Intensive Livestock Operations, Health, and Quality of Life among Eastern North Carolina Residents

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People who live near industrial swine operations have reported decreased health and quality of life. To investigate these issues, we surveyed residents of three rural communities, one in the vicinity of an approximately 6,000-head hog operation, one in the vicinity of two intensive cattle operations, and a third rural agricultural area without livestock operations that use liquid waste management systems. Trained interviewers obtained information about health symptoms and reduced quality of life during the previous 6 months. We completed 155 interviews, with a refusal rate of 14%. Community differences in the mean number of episodes were compared with adjustment for age, sex, smoking, and employment status. The average number of episodes of many symptoms was similar in the three communities; however, certain respiratory and gastrointestinal problems and mucous membrane irritation were elevated among residents in the vicinity of the hog operation. Residents in the vicinity of the hog operation reported increased occurrences of headaches, runny nose, sore throat, excessive coughing, diarrhea, and burning eyes as compared to residents of the community with no intensive livestock operations. Quality of life, as indicated by the number of times residents could not open their windows or go outside even in nice weather, was similar in the control and the community in the vicinity of the cattle operation but greatly reduced among residents near the hog operation. Respiratory and mucous membrane effects were consistent with the results of studies of occupational exposures among swine confinement-house workers and previous findings for neighbors of intensive swine operations. Long-term physical and mental health impacts could not be investigated in this study. *Key words:* African Americans, agricultural health, air pollution, epidemiology, respiratory conditions, rural health. *Environ Health Perspect* 108:233–238 (2000). [Online 8 February 2000]
http://ehpnet1.niehs.nih.gov/docs/2000/108p233-238wing/abstract.html

Industrial hog production has grown rapidly in North Carolina since the early 1980s. Once characterized by relatively small independently owned farms scattered across the state, hog production in North Carolina is now concentrated in the coastal plain region, under the domain of large corporate growers, and dominated by large-scale intensive operations (*1,2*). Persons who live near large hog operations have reported reduced quality of life as well as health problems related to airborne emissions from animal confinement houses, open waste lagoons, and spray fields (*3–8*). Airborne emissions include hydrogen sulfide, ammonia, dusts, endotoxins, and complex mixtures of volatile organic compounds. Health effects from environmental exposures could occur through inflammatory, immunologic, irritant, neurochemical, and psychophysiologic mechanisms (*5*).

In contrast to the many studies of occupational exposures of swine confinement-house workers (*9–25*), only a few field studies have investigated the health effects of lower level environmental exposures. In a study of residents near hog facilities in North Carolina, Schiffman et al. (*26*) reported that persons exposed to odors from intensive hog operations experienced "more tension, more depression, more anger, more fatigue, and more confusion" than a group of unexposed persons. A study in Iowa (*7*) compared physical and mental health symptoms among people residing within a 2-mile radius of a 4,000-head swine operation and a control group in an area with no intensive livestock operation. Those who lived in the vicinity of the intensive hog operation reported higher frequencies of 14 of 18 physical health symptoms, especially respiratory symptoms. The Iowa study did not find an excess of mental health symptoms but, in contrast to the North Carolina study (*26*), it was not designed to evaluate symptoms at the time that odors were present.

The present study addressed a number of issues raised by previous research. Unlike studies of volunteers, the sample was drawn systematically from defined populations. To increase the levels of participation and prevent exclusions based on literacy or the ability to participate in a longer study, we did not ask participants to keep a diary or respond to questions at the times that airborne emissions from livestock operations were noticeable. Instead, we asked questions about the number of times that participants experienced the symptoms of interest during the previous 6 months. Because mood disturbance and mental health effects may be acute responses to the presence of odors, we focused on physical health and quality of life rather than on short-term mood changes. We achieved high levels of participation in the study by establishing cooperative relationships with local community based organizations in planning and conducting the research.

