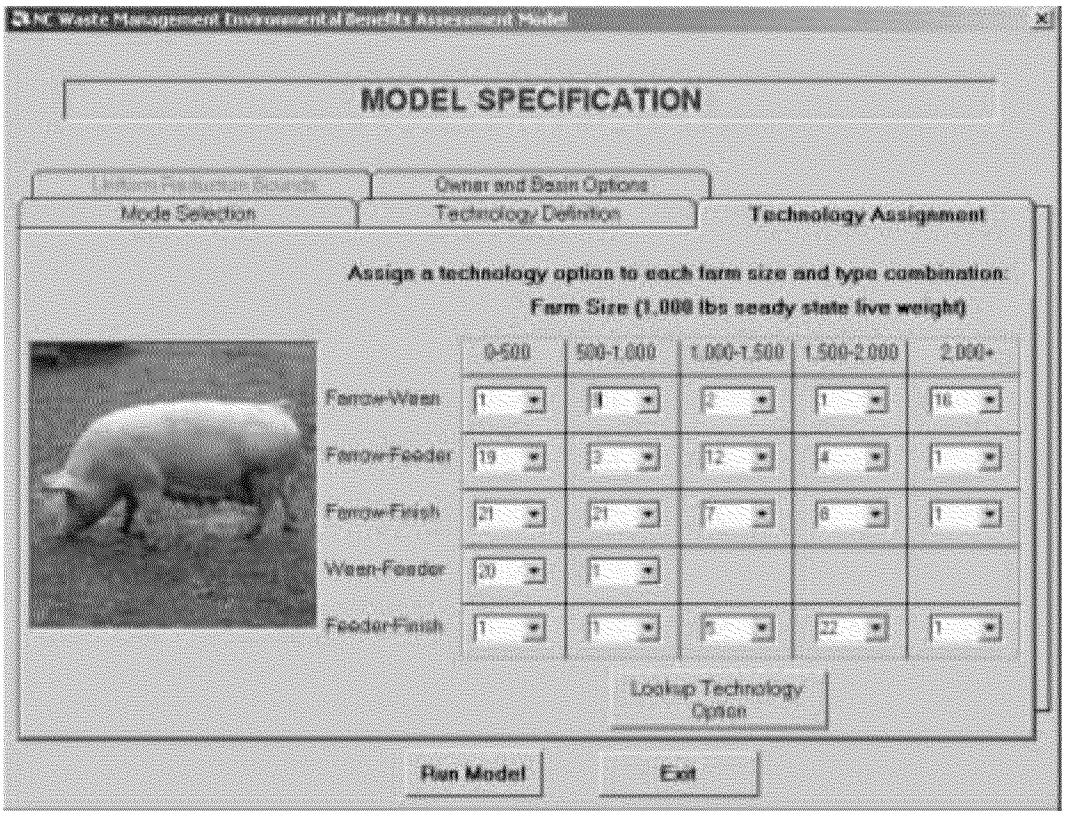
Figure 7-4. Technology Assignment Tab



to apply the technology options to all farms in the state,[2] only to the farms that are owned by companies specifically covered by the Agreement (e.g., Smithfield Foods, Premium Standard Farms), or only to farms that are owned by entities not covered by the Agreement. Similarly, the user may apply the technology options to all farms, to those located in the Neuse River Basin only, or to those located in the Albemarle-Pamlico River Basin only. If the user does select a subset of farms based on ownership or river basin, the other farms will be assigned their baseline loads, thereby reflecting the assumption of no change in waste management practices.

[2] By "all farms in the state" we refer to all 2,295 farms tracked in the North Carolina Division of Water Quality database, referred to in Chapter 1.

