

A Receptor-Based Siting Strategy for Swine Production Systems

S. Hoff, D. S. Bundy, J. Harmon, and C. D. Johnson
Iowa State University¹

Species: Swine
Use Area: Animal Housing, Manure Storage
Technology Category: Facility Siting
Air Mitigated Pollutants: Odor

Description:

A model, called the Community Assessment Model for Odor Dispersion (CAM), was developed to predict receptor odor exposure from multiple swine production sources. The intended use of CAM was to provide a tool for evaluating the odor exposure to receptors in a community when siting new swine production systems and how a change in odor control technology alters the odor exposure to receptors. CAM can handle up to 20 swine production sources with up to 100 receptors in a community of any size. The model incorporates historical (10+ years) average local weather data, coordinate locations of all sources and receptors, ground and above-ground area sources, seasonal variations in odor emission, source production footprint and orientation, and documented proven odor mitigation technologies. CAM does not predict the influence of calm conditions, topography, or obstruction downwash. CAM predicts the number of hours of exposure to weak (2:1) and greater or identifiable (7:1) and greater odors and these are used to assess siting options.

Current siting requirements for new livestock and poultry production systems in the U.S. are based mainly on animal units and distance to the nearest neighbor independent of direction (eg. Iowa DNR, 2005; Missouri DNR, 2006). Separation distance alone does not account for existing odor sources in a community, nor the influence of localized weather patterns on odor dispersion. An alternative approach would be to develop a receptor-based procedure for making decisions on where a swine facility of a given size could be placed in a community with or without a pre-existing odor load. In this manner, siting decisions could be made using historical weather patterns, size of production facility, odor mitigation measures implemented, and existing odor loads in a community.

The objective of this paper was to summarize an organized procedure for assessing odor exposure to individual receptors in localized areas of a community. The goal was to develop a procedure that could fairly and accurately describe the long-term historical exposure of odor emission from multiple swine barn ventilation air and manure area sources to multiple receptors in a community of any size. Historical average meteorological conditions in localized areas along with odor emission parameters that describe barn ventilation air and manure area odor sources were implemented in an attempt to provide a siting tool that predicts historical average expectations as opposed to hourly or daily observations.

Mitigation Mechanism:

The mitigation mechanism described with this paper is related to pre-planning siting efforts when considering new or expanding swine production systems. In terms of new construction, proper siting is a very effective odor mitigation strategy. Proper siting can alleviate in many cases the need for odor mitigation.

Modeling odor dispersion by itself is a relatively straight-forward procedure. The difficulty arises when a modeling procedure is to be used by farmers and community planners to guide facility siting choices. Any modeling procedure developed must be based on an accepted modeling platform, must incorporate site parameters that can be applied equitably to a wide range of field conditions, must have the ability to easily handle multiple sources and multiple receptors, and must predict odor concentration that is conservative for the receptor without being overly restrictive for the farmer. Any odor dispersion model that incorporates these considerations and shows good agreement with field collected odor data could be considered for siting purposes.

Applicability:

This paper discusses a technique that has been developed for swine housing and outside manure storage facilities. The current procedure is limited to swine. CAM can evaluate up to 20 swine-related sources and up to 100 receptors in a land area of any size provided local historical (10+ year average) weather data exists.

Limitations:

The modeling procedure described in this paper requires localized historical weather data, does not consider calm conditions, and can not model terrain features beyond rural agricultural terrains.

Cost:

The CAM model requires site specific information to properly implement. Currently CAM is implemented with the ½-time support of an on-campus staff member with no charge to the farmer. A more formal procedure is being developed where a CAM evaluation will require a farmer-fee of either \$500/siting case or \$1,000/siting case depending on the complexity of the proposed site. A \$500 cost to a farmer would be a situation where a campus or extension field staff member is required to visit a proposed site to help guide siting decisions using localized odor plots (described in next section). If the complexity of the proposed site warrants a full CAM modeling run, an additional \$500 is required from the farmer.