This study compared health symptoms in residents of three North Carolina communities, one in the vicinity of an intensive hog operation, one in the vicinity of two intensive cattle operations, and a third in a rural agricultural area where no livestock operations used liquid waste management systems. Although the primary motivation for the study came from an interest in airborne emissions from swine operations, the inclusion of people residing near cattle operations afforded an opportunity to examine possible health effects from a different kind of livestock, and also offered a second comparison community that may share other features common to communities with intensive livestock production.

Materials and Methods

Selection of communities. The North Carolina Division of Water Quality (Raleigh, NC) maintains a database on intensive livestock operations that use liquid waste management systems (*27*). Information on livestock operations included in the database as of January 1998 was merged with 1990 U.S. Census block group data (U.S. Census Bureau, Suitland, MD). Data for block groups, which average approximately 500 households, included information on population size, race, and poverty levels. Maps of the eastern part of North Carolina

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We thank the community members and organizations, without whom this research would not have been possible. We also thank J. Emery for the coordination of field work, E. Gregory for analytical programming and data management, and R. Avery, M. Garvin, and S. Jackson for interviewing community residents.

This research was supported by the North Carolina Department of Health and Human Services Division of Public Health and National Institute of Environmental Health Sciences grant R25-ES08206-04 under the Environmental Justice: Partnerships for Communication program.

Received 14 July 1999; accepted 29 September 1999.

were prepared showing the locations of livestock operations, towns, roads, and churches. Community consultants experienced with the hog industry and the health concerns of community members met with university researchers to review the maps and choose potential study sites. Our goal was to choose three areas with similar economic and demographic characteristics where residents would be willing to participate in an interview and where existing community based organizations would be interested in working with researchers. We sought livestock areas with 80–100 households within a 2-mile radius of the livestock facility so that we would be able to obtain approximately 50 participants in each area.

The hog and cattle study areas were defined by a < 2-mile radius around the operations and each study area was contained within a single census block group. The hog operation was a feeder-to-finish facility with a head capacity of approximately 6,000, a steady-state live weight of approximately 800,000 pounds, and one lagoon. The cattle community contained two neighboring dairy operations with a combined head capacity of approximately 300, live weight of approximately 200,000 pounds, and two lagoons. The area with no intensive livestock operations extended across two block groups. Parts of two block groups were included to ensure that eligible households were at least 2 miles away from any livestock operation using a liquid waste management system. The median annual family income of the census block groups from which the study areas were chosen ranged from approximately $17,000–23,000 and the populations were between 65 and 90% African American.

All habitable dwellings in the study areas were enumerated. The location of each dwelling was noted on an enlarged area map and was assigned a unique study number. Information on street or road location and the type of dwelling was entered into a computerized database.

Questionnaire. A structured questionnaire was developed based on previous research findings and on discussions with community members who had experienced exposures from intensive livestock operations. In addition to symptoms identified by previous studies or community residents as possibly related to airborne emissions from livestock operations, we included symptoms that we did not believe would be related to airborne emissions to evaluate the possibility that residents of exposed communities might report excesses of all types of symptoms because of negative feelings about intensive livestock operations. The questionnaire was designed to obtain information about the frequency of occurrence of each symptom over the 6 months preceding the interview. Possible responses were never; rarely (once or twice over the past 6 months); sometimes (1–3 times per month); often (1 per week); and very often (twice a week or more over the past 6 months). After all of the structured questions had been asked, respondents were asked about aspects of the environment that may have affected their own health or the health of others in the household. Interviewers took notes to summarize the types of responses. At the end of the interview, participants were asked their age, occupation, household size, source of drinking water, and whether they or others in the household smoked tobacco. The interviewers recorded race, sex, and whether anyone other than the participant and interviewer were present during the interview.

