RESEARCH REPORT
ENVIRONMENT

Title: Laying the Groundwork for Odor Control and Setback Estimation in Nebraska – **NPB #04-180**

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II. Industry Summary:

The goal of this project was to build credibility in rural communities for using the Odor Footprint Tool (OFT) as a planning and screening tool when siting swine facilities. The project had three objectives:

1) Involve a pork production operation, neighboring residents, and unbiased outside participants in an odor-monitoring study;
2) Pilot test the Odor Footprint Tool within a rural community for a proposed pork production facility; and
3) Install a biofilter on a pork production facility to demonstrate this technology and the potential for reducing odor impacts on rural communities.

Objective #1: Odor-Monitoring Study:

In the odor-monitoring study, 16 people were trained to assess odors using state-of-the-art field methods. Participants were trained to assess odor intensity, concentration, offensiveness, and character. Participants also provided a rating of the odor's 'annoyance potential' by specifying whether the odor was 'not annoying' or either "slightly", "moderately", "highly" or "extremely annoying". This subjective rating was to encompass how the state of odor would affect their behavior (i.e. any change in activity) and how long the event would be remembered (e.g. hours vs. months). This information was collected to help qualify prediction of odor annoyance and to obtain a more direct linkage between odor levels and likely consequences of odor events. Moderately, highly, and extremely annoying states of odor were collectively referred to as "consequentially annoying".

The trained participants monitored odors around a 4,800-head finishing site in eastern Nebraska during 2005 and 2006. For six consecutive Tuesday evenings during the summer of 2005, 5-7 participants from Lincoln traveled to the area to monitor odor levels at locations downwind of the selected site, both before and after dark. During late spring and summer of 2006, 2 participants from another rural community in the local county monitored odor levels at downwind locations 2-5 times a week. During that same time period, 7 people who owned residences within 1.5 miles of the selected site also monitored odors. Five of these individuals monitored for odor 3 times a day – once each during daylight, twilight and nighttime conditions – just outside their residence. Additional sources of livestock odor were limited mainly to two other swine facilities that were at least ¾ of a mile away, so the source of detected odor could generally be determined based upon wind direction.

Based upon data reported by the individuals who were hired and trained to monitor odors within the downwind odor plume, the state of odor at off-site locations (1/8 mile or further from the facilities) was reported to be consequentially annoying in 20 out of 192 assessments. When on-site data was included, the rate rose to 53 consequentially annoying ratings out of 231 total assessments. This information shows that while odor levels immediately around the swine facility were very likely to be considered annoying (33 of 39 instances); most of the time, the odors were quickly dispersed and diluted to levels not normally considered to be consequential. When atmospheric conditions kept emitted exhaust air near the ground, however, odor concentrations diminished much more slowly and the potential for negative odor effects extended greater distances downwind.

Modeling of each these assessment periods predicted that there were 18 consequentially annoying events at off-site locations. The 90% net prediction rate (18 predicted vs. 20 reported) for consequential annoyance was considered very promising given the nature of what is involved (odor, weather phenomena, and human assessments). Some steps for fine-tuning the predictive capabilities are being investigated to address the slight under-prediction of annoying odor levels and to minimize error rates.

Five residents regularly monitored for odors outside their residences and made a total of 1,007 assessments. This large number of observations covering a broad spectrum of weather conditions was desired to test the general accuracy of the Odor Footprint Tool's prediction of 'odor annoyance-free frequency'. 'Swine-related odor' was detected during 92 of the observations or 9.1% of the total, with a range of 0-14.0% among residents. On 42 of these odor events, or 4.2% of the total assessments, residents indicated that the states of odor were annoying. An annoyance frequency of 4.2% equates to a 95.8% odor annoyance-free status overall. Given the locations of the residences with respect to the three swine production facilities in the area, predicted individual odor annoyance-free frequencies using the Odor Footprint Tool ranged from 90 to 99%. Annoyance frequencies for individual residents ranged from 0 to 11.4% and showed considerable variation due to individual biases (some residents were for and some against having the swine facilities in the area), senses of smell, data collection times, etc. On the whole, the composite annoyance-free frequency based upon information supplied by area residents was comfortably within the predicted range, especially given that resident annoyance did not have to qualify as being 'consequential'.

Objective #2: Pilot-test of Odor Footprint Tool:

In March of 2005, a producer looking to construct a 2,400-head swine finishing facility in southern Madison County, NE, and the local planning and zoning commissioner agreed to utilize the Odor Footprint Tool during the application approval process. Odor footprints were developed and superimposed to scale on aerial photographs of the proposed site, showing the location of neighboring residences and the extent of the odor annoyance-free frequency curves. A 94% odor annoyance-free frequency was used to align with the tolerance level likely to be proposed for odor annoyance in agricultural areas of the county.