Implementation:

CAM has been used in the state of Iowa for over 150 specific cases since June 2005. The implementation of CAM has been a voluntary process, initiated by the farmer and implemented through a joint effort between the Coalition to Support Iowa's Farmers (CSIF, 2008), the Iowa Pork Industry Center (IPIIC, 2008), and faculty with Iowa State University's College of Agriculture and Life Sciences. A farmer proposing a new site first contacts the CSIF. An initial assessment is made of the site based on aerial and plat maps followed by a site visit. In many cases, the CSIF site visit is sufficient to assess the proposed site. If the proposed site requires a CAM modeling run, a staff member from IPIIC conducts a follow-up site visit and using aerial maps, plat maps, and on-site observations, grids the community identifying all potential receptors and existing emission sources. Special indicators are given for receptors to identify sensitive areas such as churches, cemeteries, and day cares. The mapped data is then brought to Iowa State University's Department of Agricultural and Biosystems Engineering where one of two faculty members implements CAM. A one-page report is generated and this report is given to the farmer, through a follow-up on-site visit with an IPIIC staff member.

Local weather data is incorporated with an historical 16-point wind rose, average monthly wind speed (WS), average monthly outside temperature (T), and average monthly solar radiation (SO). Monthly data from March through October is used in CAM. Monthly averaged T is used to estimate housing ventilation rate and seasonal odor concentration. Monthly averaged WS is used to estimate odor emission from above-ground and ground-level area sources. Monthly averaged WS and SO data is used to estimate daytime atmospheric stability.

The 16-point wind direction (WD) data is used to estimate the total number of hours that a receptor might be subjected to downwind events. The assumption is made that the 22.5° increment of WD data surrounding each 16-point compass direction ($\pm 11.25^\circ$) has an equal chance of occurring. A source-to-receptor (S-R) exposure angle is determined based on the equivalent diameter defining the source (area or building or both combined) and the distance from the source center to receptor. Of the total S-R hours, the fraction of nighttime to daytime hours (varied by month) is used to further discretize these hours. This procedure is used to determine the maximum number of hours that a receptor could be subjected to an odor based solely on WD. Of these total "WD" hours, the actual number of hours exposed to an odor of a given concentration is determined using CAM procedures and the average monthly weather data. The actual odor exposure hours will in most all cases be significantly less than the WD hours, depending primarily on separation distance and average monthly WS.

The practical use of CAM is presented for a multiple source-multiple receptor situation modeled in central Iowa. A 2,400-head deep-pit swine finisher (DPSF) was being planned for construction in central Iowa at the location shown in figure 1. The proposed source (PS) location met all distance requirements established in Iowa at the time of siting (Iowa DNR, 2005) where a minimum required distance to the closest receptor (unincorporated areas) is 381 m (1,250 ft). The nearest receptor to PS was R10 (figure 1) at a distance of 647 m (2,122 ft). Also present in this community were three pre-existing DPSF facilities labeled as S1, S2, and S3. In total, this community consisted of 20 potential receptors, three existing DPSF sources, and the proposed DPSF source.

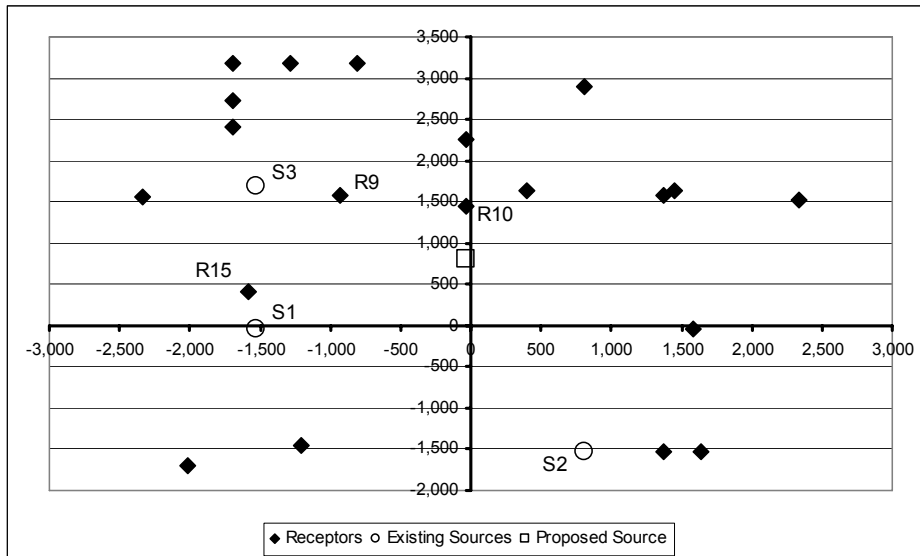


Figure 1. Case study community situation modeled. The community consists of 20 receptors (♦), 3 existing swine sources (○) along with the proposed source (□). Dimensions in meters.

