004; Ni et al., 2002; Sun et al., 2008; Thorne et al., 2009). There are fewer studies about H_2S concentrations in ambient, downwind environments; they also varied largely based on the range of conditions (Bunton et al., 2007; Donham et al., 2006; Koelsch et al., 2004; Tengman et al., 2015). Some researchers tried to relate H_2S concentration with local environment parameters (temperature, relative humidity, wind velocity) (Joo et al., 2015; Lemay et al., 2007) while some others examined the temporal and spatial variation of gas concentration (Bicudo et al., 2003). However, these studies were mostly done to explain the dynamics of release of this gas which is important to establish setback limits and mitigation strategies.

Hydrogen sulfide is used as a property line indicator of air quality nuisance in some areas. Minnesota Pollution Control Agency has an ambient air quality standard of a 30-minute average of 30 ppb found twice in five days, or a 30-minute average of 50 ppb found twice per year; there are allowances for higher concentrations during periods of manure agitation and pumping. Depending on the odor complaints and reports of nausea and headache at exposure to 30 ppb H_2S from geyser emissions, Amoore (1985) (as reported by Collins and Lewis (2000) and Koelsch et al. (2004)) estimated that H_2S was detectable by 83% of the population and was discomforting to 40% of the population(. Nebraska set a limit of maximum 10 ppm and 1-min average concentration of 0.10 ppm, at the property line for Total Reduced Sulfur (TRS) (Koelsch et al., 2004). Iowa proposed a H_2S concentration less than 0.07 ppm for a 1-hour time weighted average at the property line.

Since it is a complicated job to assess the odor and its impact, establishing an indicator of odor can help minimize the complexity in sampling method as well as regulate odor around livestock facility. Hence, the objective of this chapter is to relate the occurrence of simulated odor nuisance with measured hydrogen sulfide concentrations at various distances around livestock operations based on weather conditions, distance and topography.

4.2 Materials and Method

Three different case studies were used in this study and include dairy, swine and beef systems. Case Study 1 involved the monitoring of hydrogen sulfide around a dairy, and the monitoring methodology are presented herein. Case Study 2 is derived from Hofer (2009) for a swine system. Case Study 3 is derived from Koelsch et al. (2004) for beef cattle feedlots.

4.2.1 Site Descriptions

The general farm descriptions of the Case Study sites are provided given in Table 4.1.

Table 4.1. General description of the sites of the case studies

Case study No.	Location	Sources	No. of animals	Type of animal	Type	Dimension (length (m) x width (m))
1	Turner, SD	Barn (Type 1)	1565	Mostly milking and dry cows	Naturally ventilated	480 x 100
		Barn (Type 2)	320		Cross ventilated	98 x 34
		Manure storage	1885		Earthen basin	290 x 116
2	Bruce, SD	Barn	2000	Finisher swine	Naturally ventilated, Deep pit	122 x 24
3	Nebraska	Feedlot 1	7000	Beef cattle	-	1324 x 685
		Feedlot 2	10000		-	1295 x 852
		Feedlot 3	5000		-	1014 x 306

Case Study 1 involves a 1900-head free stall dairy barn located in Turner County, SD. Two separate 34,000 m^3 storage lagoons store liquid manure between land application periods in the spring and/or fall. Case Study 2 includes data collected from a swine finishing site with two 1000-head pig barns, located northwest of Bruce, SD. The data was collected to measure the effect of a shelterbelt on H_2S concentrations downwind from the barns (Hofer, 2009). Case Study 3 includes total reduced sulfur concentration data in the vicinity of beef cattle feedlots (Koelsch et al., 2004).

4.2.2 Sampling Methods and Periods

4.2.2.1 Case Study 1

Single Point Monitors (SPMs; Zellweger Analytics, Inc., Lincolnshire, IL), using chemcassette tapes with a dry reagent medium, detected and reported H_2S concentrations based on a rate of color change of the tape. This change of color was proportional to the concentration of the exposure of the target gas. Each SPM was connected to an Eltek 1000 series data loggers (Eltek Ltd., Haslingfield, Cambridge, UK), which recorded the SPM signal in miliampere (mA) every 17 minutes, which were then converted to parts per billion (ppb). The chemcassette tapes were designed to measure H_2S concentration between 1 and 90 ppb. Weather data was provided by the South Dakota Climate Office and the Sioux Falls Landfill Station weather data was used in the review of the concentration data relative to weather conditions. Data were collected in two sampling periods: (1) Before agitation (08/25/2016 – 09/19/2016); and (2) during agitation (10/28/2016 - 11/7/2016).

4.2.2.2 Case Study 2

Hydrogen sulfide concentrations were measured by SPMs and data were recorded with an Eltek data logger (Eltek Ltd., Haslingfield, Cambridge, UK) connected to the SPMs. The SPM chemcassette ranges were 0 to 90 ppb and 60 to 1400 ppb. An on-site weather tower and data logging system (Campbell Scientific Inc., Logan, UT) was used to record wind direction, wind speed, humidity and solar radiation every 8 minutes. Data were recorded when the wind direction was out of the south/southeast only (Hofer, 2009). Data were collected during May and June of 2007.

4.2.2.3 Case Study 3

Hydrogen sulfide concentrations were measured with a Jerome 631-S analyzer with memory modules at a dynamic range of 1 ppb to 50 ppm at three different feedlots in Nebraska. Data were collected around the perimeter and in the center of all three feedlots for one-week periods each under spring, summer and fall conditions in the year 2000. Gas concentrations around the perimeter were collected upon arrival, departure and at equipment checks by the observers during daylight hours while continuous monitoring of gas concentration was conducted at the center of the feedlots. Meteorological data including wind speed, wind direction, air temperature, barometric pressure and relative humidity were recorded with an on-site weather station (MicroMet Station) at 15-min intervals (Koelsch et al., 2004).

4.2.3 Monitoring Points

4.2.3.1 Case Study 1

Four different locations (one within the farm near the manure storage and the other three around the perimeter of the farm) were selected for continuous monitoring of H_2S concentrations during the sampling periods (Figure 4.1). The location in the farm was selected near the manure storage, which we considered the primary odor/H_2S source. The four monitoring locations were: (1) near the manure storage; (2) in the clearing of a neighbor’s yard to the southwest (827 m from the manure storage); (3) SE corner of the section (542 m from the manure storage); (4) NW corner of the section (1666 m from the manure storage).

Figure 4.1. Monitoring locations around the dairy farm in Turner County (Google Maps). The red circles indicate the gas sampling locations

4.2.3.2 Case Study 2

There were ten monitoring points in the north and south directions relative to the barns. At each of the monitoring locations, there were two monitors at 1-m and 5.5-m heights, respectively, to measure both the horizontal and vertical plume profile for the summer prevailing winds. Locations, direction and distance of the monitors are given in Figure 4.2. Monitoring point B is considered indicative of the source concentration. Point A was considered an upwind measurement.

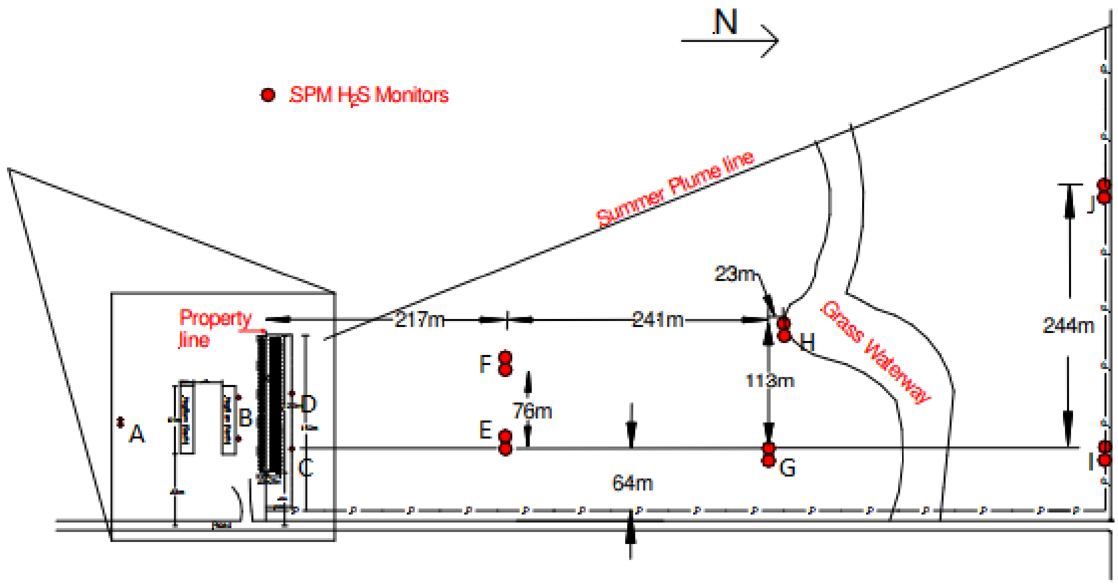


Figure 4.2. Monitoring locations at swine farm in case study 2 site (Hofer, 2009)

4.2.3.3 Case Study 3

The H_2S concentrations were monitored at 322 meter intervals on all four township lines surrounding the feedlots during the sampling periods. Data were collected at the center of the feedlot with two Jerome meters among the animal pens. One Jerome meter was kept at the center of each feedlot for an entire week while the other was moved among the three feedlot at two to three-day intervals (Koelsch et al., 2004).

4.2.4 Analysis and Comparison Methods

The continuous hydrogen sulfide data for each monitoring point were grouped and presented based on percent time greater than 30 ppb for various wind directions and weather conditions in Case Study 1. Similarly, in Case Study 2, H_2S concentration data were grouped and presented based on percent of time greater than 30 ppb for various weather conditions. For Case Study 3, H_2S concentration data were grouped and presented based on percent of time greater than 20 ppb.