Household interviews. Adults 18 years of age or older with no serious speech or mental impairment who lived in the current residence for 6 months or longer were eligible to respond to the questionnaire. The households of dairy operators who lived beside the cattle facility were excluded to avoid the complication of occupational exposures; the household of the swine facility operator was not within the 2-mile enumeration area of the facility. Interviews were conducted on Fridays and Saturdays in January and February 1999 by university-based staff. Interviewers were accompanied by a community consultant, a local resident recruited from the membership of the community based organization. The community consultant introduced the interviewer to the prospective respondent, explained the purpose and importance of the survey, and encouraged each person to participate. Interviewers were trained to administer the survey instrument systematically and uniformly to all respondents. The participant interview was conducted in a location of the participant's choosing. The questionnaire required less than 15 min to complete. The community consultant was not present for the interview unless the participant specifically asked the consultant to remain.

One adult from each household was invited to participate in the survey. Preference was given to the first person to answer the door if

Table 1. Characteristics of study households, listed by type of livestock operation.

Characteristic	Livestock operation			
	None	Cattle	Hogs	Total
Inhabited houses	104	116	92	312
Households ineligible[a]	5	2	3	10
Not home	29	44	19	92
Rescheduled or not contacted	5	14	10	29
Completed interviews	50	50	55	155
Refused	15	6	5	26
Refusal rate[b]	23.1%	10.7%	8.3%	14.4%

[a]Not living in the house for 6 months; difficulty understanding survey questions. [b]Refusal rate = completed interviews/completed interviews + refusals.

Table 2. Characteristics of respondents.

Characteristic	Livestock operation, no. (%)			
	None	Cattle	Hogs	Total
Age				
19–44 years	19 (38)	13 (26)	23 (42)	55 (36)
45–64 years	19 (38)	19 (38)	20 (36)	58 (37)
65–90 years	12 (24)	18 (36)	12 (22)	42 (27)
Race/ethnicity				
African American	45 (90)	49 (98)	48 (87)	142 (92)
White	5 (10)	1 (2)	6 (11)	12 (8)
Latino	0 (0)	0 (0)	1 (2)	1 (1)
Sex				
Female	31 (62)	33 (66)	36 (65)	100 (65)
Male	19 (38)	17 (34)	19 (35)	55 (35)
Smoking				
Yes	14 (28)	13 (26)	7 (13)	34 (22)
No	36 (72)	37 (74)	48 (87)	121 (78)
Employed outside of the home				
Yes	26 (52)	15 (30)	34 (62)	75 (48)
No	24 (48)	34 (68)	21 (38)	79 (51)
Not completed	0 (0)	1 (2)	0 (0)	1 (1)
Number in household				
1	12 (24)	8 (16)	3 (5)	23 (15)
2	21 (42)	21 (42)	20 (37)	62 (40)
3–4	12 (24)	15 (30)	15 (27)	42 (27)
5–12	5 (10)	6 (12)	17 (31)	28 (18)
Total respondents (*n*)	50 (100)	50 (100)	55 (100)	155 (100)

the person was over 18 years old and lived in the household. Those who declined to participate because the time was inconvenient were offered alternative times and the visit was rescheduled. If no one was at home, the information was recorded on the tracking form. These households were visited a second time. Households were visited sequentially using the enumeration map in approximate order of distance from the intensive livestock operation until a minimum sample size of 50 was reached. Informed consent was requested verbally by the trained interviewer.

Statistical methods. Differences in symptoms among the three communities were evaluated by comparing the average number of episodes experienced over the last 6 months for each symptom. The number of episodes over the 6 months preceding the interview was scored according to the instructions given to respondents for responding to the frequency of symptoms. A response of "never" corresponded to 0 episodes. A response of "occasionally" corresponded to two episodes. "Sometimes" corresponded to 12 episodes (2/month), "often" corresponded to 26 episodes (1/week), and "very often" corresponded to 52 episodes (2/week). Adjusted mean differences in the numbers of episodes were calculated using linear regression to control for sex, age (19–44, 45–64, or 65–90 years), respondent's smoking status (yes or no), and employment outside the home (yes or no). These variables were considered potential confounders because they may be associated with exposure to airborne emissions and experience or reporting of symptoms. Because the five response categories for the number of episodes were highly skewed, regression models were also run with the dependent variable coded as the square root of the number of episodes and as 0–4.