On June 16, 2005, these Odor Footprint Tool resources were included in the review of the pork producer's application. The following week, the odor footprint illustrating the extent of odor impact at 94% odor annoyance-free frequency was shown at a public hearing regarding the proposed facility. On July 28, 2005, the planning and zoning commissioners approved the application. At an October 2005 meeting of the Madison County Commissioners, the application was denied approval. While there was no way to know the real reasons for the differing decisions, much less time was allowed for explaining and illustrating the Odor Footprint Tool information to the county commissioners and meeting attendees.

Objective #3: Install a functional biofilter

After investigating a number of unfruitful leads with prospective pork producer cooperators, a site for installing a demonstration biofilter was found in the latter half of 2006. Design of the facility and the biofilter occurred during late 2006 and into 2007. Construction is set to begin during the summer of 2007 with demonstration of the biofilter to follow. A positive of the delay was that funds were received from the Nebraska Environmental Trust during 2006 that will more than double the biofilter expenses that we are able to cost-share.

Implications for the industry:

The odor-monitoring field study showed good agreement between odor dispersion model projections of the presence of annoying odor levels and human observations. This adds support for using tools like the Odor Footprint Tool to project out minimum separation distances between proposed swine buildings and residences.

Pilot testing the Odor Footprint Tool set a precedent in Nebraska that this tool has a place in the local decision-making process, at least from an informational standpoint. Inclusion of science-based information at public meetings impacts discussion, and county officials have been receptive to learning more about the Odor Footprint Tool. At least three counties are pursuing options for incorporating the Odor Footprint Tool into local zoning ordinances.

Sustaining growth in animal production and vibrant rural communities will likely depend on a combination of sound evaluation of the expected odor impacts of operations on surrounding areas and utilization of effective odor control – such as biofilters – where needed.

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III. Scientific Abstract:

The goal of this field research study was to validate use of the Odor Footprint Tool (OFT) with livestock building sources in rural communities. The primary objective was to evaluate the accuracy of predictions of annoyance potential (as projected by odor concentration output data from AERMOD® - the OFT's underlying dispersion model) when compared to measures of annoyance potential made in the field.

Odor assessors were trained to monitor odors around a 4,800-head finishing site in eastern Nebraska. During the summer of 2005, mobile odor assessors monitored odor levels at downwind locations. During the spring and summer of 2006, another set of mobile odor assessors monitored odor levels at downwind locations, while neighbors of the operation monitored odors at their residences. Modeling was performed for coinciding time periods using data from an on-site weather station and a 'blue book' OFT odor emission rate.

Mobile odor assessor data identified 22 instances out of 216 off-site downwind assessments where the state of odor was annoying based upon the odor concentration (group geometric mean) being 7 dilutions to threshold or greater. Similarly, in 20 off-site assessments, assessors rated the state of odor to be consequentially annoying, out of 192 instances where such ratings were provided. When modeling was performed for all coinciding time periods at off-site locations, predicted odor concentrations exceeded the threshold value 20 and 18 times, compared to 22 and 20 times when annoying states of odor existed based upon the measured concentration and rated annoyance potential, respectively. In each case, there was at least 90% agreement in the frequency of annoyance.

Five area residents evaluated the state of odor during three periods each day: daylight, nighttime, and twilight hours. Based upon an evaluation of composite data from these residents, livestock odor was detected and rated as being at an annoying state in 9.1% and 4.2%, respectively, of 1,007 total readings, for a composite odor annoyance-free frequency of roughly 96%. Given the locations of the residences with respect to the three swine production facilities in the area, predicted individual odor annoyance-free frequencies using the Odor Footprint Tool ranged from 90 to 99%. Annoyance frequencies for individual residents ranged from 0 to 11.4% and showed considerable variation due to individual biases (some residents were for and some against having the swine facilities in the area), senses of smell, data collection times, etc. The composite annoyance-free frequency based upon information supplied by area residents was comfortably within the predicted range.

Additional objectives of this project involved pilot-testing the Odor Footprint Tool within a rural community for a proposed pork production facility; and installing a biofilter on a pork production facility to demonstrate this technology and the potential for reducing odor impacts on rural communities. The Odor Footprint Tool was used during planning and zoning commission consideration of an application for construction of a new swine finishing facility, and was successful in focusing discussion of odor on objective matters. At the very end of the project, a collaborator agreed to construct a biofilter to treat exhaust air from the facility to reduce the impact on some nearby neighbors.

Via this project, rural residents have seen how the Odor Footprint Tool can be used to evaluate the odor impact of a livestock operation and have been provided information that enhances confidence in the planning and screening tool.

