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Industrial Hog Production and the Hog-barn Neighbourhood Effect in Lethbridge County, Alberta

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Hog production in North America and Western Europe is increasingly characterized by large-scale, capital intensive operations. These structural changes, combined with emerging spatial concentrations, have caused researchers to speculate that people living in the vicinity of hog barns may display some of the negative health effects that have already been well documented among hog-barn workers. This paper builds on three previous US-based studies, attempting to detect the presence of a hog-barn neighbourhood effect in the County of Lethbridge in southern Alberta. Results, while not definitive, are generally consistent with previous studies, indicating the possibility of this phenomenon in the region. The paper concludes that planning and development-control authorities should continue to apply the precautionary principle when considering development-permit applications for intensive livestock feeding operations.

Introduction

The Canadian swine sector has undergone a remarkable transformation over the last three decades or so. Key changes, which have also occurred in the United States (Hart and Mayda, 1997) and

Western Europe (Jongbloed and Lenis, 1998), include a decline in the number of individual hog operations, an increase in the scale of production, a rise in the degree of specialization, and widespread adoption of total confinement systems. We have also witnessed some noteworthy changes in the spatial distribution of hog production in Canada. Once highly concentrated in Québec and Ontario, other regions are now challenging the historical dominance of central Canada. Western Canada in general, and southern Manitoba and southern Alberta in particular, have each recorded some of the most substantial percentage increases in hog numbers in the country in recent years. Moreover, much of this growth has occurred in the context of very large, highly capitalized and specialized operations.

Coincident with these changes have been mounting concerns over the human health and quality of life implications of the trend toward large-scale industrial hog operations. A considerable amount of the research undertaken to date has focused on the health status of hog-barn workers, and a consensus now exists that, compared with the general population, hog-barn workers are more likely to exhibit a range of respiratory system ailments, suffer from mucous membrane syndrome, and present with a flu-like illness called organic dust toxic syndrome (see, for example, Von Essen and Konham, 1999). Questions regarding the "neighbourhood effect", namely the impact of large-scale hog operations on people living close to them, however, have attracted much less attention. Acknowledging that only a handful of studies have been published in the literature, there is some evidence to suggest that people living in the vicinity of large scale hog operations report many of the same symptoms as hog barn workers do, although not as severely, and experience a somewhat lower quality of life when compared with the general population. Nevertheless, it is too far early to draw general conclusions or to make any definitive statements regarding the applicability of research conducted in only two regions (Iowa and North Carolina) to other regions.

Consequently, the objective of this paper is to test for the existence of the hog-barn neighbourhood effect in the County of Lethbridge, which is located in southern Alberta's agricultural heartland. The question we ask is whether findings from research conducted in other places, where the hog-barn neighbourhood effect has been documented, can be replicated. Not only will this work contribute to the general literature on the question under investigation, but it is especially timely since the provincial government in Alberta has recently announced its intention to promote substantial expansion of the province's livestock sector, including hog production. Furthermore, concerns over the hog-barn neighbourhood effect have played a central role in heated debates in the province over several proposals for very large hog barns submitted over the last couple of years.

The paper comprises three sections. We start with an overview of what is known about the implications of large-scale, industrial hog production for humans in order to set the context. We then outline the research design used, and present and discuss our empirical results. The paper concludes with some general observations regarding the implications of our findings for local development control authorities.

Industrial Hog Production and Human Health

The odors we typically associate with swine operations come from a variety of volatile organic compounds (VOCs) and other odorants, and include ammonia and various sulfur and sulphide-containing compounds (see, for example, Hobbs et al, 1995). The product of the anaerobic decomposition of proteins and carbohydrates contained in hog manure and urine, Schiffman (1998) has identified four ways that VOCs can negatively affect humans. First, at sufficient concentrations, VOCs can be toxic (Shusterman, 1992). Because such concentrations are rare, however, even close to very large confined animal feeding operations (CAFOs), any health symptoms associated with VOCs are far more likely to be the product of non-toxicological mechanisms (Reynolds et al., 1997; McGinn et al., 2003). Secondly, VOCs have been shown in experimental research to irritate eyes, nose, and throat, and to cause headaches and drowsiness (see, for example, Hudnell et al, 1992). Third, neuro-scientists have known for some time that odors, including VOC's, can affect neuro-chemical activity which can impair a person's mood and performance (see, for example, Lorig et al, 1991). Finally, it has been shown that odors, acting as what Cann and Ross (1989) called context cues, can trigger memories that affect cognitive function, altering one's emotional state and mood (Herz and Engen, 1996).