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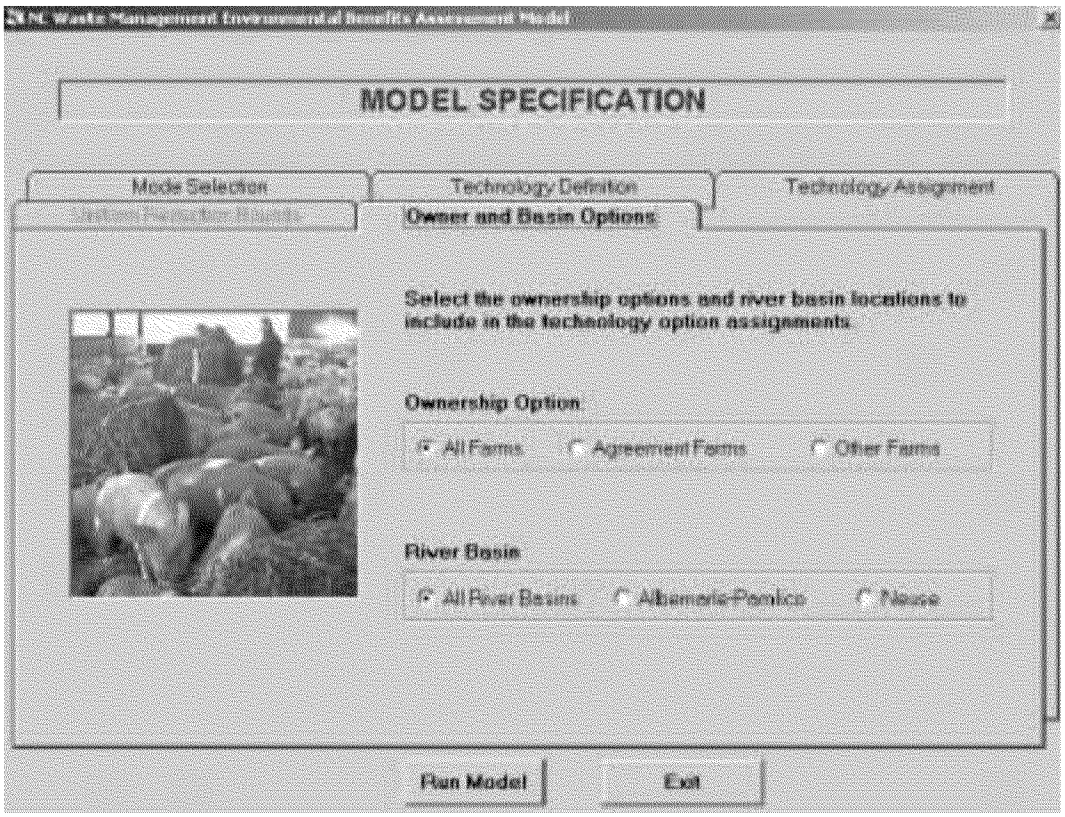
Figure 7-5. Owner and Basin Options Tab



Once the technology adoption scenario has been defined through these three tabs, the user can run the model and generate benefit estimates by selecting the "Run Model" button on the Technology Definition tab.

7.3 UNIFORM REDUCTIONS MODE

In the uniform reduction mode, the user defines percent reductions for each of the four pollutant release categories and applies these reductions to all hog farms. In other words, percent reductions can vary across the four pollutant categories, but they are applied uniformly to all farms. In effect, this is like applying a single technology option to all farms.

In EBAM, this mode is also set up to run multiple uniform reduction scenarios, using different combinations of reductions for the four pollutant categories. The Uniform Reduction Bounds tab allows the user to enter the minimum, maximum, and stepwise percent

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reductions for each pollutant load input variable, as shown in Figure 7-6. These variables determine which load variables are reduced from their baseline values and how many integrated model runs are conducted.

