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Annoyance-Exposure Relation for Swine Odour

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ABSTRACT The goal of this project is to determine the odour annoyance-exposure correlation based on which setback distances can be determined. The odour annoyance is assessed by face-to-face interviews of residents living nearby swine operations. The odour exposure is quantified through dispersion modeling. Two dispersion models were used to predict the odour concentrations and frequencies at each household interviewed surrounding the odour source, and the predictions are then converted to odour hours to quantify the odour exposure. It appears that the odour annoyance could be assessed by face-to-face interviews with properly designed questionnaire. The dispersion models could be used to quantify the odour exposure. Although the results presented in this paper was preliminary and only limited data was collected, the plot of percentage of acceptability vs. odour hours predicted by dispersion models represented the trend of annoyance-exposure relationship for hog odour.

Keywords: Swine odour, annoyance, exposure, dispersion model, survey

INTRODUCTION

The odour from swine operations has been a great concern to the residents in the surrounding areas. How to manage swine odour becomes a complicated question for both producers and governmental regulators. Maintaining the minimum setback distances has been the commonly used tool for community planners for odour mitigation (Guo et al., 2006). The setback distance is defined as the distance between the odour sources (e.g., agricultural animal facilities, manure spreading land) and the nearest tolerable receptor (e.g., neighboring communities). To scientifically establish the setback distances, methodologies are required to fairly evaluate the swine odour impact on the communities (i.e., odour annoyance) and to quantify the actual odour levels at the receptors (i.e., odour exposure).

The odour level and the occurrence frequency at which the odour becomes a concern should be included in the acceptance criteria. A commonly used criterion is the acceptable odour concentration along with the percentage of annoyance free time (Jacobson et al., 2000). This criterion has two major shortcomings: 1) the acceptable odour concentration selected is somehow arbitrary and not applicable for all the perceivers, 2) the annoyance level varies with livestock species due to different offensiveness properties of manure from different species. In addition, limited success was achieved from the attempt made to develop odour impact indices to capture the overall effect of such parameters as odour concentration (intensity), occurrence frequency, duration, and offensiveness (hedonic tone).

Therefore, in order to fill the gap for the acceptable odour exposure criteria requirement, this study aimed at establishing the relations between odour annoyance and odour exposure evaluated or predicted by the dispersion models.

RELATED BACKGROUND

Although limited studies could be found in the literature on the annoyance-exposure relationship for odours emitted from animal operations, relevant research on industrial air pollution can provide us valuable thoughts on the odour annoyance-exposure relationship establishment.

Annoyance due to air pollution was recommended as an indicator for ambient air pollution exposure estimation (Piro et al., 2008), which involves such broad scopes as quality of life and community values (Williams et al., 2003). In most studies, annoyance scores were taken from a community health survey and respondents' exposure to the certain air pollution gases were estimated using different modeling techniques. However, the reports demonstrating the annoyance scores and modeled exposures were often inconsistent with each other (Forsberg et al., 1997; Rotko et al., 2002; Heinrich et al., 2005; Oglesby et al., 2000; Modig and Forsberg, 2007; Jacquemin et al., 2008; Piro et al., 2008).

On the one hand, a few results showed no relevance or very weak association existed between these two factors. For example, In Sweden, Forsberg et al. (1997) concluded there was no significant association between sulphur dioxide and annoyance scores. Rotko et al. (2002) examined the predictors of detected annoyance from air pollution in six European cities (Athens, Basel, Milan, Oxford, Prague, and Helsinki) but no association was found between outdoor nitrogen dioxide (NO_2) pollution levels and annoyance scores from individual perceptions. Heinrich et al. (2005) reported weak association between the subjective assessments of exposure and modeled NO_2 modeled results while making comparisons between traffic intensity and air pollution caused by traffic modeling estimates in three age cohorts from three European countries: the Netherlands, Germany, and Sweden.