As observed by Merchant et al (2002), concerns over the health effects of working in CAFOs is a relatively recent phenomenon, having been first raised in the 1970s (Donham et al, 1977). Nevertheless, the occupational risks faced by these workers have now been widely studied and "the scientific literature is quite clear that workers in swine or poultry CAFOs are at risk to diseases from concentrated emissions inside CAFOs" (Merchant et al, 2002: 136). However, the effects of large-scale, industrial hog operations on the health status and quality of life of people living in the vicinity of such operations, referred to in the literature as the "hog-barn neighbourhood effect", have received considerably less attention. To date only a few studies on the question have been published in the scientific literature.

In the first published study to examine the question, Schiffman et al (1995) used a psychological test known as the "Profile of Mood States Test" to compare a study group living close to large-scale hog operations with a control group. They found that the study group was much more likely to report being tense, depressed, angry, fatigued, and confused. The relationship between odours and health status, including mental state and mood is complex, and so "complaints of health effects from odors associated with livestock operations probably derive from a combination of physiological and psychogenic sources" (Schiffman, 1998: 1343). Nevertheless, despite a lack of understanding of the particular mechanism or combination of mechanisms at work, the research undertaken by Schiffman and her colleagues suggests that people living close to industrial-scale hog operations may confront risks that the general population does not, for no other reason than where they live.

In a second study, Thu et al (1997) matched 18 people living within 3.2 km (two miles) of a large swine operation (4,000 sows) with 18 demographically similar people living more than 3.2 km (two miles) away from the operation. Respondents identified which of 18 physical symptoms, organized into four clusters, they had experienced. The study group reported statistically significantly higher rates of respiratory symptoms (Cluster 1), headaches and plugged ears (Cluster 3) and burning eyes, runny nose, and sore throat (Cluster 4). No significant difference between the study and control groups in the incidence of nausea, dizziness, weakness, and fainting (Cluster 2) was found.

In a third study Wing and Wolf (1999) surveyed three groups of rural North Carolina residents collecting information on their health status and three quality of life indicators. Data were collected on 155 respondents in total, 55 from households located in the vicinity of a 6,000 head hog operation, 50 living in the vicinity of two intensive livestock operations, and 50 people from a rural agricultural area where none of the livestock operations stored or spread liquid manure. Consistent with the findings from studies of hog-barn workers, this research found that respondents in the vicinity of the hog operation reported significantly higher "occurrence of headaches, runny nose, sore throat, excessive coughing, diarrhea, and burning eyes" (Wing and Wolf, 1999: 233).

It is worthwhile at this point to echo the caution made by Merchant et al (2002: 138): "The three published, peer reviewed studies of community residents exposed to confined animal-feeding operation emissions are limited and should be interpreted with caution because of the relatively small numbers of participants, because they did not report environmental exposure data and likely contain some recall bias". Nevertheless, Merchant and his colleagues go on to observe that the studies are "notable because they were all well designed, controlled studies, and because two of the three that examined respiratory and other symptoms common among confined animal-feeding operation workers found similar symptom patterns (while not as prevalent or severe) as those observed among confined animal-feeding operation workers".