Figure 7-6. Uniform Reduction Bounds Tab

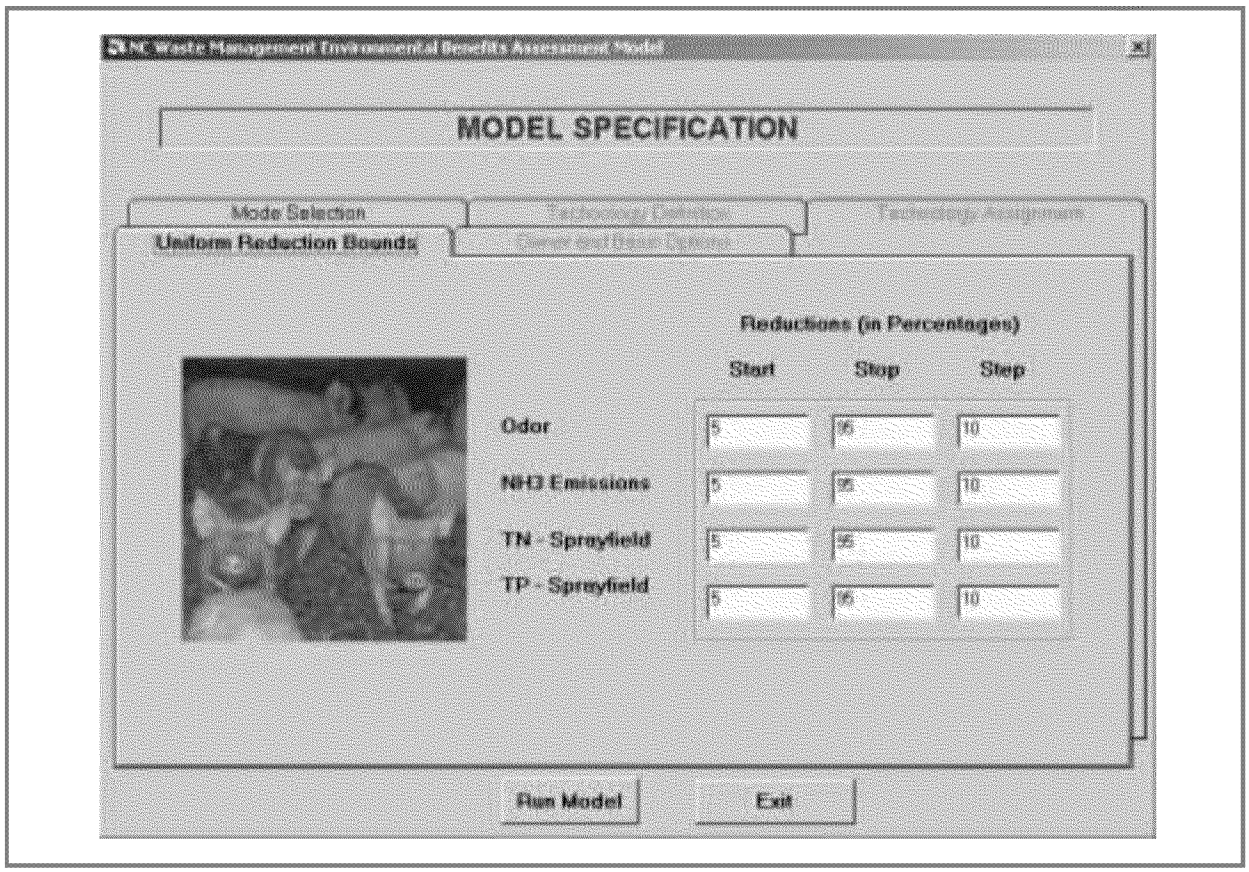

Figure 7-6 shows example inputs for this screen. In this case, each pollutant variable is reduced from its baseline value by between 5 percent and 95 percent, using 10 percent increments. For each of the four variables, this implies 10 reduction values (5, 15, 25,…95). This example results in 10,000 (10 X 10 X 10 X 10) combinations of pollutant reductions, each of which represents a separate model run.

Once this screen is finalized, the user can hit the "Run Model" command button. This will commence the automated uniform reduction model runs. Each model run takes approximately 45 minutes.

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The reason for examining multiple combinations of pollutant reductions is that the estimated benefits of a percent reduction in one pollutant are not necessarily independent of the assumed percent reductions in the other pollutants. In other words, nonlinearities in the underlying models may imply, for example, that a 10 percent reduction in ammonia emissions from all farms will generate different estimates of water recreations benefits if sprayfield nitrogen loads are reduced by 10 percent than if sprayfield nitrogen loads are reduced by 90 percent. The nonlinearities and interdependencies in the modeling system (in particular through the water quality and recreation benefits model) can most easily be evaluated by running multiple combinations in the uniform reduction mode.[3]

7.4 RESULTS WITH THE INTEGRATED MODELS

To illustrate how EBAM can be used and to evaluate the relative magnitude (and interdependencies) of benefit estimates for different pollutant reductions, we ran multiple scenarios through the uniform reductions mode. In particular, we varied reductions in each pollutant between 5 and 85 percent, with "steps" of 20 percent (i.e., by 5, 25, 45, 65, and 85 percent). This procedure resulted in 125 (= 5 X 5 X 5) model runs for different combinations of ammonia and sprayfield (TN and TP) loadings reductions. The five levels of odor reductions were run separately. The results are summarized below.

Figures 7-7, 7-8, and 7-9 show how different combinations of reductions in ammonia emissions and sprayfield loadings affect the aggregate estimates of recreation benefits from modeled surface water quality improvements. One clear implication of these results is that the benefit estimates increase almost linearly with respect to percent reductions in each of the pollutant categories (i.e., there is little to no curvature in the plotted relationships). A second implication is that the interdependencies between reductions in three pollutants are relatively small.

[3]As implied by Figure 7-1, the estimated odor reduction benefits are independent of the benefits from reductions in ammonia emissions and sprayfield loadings. Therefore, the odor reduction benefits can be run separately in the uniform reduction mode, thereby reducing the number of combinations to be examined.