These occurrences were compared to odor annoyance frequencies estimated by odor footprint tools. For Case Studies 1 and 2, these estimates were made using the South Dakota Odor Footprint Tool (SDOFT) as the study sites were in South Dakota. For Case Study 3, odor annoyances were calculated with Nebraska Odor Footprint Tool (NOFT). The NOFT tool is limited in the calculation of odor annoyances for beef feedlot. Therefore, we used the odor emission factors for deep-bedded swine finishing building which is similar as beef feedlots (Stowell and Power, 2017).

The variation in H_2S concentration occurrences and model estimations is discussed relative to atmospheric stability conditions for Case Studies 1 and 2. The stability conditions were categorized according to Pasqual-Gifford stability class as follows: A= Very unstable, B = Unstable, C = slightly unstable, D = Neutral, E = slightly stable, F = Stable. The stability classes were estimated with turbulence based δ_A method which uses the standard deviation of the wind direction in combination with the scalar mean wind speed. The most closely comparable classes are grouped together in this study as follows: A & B = Unstable; C & D = Neutral; E & F = Stable.

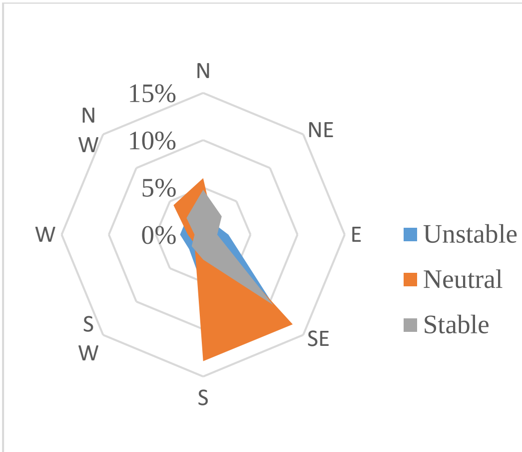
The variation in H_2S concentration according to the time of day is also discussed for Case Studies 1 and 2.

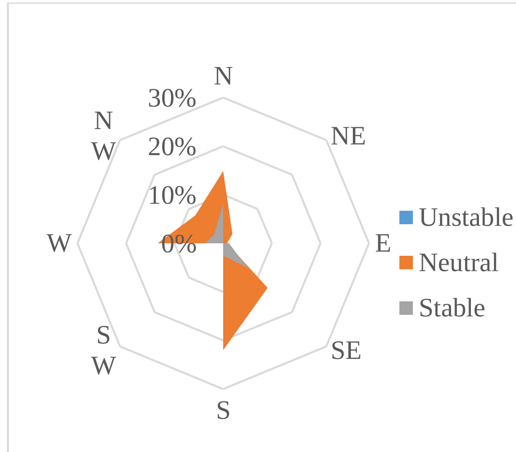
4.3 Results and Discussions

4.3.1 Weather Data Analysis

4.3.1.1 Case Study 1

The wind rose in Figure 4.3 depicts the percentage of time wind was blowing in the eight main directions for the unstable, neutral and stable wind classes. The dominant wind direction for both monitoring periods was from the S and SE directions, with often neutral or stable atmospheric conditions. During the agitation period, there were also considerable neutral winds from the N and W directions.





(a) **(b)**

Figure 4.3. (a) Wind rose for the sampling periods before agitation for Case Study 1, (b) Wind rose for the sampling periods after agitation for Case Study 1

4.3.1.2 Case Study 2

Data were only recorded when the wind direction was out of the S and SE directions. Figure 4.4 gives the frequency of occurrence for the recorded stability class categories for the monitoring period. Data indicated that the atmospheric stability for the site was mostly neutral to slightly unstable.

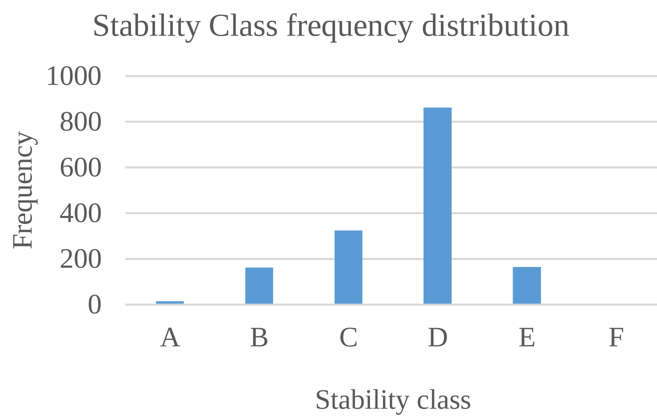


Figure 4.4. Frequency of Pasquill-Gifford stability classes for all observations in case study 2 (Hofer, 2009)

4.3.1.3 Case Study 3

The atmospheric conditions during sampling period were mostly stable (Koelsch et al., 2004)

4.3.2 Gas Concentration Measurements and Frequencies

4.3.2.1 Case Study 1

Based on the total percentage of time, in the sampling period prior to agitation, the frequency of occurrences of hydrogen sulfide greater than 30 ppb was higher in the SW corner of the section compared to the SE corner of the section, despite a longer distance. This may be related to the number of obstacles (i.e. buildings) in the span between the manure storage and receptor positions, atmospheric condition and wind direction. The SW location was also prone to concentration elevations for southeast winds. Under stable wind conditions, it is possible that gas diffused rather than dispersed into the vicinity of the SW corner, despite the wind conditions. During agitation, due to instrumental error, there were no valid measurements recorded for the SW corner and manure storage. There were few instances of hydrogen sulfide concentrations greater than

30 ppb detected at the SE and NW corners. Weather condition was dominantly stable during this monitoring period. Therefore, diffusion may have been responsible for those instances rather than wind.

Table 4.2. Frequency and occurrence of H_2S concentrations greater than 30 ppb at four receptor points, based on wind direction (i.e. N: Wind blowing from the north). Bold values indicate the wind directions blowing past the farm in the direction of the receptor

Period	Receptor	Valid Data *	Percentage of Time Monitored Hydrogen Sulfide Concentrations Exceeded 30 ppb								
			N	NE	E	SE	S	SW	W	NW	Total
Before Agitation	*Wind Conditions*		*13*	*6*	*5*	*35*	*22*	*5*	*5*	*9*	
	Manure Storage	100%	1.5	0.3	0.8	1.3	0.6	1.1	3.4	3.0	12
	SW Corner	100%	**1.4**	**0.9**	**1.0**	1.4	0.1	0.4	0.0	0.1	5
	SE Corner	79%	**1.1**	0.1	0.1	0.2	0.2	0.4	**0.1**	**0.6**	3
	NW Corner	51%	0.3	0.0	**0.0**	**0.9**	**0.0**	0.0	0.0	0.0	1
During Agitation	Wind Conditions		*23*	*3*	*2*	*20*	*24*	*0*	*17*	*11*	
	Manure Storage	0%									
	SW Corner	0%									
	SE Corner	100%	**4**	0	0	0	2	0	**1**	**2**	7
	NW Corner	100%	0	0	**0**	**0**	**0**	0	0	0	0

* Percentage of time during the monitoring period where data were collected and considered valid

4.3.2.2 Case Study 2

At the swine facility, the frequency of occurrences of hydrogen sulfide greater than 30 ppb was higher for monitoring stations closer to the barns. In the upwind direction, there was almost no occurrence of H_2S greater than 30 ppb. This may be due to wind direction, as the data was recorded only for S-SE wind. Despite the further distance, at point I, there were more occurrences of H_2S concentration greater than 30 ppb than the closer points E and G. This may be related to the unstable or neutral weather condition. There may be some other sources of H_2S emission near to that point. Percent of time monitored H_2S greater than 30 ppb is given in Table 4.3.

Table 4.3. Frequency and occurrence of H_2S concentrations greater than 30 ppb at different receptor points for the wind blowing from the south/southeast direction

Monitoring points	Monitor location[1]	Valid data[2]	Percentage of Time Monitored Hydrogen Sulfide Concentrations Exceeded 30 ppb
A	H	100.00%	0.0
	L	100.00%	0.0
B	E	99.93%	59.9
	W	82.08%	57.7
C	H	99.87%	4.5
	L	100.00%	0.0
D	H	100.00%	3.5
	L	100.00%	4.6
E	H	100.00%	0.5
	L	100.00%	0.0
F	H	100.00%	0.3
	L	100.00%	0.1
G	H	73.51%	0.5
	L	70.31%	0.6
H	H	73.51%	0.0
	L	73.51%	0.3
I	H	72.99%	1.1
	L	73.51%	0.7
J	H	57.82%	0.0
	L	73.51%	0.0

[1]Two location for every monitoring point: H(high) and L(low)
[2]Percentage of time during the monitoring period where data were collected and considered valid

4.3.2.3 Case Study 3

At the perimeter of the feedlots, average H_2S concentration ranged from 0.003 to 0.009 ppm (3 to 9 ppb) which is shown in Figure 4.5. Single observations for all the feedlots ranged from 0.004 to 0.015 ppm (4 to 15 ppb). At feedlot 1, only one observation of 0.030 ppm (30 ppb) was observed around the perimeter, which was approximately 1287 meter from the feedlot. At feedlot 2, there was one observation 0.019 ppm (19 ppb) which was observed near the holding pond. Hydrogen sulfide gas is mainly produced by anaerobic decomposition of manure, thus the feedlot had less H_2S concentration due to aerobic decomposition. Also, higher concentrations are more likely to occur during night time due to more stable atmospheric condition but in this study all the readings were taken at day light, hence lower concentrations were anticipated (Koelsch et al., 2004).