The Lethbridge County Study

In light of the findings reported in the literature and given the Alberta government's plans to promote expansion of the livestock sector, we set out to determine whether or not a hog-barn neighbourhood effect could be detected in the County of Lethbridge. The county is located in south-central Alberta, about 200 km south of Calgary. It is dominated by agriculture, although the City of Lethbridge, with a population of nearly 73,000, is an important educational, research, and administrative centre. The county has one of the highest concentrations of beef-cattle feedlots in Canada (Beaulieu et al, 2001), but there has also been a noteworthy increase in the number of large-scale hog operations over the last decade or so. The region's location relative to the US, its bio-physical setting, a secure supply of high-quality feed supported by irrigation agriculture, and a political climate long sympathetic to agriculture have combined to make the county very attractive to this form of investment. The decision in the early 1990s by Maple Leaf Foods, one of the Canada's largest meat packers, to devote its Lethbridge plant to hog processing has also been an important factor in the expansion of hog production in the county.

We began by developing and piloting our survey instrument. Using Thu et al (1997) and Wing and Wolf (1999) for guidance, our questionnaire comprised two sections. The first part asked for information on each respondent's age, gender, employment, tobacco use, residential history, and occupation. This was followed by a section in which respondents were presented with a list of 23 physical-health symptoms. Here we replicated the questions asked by Wing and Wolf (2000), who provided us with a copy of their questionnaire. Eighteen of the symptoms can be directly matched to those used by Thu el al (1997), whose published article contains a copy of their questionnaire.

We then obtained two maps from the County of Lethbridge Planning and Development Department. The first showed all of the approved intensive livestock operations in the county in operation at the time, categorized by livestock type, while the second map showed the locations of individual residences. Hog-operation locations were transferred to the second map and a 3.2 km (two-mile) radius was drawn around each unit to replicate the protocol used by Thu et al (1997). Households located within the specified zone and downwind of a hog operation were identified and used to draw the study group. Respondents living outside the study zone in any direction were allocated to the control group. Households from which the study group members were to be drawn were each assigned a unique identifier, and then selected randomly. Interviews concluded when the target number (n=30) was achieved. The control group was geographically stratified in order to avoid encountering unforeseen localized problems such as possible groundwater contamination.

Many of the symptoms included on the survey are often unreported (they are not life threatening), and so, acting on the advice of the Medical Officer of Health for the Chinook Health Region, the interviewer made sure to stipulate that respondents should answer in the affirmative if the symptom had been experienced, whether or not medical attention had been sought. Since growth in the number of large, intensive livestock-feeding operations in the region has been a matter of heated debate in recent years, the study was introduced as "an investigation of the health status of rural residents in the County of Lethbridge" in order to reduce the possibility of respondent bias. The survey was administered in face-to-face interviews during the late winter and early spring of 2003 to one person aged 18 or over per identified household. Potential respondents employed on a hog operation at the time of the interview were excluded from the study.

In order to achieve a target of 60 participants overall, 83 potential respondents were contacted, 44 potential study group members and 39 potential control group members. The refusal rate for potential study group members was 31.8% and for the control group 23.7%. Because we neglected to record basic demographic information for those who refused to participate in the survey, we were unable to consider non-response bias.

Following the collection of basic demographic information, respondents were asked to indicate on a 5-point scale (never, rarely, sometimes, often, and very often) the frequency of occurrence of 21 specific physical-health symptoms over the six months prior to being interviewed. For purposes of this paper we have collapsed the 21 symptoms into five separate symptom clusters (see Table 1). The first four clusters are consistent with the categories used by Thu et al (1997), grouping symptoms that have been found in empirical studies in combination with one another. The final category is, more or less, a "catch all" one.

Table 1 The Physical Health Symptoms Included in the Survey

Cluster #	Symptoms in Cluster	Comments
1	Coughed up Mucus or Phlegm, Excessive Coughing, Wheezing, Tightness in Chest, and Shortness of Breath	According to Thu et al, these symptoms are associated with "chronic bronchitis and hyperreactive airways.
2	Felt faint/dizzy, Fainted, Felt Weak, Nausea, and Lack of Appetite	Thu et al (1997: 18) observed that Auger et al (1994) argued that these symptoms suggest "long term exposure to less than acutely toxic levels of endotoxin and hydrogen sulfide".
3	Headaches and Plugged Ears	These symptoms, which have been found in up to 25% of hog-barn worker in at least one study (Donham, 1993), are often associated with chronic sinusitis.
4	Burning Eyes, Runny Nose, Scratchy Throat, Teary Eyes, and Burning Nose	These symptoms are associated with a condition called mucus membrane irritation (Thu et al, 1997).
5	Fever, Trouble Hearing, Joint and/or Muscle Pain, Trouble any specific condition or syndrome.	Symptoms in this cluster are not associated with Sleeping, and Sore Throat*