The ratio of the β-coefficient (adjusted mean difference in number of episodes) to its SE yields a t-value. Larger absolute values of t indicate that the livestock variable is more important for statistically predicting numbers of symptom episodes. Significance tests are not presented because exposures were not randomized in this observational study; however, t-values > 1.66 would produce a significant one-tailed test of the hypothesis that average numbers of symptoms are greater in the livestock than in the control community at $p < 0.05$. Values > 1.98 would produce a significant two-tailed test at $p < 0.05$.

Table 3. Number and percent of respondents reporting 12 or more episodes, and mean number of episodes.

	Livestock operation					
	None		Cattle		Hogs	
Symptom	No. (%)[a]	Mean[b]	No. (%)[a]	Mean[b]	No. (%)[a]	Mean[b]
Total respondents	50 (100.0)	–	50 (100.0)	–	55 (100.0)	–
Upper respiratory/sinus						
Headache	16 (32.0)	7.8	18 (36.0)	9.4	34 (61.8)	15.5
Stuffy nose/sinuses	14 (28.0)	7.2	17 (34.0)	8.8	24 (44.4)	10.2
Runny nose	8 (16.0)	3.9	10 (20.0)	5.4	16 (29.1)	8.5
Burning nose/sinuses	11 (22.0)	4.1	9 (18.0)	3.4	14 (25.5)	6.7
Sore throat	2 (4.0)	0.9	6 (12.0)	2.5	9 (16.4)	4.7
Plugged/popping ears	10 (20.0)	5.5	11 (22.0)	5.2	11 (20.0)	4.6
Scratchy throat	6 (12.0)	2.2	10 (20.4)	3.8	10 (18.2)	4.4
Lower respiratory						
Mucus/phlegm	14 (28.0)	5.9	14 (28.6)	7.2	16 (29.1)	8.5
Excessive coughing	5 (10.0)	1.8	6 (12.0)	3.7	12 (21.8)	6.3
Shortness of breath	12 (24.0)	7.0	13 (26.0)	6.1	11 (20.0)	5.5
Tightness in chest	6 (12.0)	3.0	9 (18.0)	4.9	11 (20.0)	3.9
Wheezing	8 (16.0)	4.4	7 (14.0)	3.7	9 (16.4)	3.6
Strange breathing sounds	10 (20.0)	5.2	5 (10.2)	3.0	6 (10.9)	2.3
Gastrointestinal						
Heartburn	10 (20.4)	5.2	10 (20.0)	8.1	17 (30.9)	7.1
Nausea/vomiting	7 (14.0)	3.0	7 (14.0)	4.8	15 (27.3)	5.9
No appetite	8 (16.0)	2.8	8 (16.3)	4.1	12 (21.8)	5.5
Diarrhea	2 (4.0)	1.7	4 (8.2)	1.3	10 (18.2)	4.3
Skin/eye irritation						
Burning eyes	8 (16.0)	3.8	5 (10.0)	3.4	19 (35.2)	9.4
Tearing eyes	16 (32.0)	9.5	14 (28.0)	8.7	20 (36.4)	9.3
Dry/scaly skin	10 (20.0)	4.4	11 (22.0)	7.1	12 (21.8)	7.1
Skin rash or irritation	4 (8.0)	1.6	4 (8.0)	2.0	8 (14.6)	4.0
Skin redness	1 (2.0)	1.2	0 (0.0)	0.1	4 (7.3)	1.3
Miscellaneous						
Joint/muscle pain	24 (48.0)	16.1	26 (52.0)	17.2	28 (50.9)	16.7
Unexplainably tired	19 (38.0)	12.8	19 (38.0)	10.5	23 (41.8)	13.7
Blurred vision	15 (30.0)	8.8	9 (18.0)	5.4	16 (29.6)	9.7
Dizzy/faint	11 (22.0)	5.5	10 (20.0)	5.3	12 (21.8)	4.1
Hearing problems	7 (14.0)	7.4	5 (10.0)	2.0	6 (10.9)	2.7
Chest pain	10 (20.0)	3.4	6 (12.0)	1.6	6 (10.9)	2.7
Fever/chills	5 (10.0)	2.3	2 (4.0)	1.2	5 (9.3)	1.9
Fainted	0 (0.0)	0.04	0 (0.0)	0.04	1 (1.9)	1.0
Quality of life						
Can't open windows	7 (14.3)	3.2	4 (8.2)	1.8	31 (57.4)	18.5
Can't go outside	5 (10.0)	2.1	3 (6.0)	1.2	30 (55.6)	15.4