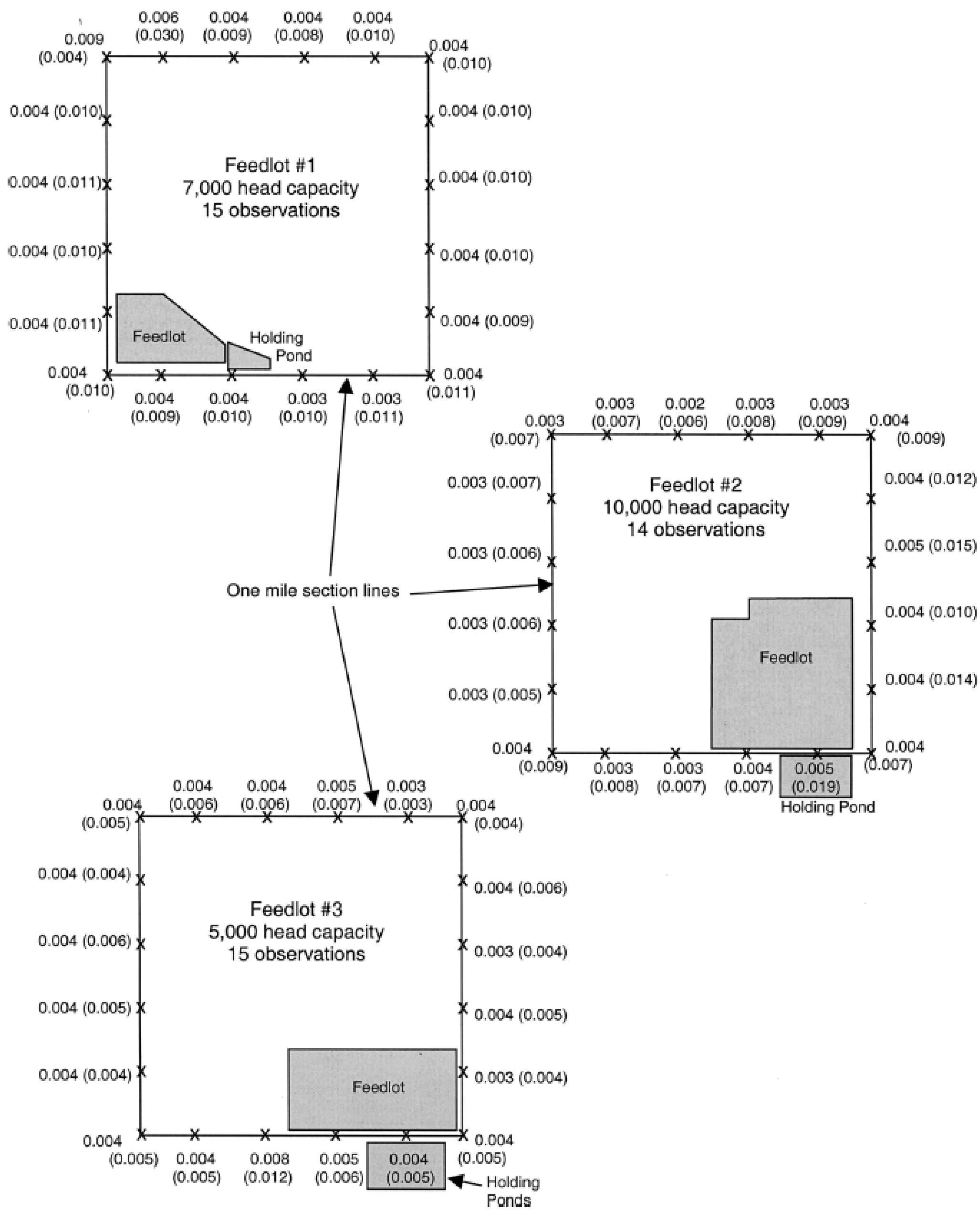


Figure 4.5. Summary of average (and maximum) H_2S observations at perimeter of feedlots (ppm). Each observation represents a single point in time (Koelsch et al., 2004)

4.3.3 Time of Day

4.3.3.1 Case Study 1

The H_2S concentration detected near the manure storage increased during the day, which may be related to the manure management activities by the farm. Around the perimeter of the farm at the receptor locations, concentrations were more likely to be higher during the night when the wind speed is typically lower and there is a temperature inversion.

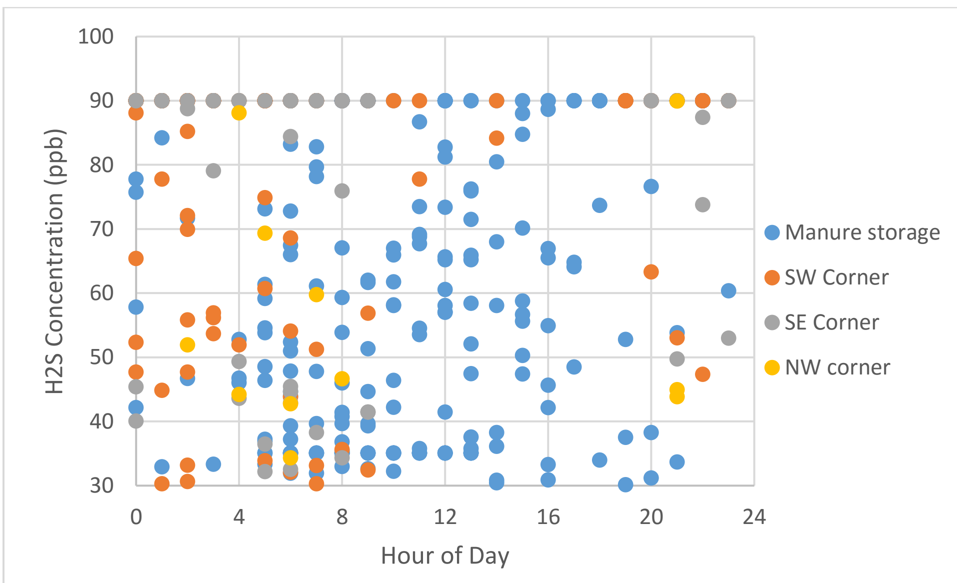
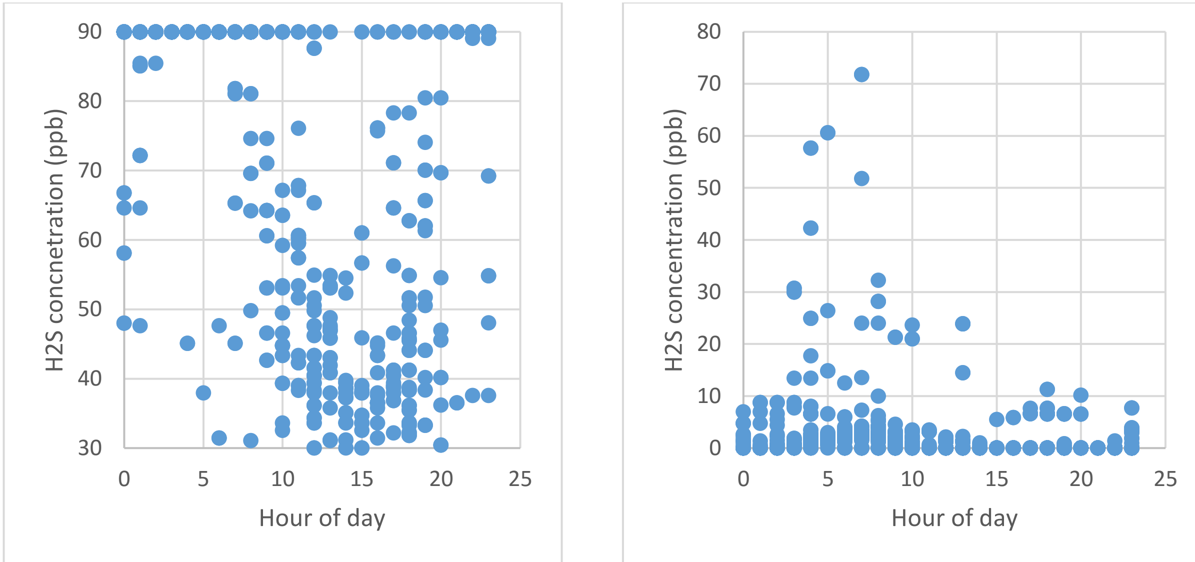


Figure 4.6. H_2S concentration greater than 30 ppb based on time of day (before agitation only)

4.3.3.2 Case Study 2

A similar pattern to Case Study 1 was observed at the swine facility. The number of occurrences of H_2S greater than 30 ppb was higher during the daytime (Fig 4.7a) near the barn. At farther monitoring points from the barn, concentration was more likely to be higher between midnight and early morning hours (Fig 4.7b).



(a) (b)

Figure 4.7. (a) H_2S concentration greater than 30 ppb near barn based on time of day (b) H_2S concentration greater than 30 ppb at monitoring point I (0.5 mile away from the barn) based on time of day

4.3.3.3 Case Study 3

A strong diurnal pattern of H_2S concentration was observed in this case (Koelsch et al., 2004). Midafternoon was more likely to have peak concentrations whereas early morning hours observed the lowest concentration at the feedlots. Animal activities were possible reason for the increased concentration in the afternoon (Koelsch et al., 2004).

4.3.4 Comparison of H_2S Concentration with Odor Annoyances from Odor Impact Estimation Tool

The percent of time when H_2S concentration measurements were greater than 30 ppb at different monitoring points were compared with percent of time of odor annoyances estimated by odor estimation tool. This comparison draws heavily on the assumption that average hydrogen sulfide concentrations of 20 to 30 ppb are considered annoying to the majority of the population.

4.3.4.1 Case Study 1

Table 4.4 presents the percent of time when hydrogen sulfide concentrations were more than 30 ppb in different receptor locations and percentage of total time of odor annoyance calculated by South Dakota Odor Footprint Tool (SDOFT) for those locations. The NW corner falls within 99% odor annoyance free curve, hence this site is expected to have annoying odor levels approximately 1% during the spring-through-fall period. From the monitored data, 1% of total time, H_2S was more than 30 ppb in this location for varying wind directions. The SW corner and SE corner odor annoyances were 4% and 6%, respectively, estimated by SDOFT, while monitors located at these sites recorded 5% and 3% of H_2S concentrations more than 30 ppb of the total monitoring period.