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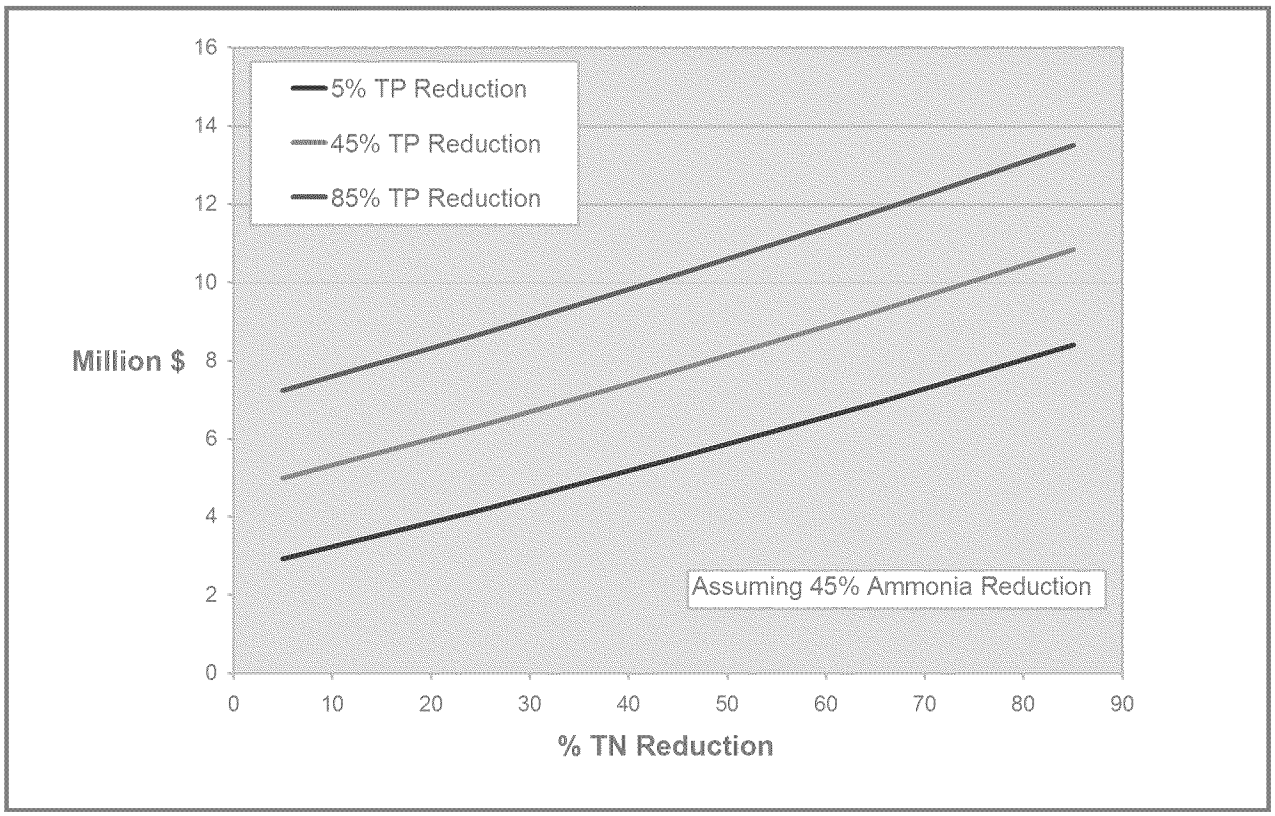
Figure 7-7. Total Estimated Fresh Water Recreation Benefits for Different Combinations of TN, and TP Reductions (in 2002 dollars)



For ammonia emissions, each percent reduction generates an estimated $62,000 in additional benefits to freshwater recreators. For TN and TP sprayfield loadings, the incremental benefits are $73,000 and $59,000, respectively.

The graphical results displayed in Figures 7-7 through 7-9 are also summarized numerically in Table 7-1. This table reports regression results, where the dependent variable is the total water recreation benefit estimate and the independent variables are the percent reductions in the three pollutant categories. The first column of results does not include any interactions (multiplication) between the independent variables. The coefficients on the pollutant reduction variables (each of which is positive and statistically significant) measure the increment in total estimated benefits associated with each percent reduction in the pollutant. For ammonia emissions, each percent reduction generates an estimated $62,000 in additional benefits to freshwater recreators. For TN and TP sprayfield loadings, the incremental benefits are $73,000 and $59,000, respectively. The second column of results includes interactions between the three pollutant reduction variables. The model fit improves slightly, and the coefficients for

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Figure 7-8. Total Estimated Freshwater Recreation Benefits for Different Combinations of TP and Ammonia Reductions (in 2002 dollars)