On the other hand, numerous contrasting reports showed there was strong association between annoyance scores and the air pollutions' exposure. Forsberg et al. (1997) reported that annoyance caused by air pollutions from traffic exhaust fume was highly correlated with NO_2 concentration although they showed a lack of association between annoyance and SO_2 concentration. Oglesby et al. (2000) showed a strong association existed between annoyance and modeled NO_2 concentration at homes while studying whether the potential indicator of annoyance can become a helpful tool for the within-area variability assessment for air quality in Switzerland. Modig and Forsberg (2007) found that the self-assessed annoyance was raised significantly as the modeled NO_2 concentrations increased in three Swedish cities. Jacquemin et al. (2008) concluded that annoyance scores can be a helpful indicator for the outdoor air quality assessment while reporting an association existed between self-reported annoyances due to ambient air pollution and outdoor NO_2 concentration levels in 20 cities in 10 European countries. Similarly, Piro et al. (2008) also found the annoyance of air pollutions was closely related to the increased levels of modeled air pollutant concentrations in Oslo, Norway.

Odour is the sensations of human olfactory system produced by complicated chemical compounds. Unlike the air pollution gases, odour is difficult to measure using current analytical instruments and technologies. Intensity and concentration, as well as occurrence frequency, duration and offensiveness, are often used to define the characteristics of odour. It is expected that the relation between odour annoyance and odour exposure is more complicated in comparison with other air pollutants.

MATERIALS AND METHODS

Odour annoyance determination

The odour annoyance was determined by interviewing the local residents living in the vicinity of the hog farms in the rural areas of Manitoba. Fully trained and supervised interviewers carried out face-to-face interviews with the households.

The questionnaire to assess the degree of annoyance expressed by the residents has been designed according to several criteria (La et al., 2011). First, the questions should be able to obtain the odour annoyance data reflected by the communities. So the first set of questions directly asks the odour existence, identifiable odour sources, and odour annoyance levels in both verbal and numerical scales. The second set of questions indirectly measures the odour annoyance through interferences, i.e., the impacts on daily activities by the presence of the odour. Second, the responses by the residents to odour should be unbiased. In some rural areas, residents have preconceived notions of hog odour being a problem. Therefore, our interview questions were designed to focus on "the quality of the life assessment for rural Manitoba". Such questions as water quality, noise interference and services, were part of interview questions. Third, the questionnaire should take into account the potential factors that may result in different odour annoyance levels. Therefore, there are demographic questions following the basic survey questions, including the age range, gender, length of living in the area, etc.

The interviews were completed at the first of the six selected sites. This site was about 50 km northwest of Winnipeg, Manitoba. There were two major hog farms in this area. The first farm had 400 sows and a two-stage earthen manure storage located southwest of the farm with about 4 million liter capacity. The second farm, located approximately 10 km northeast of the first farm, had1200 sows in two barns and manure storage at the northeast corner of the farm with nearly 7.6 million liter capacity. All households within a 3-mile radius from each farm were regarded as the interviewee candidates. A total of 89 residents were interviewed.

Odour exposure quantification

The odour exposure was quantified by odour hours (OH), defined as the exceedance of the designed odour concentration setpoint within certain period of time. The odour hours may be calculated by dispersion modeling or measured in the field by human assessors. In the present study, we employed two air dispersion models, i.e., CALPUFF and AUSPLUME, to predict the odour hours.

The input to the dispersion models included meteorological data, odour source information (locations and the odour emission rates) and the receptors information. We used Winnipeg meteorological data set for a 10 year period (1998-2007) (SDA Weather Services, Winnipeg, MB. Canada).

Odour emission rate models were developed by collecting and analyzing data published in the literature. The odour emission data was first compiled based on the literature review for hog operations in North America. A database and a query box were developed using Microsoft Access to obtain the odour emission rate by selecting the housing types, manure storage systems and ventilation systems. This rate would reflect the average odour emission rate of all the referred measurements in the literature for the types of operation. The model also took the diurnal and monthly variations into account.