Table 4.4. Frequency of H_2S concentrations greater than 30 ppb in different location and odor annoyance frequency calculated by SDOFT for case study 1

Monitoring locations around the perimeter of the farm	Distance from source (meter)	% of total time having odor annoyances calculated by SDOFT	% of total time when H_2S Concentration is greater than 30 ppb
NW corner	1658	1% -2%	1%
SW corner	805	4% - 6%	5%
SE corner	547	6% -9%	3%

The SDOFT is based on historical meteorological data, prevailing wind direction, flat terrain and cumulative odor impact of multiple farm sites. The data collected were specific to a brief period in 2016. Despite these underlying assumptions and simplifications in the SDOFT, the percentage of total time when H_2S concentrations greater than 30 ppb for monitoring points were within a few percentage points of odor annoyances estimated from SDOFT.

The H_2S concentrations are not direct measurement of odor concentrations, but the similarity in the amount of H_2S and odor annoyance frequency for monitoring locations tells us H_2S concentration could be an indicator of odor annoyance for similar systems.

4.3.4.2 Case Study 2

In Case Study 2, H_2S concentration data was only recorded when wind was blowing from S-SE direction. Hence the odor annoyance was compared to H_2S concentration for the monitored time only. Table 4.5 shows the comparison of odor annoyances and percent of time when H_2S was greater than 30 ppb.

Table 4.5. Frequency of H_2S concentrations greater than 30 ppb in different location and odor annoyance frequency calculated by SDOFT for case study 2

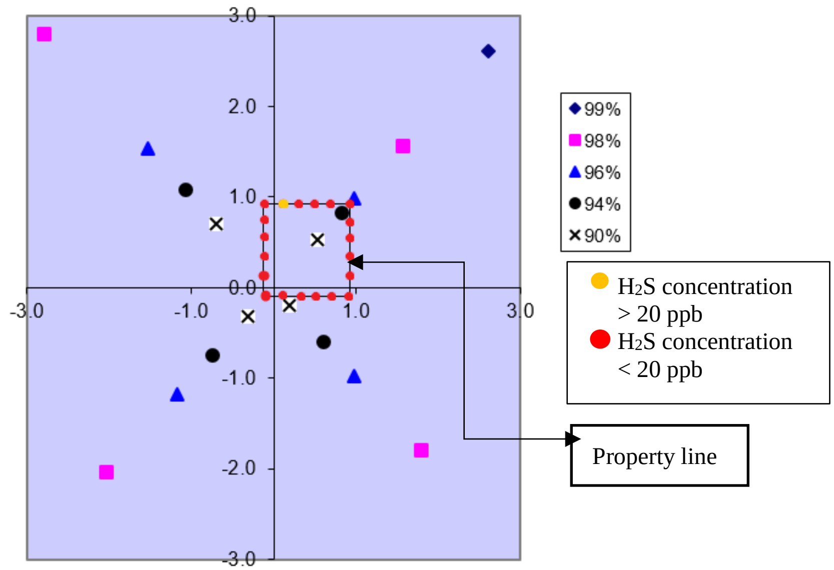
Monitoring points	Monitor location	Distance from the barn (mile)	% of total time having odor annoyance from SDOFT	% of monitored time when H_2S concentrations >30 ppb
A	H	0.028	**More than 9%**	0.0%
	L			0.0%
B	E	Source	**More than 9%**	59.9%
	W			57.7%
C	H	0.051	**More than 9%**	4.5%
	L			0.0%
D	H	0.051	**More than 9%**	3.5%
	L			4.6%
E	H	0.153	**More than 9%**	**0.5%**
	L			0.0%
F	H	0.160	**More than 9%**	**0.3%**
	L			0.1%
G	H	0.317	**4% - 6%**	**0.5%**
	L			**0.6%**
H	H	0.324	**4% - 6%**	0.0%
	L			**0.3%**
I	H	0.501	**3% - 4%**	**1.1%**
	L			**0.7%**
J	H	0.523	**2% - 3%**	0.0%
	L			0.0%

The data were collected only when wind was blowing from S-SE direction. Availability of all the data from all wind direction conditions would lower the percentage of occurrences of H_2S concentration more than 30 ppb. In Case Study 2, for only one of the ten monitoring points was the amount of the percent of total time when H_2S was greater than 30 ppb similar to the amount of time of odor annoyances; the other points varied to a large extent. At point I, the expected odor annoyance was less than 4% of total time, while H_2S concentration greater than 30 ppb was 1.1% at the high SPM and 0.7% at the low SPM at the time when wind was blowing in a singular direction. One limitation in this outcome was the nearer locations E, F, G, and H to the barn had less percentage of time when H_2S concentration was greater than 30 ppb than a distant point I. It may be related to unstable weather conditions or some other source of odor near to that point.

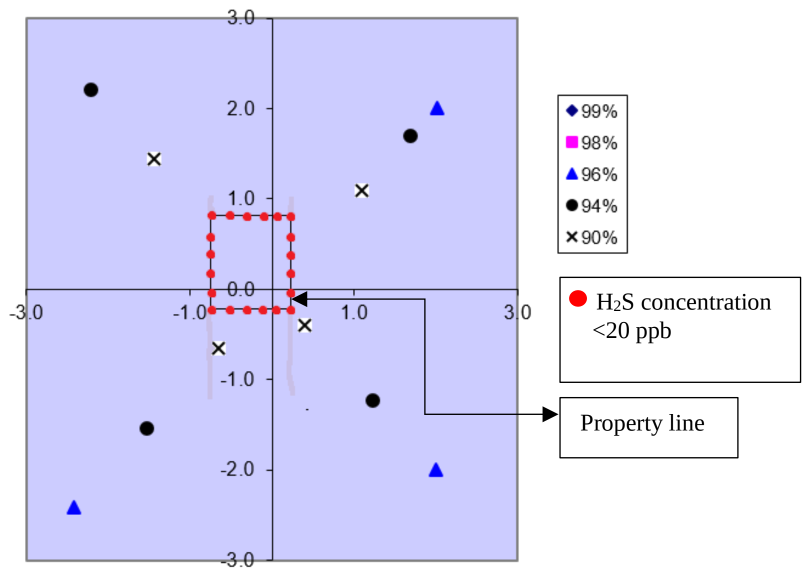
Although only one monitoring point out of ten showed some similarities in odor annoyance and H_2S concentration greater than 30 ppb in this short span of monitoring period, more accurateness of sampling method and larger number of samples would have impacted this result.

4.3.4.3 Case Study 3

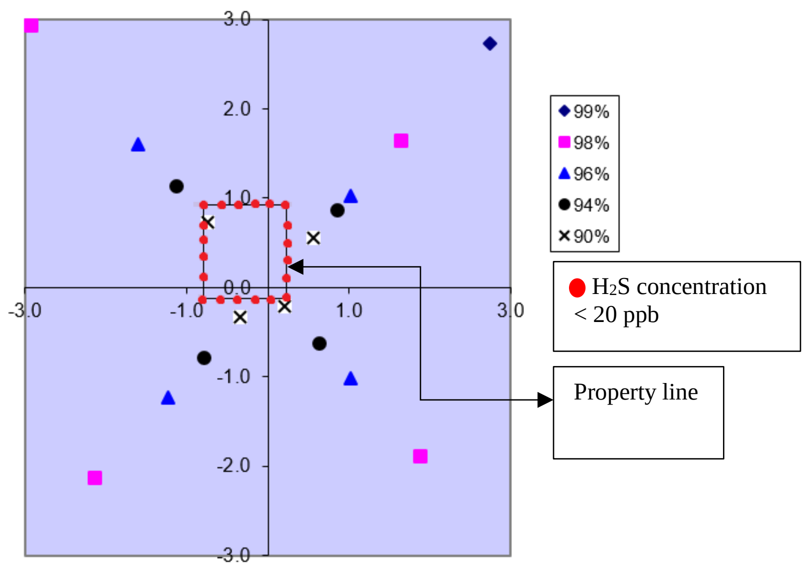
In this case, we had to compare the percent of H_2S concentration with the odor annoyances from Nebraska Odor Footprint Tool (NOFT) because of the sampling location. Unlike the previous studies, this study reported almost no occurences of H_2S greater than 30 ppb except once at the property line around feedlot 1. But this one occurrence was out of 15 occurrence represents 6.6% of total monitoring time. Figure 4.8 shows the odor annoyance free curves along with all the monitoring locations with the maximum single observed H_2S concentration.



a) Feedlot 1



b) Feedlot 2



c) Feedlot 3

Figure 4.8. Odor annoyance curves at different levels from NOFT with the H_2S monitoring locations around three feedlots

The monitoring location which observed a maximum H_2S concentration of 30 ppb falls within 94% odor annoyance free curve which means this point is supposed to have odor annoyances more than 6% of time which is almost similar to our percentage of time when H_2S was greater than 30 ppb. Other locations on the property line observed maximum H_2S concentration ranged from 4 to 11 ppb. For the other two feedlots no single occurences exeeded 20 ppb. One limitation at this study was a very few observations. If there were more observation we could have more supporting data to justify H_2S as an indicator of odor annoyances. The amount of H_2S production among the cases were also different due to difference in species and management. The beef feedlot was expected to produce less amount of H_2S due to its open dried atmospheric condition.

4.4 Conclusions

Various factors (weather conditions, separation distance, and topography) affected the intensity and frequency of H_2S around the livestock operations. Despite various species, weather conditions, topography and distances at different sites, we found the percentage of odor annoyance were sometimes similar to the percent of time when H_2S concentration was more than 20 to 30 ppb. These number of occurrences could be significant with additional H_2S concentration data from several other types of livestock facilities for longer sampling periods with fewer instrumental errors. Our analysis could be a starting point as a methodology to establish H_2S concentration as a significant indicator of odor impact/nuisance level downwind of livestock facilities.