[a]Number and percentage of respondents answering sometimes (1–3 times/month), often (1/week), and very often (≥ 2 times/week over the past 6 months). [b]Average number of episodes per person over 6 months.

Results

Table 1 shows the numbers of households enumerated and surveyed. Enumerated households were within 2 miles of an intensive livestock operation in the cattle and hog communities. In the control area, enumerated households were > 2 miles from an intensive livestock operation in the control area. Approximately 100 households were enumerated in each area. Fifty interviews were completed in the cattle and control communities, and 55 interviews were completed in the hog community. The refusal rate was 23.1% in the control community, 10.7% in the cattle community, and 8.3% in the hog community.

Characteristics of the respondents are shown in Table 2. The cattle community had the largest proportion of respondents older than 65 years of age. All three communities were predominantly African American. Approximately two-thirds of the participants were female. The proportion of respondents who reported smoking tobacco was lower in the hog community than in the other two communities, whereas the proportion employed outside of the home was higher. None of the study participants reported that they worked in the livestock industry. Household size was largest in the hog community.

Responses to the symptom questions in the three communities are shown in Table 3. The symptoms were categorized in six groups: upper respiratory and sinus, lower respiratory, gastrointestinal, skin and eye irritation, miscellaneous, and quality of life. For each community we tallied the number of persons who answered "sometimes," "often," or "very often" corresponding to ≥ 12 episodes during the 6-month period. Table 3 also shows the percentage of "sometimes" or more often and the average number of episodes for the 6 months.

Most of the percentages in Table 3 are < 50; the majority of participants responded "never" or "occasionally" to most of the symptom questions. Among the upper respiratory and sinus conditions, the percentage of respondents reporting ≥ 12 episodes was the largest in the hog community except for

plugged ears and scratchy throats. Percentages were generally intermediate in the cattle community. The percentage of respondents reporting ≥ 12 episodes was generally smaller for lower respiratory, gastrointestinal, and skin or eye irritation symptoms. Percentages were the highest in the hog community for all four gastrointestinal symptoms. In all three communities, more than one-third of the participants reported experiencing joint or muscle pain and unexplained tiredness ≥ 12 times. By far the biggest differences between the communities were seen in the quality-of-life questions. Over half of the respondents in the hog community, as compared to less than one-fifth in the other two communities, reported not being able to open windows or go outside, even in nice weather, ≥ 12 times over the last 6 months.

Table 4 presents the results of the linear regression showing differences between the average number of episodes in each livestock community as compared to the community with no intensive livestock. Table 4 shows the difference in the mean number of episodes adjusted for sex, age, smoking, and work outside the home; the SE of the β-coefficient; and the *t*-value, which is the ratio of the β-coefficient to its SE (see "Statistical Methods"). The adjusted mean differences for the cattle community were generally small, with lower mean scores (negative β-coefficients and *t*-values) for many symptoms in the cattle as compared to the control community. Only episodes of excessive coughing and heartburn occurred on average > 2 times more in the cattle than in the control community (β > 2), and the *t*-values for these differences were only approximately 1.0. All of the symptoms in the miscellaneous category appeared less frequently in the cattle than in the control community. Hearing problems showed the largest difference in adjusted mean episodes, although this is based on a small number of people in the higher categories (Table 3).

In contrast, there were many mean differences of more than two episodes for the hog as compared to the control community. The average number of episodes was the most consistently elevated for upper respiratory and sinus conditions, gastrointestinal conditions, and skin or eye irritation. *t*-Values for headache, runny nose, sore throat, excessive coughing, diarrhea, and burning eyes showed that residence in the hog community was an important predictor of these physical health symptoms. In contrast, none of the miscellaneous symptoms showed important excesses in the hog community.