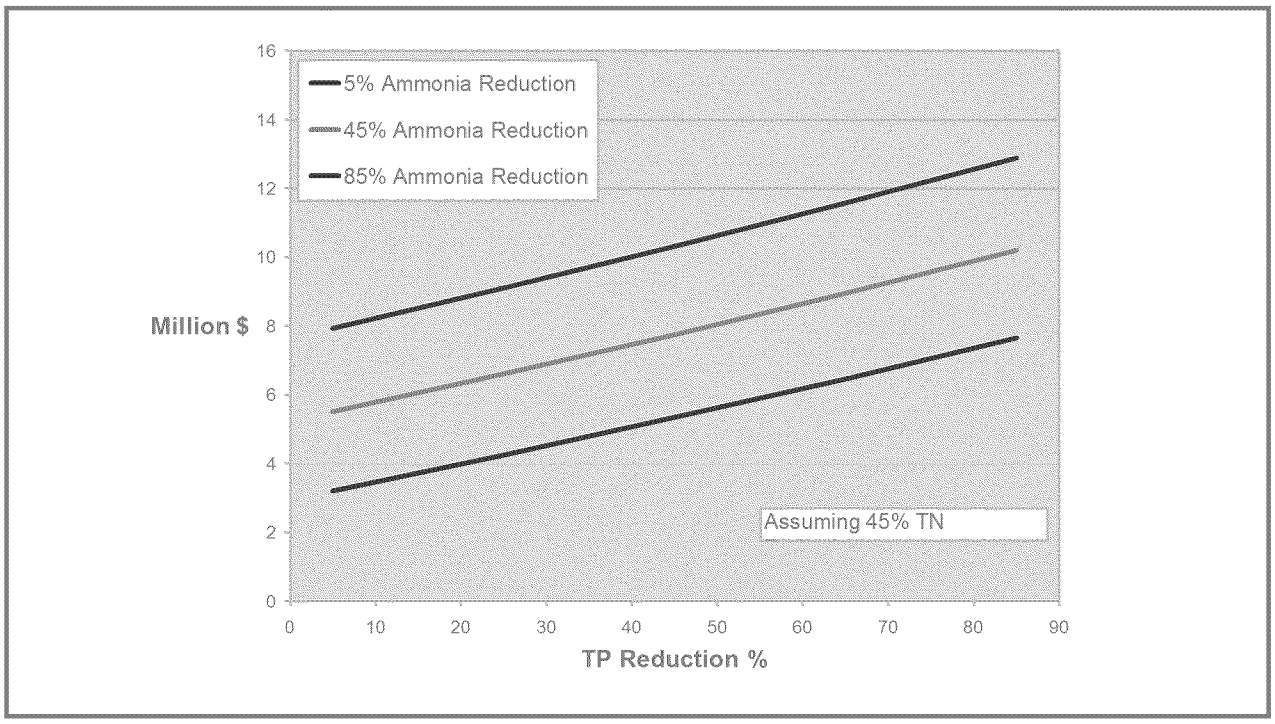

Figure 7-9. Total Estimated Freshwater Recreation Benefits for Different Combinations of Ammonia and TN Reductions (in 2002 dollars)