CHAPTER 5: DEVELOPMENT OF AN ODOR MANAGEMENT PLAN TEMPLATE

5.1 Introduction

An odor management plan (OMP) is a proactive strategy to mitigate odor nuisance that may result from a livestock operation. An OMP generally comprises of a thorough inventory of odor sources in an operation with the odor mitigation strategies for all those sources and complaint response protocols (Ndegwa and Harrison, 2017; Schmidt et al., 2001). Although odor is not typically regulated at the federal or state level, some county level rules exist in US. However, an OMP can be a useful voluntary exercise and document to help a producer demonstrate his/her activities to manage odor.

An OMP is typically prepared by a producer, and may be used in discussions with community members from a broad range of backgrounds. To build a guide and template for an OMP, it is important to understand what different audiences deem important in a plan. The objective of this chapter is to use the results from a small survey on community views of OMP components to develop a guide and template for an OMP for the use in SD and surrounding region.

5.2 Methodology

There was no request or demand from any agricultural, environmental or policy maker group to develop an odor management plan for South Dakota livestock operations. We are developing this voluntarily to address odor issues here for SD and surrounding region. The components of several existing odor management planning tools and guides (Atia, 2007; Koelsch, 2002; May, 2012; PSU, 2002; WSU, 2017) were reviewed in Chapter 1 and 2. Using the identified components, as well as some additional ideas, a survey was developed to gauge opinions about the importance of these components when discussing and planning for odor management.

The full survey is included as Appendix B. The survey was divided into two parts: 1) General information of the participants and their opinions and experiences related to livestock odor; and 2) Potential content and format for an OMP for South Dakota and surrounding region.

The survey was built in QuestionPro (QuestionPro Inc.Headquarters, San Francisco) with the help of Instructional Design Service (IDS), South Dakota State University. The survey link was shared via emails to several personal and livestock industry contacts by project personnel with forwarding encouraged (snowball technique), and posted publically on the South Dakota State University Extension web platform, iGrow.org. The period of the survey was from 10/17/2017 to 11/17/2017. This survey and process was deemed exempt by South Dakota State University Institutional Review Board (IRB-17090120- EXM).

Based on the general sections of existing OMPs, and feedback on section components by survey participants, a guide and template OMP was developed.

5.3 Result and Discussion

5.3.1 Survey Results

5.3.1.1 Survey Participants and Background

All the survey participants were from South Dakota, and there were 25 total participants. A total of 17 people fully completed the survey. From a limited choice list, participants identified themselves as livestock producers (41%), local government and/or county officials (18%) or none of the above (41%).

The range of distances between survey participants and the nearest operation with more than 100 head of livestock (cattle, pigs, or goats) or more than 1000 head of poultry (chicken, turkey) was 402 m to 6438 m.

A series of questions collected opinions and experiences of survey participants related to livestock production and associated odors. The following questions allowed participants to agree or disagree:

- 53% agreed their quality of life is not lowered by livestock odor on a regular basis
- 88% agreed livestock odor cannot be eliminated fully from an operation
- 94% agreed that livestock odor can be managed for an operation
- 70% agreed that every farm should be prepared to invest in odor mitigation technologies
- 81% agreed odor is measurable
- 94% agreed odor experience varies person to person
- 70% agreed that "if you live in a rural area, you should expect some rural odors"
- 82% agreed some reduction is better than nothing
- 52% agree livestock odor management is a county's responsibility
- 100% agreed managing livestock odor is a producer's responsibility
- 76% agreed odor mitigation should not be used only when there is a complaint

Around 82% of the participants had never written or contributed to OMP for a livestock operation prior to this survey but 53% of the total participants were previously involved in a review process of an OMP.

Hence, the participants participated in this survey reflects a diversity of experience and opinions with respect to odor and odor management.

5.3.1.2 OMP Inventory Components

All the survey participants identified the following components as potential odor sources:

- Animals
- Barns
- Open lots or feedlots
- Manure collection, transport, treatment and storage facilities
- Land application
- Animal mortalities
- Spilled and wash water

When asked if there were any other options other than the above-mentioned choice, "human waste" and "confinements" were listed. However, confinements already belong to barns. Human waste was one exceptional source of odor listed by one participant.

An OMP can include various components to help describe or evaluate the potential of odor sources. The survey participants' opinions of the usefulness of these components when describing or discussing the potential of any source in an operation (Not useful<Useful<Critical or Unsure) are shown in Table 5.1.

Table 5.1. Survey participants' description of usefulness of several components in describing the potential of odor sources

Components	Usefulness (% of participants)			
	Not Useful	Useful	Critical	Unsure
A map or aerial image of the farm and surrounding area	17	35	47	0
Topography	11	47	41	0
Average weather conditions	12	41	41	6
Time and frequency of manure-related activities (i.e. transfer, hauling)	6	29	65	0
Surface area of odor sources	0	29	71	0
Number of animals or birds	0	29	71	0
Volume of manure	6	23	71	0

The following components were listed by the participants as other components:

- "Kinds of manure related activities, types of manure storage"
- "Distance to the nearest farm site that is inhabited by people engaged in farming"
- "Community uniqueness, seasonal wind direction, inversions"
- "Trees, shrubs, visual screens, additives"
- "Bio-filter needs to be used"

5.3.1.3 Odor Risk Assessment Components

Among different options for selecting the most important information to be listed to assess odor risk of an operation, 64% of the total participants selected potential odor intensity and frequency for neighbors surrounding an operation.

We provided some options that could be selected to add in an OMP to assess the odor risk of sources. Survey participants' choices are listed below along with the participants' percentage of selection in the bracket:

- Potential odor intensity and frequency for neighbors surrounding an operation. (26%)
- Relative odor emission rates for each potential odor source on an operation (18%)
- Numerical odor emission rates for each potential odor source on an operation (20%)
- Regularly updated measurements of odor intensity and frequency around an operation, once an operation is operating. (22%)
- Where odor emission rates or impacts are unknown, a qualitative description of the odor source. (12%)

Both qualitative and quantitative assessments, where possible/ applicable, were suggested by the survey participants.

The South Dakota Odor Footprint Tool (SDOFT) is a science based tool which estimates odor impacts from livestock and poultry facilities to the surrounding community (Nicolai, 2017). Around 30% of the participants were not familiar with this tool. When asked about experience using SDOFT, 30% selected SDOFT as easy to understand and use, 23% selected SDOFT as easy to understand but not to use, and 24% selected it as not easily understandable or useable. In an open-ended option, some participants cited the unreliability of results and lack of several variables which affect odor in the tool as reasons for not accepting the tool to estimate odor impacts of an operation; one positive result of this survey was introducing this science based tool to a survey participant who had no idea about this tool.

We wanted to know if it is necessary to engage a third party to assess the odor risk of an operation. About 64% of the total participants of the survey deemed it was essential, while the rest disagreed. The possible options as third party participants (someone external to the livestock operation) from people's opinion were:

- Engineer
- EPA
- County Govt.
- An unbiased person, possibly a county employee
- Extension
- A neutral party who is trained in odor assessment
- SDSU

A common characteristic of the open-ended responses was that if someone has to be engaged he/she has to be neutral or unbiased to make a fair assessment.

5.3.1.4 Components for Odor Mitigation Strategy:

There were some questions in the survey about peoples' agreements (agree/disagree options) regarding odor control strategies. The following are the summarized responses:

- 50% agreed only planned or currently implemented odor control practices should be listed in an odor management plan
- 86% agreed that all odor management strategies for each odor source should be listed and described
- 71% agreed all odor sources should have an odor management strategy
- 21% agreed odor mitigation strategies only need to be implemented if there are conflicts between producer and neighbors
- 71% were aware of reasonable odor mitigation strategies for outdoor manure storages
- 79% of the total participants were aware of the mitigation strategies for land applied manure
- 79% agreed producers should inform neighbors when periodic odor events (like manure agitation or hauling) are going to occur

In summary, survey participants felt all odor sources should have an odor management strategy included in an odor management plan. The implementation of any strategy should not depend only on conflicts between producer and neighbor. Another important inference from these questions was a very good percentage of people are already aware of the mitigation strategies for different sources.

5.3.1.5 Components for Odor Complaint Response Protocols

Odor may bring conflicts between neighbors, or in a community, hence an OMP can provide guidance and forethought on the handling of the conflicts in a proper way.

To take actions or build protocol strategies, it is important to know what the problem is and it effects. The following features cited by participants identify the problem, its effects and causes:

- Possible source location
- Day and time of the day, duration of occurrence
- Intensity, frequency, strength of odor, severity
- Physical effects, how affects quality of life, personal experience (ex. Can I go outside)
- Name of the person who complains
- Wind speed and direction, temperature
- Nature of complaint, i.e. hauling of manure, application of manure

We wanted to know if odor nuisance complaints need to be brought to the attention of local government official, and when. Around 18% participants preferred a complaint be made immediately when the odor issue occurs. One participant suggested that if there is a violation of existing ordinance, the odor issue needs to be brought to local government officials. One other participant said if the odor nuisance disrupts the life of community members, then they can go to the local government. One participant suggested to engage local government after validating the issue, i.e. quantified or qualified information. One participant suggested offended person could go to local government at any time, as they thought all CAFO (confined animal feeding operation) are responsible for odor management. One participant thought it would be wise to let governing bodies know of an issue, so they can at least be aware in case they are asked to step in at some point in time. Hence, the role of governing bodies varies person to person.

Monitoring odor to verify complaints could be a part of an OMP. Qualitative assessments of when and where an annoying odor was experienced to support a nuisance complaint was agreed upon by 57% of the total participants. Around 64% of total participants thought a quantitative measurement of odor or gases should be required to support the complaint. According to 30% of the total participants, a third party should be involved if any form of quantitative or qualitative monitoring is required. Producer's involvement in monitoring was selected by 27% of the participants, while 24% of total thought community members' who are experiencing the nuisance involvement should be required. A lesser number of participants (18%) wanted to involve local government to monitor odor occurrence.