Responses to the quality-of-life questions were very different in the control and cattle communities as compared to the hog community. The adjusted number of episodes during which participants could not open windows or go outside even in nice weather differed little for the cattle and control communities, whereas excesses of approximately 13–15 episodes were seen in the hog as compared to the control communities. *t*-Values for these β-coefficients were large.

To evaluate the sensitivity of the regression results to the coding of the dependent variable, the models shown in Table 4 were rerun using values of the square root of the number of episodes and as 0, 1, 2, 3, and 4. *t*-Values for differences between the hog community and the control community were larger in these models. The *t*-value for nausea/vomiting was 1.61 with the original metric, 2.68 using the square root of the number of episodes, and 2.88 with a coding of 0–4. To consider whether elevated gastrointestinal symptoms in the hog community might be related to well contamination, the models shown in Table 4 were rerun for the four gastrointestinal symptoms including a variable for well versus municipal water supply. The coefficients for well water were small and had little influence on the estimates of differences between livestock and control communities.

Responses to open-ended questions about how the environment around the home affected the life or health of the respondent or members of her household are shown in Tables 5 and 6. Responses that were given by two or more persons in the study are shown. Most participants from the control and cattle communities had little to report in response to these open-ended questions, although eight participants in the cattle community mentioned livestock odor. In contrast, livestock odor was noted as a problem for many residents of the hog community and for members of the residents' households.

Discussion

To our knowledge this is the first population-based study of physical health symptoms and

Table 4. Linear regression results: average number of episodes in two livestock communities as compared to a community with no intensive livestock.

	Livestock operation					
	Cattle			Hogs		
Symptom	β[a]	SE[b]	*t*-Value	β[a]	SE[b]	*t*-Value
Upper respiratory/sinus						
Headache	1.57	3.02	0.52	7.62	2.94	2.60
Stuffy nose/sinuses	1.33	2.86	0.47	2.97	2.79	1.06
Runny nose	1.26	2.44	0.52	5.18	2.37	2.18
Burning nose/sinuses	-0.42	2.19	-0.19	1.99	2.13	0.93
Sore throat	1.71	1.52	1.12	3.64	1.48	2.45
Plugged/popping ears	-1.07	2.28	-0.47	-0.79	2.22	-0.35
Scratchy throat	1.63	1.49	1.09	2.09	1.45	1.44
Lower respiratory						
Mucus/phlegm	0.56	2.65	0.21	3.91	2.57	1.52
Excessive coughing	2.15	2.06	1.04	4.74	2.01	2.36
Shortness of breath	-1.62	2.66	-0.61	-0.74	2.59	-0.29
Tightness in chest	1.45	2.08	0.70	1.37	2.02	0.68
Wheezing	-0.63	2.05	-0.31	-0.50	1.99	-0.25
Strange breathing sounds	-2.31	2.16	-1.07	-2.57	2.09	-1.23
Gastrointestinal						
Heartburn	2.35	2.86	0.82	1.94	2.78	0.70
Nausea/vomiting	1.15	2.20	0.52	3.46	2.15	1.61
No appetite	0.92	2.02	0.46	3.03	1.96	1.55
Diarrhea	-0.92	1.44	-0.64	2.96	1.39	2.13
Skin/eye irritation						
Burning eyes	-1.39	2.47	-0.56	5.58	2.42	2.31
Tearing eyes	-1.70	3.24	-0.52	0.64	3.16	0.20
Dry/scaly skin	1.85	2.81	0.66	2.67	2.74	0.98
Skin rash or irritation	0.54	1.72	0.31	2.28	1.67	1.36
Skin redness	-1.25	1.01	-1.23	0.12	0.99	0.12
Miscellaneous						
Joint/muscle pain	-0.22	4.03	-0.06	1.22	3.93	0.31
Unexplainably tired	-3.43	3.78	-0.91	0.76	3.68	0.21
Blurred vision	-4.67	3.14	-1.49	1.25	3.07	0.41
Dizzy/faint	-1.22	2.17	-0.56	-1.32	2.11	-0.63
Hearing problems	-6.44	2.50	-2.57	-3.58	2.44	-1.47
Chest pain	-2.30	1.32	-1.74	-0.35	1.29	-0.27
Fever/chills	-1.32	1.04	-1.27	-0.39	1.02	-0.38
Fainted	-0.18	0.86	-0.20	1.02	0.84	1.21
Quality of life						
Can't open windows	-1.33	2.88	-0.46	14.74	2.80	5.26
Can't go outside	-0.79	2.38	-0.33	12.73	2.32	5.47