The estimated odor emission data along with monthly variations in wind direction, wind speed, solar insolation, and daytime/nighttime hours for central Iowa were incorporated into CAM resulting in the receptor odor exposure predictions given in table 1 (3/20 receptor results given).

Table 1. Predicted number of hours of exposure to weak ($\geq 2:1$) and identifiable ($\geq 7:1$) odors for receptors 9, 10, and 15 (see figure 1).

Receptor	OU/m ³	PS Hrs.	S1 Hrs.	S2 Hrs.	S3 Hrs.	Total Hrs.	PS % Time	Total % Time
R9	2:1	22	16	4	64	106	0.4	1.8
	7:1	15	8	0	37	60	0.3	1.0
R10	2:1	50	7	5	14	76	0.9	1.3
	7:1	38	4	0	5	47	0.6	0.8
R15	2:1	9	194	4	18	225	0.2	3.8
	7:1	4	78	0	15	97	0.1	1.6

From the data presented in table 1, along with odor-limit criteria, an assessment could be made regarding this siting choice. For the test cases conducted in Iowa (150+ since 2005), a 4-criteria approach has been used to guide siting decisions. This 4-criteria approach is summarized as (Mar-Oct hours);

1. (PS 2:1 or greater hrs) to any receptor < 1.0 % time (59 hrs)
2. (PS 7:1 or greater hrs) to any receptor < 0.5 % time (29 hrs)
3. \sum_i (PS + S_i 2:1 or greater hrs) to any receptor < 2.0 % time (118 hrs)
4. \sum_i (PS + S_i 7:1 or greater hrs) to any receptor < 1.0 % time (59 hrs)

Criteria 1 and 2 limit the odor load to any receptor from the proposed source (PS) to no more than 1% exposure to a weak 2:1 odor (or stronger) and no more than 0.5% exposure to an identifiable 7:1 odor (or stronger). Criteria 3 and 4 are used to assess the cumulative effect from all sources in the community including the proposed source. For this final consideration, all receptors are limited to 2% exposure to a weak 2:1 odor (and stronger) and 1% exposure to an identifiable 7:1 odor (and stronger). Any siting choice not meeting all four criteria for all receptors in the community is relayed to the farmer.

If the 4-criteria approach is applied to the community situation shown in figure 1, three of the 20 receptors had at least one of the 4-criteria exceeded. These receptors were R9, R10, and R15. With the data shown in table 1, R9 exceeds criteria 4, R10 exceeds criteria 2, and R15 exceeds criteria 3 and 4. Note that R15 odor exposure was the result of a prior siting (S1) with very little added odor exposure from PS to R15.

For the case study presented, the farmer made the decision to move the actual construction of PS to a location further south because of the results predicted between PS and receptors R9 and R10. Once PS was moved, all four criteria were met for R9 and R10. It should be noted that the 4-criteria approach established is very conservative for the receptor as it should be in pre-planning applications. This is an important reason why the approach prescribed in this

paper with the four criteria given above *must not be used to assess existing source situations*. This is an extremely important aspect of pre-planning siting tools; they should be conservative for the receptor but not applied in such a manner as to implicate farmers who built under pre-existing criteria.

The implementation of CAM is more involved than other proposed siting tools (Guo et al., 2001; Jacobson et al., 2003; Koppolu et al., 2004; Schulte et al., 2004). The experiences gathered from the collaboration between CSIF and IPIC clearly indicate that the majority of siting choices do not need a full CAM modeling run to properly assess a siting choice. To accommodate cases where a low-cost field assessment can be made, a series of odor plots were developed for thirteen regions in Iowa. A typical odor plot is shown in figure 2. Figure 2 represents the odor plot for a 2,500-head DPSF located near Algona, Iowa for receptors located 610 m (2,000-ft) from the proposed source, in any direction from the source. Each plot ring represents a 1% increase in March to October odor exposure hours. The two inner circles represent the 0.5% and 1% criteria corresponding to criteria 1 and 2 as described before.