*The final two symptoms in Cluster #5 were included in Wing and Wolf (2000), but not in Thu et al (1997).

Results and Interpretation

The characteristics of the study and control groups were quite similar. The majority of respondents in each group were women (73% and 60% respectively) and all but one person in each group were non-smokers. The average age of the control group (48 years) and the study group (51 years) was also similar. Of the 31 respondents who answered the question about their occupation, 20 (8 study group and 12 control) told us there were employed in agriculture, while the rest were employed primarily in the tertiary sector. These results were expected since agriculture is an important activity in the County of Lethbridge. Finally, respondents lived an average 20 years in their place of residence (19 years for the study group and 21 years for the control group). Because the control and study groups were so similar, any differences observed between the two groups are unlikely to stem from demographic differences.

Table 2 summarizes the results of data collected regarding the health status of the respondents during the in the six months prior to the study. In order to meet the requirements of the Chi-square test vis-à-vis expected values, we have collapsed the response categories from 5 to 2. Specifically, "never" and "rarely" have been combined in the first response category, while "sometimes", "often" and "very often" have been grouped together.

Table 2 Frequency of Clustered Health Symptoms Experienced by Study and Control Groups

Cluster Number	Never or Rarely		Sometimes to Very Often		Total	Chi-Square Calculated Value	Stat. Sig. Diff at 95% (_2critical = 3.841)
	Study Group	Control Group	Study Group	Control Group			
1	142	145	8	5	300	1.02	No
2	134	143	16	7	300	3.82	No
3	36	47	24	13	180	4.74	Yes
4	130	140	20	10	300	3.72	No
5	139	156	41	24	360	5.42	Yes

As shown in Table 2, for every cluster of symptoms, the number of control group members experiencing various symptoms within the clusters "sometimes", "often" or "very often" exceeds the number of control group members. Similarly, more of the control group members reported experiencing the various symptoms comprising the five clusters "never" or "rarely" as compared to the study group. As regards the sample data, then, our findings are indicative of the existence of a hog-barn neighbourhood effect and are consistent with expectations based on the literature.

The seventh column in Table 2 reports the results of the Chi-square tests that were undertaken to look for statistically significant differences in terms of the experiences of the study and control groups. For two of the five symptom clusters, Cluster 3 which is indicative of chronic sinusitis and has been well documented amongst hog-barn workers, and Cluster 5 which was our "catch all" category, the reporting incidence for the study group is significantly higher than for the control group at the 95% (_ = 0.05) confidence level. However, if we relax our confidence level to 90%, then we find statistically significant differences between study and control groups for all but one of the symptom clusters (Cluster 1). Interestingly, Thu et al (1997) found that respondents living in the vicinity of large-scale intensive livestock feeding operations reported significantly higher rates of symptoms contained in this cluster.

These results, both for the sample data and from the inferential testing, are consistent with the general picture painted by previous studies, and are indicative of the existence of a hog-barn neighbourhood effect in the study area. However, the absolute number of respondents reporting the various symptoms beyond the rare occurrence is relatively low, and with the exception of Cluster #3, the margin of difference between the number of respondents occupying the "never or rarely" category as compared to the number in the "sometimes to very often" category, is large. Consequently, having produced results that are generally consistent with previous studies but not startlingly definitive, we now face the task of explaining our findings. Given that our study was broadly similar in research design, even to the point of replicating many of the questions used by previous researchers, we should first identify any regional differences that might account for our findings. Because Wing and Wolf's work was conducted in North Carolina's coastal plain, we will use Duplin County, which is located in heart of North Carolina's southern coastal plain hog belt, for purposes of comparison.