IV. Introduction

Rural residents are very concerned about the potential impacts of nearby animal production facilities on the local environment, having fears that air quality will be degraded and that neighbors will have to frequently endure annoying odors. The Odor Footprint Tool is a science-based setback-estimation tool that has been developed at the University of Nebraska. It uses historical weather information to project minimum setback distances in differing directions from the site. The Odor Footprint Tool allows visualization of both the projected impact of odors on the area surrounding a [proposed] livestock facility and the reduction in odor impact that can be achieved by implementing a proven odor control technology. A key step is to validate

the tool's prediction of community impact within a rural setting. Ground-truthing of the tool should encourage acceptance and subsequent adoption of the tool.

From interactions with representatives serving on the Nebraska Odor Footprint Tool Advisory Group, it is apparent that, while many local officials and livestock producers desire to have a science-based siting tool at their disposal, considerable hesitancy exists in actually implementing such a tool. Pilot testing of the OFT is one way to provide the communication, education, and experience needed to alleviate concerns.

The Odor Footprint Tool can identify situations where odor control may be needed to avoid excessive annoyance. Proven approaches for controlling odor, such as the biofilter, may need to be implemented when production facilities are already in place or when a proposed site is near residences. Unfortunately, biofilters are rarely installed on livestock operations in Nebraska. The operable units in the state are on isolated facilities with strict limitations on access, making them of little use for demonstration purposes. Producers have expressed interest in biofilters, but the uncertainty about their cost and performance seem to be hurdles for their adoption.

V. Project Objectives:

The overall goals of this project were to increase confidence in using a science-based setback estimation tool at the community level and to demonstrate the effectiveness of biofilters for odor control, thereby enhancing sustainability and potential growth opportunities for the pork industry. Specific project objectives are to:

i) Validate the Odor Footprint Tool in a rural community setting by involving a pork production operation and neighboring residents in field-testing of the tool;

ii) Pilot test the Odor Footprint Tool within a rural community for a proposed pork production facility to obtain critical feedback from producers and community stakeholders about the setback-estimation tool; and

iii) Install a functional biofilter on a working pork production facility in Nebraska to demonstrate this technology and the potential for reducing odor impacts on rural communities.

VI. Materials and Methods:

Obj. #1: Validate use of the Nebraska Odor Footprint Tool in a rural community setting…

Odor assessors were trained to monitor odors around a 4,800-head finishing site (with year-round mechanical ventilation and deep pits for storing manure) in eastern Nebraska. Representative odor emission rates from the facility were determined based on olfactometry analysis and measurement of ventilation capacity to compare with 'blue-book' emission rates. For six consecutive Tuesday evenings during the summer of 2005, 5-7 participants from Lincoln traveled to the area to monitor odor levels at locations downwind of the selected site, both before and after dark. During late spring and summer of 2006, two participants from another rural community in the local county monitored odor levels at downwind locations 2-5 times a week. During that same time period, 7 people who owned residences within 1.5 miles of the selected site also monitored odors. Five 5 of these individuals monitored for odor 3 times a day – once each during daylight, twilight and nighttime conditions – just outside their residence.

Participants were trained to assess the following information:

Odor intensity – assessment of odor strength on a standardized 0-5 scale;

Odor concentration – the dilution setting on a specially designed mask at which odor was first detected;

Hedonic tone – rating of pleasantness or unpleasantness (offensive) on +4 to -4 scale; and

Character – response to the question "The odor smells like…".

Participants also provided a rating of the odor's 'annoyance potential' by specifying whether the state of odor was 'not annoying' or either "slightly", "moderately", "highly" or "extremely annoying". This subjective rating was to encompass whether the present state of odor would likely affect behavior (i.e. change activity) and how long the event would be remembered (i.e. hours vs. months). This additional information was collected to help qualify prediction of odor annoyance and to obtain a more direct linkage between odor levels and likely consequences of odor events. At moderately or more annoying states of odor, individuals indicated that they would tend to behave differently (e.g. adjust activity) and/or have more than momentary recollection of the odor event, so these conditions were collectively referred to as being "consequentially annoying".

Objective #2: Pilot-test Odor Footprint Tool in rural community

In March of 2005, it was brought to our attention that an individual wanted to construct a 2,400-head swine finishing facility in southern Madison County, and that this individual was open to utilizing the Odor Footprint Tool during the application approval process. We initiated communications to get the producer and the Zoning Administrator for Madison County together to pilot test the Odor Footprint Tool.

We developed odor footprints for use with this operation and superimposed them to scale on aerial photographs of the proposed site, showing the location of neighboring residences and the extent of the odor annoyance-free frequency curves. For interaction with the public, we used a 94% odor annoyance-free frequency to align with the county's preliminary judgment regarding the tolerance level to be used for agricultural areas.