Two odor profiles are shown in figure 2. The outer odor plot shows exposure hours for weak and greater ($\geq 2:1$) odors with the inner odor plot corresponding to identifiable and greater odors ($\geq 7:1$). For example, if a receptor exists 610 m due north of the proposed site, CAM would predict a 2.4% time exposure to weak and greater odors and a 1% time exposure to identifiable and greater odors. Both of these exposure levels exceed the criteria 1 and 2 levels. If instead a receptor is located southwest of the proposed source, at a distance of 610 m, the exposure to weak and identifiable odors fall below the criteria 1 and 2 levels.

Odor plots like that shown in figure 2 have been developed for thirteen regions in Iowa, and within each region odor plots have been generated for 2,500, 5,000, and 7,500-head DPSF facilities at receptor distances between 457 m (1,500 ft) and 1,220 m (4,000 ft), in 152 m (500 ft) increments. These odor plots in-turn can be used and implemented by field staff to assess potential siting options. When situations arise where odor plots can not be used to assess siting options, a full CAM modeling run is required. For example, if a siting decision is being made in a community with existing sources, the odor plots developed can not be used, requiring a full CAM modeling assessment.

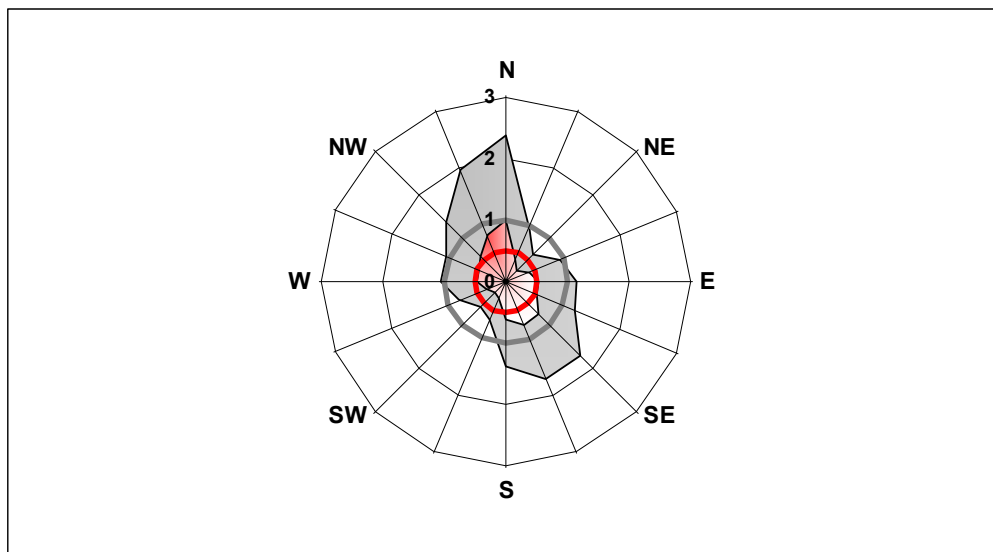


Figure 2. Odor plot for a 2,500-head deep-pit swine finisher located near Algona, Iowa valid for receptors at a separation distance of 610 m (2,000-ft).

Figure 3 presents Algona, Iowa odor plots for a 2,500-head DPSF with four increments of receptor separation distances. One of the useful features with odor plots is that a visual image of the importance of separation distance can be readily demonstrated. The impact of incremental 152 m (500 ft) separations as shown in figure 3 is dramatic. This fact is important if discussions of unreasonably far separation distances surface. Odor plots can help dispel concerns. The natural reaction with legislation for example is to increase separation distances unreasonably as a conservative approach. Using odor dispersion modeling, along with summary odor plots, the benefits of small incremental increases in separation, or, the placement of sources relative to receptors that experience a small percentage of odors based on historical weather patterns can be readily demonstrated.