5.3.1.6 About the Overall OMP

Based on experience or first impressions on the OMP process from this survey, 75% of the total participants described odor management planning as "a proactive solution to eliminate odor issues in a community", while only 8% took it as "a mediocre approach with community acceptance", and another 17% thought "a theoretical idea with no practical outcome". About 77% of the total participants agree it is important to have a common OMP template for livestock operations in SD. More than 60% of the participants thought an OMP should be required for livestock operations, but for specific animal types and/or sizes. Around 15% of the participants thought it could a voluntary while on the other hand, another 15% thought it should be a mandatory requirement regardless of number or size of the operation.

According to the participants of this survey, everyone, including producers, neighbors, and local government personnel, can benefit from an odor management plan.

To benefit from an OMP it has to be reasonable and logical. According to one participant, "odor destroys people's livelihood and property values" and one other mentioned "odor is a health issue", hence odor management brings benefit to the surrounding community. One participant mentioned that a producer can be a good neighbor by utilizing an odor management plan. One participant said "through an OMP, producer helps create community awareness." Odor management plan was considered by some participants a benefit to the SD livestock industry as it will help promote animal production and hence lead to expansion here. On the other hand, some participants see an OMP of bringing least benefit to the producers, as they think it will involve costs and if it is forced on producer maybe it will lessen animal numbers as well as economic activity. However, odor management plan is potential to bring benefit to everyone involved in an odor issue.

5.4 Components of the OMP template

We wanted to develop a template which any user can print, complete and keep as a record. We developed a template based on survey results, existing templates, and with novel suggestions for the current and future livestock operations in SD and surrounding region. In this section we will describe each of the sections of our OMP template. The template is attached in Appendix C.

5.4.1 Cover Page

The purpose of the cover page is to formally identify the farm. This section will introduce the farm and its owner. The name of the OMP developer and manager or any contact person's number needs to be added so that anyone who wants to talk or discuss an odor-related problem knows who to contact.

The cover page also describes the purpose of writing/having an odor management plan for his/her operation.

5.4.2 Odor Source Inventory

This section is designed to help a producer document and evaluate the potential odor sources around his/her operation.

A thorough inventory of all the odor sources along with the activities which may produce odor needs to be listed in this section. Potential odor sources include animals, barns, open lots, manure handling activities, animal mortalities, and land application of manure. Any other sources that a producer thinks may generate odor or contribute to odor can be added. Factors or management activities that impact odor should be included in the description to help estimate odor impact potential. Odor emission from animal housing and manure storage structures can be estimated using the South Dakota Odor Footprint Tool. Surface area and type of each sources (ex. free stall or tie stall for dairy barn, earthen storage for manure storage) can be included in the description. The National Air Quality Site Assessment Tool (NAQSAT) does not give any emission value but it identifies the potential for emission based on the management practices specific to the site (NRCS, 2017). The NAQSAT will give report on the basis of answers to some multiple choice questions set for different sources. The listing of odor sources and their possible impact in this sections will help identify the relative potential of these sources based on the size, intensity and frequency of odor.

Printed copies of the report from the odor estimation tools can and should be attached with this section for complete documentation and easy reference. Other references can also be attached.

A map or areal image of the farm and surrounding area, topography, and average weather conditions can be added in this section.

Besides using odor impact estimation tools, any producer can engage expert personnel to help assess the odor risk of an operation. Engineer, County officials, University and extension employees, trained odor expert are some options.

Nicolai (2017) states the procedure to use the SDOFT. NRCS (2017) describes how to use NAQSAT with the available resources.

5.4.3 Odor Impact on Neighborhood Stakeholders

This section is to help evaluate and estimate the odor impact around a current or future operation.

The impact of odor on surrounding neighbors or places can be estimated using the SDOFT tool. This tool estimates odor annoyance free time on the surrounding neighborhoods. This tool gives odor annoyance free curves to various degrees around the operation.

Any producer who will use odor impact estimation tool needs to attach a copy of the print-out of the odor annoyance free curves from the results.

Possible odor impact from other sources which are not included in the footprint tool (e.g. land application of manure, disposal of dead body) need to be added in this section which will help address management practices in the later. Brief description of intensity or frequency of odor event would be helpful to address the impact from these sources.

5.4.4 Odor Mitigation Strategies

The goal of this section is to describe odor control strategies for the identified sources within an operation with the implementation protocols.

The identified potential sources from inventory will be listed with the current/planned odor management activity or technology. The listing of mitigation technology will be dependent upon the relative potential of each sources as all the sources are not equally responsible for creating odor. Akdeniz et al. (2011) specifies the practices that help reduce emission from a potential source which could be a helpful resource in this context. The effectiveness of these technologies will be identified in this section also. There exists a science based tool “Air Management Practices Tool” which determines the effectiveness of many mitigation technologies (ISU, 2017).

The protocols to implement technologies will be described in the implementation protocol column. The criteria to implement mitigation technology will depend on the proximity of impact i.e. the size, intensity and frequency of odor. Hence, this protocol of implementing technology will provide a road map to manage odor systematically.

5.4.5 Odor Complaint Response

This part of the odor management plan template is one of the most important parts of an odor management plan. This section documents a producers’ plan to respond during any instances of conflicts.

By outlining the information needed to evaluate complaints or issues ahead of time, both producers and neighbors can play an active role in evaluating issues and seeking solutions, where necessary. A complaint record form should describe the issue, cause and nature of the problem. The information about possible source location, day and time of the day when problem occurred, duration and frequency of the odor occurrences, nature and severity of complaint, relative weather condition will help to identify response strategies. Complaints may or may not be a result of excessive odor emission from the farm. Implementation of odor control technologies should not depend only on the number of complaints, but also the validity of complaints.

Quantitative measurements of odor or gases may help support a nuisance complaint. Hence, any data collected to check the odor annoyances produced by an operation, should be documented. This may sometimes involve the community members, local government personal. If monitoring is on a fixed, pre-planned schedule, the plan can be documented as part of the template. If monitoring is on an as-needed basis, it is still important to document the results in a record.

A good relationship with neighborhood stakeholders will help reduce potential of conflicts during complaints. Reaching out to the neighbors, discussing the issues, seeking out suggestions will build a proper flow of information which is vital in responding to complaints.

Depending on the evaluation of the complaint(s), possible actions may need to be implemented which has to be included in the follow-up section of the complaint response form.

5.4.6 Review of the OMP

A review form is an important part of an OMP because this will reflect the goal of the odor management plan towards reducing odor and hence complaints against odor. This will focus on the changes any producers make to the OMP under various circumstances.

All the changes and the cause of the changes should be recorded in this section. The changes need to be evaluated to check the effectiveness. This evaluation has to be done by the people who identify the issue and who brought the changes together.

5.5 Summary

The OMP developed for SD will help to show producer's intention to manage odor on site and hence an OMP acts like a proof of the thought of a producer about the implications of odor nuisance. This planning template could be a self-explanatory and an easy to handle document. Our development process was inspired and guided by the OMP developers from other states. The engagement of multiple groups from SD helped identify scope, use and dissemination of an OMP for SD. This template reflects input of persons who have experience with livestock odor.

CHAPTER 6: GENERAL DISCUSSION

6.1 Introduction

Odor is an unavoidable circumstance from livestock industries which has potential to create nuisance among community members. Odor-related issues are increasing with the expansion of the livestock industries but there is no single solution to completely remove or reduce this, as odor can occur from a single source or multiple sources together. Managing odor is a challenge as it involves various steps from odor generation to perception by neighbors. A proactive odor management plan could be a part of odor management within a livestock operation and provide guidance in instances of odor complaints. Like in other states, voluntary adoption of an odor management plan will help address odor issues associated with livestock production in South Dakota.

6.2 Overall Summary

This research project was extensively focused on developing an odor management plan template for South Dakota and surrounding region. This development was a multiple step process where each and every step was designed to move the development process forward.

The first step towards development was to become familiar with the odor management plan which involved extensive literature review about the topic. Various resources including published literature, websites, news articles etc. were used in this section to acquire knowledge about OMPs. Various features of odor including generation, transportation, perception and impact was studied to understand odor related issues clearly. Definition, availability, component, content and format of OMP; usage of tools and techniques in OMP; applicability of OMP; usefulness of OMP were extensively searched in this step. An OMP is a systematic approach towards odor issue which involves proper identification of odor sources; developing a protocol to odor mitigation strategies; and reducing odor complaints to avoid nuisance. An OMP is required in very few states for permitting process of livestock operation and that is applicable to some specific size of operation mostly. However, researchers from several other states developed OMP guides or template voluntarily though it was not required to help address odor issues. Content wise OMP is mostly similar everywhere while the format or template varies sometimes.

The second step involved the developers of existing OMP templates and guides to become familiar with the development process. Valuable answers about the development process through a survey by the developers of existing OMPs identified strengths and weaknesses in the construction, deployment and follow-up of odor management guidance. The feedback from developers of existing OMPs suggested there has been a lack of collaboration in the course of development of existing OMPs, and little incorporation of odor impact estimation tools. There was no demand or request to develop an OMP in any of these prior development process. Although, some of this surveyed states did not require OMP, they developed OMP voluntarily for the sake of bettering their state. The necessity of an OMP was not assessed anywhere. These templates were not marketed extensively.

In the third step, we wanted to overcome the lack of collaboration in OMP development which we found in noted in Chapter 2. At the same time, we wanted to verify the needs of an OMP for this state and region which was not addressed either previously in any state. An existing group primarily assessed the needs by a meeting.

This group was mostly focused to resolve livestock management related issues in SD. According to the discussion, an OMP has potential to address odor issues involved with livestock operations from SD. Participants of this discussion suggested almost similar content for an OMP for SD like the other existing ones reviewed in previous steps. Adaption of science based tools of techniques were encouraged. From this chapter we were encouraged to develop an odor management planning template for SD. We decided to incorporate science base tools and techniques to assess the odor impact potential of any operation as a vital part of an OMP template. The content of our OMP followed and was guided by the existing OMPs.