To begin, as observed by Furuseth (1997), North Carolina's hog sector has been at the forefront of the adoption of the split-phase production model of industrial hog production. Under this system, animals are moved between highly specialized structures each dedicated to a specific phase of the swine life-cycle (viz, farrowing, weaning and then finishing). Feed rations are designed to maximize daily weight gain for each specific phase. Animals may also be separated by sex. First employed in the poultry industry, this system is highly specialized, capital intensive and sensitive to economies of scale. It has yet to be widely adopted in southern Alberta and so, not surprisingly, the average hog operation in Duplin County in 1997 housed 5,086 animals, as compared with an average of 1,309 in the County of Lethbridge, indicating a substantial difference in the scale of production.

Adoption of the split-phase production model also tends to result in increasing geographic concentrations of individual barns at the local scale as a means of reducing animal mortality and controlling transport costs when animals are moved between structures. Here again, we observe a difference between our two regions in terms of hog densities. According to the US Census of Agriculture, the density of hogs in Duplin County in 1997 was 1,545 swine per square kilometer, whereas according to the 2001 Canadian Census of Agriculture, the density of hogs in County of Lethbridge is considerably lower (47 hogs per square kilometer).

We should also take into account some climatic differences between southern Alberta and eastern North Carolina, specifically differences in the potential for the dispersion of hazardous agents by wind. For those familiar with southern Alberta it will come a little surprise that it is one of the windier regions in the country. Based on 30-year climate norms obtained from Environment Canada, the Lethbridge area experiences an average annual wind speed of 18.2 km/hr, with average monthly wind speeds ranging from a low of 14.3 km/hr in August to a high of 21.2 km/hr in January. By contrast, the Raleigh-Durham region is less windy with an average annual wind speed of 11.9 km/hr, and a range in mean monthly wind speeds from 9.1 km/hr in August to 16.2 km/hr in March. The wind dispersion thesis may help explain why McGinn et al (2003: 1173) found that concentrations of atmospheric ammonia, volatile fatty acids and other odorants "declined sharply with distance" away from large-scale beef feedlots.

A fourth factor that might help explain our findings relates to differences in the land-use policies having to do with negative externalities generated by livestock operations, especially odours. Odours are a natural product of livestock production and are, to some extent, unavoidable. However, land-use planning has developed several tools to limit their impact. In areas where confined-feeding operations are permitted, planners often apply a minimum distance separation formula, or use a set-back policy to distance these operations from other land uses. In Lethbridge County, for example, provincial guidelines stipulating minimum distance separations between confined-feeding operations and "other significant buildings", have been employed in the county for nearly 20 years (Paladino, 2004), even though they have only recently been made binding. By contrast, Osterberg and Melvin (2002) report that local planning restrictions vis-à-vis hog operations in North Carolina are generally less strict and less widely adopted. Moreover, recent court decisions striking down county-level planning ordinances concerning CAFO's in two North Carolina counties have placed similar ordinances throughout the state in question (Osterberg and Melvin, 2002).

Fifth, there is evidence in the literature to suggest that our sample may have been desensitized to the effects of odours associated with hog-related emissions. To illustrate, Wysocki et al (1997) tested workers who had repeatedly been exposed to acetone and butanol and found that when compared with a control group, the exposed workers were able to withstand higher concentrations before detecting the odours and even higher concentrations before reporting irritation. If we translate these findings to our study and take into account that a majority of our respondents (both study and control group members) were long-time rural residents, many of whom were also employed in agriculture, then it is possible that a substantial number of people in our sample may have also undergone a similar process of desensitization. Now let us turn our attention to the North Carolina case. Even though hog production has long been part of the agricultural fabric in eastern North Carolina, the rate of growth in the number and concentration of very large industrial hog operations has been stunning in comparison to the situation in southern Alberta (Furuseth, 1997). Consequently, it is conceivable the rapid rate of industry expansion, combined with its spatial concentration and density, have not enabled a similar adaptation processes to occur.