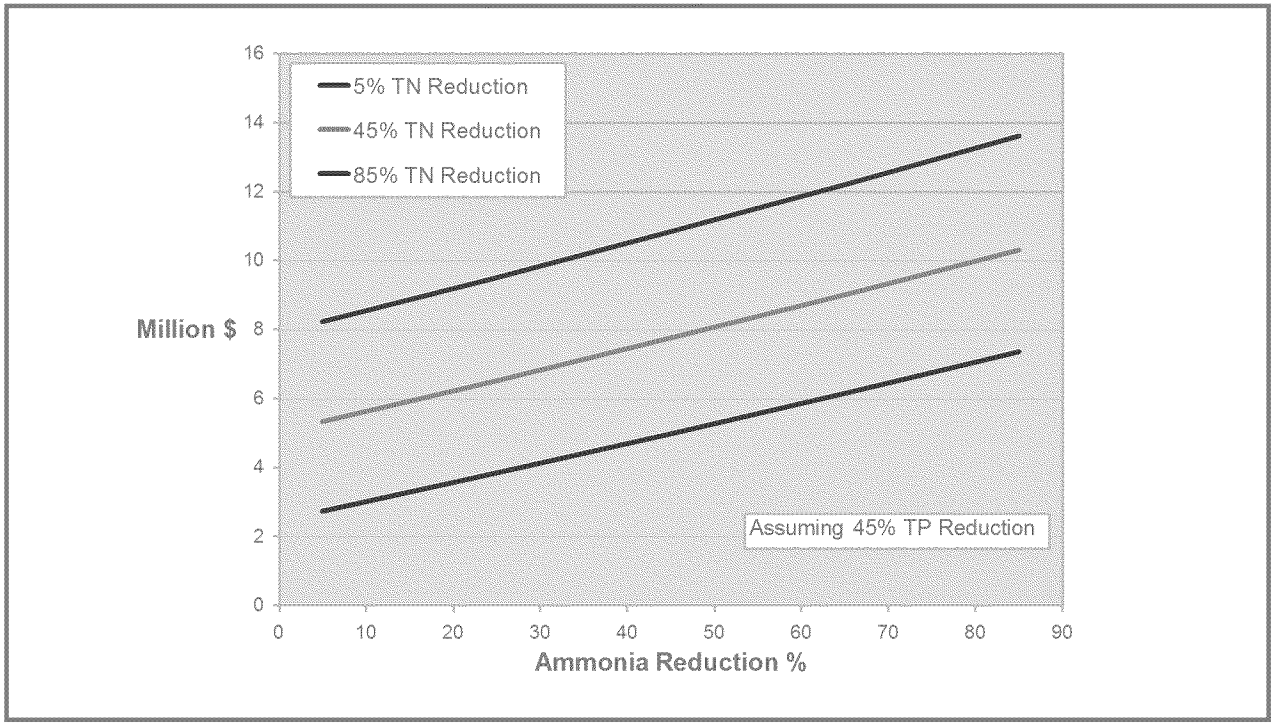

Table 7-1. Response Surface Regression for Estimated Water Recreation Benefits

Dependent Variable = Total Estimated Water Recreation Benefits		
Explanatory Variables	**Coef (t-Stat)**	**Coef (t-Stat)**
% TN reduction	73,401 (131.14)	62,331 (93.12)
% TP reduction	58,896 (105.22)	49,685 (74.23)
% ammonia reduction	62,424 (111.53)	53,474 (79.89)
% TN reduction X % TP reduction		126 (13.1)
% TN reduction X % ammonia reduction		120 (12.5)
% TP reduction X % ammonia reduction		79 (8.2)
Constant	–826,521 (–17.81)	–168,808 (–4.16)
R-squared	0.997	0.9993
N	125	125

these interaction terms are also positive and significant, but their magnitude is relatively small. These results suggest that the incremental benefits of reducing one pollutant are higher when the reductions in the other pollutants are higher, but only by a small amount. This can also be seen by the slight "fanning" out of the lines in Figures 7-7 through 7-9 as one moves to the right.

The estimated health benefits associated with reductions in PM_{Fine} levels are strictly associated with reductions in ammonia emissions. The relationship between these two variables is shown in Figure 7-10. Again, the relationship between reductions in ammonia emissions and total estimated benefits (in this case health benefits) is very close to linear. Each percent reduction in ammonia emissions is estimated to generate approximately $3.78 million in health benefits.

The estimated odor-related benefits are represented in Figure 7-11. In this case, the estimated benefits are nonlinear with respect to percent reductions odor. At lower levels (between 5 and 25 percent reductions) each percent reduction in odor generates roughly

Figure 7-10. Total Estimated PM-Related Health Benefits from Reductions in Ammonia Emissions (in 2002 dollars)