The study site was mapped with a GPS unit and the coordinates of the farms (odour emission sources) and households (receptors) were entered to the dispersion software. It should be mentioned that farms were modeled as area sources in dispersion models. The hourly odour concentration for each receptor (1998-2007) was predicted by the dispersion models, and then a threshold was set to be 2 OU to calculate odour hours – cumulated hours with odour concentration exceeded 2 OU. The annual odour hours for each receptor were taken as the average of years between 1998 and 2007.

PRELIMINARY RESULTS AND DISCUSSIONS

The results of odour hours predicted by CALPUFF and AUSPLUME along with the locations of receptors are demonstrated in figures 1 and 2, respectively. As seen in fig. 1, the lower odour hours generally appeared at the further distance from the odour source, and the odour hours increased as the receptor became closer to the odour sources. The similar trend was observed for AUSPLUME (fig. 2). The odour hour differences existed between CALPUFF and AUSPLUME modeling results. For example, the receptors at the southeast corner of Farm B had 100-150 OH from CALPUFF, whereas the smaller range of 0-50 OH was found from AUSPLUME.

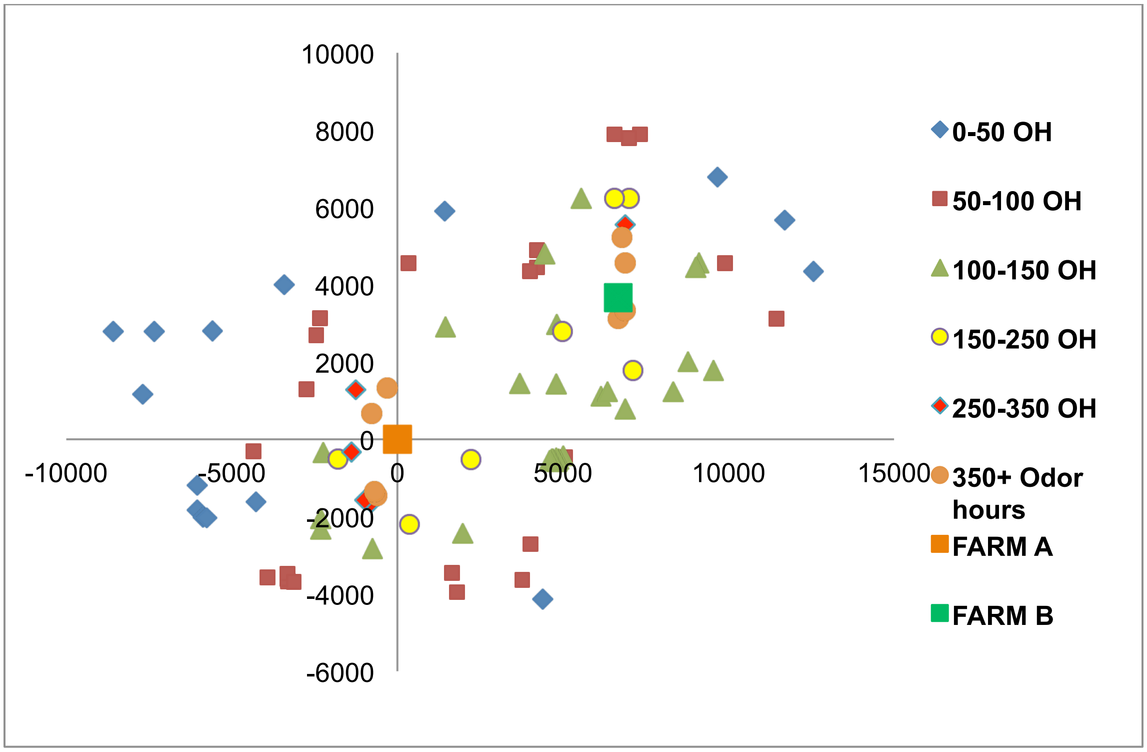

Figure 1. Odour hours (exposure) at interviewed receptor locations predicted by CALPUFF