[a]Difference in the average number of episodes between communities with and without livestock operations, adjusted for sex, age, smoking, and work outside of the home. [b]Of the β-coefficient.

quality of life among community residents in North Carolina that focused on the possible health effects of airborne emissions from intensive livestock operations. The study sample was drawn from areas of the state with a majority of African American residents who have low median income. This was not unexpected because intensive hog operations in North Carolina are located disproportionately in poor and nonwhite areas (*27*). Despite the legacy of distrust of biomedical research in the African American community (*28*), refusal rates were low because of the participation of community based organizations in introducing researchers to participants. The preponderance of women in the study reflects, in part, who was at home and who answered the door when approached by the community consultant and interviewer.

A number of symptoms previously reported as elevated among persons occupationally exposed in swine confinement houses were elevated among the residents of the hog community as compared to the community with no livestock operations. In particular, headache, runny nose, sore throat, excessive coughing, diarrhea, and burning eyes were reported more frequently in the hog community. Members of the cattle community did not report similar elevations, nor did they report reduced quality of life. The quality of life measures (not opening of windows and not going outside even in nice weather) showed a large excess in the hog community.

As in all studies, measurement problems and differences between the communities other than the exposure of interest could have influenced the results. Recall bias is an issue in any survey. We were particularly concerned that residents living in proximity to a hog operation might report a greater number of symptoms because of negative feelings about the effect of the operation on their lives and their community. Therefore, we were careful to present the study as a rural health survey, not as a livestock and health study, and we did not include any questions in the survey that referred to hogs, livestock, or odors. During debriefings after the field work, interviewers reported that some respondents did not understand that questions about the environment referred to problems including odor. Such misunderstandings would have led to an underestimate of the impact of livestock operations on health and quality of life.

It is possible that residents of the hog community could have reported more symptoms because of their feelings about the negative impact of the hog operation on their community. However, if this had occurred, we would have expected excess reports for most symptoms. In fact, the eight symptoms in the miscellaneous category, none of which were expected to be related to exposure to airborne emissions, occurred with about the same frequency in the hog and control communities (Table 4). This suggests that there was not a tendency for over-reporting among residents of the hog community. Negative feelings might also have been evident in the open-ended questions, when respondents had the opportunity to report concerns beyond the environmental health and quality-of-life issues addressed in the structured questionnaire. As shown in Table 6, two persons in the hog community expressed concerns about property values.

Other circumstances of the survey may have led to an underestimate of the impact of swine operations on health of area residents. Perhaps most important, we studied an area with only one intensive hog operation. We would have expected to see larger effects in areas of the state with larger and more numerous operations and consequently heavier airborne emissions. Differences between the livestock and control communities may also have been reduced because of exposures to agricultural chemicals and dusts from row cropping in the control community.

Levels of emissions and weather conditions at the time interviewers were in the field may also have influenced the findings. With one exception, interviewers did not notice an odor from the hog operation while conducting the interviews. If interviews had been conducted when odors were strong, respondents may have reported a greater frequency of health symptoms.