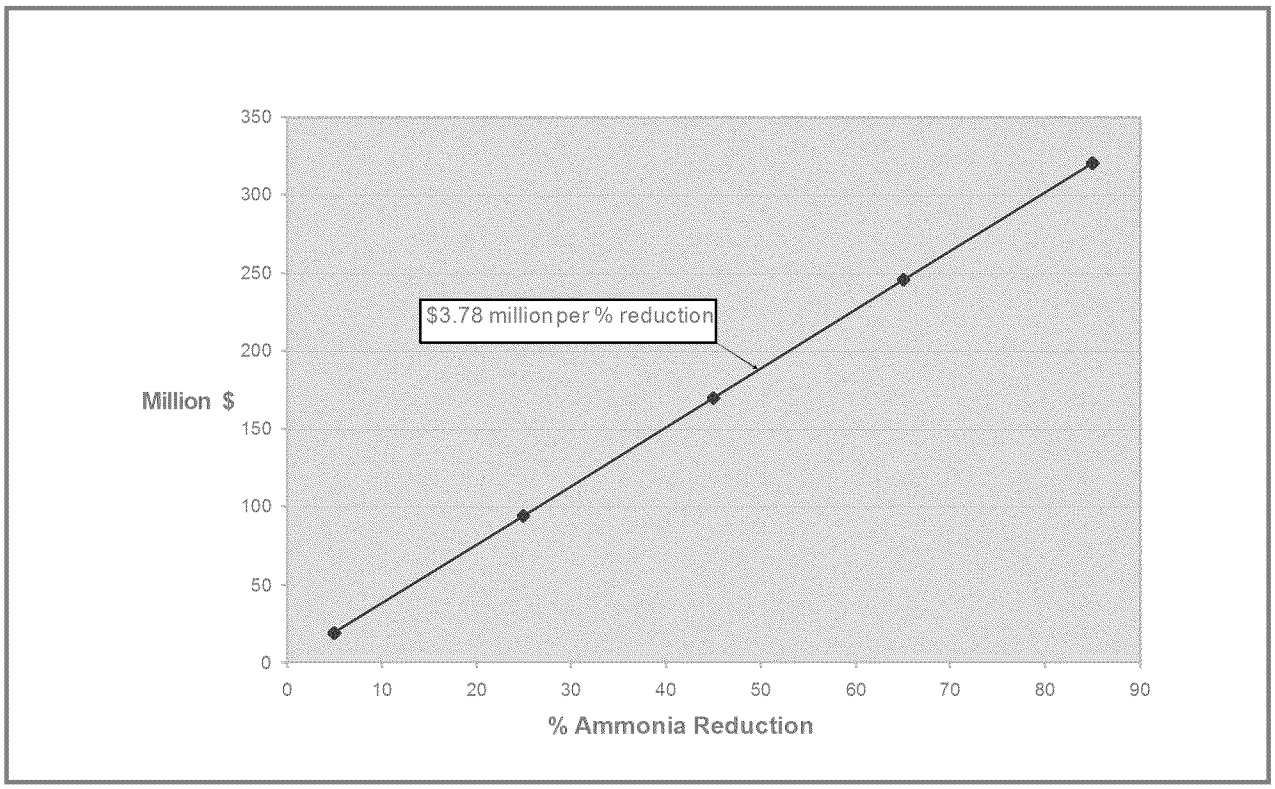

Figure 7-11. Total Estimated Property Value Benefits of Odor Reductions (in 2002 dollars)