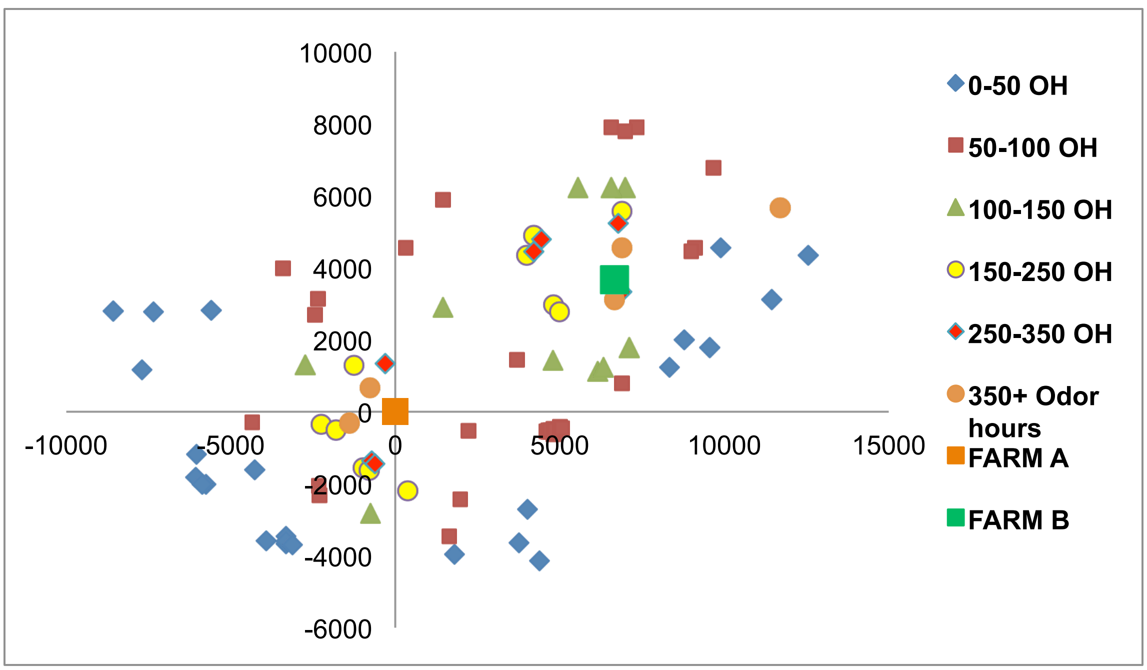

Figure 2. Odour hours (exposure) at interviewed receptor locations predicted by AUSPLUME

Figures 3 and 4 demonstrate the odour annoyance-exposure relations based on odour hours predicted by CALPUFF and AUSPLUME, respectively. The X-axis of both graphs represents the sorted odour hour zones based on odour hours and the number of interviewees within each zone. The Y-axis shows the percentage of acceptability within each zone. The acceptability was regarded as either no odour annoyance indicated by interviewees, or there was odour annoyance but not from hog operations, or the annoyance numerical scale was 0 on the 0-10 scale if hog odour was detected.

As expected, the percentage of acceptability generally decreased as the odour hours increased. It was observed that the percentage of acceptability did not follow a “smooth” curve. The main reason for this was that the number of receptors were very limited to reflect the proper percentage of acceptability within each zone. More data is required to increase the sample sizes within each range of odour hours.