Our final observation concerns two elements in our research design. First, by conducting the interviews during the late winter and early spring, and having respondents report on their experiences during the six months previous, we focused on a period of time during which it is unlikely that respondents would have been spending extended periods of time out-of-doors or would have had windows open in their homes for appreciable periods of time. Had we been able to administer our survey in the fall, perhaps different results may have been produced. Secondly, because many of the symptoms listed in our questionnaire go unreported, we relied on respondents to recall whether or not they had experienced the various symptoms in the six months prior to being interviewed.

Given the problems of recall, the possibility of some symptoms being under-reported cannot be discounted.

Conclusion

Over the past several decades, hog production in North America, as elsewhere, has undergone a remarkable transformation. Large-scale, capital intensive, confined feeding systems have become the norm in many regions. These changes have transformed local landscapes and economies, increasingly embedding local areas in global systems of production, processing, distribution and consumption. Proliferation of industrial hog production has also sparked much concern over the consequences of this phenomenon for the health and well being of humans. Most of the research to date has focused on the health status of hog-barn workers, and we now know that this group is at significantly greater risk than the general population for a variety of ailments. More recently scientists have turned their attention to the possibility that populations living in the vicinity of industrial hog operations face risks similar to hog-barn workers. The "hog-barn neighbourhood effect" has been documented in three studies conducted in the United States, two in North Carolina and one in Iowa, and has figured prominently in debates over the construction of new hog operations in many parts of Canada, including southern Alberta where the study reported here was undertaken.

Our work replicated previous research on the hog-barn neighbourhood effect, and produced results that suggest the existence of this phenomenon in southern Alberta, although perhaps at a lower level than elsewhere. The problem might be more prevalent than our findings indicate, however, and we were just not able to detect it. Alternatively, the hog-barn neighbourhood effect could be less problematic in the County of Lethbridge than elsewhere owing to regional differences in (1) the structure of hog production, (2) the bio-physical environment, (3) local planning policy, or (4) in the rate and magnitude of growth of the industry.

Even if we accept the second of these two positions, namely that the hog-barn neighbourhood effect is less problematic in southern Alberta than elsewhere, it does not follow that development authorities should abandon employing the the precautionary principle when considering permit applications for large-scale hog operations. Indeed, our results may well underscore the effectiveness of the precautionary principle. Given experience elsewhere, there is little reason to believe that, if the number, size, and density of hog barns goes unchecked, and especially if the split-phase production system becomes more widely adopted, a threshold will not be met beyond which hog-barn emissions will become a greater problem than they appear to be today. Based on available evidence, no one can conclusively identify where that threshold is. However, once it has been exceeded, human health will be negatively affected and remedial action will be prohibitively expensive. Development authorities face a difficult and unenviable task. Confronted with much scientific uncertainly, they must strike a balance between the legitimate interests of producers and investors, and local residents who increasingly expect environmental quality to be preserved and enhanced. Clearly, more research needs to be done to reduce these uncertainties.

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Notes

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References

Auger, P.P. Gourdeau and J. Miller (1994). Clinical experience with patients suffering from a chronic-like syndrome and repetitious upper respiratory infection in relation to airborne molds. *American Journal of Industrial Medicine*, 25(1): 41-42.

Beaulieu, M.S., Bedard, F., and Lanciault, P. (2001). Distribution and Concentration of Canadian Livestock. Agricultural and Rural Working Paper Series, Working Paper No. 47, Agriculture Division, Statistics Canada, Ottawa.

Cann, A., and Ross, D. (1989). Olfactory stimuli as context cues in human memory. *American Journal of Psychology*, 102, 91-102.

Donham. K.J. (1993). Respiratory disease hazards to workers in livestock and poultry confinement structure. *Seminars in Respiratory Medicine*, 14(1): 49-58.

Donham. K.J., Rubino, M., Thedell, T.D., Kammermeyer, J. (1977). Potential health hazards to agricultural workers in swine confinement buildings. *Journal of Occupational Medicine*, 19, 383-387.