On June 16, 2005, these Odor Footprint Tool resources were included as part of the Madison County Planning and Zoning Commission's review of the pork producer's application. The following week, June 23, the odor footprint illustrating the extent of odor impact at 94% odor annoyance-free frequency was shown at a public hearing that was held to present 'statements of fact' regarding the proposed facility. At the county commissioners' meeting, held in October of 2005, more limited discussion of these resources was allowed.

Objective #3: Install a functional biofilter

Several possible sites for cost-sharing and helping to install a demonstration biofilter were investigated. After finding little success in finding a collaborator – due to producer concerns about biosecurity, cost, management concerns, etc. – two producers expressed strong interest in biofilters very near the end of the project (fall of 2006).

VII Results:

Objective #1: Odor-Monitoring Study:

In 20 out of 192 off-site assessments made by the mobile odor assessors, the state of odor was rated as being consequentially annoying – that is, it would have influenced assessor behavior in a normal setting and/or produced a more-than-momentary remembrance of the event. Off-site locations were 1/8 mile or further from the facilities. When on-site data (from odor assessments made within 200 feet of the facilities) were included, the rate rose to 53 annoying assessments out of 231 total. Mobile odor assessor data identified 22 instances out of 216 off-site downwind assessments where the state of odor was annoying based upon the geometric mean odor concentration being 7 dilutions to threshold or greater.

Modeling of each these off-site assessment periods, was performed using 'bluebook odor emission rates' and current thresholds for odor annoyance that are based upon an odor intensity of 2.0 or greater. The modeling predicted that odor concentrations exceeded the threshold value 20 and 18 times, compared to 22 and 20 times when annoying states of odor existed based upon the measured concentration and rated

annoyance potential, respectively. In each case, there was at least 90% agreement in the frequency of annoyance.

The five residents who monitored odor status outside their respective residences made a total of 1,007 odor assessments. This large number of observations covering a broad spectrum of weather conditions was desired to test the general accuracy of the Odor Footprint Tool's prediction of 'odor annoyance-free frequency'. 'Swine-related" odor was detected during 92 of the observations or 9.1% of the total, with a range of 0-14.0% among residents. On 42 of these odor events, or 4.2% of the total assessments, residents indicated that the states of odor were annoying. Annoyance frequencies for individual residents ranged from 0 to 11.4%. The residents were thorough in taking baseline data, but often did not record the extra details needed to assess whether annoyances were consequential, and little pressure was exerted on them to supply this information. An annoyance frequency of 4.2% equates to a 95.8% odor annoyance-free status overall. Given the locations/separations of the residences with respect to the three swine production facilities in the area, individual odor annoyance-free frequencies were estimated using the Odor Footprint Tool. The resulting annoyance-free predictions ranged from 90 to 99%.

Objective #2: Pilot-test Odor Footprint Tool in rural community

On July 28, 2005, the Madison County Planning and Zoning Commissions approved the application for the finishing facility that participated in the pilot test of the Odor Footprint Tool. The Madison County Commissioners, however, did not approve the application, citing health concerns.

Objective #3: Install a functional biofilter

Late in 2006, a producer who is planning a 2,000-head finishing facility committed to install a horizontal biofilter to treat exhaust air from the mild-weather fans in a fully mechanically ventilated building. The building and biofilter designs are nearing completion and construction is set to begin during the summer (2007). Cost-share funds were expended to purchase some basic needed biofilter supplies.

VIII. Discussion:

The information collected by mobile assessors in the field study showed that while odor levels immediately around the swine facility were very likely to be considered annoying (33 of 39 instances); most of the time, the odors were quickly dispersed and diluted to levels not normally considered to be consequential. When atmospheric conditions kept emitted exhaust air near the ground, however, odor concentrations diminished much more slowly and the potential for negative associated effects extended much greater distances downwind.

The 90% prediction rate (18 predicted vs. 20 reported) for consequential annoyance was considered very promising given the nature of what is involved (odor, weather phenomena, and human assessments). Some steps for fine-tuning the predictive capabilities are being investigated to address the slight under-prediction of annoying odor levels and minimize error rates.

Resident data showed considerable variation and the influences of biases (some residents were for and some against having the swine facilities in the area), differing senses of smell, data collection times, etc. On the whole, though, the composite annoyance-free frequency from resident-supplied information lies comfortably within the Odor Footprint Tool's predicted range, especially given that there was no minimum bar applied to residents for qualifying annoyance.

While the resources produced using the Odor Footprint Tool were not used in an official way for making decisions regarding the pilot test pork production facility, the resources were included in the approval process and impacted the discussion toward more factual information.

While it took much longer than desired to find a workable demonstration facility for a biofilter, the impact of having a demonstration facility on privately operated swine facility in southeastern Nebraska should be

very positive and should provide additional incentive to producers to install this technology for controlling odor. Also, additional funds were obtained from the Nebraska Environmental Trust that will more than double the amount of biofilter expenses that we are able to cost-share.