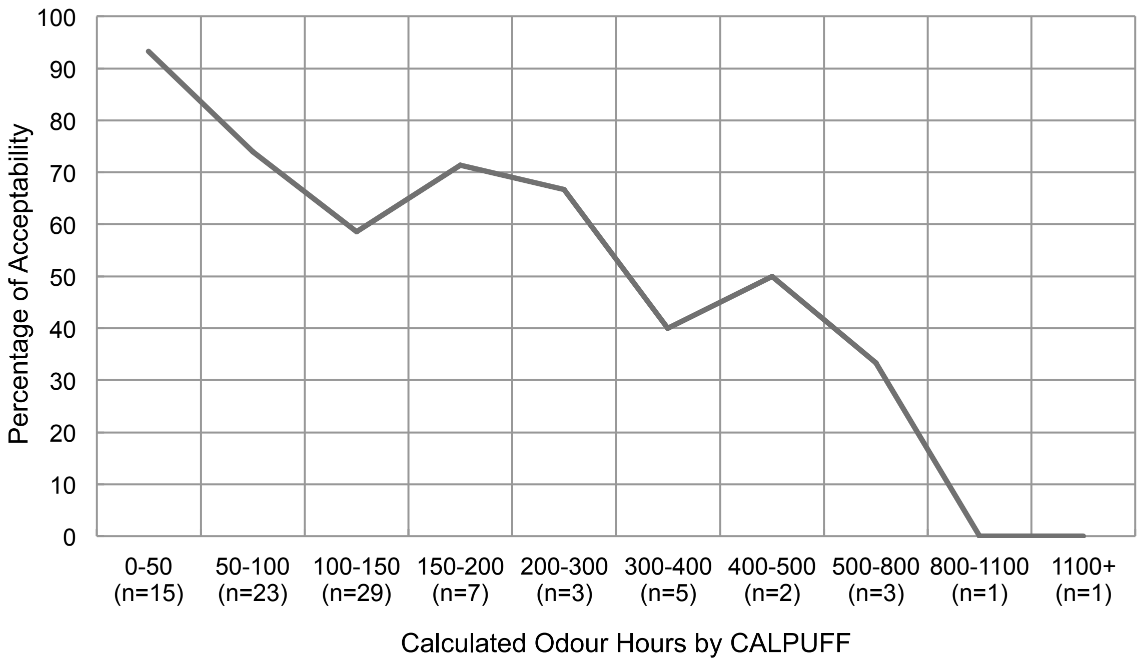

Figure 3. Percentage of acceptability at odour hours calculated by CALPUFF

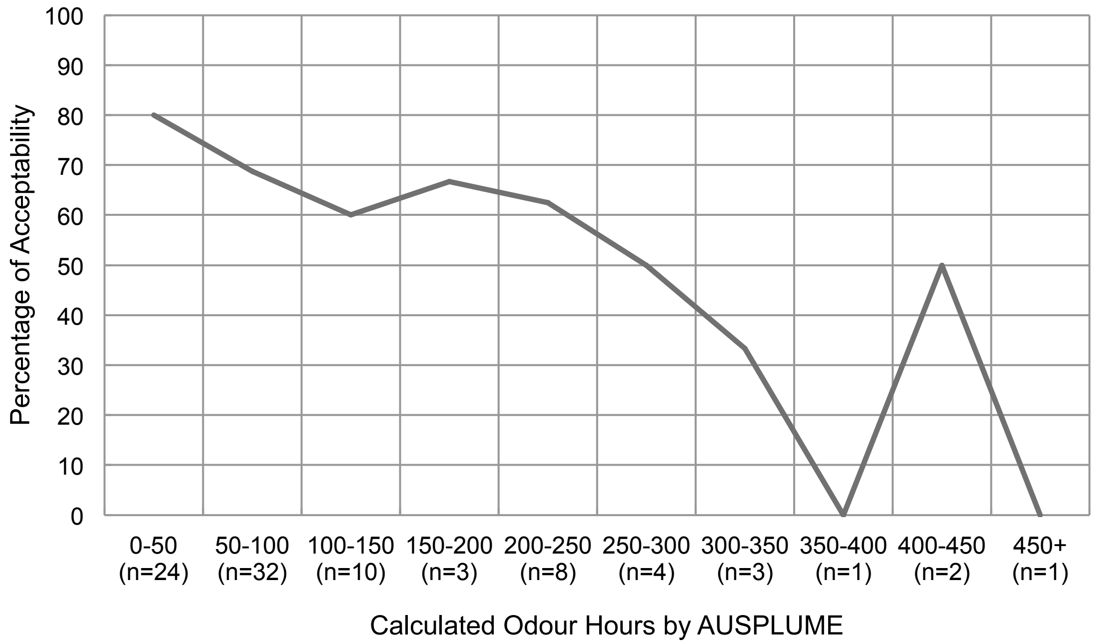

Figure 4. Percentage of acceptability at odour hours calculated by AUSPLUME

PRELIMINARY CONCLUSIONS

1. It appears that the odour annoyance could be assessed by face-to-face interviews with properly designed questionnaire.

2. The dispersion models could be used to quantify the odour exposure.

3. Although the results presented in this paper was preliminary and only limited data was collected, the plot of percentage of acceptability vs. odour hours predicted by dispersion models represented the trend of annoyance-exposure relationship for hog odour.

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REFERENCES

Forsberg, B.; Stjernberg, N.; Wall, S. People can detect poor air quality well below guideline concentrations: a prevalence study of annoyance reactions and air pollution from traffic. *Occup. Environ. Med*. 1997, 54, 44-48.

Guo, H., Y. Li, Q. Zhang and X. Zhou. 2006. Comparison of four setback models with field odour plume measurement by trained odour sniffers. *Canadian Biosystems Engineering*: 48 6.39-6.48.

Heinrich, J.; Gehring, U.; Cyrys, J.; Brauer, M.; Hoek, G.; Fischer, P.; Bellander, T.; Brunekreef, B. Exposure to traffic related air pollutants: self-reported traffic intensity versus GIS modeled exposure. *Occup. Environ. Med.* 2005, 62, 517-523.

Jacobson L.D., H.Guo, D.R. Schmidt, R.E. Nicolai, J. Zhu and K. Janni. 2000. Development of an odour setback determination tool for animal feedlots. ASAE Paper No.004044. St. Joseph, MI: ASAE.