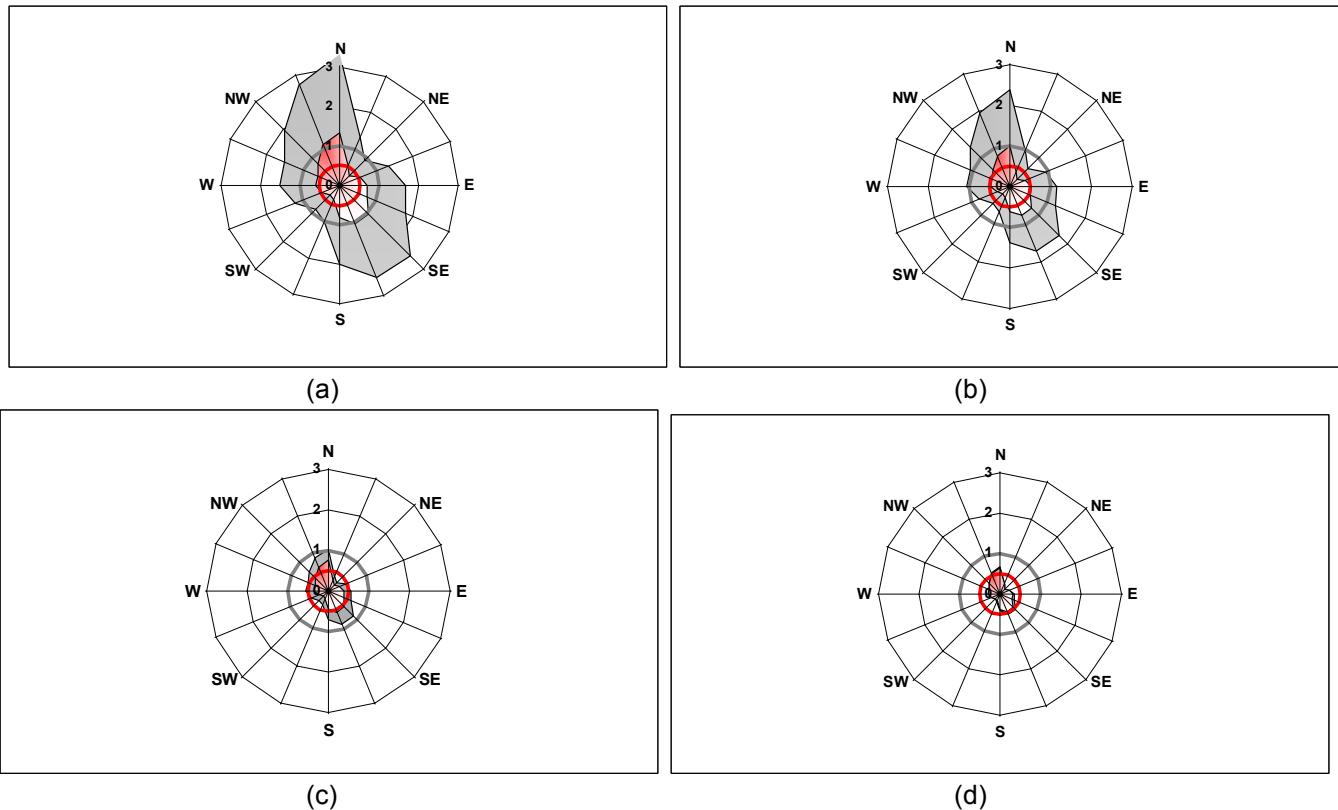


Figure 3. Example odor plots for a 2,500-head DPSF located near Algona, Iowa. The plots show directional effects for this facility at separation distances of (a) 457 m (1,500 ft), (b) 610 m (2,000 ft), (c) 762 m (2,500 ft), and (d) 915 m (3,000 ft).

Technology Summary:

The technology described in this paper uses odor dispersion modeling, combined with local historical weather data, receptor and existing source locations, and a criteria for assessing odor loads to each receptor to assess proposed swine production siting.

Additional Resources:

Additional details related to CAM can be found in Hoff et al. (2003) and Hoff et al. (2008).

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<p>Point of Contact:</p> <p>Steven J. Hoff, Ph.D. Iowa State University 212 Davidson Hall Ames, IA 50011 USA 515-294-6180 hoff@iastate.edu</p>	<p>As published in the proceedings of: MITIGATING AIR EMISSIONS FROM ANIMAL FEEDING OPERATIONS CONFERENCE Iowa State University Extension Iowa State University College of Agriculture and Life Sciences Conference Proceedings Sponsored by: NRI Air Quality Extension & Education Iowa Farm Bureau Federation Iowa Egg Council Iowa Pork Industry Center Iowa Pork Producers Association U.S. Pork Center of Excellence</p>
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