The lack of environmental exposure monitoring data is also a concern in this study. We assumed that if persons resided within 2 miles of the hog operations, they were exposed to the emissions. We were not able to distinguish higher or lower exposure levels within the community. Exposure differences could occur because of differences in distance, direction, elevation, physical barriers, the amount of time spent at home, the amount of time spent outdoors, and the availability of air conditioning and filters in the home. Quantitative evaluation of exposure differences between individuals would increase the ability of an epidemiologic study to identify health effects of airborne emissions.

Similarly, clinical or biologic measures of outcome would strengthen information about relationships between environmental exposures to emissions from livestock operations and health. Future studies could be designed to obtain information on respiratory and immune function and standardized clinical evaluation of physical and mental health conditions. Such studies could evaluate possible mechanisms linking environmental exposures and health.

This study was not able to evaluate specific populations that may be more susceptible to health impacts of environmental exposures. These groups include children, asthmatics, and older persons with compromised pulmonary or cardiovascular function. Future studies should evaluate whether these subgroups are more sensitive to airborne emissions from intensive livestock operations. We were also unable to evaluate the acute impact of odors on mental health or the long-term impacts of reduced quality of life on mental, physical, or community health.

This study supports previous research suggesting that community members experience health problems due to airborne emissions from intensive swine operations (*7*). In North Carolina there are approximately 2,500 intensive hog operations, and they are located disproportionately in areas that are poor and nonwhite (*27*). The public health

Table 5. Problems that affect respondents' own life or health.[a]

Problem	Livestock operation		
	None	Cattle	Hogs
Livestock odor	0	8	25
Livestock odor (limits adult recreation)	0	0	14
Livestock odor (respiratory symptoms)	0	0	6
Livestock odor (can't open windows)	0	0	4
Livestock effluent (contaminated well)	0	0	4
Livestock odor (try not to breathe)	0	0	3
Livestock odor (nausea)	0	0	3
Livestock operation (flies and insects)	0	0	3
Crop sprayers (dust or noise)	1	0	2

[a]Respondents were asked, "Has the environment around your house affected your life and health?"

Table 6. Problems that affect family members' life or health.[a]

Problem	Livestock operation		
	None	Cattle	Hogs
Livestock odor	0	0	18
Livestock odor (limits child recreation)	0	0	10
Livestock odor (limits adult recreation)	0	1	4
Livestock odor (try not to breathe)	0	0	4
Livestock odor (respiratory symptoms)	0	0	4
Respiratory ailments	3	0	3
Complaints of skin symptoms	1	0	2
Livestock effluent (contaminated well)	0	0	2
Livestock odor (decreases property value)	0	0	2

[a]Respondents were asked, "Has the environment around your house affected the life or health of other members of your household?"

and environmental injustice implications of this geographical pattern extend beyond the physiologic impact of airborne emissions to issues of well-water contamination (*29*) and the negative impact of noxious odors (*8*) on community economic development (*30,31*). Populations in these areas may be at greater risk of health impacts due to high disease rates (*32,33*), low income (*27*), and poor housing conditions. Future research could provide a better understanding of the health effects of intensive livestock operations by combining individual exposure assessment, physiologic measures, clinical evaluation of physical and mental health, and follow-up of exposed communities.

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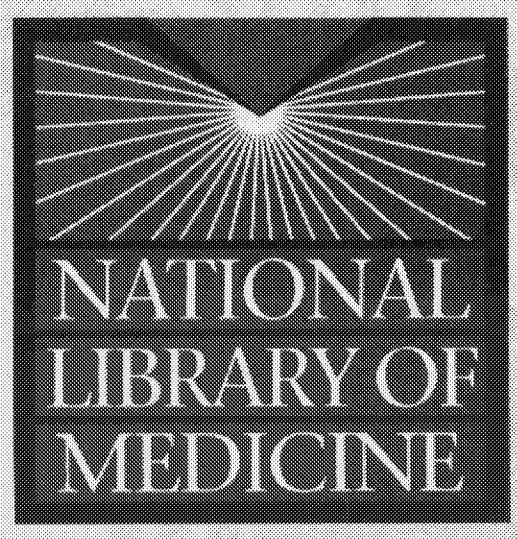

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