The fourth step involved three different case studies. In the first case, ambient hydrogen sulfide concentration was measured around a dairy operation at the request of the dairy. The management of that dairy wanted to monitor odor as they were accused of producing offensive odor. Measuring odor is usually a complex process, hence H_2S was selected as indicator of odor. This study gave us a practical experience of how a dairy operator wanted to address an odor issue. The data collected in this study was used in this thesis to relate the occurrence of simulated odor nuisance with a measured indicator gas around a livestock operation based on weather conditions, distance and topography. The H_2S concentration and the simulated odor nuisance from odor impact estimation tool showed a similarity. At this point we involved two other studies of similar data for different species to verify the relationship. Although the other two studies did not result in a similarity like the first study, our analysis could be a starting point as a methodology to establish H_2S concentration as a significant indicator of odor nuisance. This methodology would be helpful to monitor odor nuisance which is an important part of an odor management planning.

The fifth and final step was the development of an OMP template. The content and format was guided by the existing ones. Moreover, the input for the template was enhanced by a public survey, where people form SD participated and contributed to the template. We developed a template which is user friendly and easier to understanding. Any producer can print and keep this template to properly document his odor management plans. This document will help communicate between producer and neighbor. The information included in the template will help producer to demonstrate his/her intent to address odor issues associated by their operation in a convenient way. Incorporation of science-based tools to assess the odor impact was selected by the participants which made our template simpler in the odor impact assessment part. However, producers from other places rather than SD can also follow this document for odor management planning process.

6.3 Lessons Learned from this Research

This project provided an opportunity to learn extensively about the air quality of livestock facilities, which is a very important aspect of environment. Another opportunity was to learn how to engage various groups of people in OMP template building process. A focus group meeting, interaction with a producer and his neighbors, and a public survey helped to gage views of the people who are frequently dealing with the odor issue in real life. The most remarkable achievement from this study was to get an odor management planning template for South Dakota livestock producers which will help them respond to odor-related impacts of their operation. This tool incorporates science based odor estimation tools and other resources which will be an advancement in odor management planning process in scientific way. Above all, this study will be helpful for the people who wants learn odor management for livestock environment.

6.4 Limitations or Shortcomings

The focus group who assessed the needs of development of an OMP in step three, were mostly associated with zoning or planning people rather than neighbors or producers, which could bias the assessment. The template of an OMP would have been enhanced with more content and ideas if the number of participants and type of participants had larger variation. The case studies in step four did not uncover a significant relationship between simulated odor annoyance and a specific gas concentration but the methodology has potential to begin an extensive study to establish a standard monitoring process. The template has not been reviewed by anyone yet. The impact of using this template is not evaluated yet.

6.5 Next Steps

This developed OMP template needs to be reviewed by various groups, including producers, neighbors or policy makers. The developed OMP now needs a better marketing through which producers in SD will be encouraged to adopt one voluntarily. Some training programs on the adoption will make the usage easier and may make the OMP process more acceptable. The impact of adaption of an OMP template can be checked in a small scale study where a specific number of operation can be evaluated before and after adapting an OMP. Although many researchers have studied odor, a standard monitoring process of odor or relationship between odor and any gas is not established yet. Most of these experiments were limited to specific type of animal or small period of study. Hence, a standard odor monitoring process needs to be established which needs extensive and thorough experiments for significant types and number of species and farms. An establishment of an indicator gas of odor annoyance is necessary to establish a standard odor monitoring process.

6.6 Conclusions

Odor management planning is a proactive process to address odor issues. The self-explanatory template we built in this project will help address odor conflicts associated with livestock community. This template incorporates various focus groups' ideas, knowledge and experience in various ways. This odor management planning template could be an advancement in minimizing odor impacts from livestock industry by initializing communication between the groups involved.

APPENDIX A

QUESTIONNAIRE SURVEY FOR THE OMP DEVELOPER

"South Dakota is home to over 31,000 farm and ranch families who work daily to ensure a safe and affordable product for consumers across the world." (Ag United, 2016). Being 21st in national milk production, 9th in national beef production, 11th in national pork production this state is continuously playing a vital role in national economy.

The emerging and expanding livestock industry in South Dakota is facing some issues, however. The major concerns are odor and manure nutrient management of the operation. Several instances of neighbor complaints regarding odor from livestock operations have been brought before county officials, but there is little guidance on how to resolve the situation. Though it is not possible to completely eliminate all odors and gases produced by an operation, a well-managed and designed Odor Management Plan can help all parties involved be both proactive and reactive to air quality concerns.

Currently South Dakota has no formal state-level rules regarding odor or air quality, nor an established Odor Management Planning program. Our goal is to develop an odor management plan for livestock operations in South Dakota that considers the needs of local producers, neighbors and country officials. As you all have already developed some plans for your state, we are looking for some voluntary feedbacks to help guide our actions moving forward. The following questions about the development, marketing and usage of the Odor Management Plan can show us the right path to start with.

1. **About Development:**

   - Is the OMP mandatory or optional for producers in your state?

- Was there any request from any certain group to develop an OMP?
- Who was the developer?
- Was there any review of this OMP?
- Was there any exchange program between neighbors, producers or other interested parties during the OMP development?

2. **About User:**
   - Was the OMP designed for your state or for more of a regional approach?
   - Was the OMP developed commonly for all species (dairy, poultry, swine, etc.) or targeted?
3. **About Marketing:**
   - How was the OMP marketed?
   - Were there any special/specific steps taken to make specific interest groups aware of the OMP?
   - Was there any specific training program offered for the users? If So:
     - Who offered the training? (e.g. by university or by state or by any specific agent)
     - Who was the trainer?
     - Who was the audience?
4. **About the Template:**
   - Did you follow an existing template?
   - Is there a “lifetime” or expiration for an OMP?
   - How often should an OMP be reviewed?

- Does the OMP require or suggest odor monitoring? If so, what type and frequency of monitoring required or suggested?

5. Result/Effect

- Is there any record about the number of users of the OMP template?
- Have you received any feedback after implementation?
- Has any producer indicated changes made to their operation after implementation? If so, how was that changes evaluated?

6. For future

- If you were to develop an OMP template again, what would you do differently?

APPENDIX B

QUESTIONNAIRE SURVEY FOR OMP TEMPLATE AND CONTENT

This survey is a part of a research and outreach project at South Dakota State University entitled "Developing an Odor Management Plan for livestock operations in South Dakota". The objective of this survey is to assess the needs of both producers and surrounding community members in the development of an Odor Management Plan template. An Odor Management Plan is a document showing the process of planning for the odors produced by a livestock operation. This planning process has implications for producers and the surrounding community. The planning process is ideally conducted before an operation is built or expanded, but can also be documented and reviewed once an operation is operational.

You are invited to participate in this study by completing the survey. We realize that your time is valuable and have attempted to keep the requested information as brief and concise as possible. It will take approximately 20-30 minutes of your time. Your participation in this project is voluntary. You may leave the survey at any time without consequence. There are no direct benefits.

All of the responses are strictly confidential and anonymous.

Please assist us in our research by completing the survey.

Your consent is implied by starting the survey. Thank you very much for your time and assistance. If you have any questions regarding your rights as a research participant in this study, you may contact the SDSU Research Compliance Coordinator at 605-688-6975, or SDSU.IRB@sdstate.edu. If you have any questions regarding the project, now or later, you may contact the following persons:

Suraiya Akter,

Graduate student,

South Dakota State University

Email: suraiya.akter@jacks.sdstate.edu,

Erin Cortus,

Assistant Professor and Extension Specialist

University of Minnesota,

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Questions

1. Please enter your zip code

[ ]

2. Which group do you primarily associate with?

a. Livestock producer

b. Local government and/or county planning administration

c. None of the above

(For brevity, we refer to any livestock or poultry farm, of any size, as a livestock operation)

First, we would like to gage your opinions and experience related to livestock odors.

These opinions and experiences may be related to your personal life, occupation, or both.

1. Please indicate your agreement to each of the following statements:

	I strongly agree	I agree	I do not agree	I strongly disagree
My quality of life is lowered by livestock odors on a regular basis.				
Livestock odor can be completely eliminated for an operation.				
Livestock odor can be managed for an operation.				
Every farm should be prepared to invest in odor mitigation technologies.				
Odor is measurable.				
Everyone experiences odor differently.				
If you live in a rural area, you should expect some rural odors.				
Some odor reduction is better than nothing is.				
Managing livestock odor is a county’s responsibility.				
Managing livestock odor is a producer’s responsibility.				
Odor mitigation should only be used when there is a complaint.				

2. What is the distance, to the nearest half-mile, from your residence to the nearest operation with more than 100 head of livestock (cattle, pigs, sheep or goats) or more than 1000 head of poultry (chickens, turkeys).

3. Have you ever written or contributed to an odor management plan for a livestock operation?

Yes/No

If yes how?

4. Have you ever reviewed an odor management plan for a livestock operation?

Yes/No

Based on procedures and templates developed in the past around the United States, an odor management plan usually involves the following components: (1) making an inventory of potential odor sources on an operation, (2) assessing or ranking the odor risk each source, (3) identifying current and/or potential odor control strategies; and (4) developing a protocol for responding to odor complaints.

We would like to gage your opinions on the potential content and format for an odor management plan for South Dakota and surrounding region. These opinions may be related to your personal life, occupation, or both. We recognize and value perspectives from those that may be involved in making a plan or reviewing a plan (i.e. as engaged community members), with varying levels of experience in an around livestock operations.

The following items have been identified as potential sources of odor. Please select all that you feel should be listed in an odor management plan.