Furuseth, O.J. (1997). Restructuring of hog farming in North Carolina: Explosion and implosion. *Professional Geographer*, 49, 391-403.

Hart, J.F., and Mayda, C. (1997). Pork palaces on the panhandle. *Geographical Review*, 87: 397-400.

Herz, R.S., and Engen, T. (1996). Odor memory: Review and analysis. *Psychological Bulletin Review*, 3, 300-313.

Hobbs, P., Pain, B.F., Misselbrook, T.H. (1995). Odorous compounds and their emission rates from livestock waste. In Proceedings of the International Livestock Odor Conference '95, New Knowledge in Livestock Odor Solutions (pp.11-15) Ames: Iowa State University.

Hudnell, H.K., Otto, D.A., House, E., and Molhave, L. (1992). Exposure of humans to a volatile organic mixture. *Archives of Environmental Health*, 47, 31-38.

Jongbloed, A.W., and Lenis, N.P. (1998). Environmental concerns about animal manure. *Journal of Animal Science*, 76: 2641-2648.

Lorig, T.S., Huffman, E., DeMartino, A., and DeMarco, J. (1991). The effects of low concentration odors on EEG activity and behavior. *Journal of Psychophysiology*, 5, 69-77.

McGinn, S.M., Janzen, H.H., and Coates, T. (2003). Atmospheric ammonia, volatile fatty acids, and other odorants near beef feedlots. *Journal of Environmental Quality*, 32, 1173-1182.

Merchant, J.A., Kline, J., Donham, K.J., Bundy, D.S., and Hodne, C.J. (2002). Human Health Effects. In J.A. Merchant and R.F. Ross (Eds.), *Iowa Concentrated Animal Feeding Operation Air Quality Study* (pp. 121-145). Environmental Health Sciences Research Center, The University of Iowa, Iowa City, Iowa.

Osterberg, D., and Melvin, S.W. (2002). Relevant Laws, Regulations and Decions. In J.A. Merchant and R.F. Ross (Eds.), *Iowa Concentrated Animal Feeding Operation Air Quality Study* (pp. 184-201). Environmental Health Sciences Research Center, The University of Iowa, Iowa City, Iowa.

Paladino, N, (2004). Personal Communication. Supervisor, Planning and Development, County of Lethbridge, (July 15).

Reynolds, S.J., Donham, K., Stookesberry, J, Thorne, P.S., Subramanian, P., Thu, K., and Whitten, P. (1999). Air quality assessments in the vicinity of swine production facilities. *Journal of Agromedicine*, 4, 37-46.

Schiffman, S. (1998). Livestock odors: implications for human health and well being. *Journal of Animal Science*, 76, 1343-1355.

Schiffman, S.S., Stattely-Miller, E.A., Suggs, M.S., and Graham B.G. (1995). The effect of environmental odors emanating from commercial swine operations on the mood of nearby residents. *Brain Research Bulletin*, 37, 369-375.

Shusterman, D. (1992). Critical Review: The health significance of environmental odor pollution. *Archives of Environmental Health*, 47: 76-87.

Thu, K., Donham, K., Ziegenhorn, R., Reynolds, S., Thorne, P.S., Subramanian, P., Whitten, P., and Stookesberry, J. (1997). A control study of the physical and mental health of residents living near a large-scale swine operation. *Journal of Agricultural Safety and Health*, 3, 13-26.

Von Essen, S., and Konham, K. (1999). Illness and injury in animal confinement workers. *Occupational Medicine: State of the Art Reviews*, 14: 337-350.

Wing, S. and Wolf, S. (1999). Intensive livestock operations, health and quality of life among eastern North Carolina residents. *Environmental Health Perspectives*, 102, 233-239.

Wysocki, C.J., Dalton, P., Brody, M.J., and Lawley, H.J. (1997). Acetone odor and irritation thresholds obtained from acetone exposed factory workers and from control (occupationally unexposed) subjects. *American Industrial Hygiene Association Journal*, 58, 704-712.