Jacquemin, B.; Sunyer, J.; Forsberg, B.; Aguilera, I.; Briggs, D.; Götschi, T.; Heinrich, J.; Torén, K.; Vienneau, D.; Künzli, N. Association between annoyance and individuals' values of nitrogen dioxide in a European setting. *J. Epidemiol. Commun. Health* 2008, 62, e12.

La, A.; Allston, J.; Gao, Z.; Zhang, Q.; Guo, H. Assessing acceptable odour levels. *2011 CSBE/SCGAB Annual Conference*.

Modig, L.; Forsberg, B. Perceived annoyance and asthmatic symptoms in relation to vehicle exhaust levels outside home: across-sectional study. *Environ. Health.* 2007, 6, 29.

Oglesby, L.; Kunzli, N.; Monn, C.; Schindler, C.; Ackermann-Liebrich, U.; Leuenberger, P. Validity of annoyance scores for estimation of long term air pollution exposure in epidemiologic studies: the Swiss Study on Air Pollution and Lung Diseases in Adults (SAPALDIA). *Am. J. Epidemiol.* 2000, 152, 75-83.

Piro, F.N.; Madsen, C.; Naess, O.; Nafstad, P.; Claussen, B. A comparison of self-reported air pollution problems and GIS-modelled levels of air pollution in people with and without chronic diseases. *Environ. Health* 2008, 7, 9.

Williams, I.D.; Bird, A. Public perceptions of air quality and quality of life in urban and suburban areas of London. *J. Environ. Monit.* 2003, 5, 253-259.

Rotko, T.; Oglesby, L.; Kunzli, N.; Carrer, P.; Nieuwenhuijsen, M.J.; Jantunen, M. Determinants of perceived air pollution annoyance and association between annoyance scores and air pollution (PM2.5, NO2) concentrations in the European EXPOLIS study. *Atmos. Environ*. 2002, 36, 593-602.