- Animals
- Barns
- Open lots or feedlots
- Manure collection, transport, treatment and storage facilities
- Land application
- Animal mortalities
- Spilled and wash water

2. Are there other sources that should be included?

3. From your perspective, how useful are the following components when describing or discussing the potential odor sources on an operation: (Not useful, Useful, Critical, Unsure)

a. A map or aerial image of the farm and surrounding area

b. Topography

c. Average weather conditions

d. Time and frequency of manure-related activities (i.e. transfer, hauling)

e. Surface area of odor sources

f. Number of animals or birds

g. Volume of manure

4. Are there other components that should be included?

5. Any additional comments or suggestions regarding the odor source inventory?

Once an inventory of odor sources is developed, there are various qualitative and quantitative means to assess, rank, or further describe the odor potential. Qualitative assessments may involve prior experience or relative risk (i.e. low, medium, high) among odor sources or for a given odor source based on how the source is managed. Quantitative assessment may include the use of emission factors, odor footprint or setback tools, or measurement (once an operation is operational).

1. From your perspective, what type of information is most important? Please select one.

- Potential odor intensity and frequency for neighbors surrounding an operation
- Relative odor emission rates for each potential odor source on an operation
- Numerical odor emission rates for each potential odor source on an operation
- Regularly updated measurements of odor intensity and frequency around an operation, once an operation is operating

2. From your perspective, what should be included in an odor management plan? Select all that apply.

- Potential odor intensity and frequency for neighbors surrounding an operation.

- Relative odor emission rates for each potential odor source on an operation
- Numerical odor emission rates for each potential odor source on an operation
- Regularly updated measurements of odor intensity and frequency around an operation, once an operation is operating.
- Where odor emission rates or impacts are unknown, a qualitative description of the odor source.

3. How would you describe the South Dakota Odor Footprint Tool?

a. I am not aware of the South Dakota Odor Footprint Tool

b. The South Dakota Odor Footprint Tool is easy to understand and easy to use

c. The South Dakota Odor Footprint Tool is easy to understand but not easy to use

d. The South Dakota Odor Footprint Tool not easy to understand and not easy to use

4. Do you think it is necessary to engage a third party (someone external to the livestock operation) to assess the odor risk for an operation?

(Yes/No. If yes, who?)

5. Any additional comments or suggestions regarding the odor impact assessment?

(OE)

Based on the inventory and assessment of potential odor sources, an odor management plan may include a list of implemented or potential odor control or odor mitigation strategies.

1. Please indicate your agreement to each of the following statements:

	I agree	I do not agree
Only planned or currently implemented odor control practices should be listed in an odor management plan.		
All odor management strategies for each odor source should be listed and described.		
All odor sources should have an odor management strategy.		
Only the primary odor source for an operation requires an odor management strategy.		
Odor mitigation strategies only need to be implemented if there are conflicts between producers and neighbors.		
I am aware of reasonable odor mitigation strategies for livestock barns.		
I am aware of reasonable odor mitigation strategies for outdoor manure storages.		
I am aware of reasonable odor mitigation strategies for land-applied manure.		
Producers should inform neighbors when periodic odor events (like manure agitation or hauling) are going to occur.		

2. Any additional comments or suggestions regarding odor mitigation?

(OE)

Odor can be a cause of conflict between neighbors and within a community. An odor management plan may include a protocol for responding to conflicts.

1. What information should be included in a nuisance complaint?

(OE)

2. When should odor nuisance complaints be brought to the attention of local government officials?

(OE)

3. What number or frequency of complaints should trigger odor control strategies?

- **a.** One complaint
- **b.** One complaint per month
- **c.** One complaint in a year
- **d.** Implementation should not depend on number of complaints

4. Are qualitative assessments of when and where an annoying odor was experienced sufficient to support a nuisance complaint?

(Yes/No)

5. Should quantitative measurements of odor or gases required to support a nuisance complaint?

(Yes/No)

6. If any form of qualitative or quantitative monitoring is required, who should be involved in monitoring? Check all that apply

- **a.** Producers

b. Community members who are experiencing the nuisance

c. Local government

d. A third party

7. Any additional comments or suggestions regarding nuisance response and conflict resolution?

(OE)

8. Based on experience or first impressions, how would you describe odor management planning?

a. A theoretical idea with no practical outcome

b. A mediocre approach with community acceptance

c. A proactive solution to eliminate odor issues in a community

9. Do you think it is important to have a common odor management planning template and/or guide for livestock operations in South Dakota?

(Yes/No) Please explain why.

10. Do you think an odor management plan should be a mandatory requirement for all livestock operations and part of public record?

a. A plan should be required of all livestock operations, regardless of type of animal or number of animals

b. A plan should only be required for specific animal types and/or sizes of operations.

c. A plan should not be required

d. A plan should be voluntary

11. Who benefits the most from an odor management plan? Producer/Neighbor or Concerned Citizen/Local Government. Please explain why?

(OE)

12. Who benefits the least from an odor management plan? Producer/Neighbor or Concerned Citizen/Local Government. Please explain why?

(OE)

13. Assuming an odor management plan is created for an operation before construction of the operation occurs, when should the plan be reviewed? (Select all that apply)

- **a.** When a component or source in the odor inventory changes
- **b.** After one year of operation
- **c.** Annually
- **d.** If a complaint arises

Thank you message:

Thank you for participating in this survey. We appreciate your valuable time.

APPENDIX C

ODOR MANAGEMENT PLAN TEMPLATE

Farm Name: ________________________
Address: ___________________________

Odor Management Plan

This odor management plan is a part of the integrated plan for daily operation of Name of the farm. This document specifically addresses odor management based on the existing design and planned management practices.

Owner:

Date farm established:

Manager/contact person:

Contact Number:

OMP developer:

Date OMP developed:

Table 1 identifies all the possible odor sources for Name of the farm along with a description of the odor potential for each source.

Table 1. Odor source inventory

Odor Source Inventory		
Source[1]	**Description[2]**	**Odor potential[3]**

[1] Animal housing (barns or open lots), manure collection, transport, treatment and storage structures, land application, animal mortalities and other odor sources. Potential sources of odor within an operation are listed in a resource link in Online Resources section ("Airborne emissions sources and management on animal agriculture production systems").

[2] Factors and activities that affect odor emission from any source (eg. size/area of source, associated animal numbers, frequency of use, etc.).

[3] Quantitative odor emission data for sources (animal housing and manure storage structures) from "South Dakota Odor Footprint Tool" or qualitative score for emissions from "National Air Quality Site Assessment Tool", or other references.

***A star indicates a printed copy of odor potential estimations or references are attached to this document.**

Figure 1 is a plan view/map of the operation to visualize the odor sources and distances of the surrounding neighborhood locations.

Figure 1: Odor source and neighbors location around the farm

.

Table 2 indicates the potential of local odor impact of Name of the farm

Table 2. Odor impact assessment on neighborhood stakeholders' locations

Odor impact on neighborhood stakeholders		
Neighbor or Receptor[1]	**Location[2]**	**Description of frequency and/or intensity of odor impact[3]**

[1]All the potential receptors, including neighbors, schools or other public institutions
[2] Distance of the receptors from the farm and direction from the operation (ex N, NE, E, SE, S, SW, W, NW)
[3] Estimated odor annoyance from "South Dakota Odor Footprint Tool" i.e. percentage of time of odor annoyances. Any location which has a possibility of being impacted by sources which are not addressed in any footprint tool (e.g. land application of manure), need to have description of odor intensity or frequency.
***A star indicates a printed copy of odor impact estimations or references are attached to this document.**

Table 3 addresses all current and/or planned odor control technologies for specific odor sources associated with Name of the farm, along with the estimated effectiveness and implementation protocol.

Table 3. Odor control strategy

Odor control strategy			
Source	**Odor management technology/activity[1]**	**Effectiveness of the practices[2]**	**Implementation protocol[3]**

[1] All the current and/or planned odor control technologies or management activities
[2] The effectiveness is based on the "Air Management Practices Tool" and/or other literature
[3] How and when odor management practices are or will be implemented.
***A star indicates a printed copy of odor impact estimations or references are attached to this document.**

Table 4 is a form that will be copied and used to document instances of odor annoyance or complaints. All copies will be attached to this document, regardless of action.

Table 4. Odor complaint documentation

Odor complaint report form	
Time and date of complaint:	
Name of complainant:	
Address:	
Telephone Number:	
Date of odor:	
Time of odor:	
Location of odor, if not at above address:	
Weather condition (i.e., dry, rain, fog, snow):	
Temperature (if degrees not known warm, cold, mild):	
Wind characteristic (if speed not known light, steady, strong, mild)	
Wind direction:	
Description of odor:	
What does it smell like:	
Duration (time):	
Other comments:	
Follow-up actions regarding this complaint or issue:	

Table 5 is to document odor monitoring and reporting. Odor monitoring may be on a fixed or as-needed basis.

Table 5. Odor monitoring record

Date	Time	Location	Person (who was involved in monitoring)	Type of odor (strength, intensity)

Table 6 lists the planned activities that will establish a working relationships with the surrounding community.

Table 6. Plans and actions planned to establish working relationships with the surrounding community

Type of activity	Plan of action[1]	Remarks[2]

[1]How things will be done and when i.e. fixed schedule or as-needed basis
[2]Any suggestions or comments from the community which could affect odor impact of the farm.

Table 7 documents when and what type of changes have been made to this odor management plan.

Table 7. Record of changes to odor management plan

Date of review	Cause of review	Summary of changes made	Evaluation	Signature

Online Resources:

1. "Airborne emissions sources and management on animal agriculture production systems": https://articles.extension.org/sites/default/files/AirbornEmissionsFINAL.pdf
2. South Dakota Odor Footprint Tool: https://www.sdstate.edu/agricultural-and-biosystems-engineering/south-dakota-odor-footprint-tool website with the user manual
3. National Air Quality Site Assessment Tool: http://naqsat.tamu.edu/ with the user manual
4. Air Management Practices Assessment Tool: http://www.agronext.iastate.edu/ampat/ with the user manual.

Other Resources:

1. "Odor management plans for dairy operations": https://labs.wsu.edu/ndegwa/documents/2016/09/omp-dairy.pdf/
2. "EC02-721 Nebraska 's CNMP Odor Management Plan Workbook": https://digitalcommons.unl.edu/cgi/viewcontent.cgi?referer=https://www.google.com/&httpsredir=1&article=5768&context=extensionhist

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