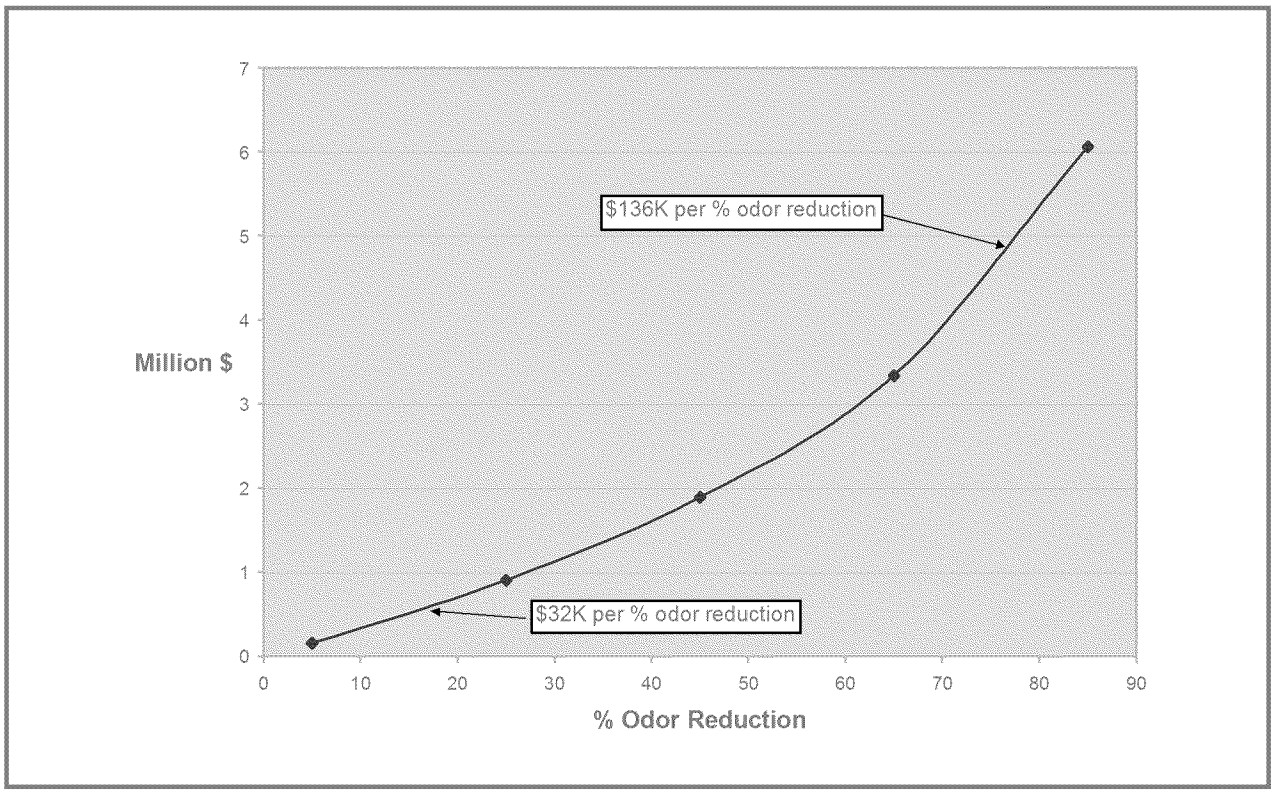

Table 7-2. Estimated Incremental Benefits per Percent Reduction in Pollutant Releases

Benefit Category	Controlled Emissions/Loadings	Additional Benefits (millions of 2002 dollars per year) per Percent Reduction
Freshwater recreation	Ammonia	0.06
	Total nitrogen	0.07
	Total phosphorus	0.06
Avoided PM-related health effects	Ammonia	3.78
Odor reduction for local residents	Odor	0.03 – 0.14

One result that stands out rather starkly from the summary estimates in Table 7-2 is that the estimated health benefits associated with ammonia reductions are distinctly (nearly two orders of magnitude) larger than the other benefit estimate categories.

$32,000 in estimated benefits to local residents. At higher levels, this estimate increases to $136,000 per percent reduction.

The incremental estimated benefits associated with percent reductions in each of the four pollutant categories are summarized in Table 7-2. It must be emphasized these are modeled estimates and are best interpreted as midpoints within a range of uncertainty.

The inherent limitations and uncertainties associated with each of these estimates are discussed in detail in previous chapters. One result that stands out rather starkly from the summary estimates in Table 7-2 is that the estimated health benefits associated with ammonia reductions are distinctly (nearly two orders of magnitude) larger than the other benefit estimate categories. This result in particular has potentially important implications when comparing the benefits of alternative technologies with different pollutant reductions.

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A Surface Water Model Technical Specification

A.1 SWINE SOURCE SPATIAL CONSIDERATIONS

The model development process included associating the point location of each facility available in the facility database with adjacent land application areas. The first step in this analysis involved estimating the area of land required using North Carolina State University (NCSU) Extension Service guidelines (1980) that include ranges for swine waste for different waste treatment systems/lagoon capacity, crop, and facility/animal type. From the applicable ranges, we assumed that the operative range was equal to the lower quartile within the range (0.5 X median). This approach was chosen to subjectively account for the assumed economic incentives in minimizing costs associated with waste spray/distribution systems. The algorithm for specifically associating facilities with land cover cells was the following:

1. For facilities assumed to require up to 1 sq km, with the facility latitude and longitude locating the operation on a land cover cell with the category of agriculture or agriculture/herbaceous or agriculture/woodland: associate that cell alone with the facility.
2. For all facilities assumed to require up to 1 sq km, with the facility latitude and longitude not locating the operation on a land cover cell with the category of agriculture or agriculture/herbaceous or agriculture/woodland: associate the nearest cell with the category of agriculture or agriculture/herbaceous or agriculture/woodland alone with the facility.
3. For all facilities assumed to require >1 sq km, a GIS algorithm was written that searched adjacent cells for the agriculture or agriculture/herbaceous or agriculture/woodland cells in closest proximity, and associated found cells until the facility's area requirement was met.

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4. No cell was assigned more than one facility.
5. Agriculture/herbaceous or agriculture/woodland cells were assumed to be evenly divided (50/50) between these two categories, with a total of 0.5 sq km, therefore available for land application on any one cell in these categories.

In developing this algorithm, the primary assumption was that identified land cover cells receive swine waste, although the precise area within the cell or quantity applied is not specified or required information. This assumption may result in some very localized spatial bias but should generally be unbiased for reporting at a 14-digit watershed scale. The major determinant in the spatial accuracy of locating land application areas may be associated with the degree to which manure is transported off site for application. For the purposes of this study, it was therefore assumed that any transportation outside of the 14-digit watershed in which a facility was located was negligible.

Of the total population of facilities, 87 percent were assumed to require 1 km^2 (or less) of land, with 6 percent requiring 1 to 2 km^2, and 6 percent requiring 2 to 10 km^2. The largest facility was assumed to require 16 km^2.

Data from the North Carolina Division of Water Quality were used to locate facilities and determine facility type and size.

The database was enhanced by assigning geographic coordinates (latitude/longitude) to swine facilities in eastern North Carolina that were lacking georeferencing in the NCDWQ database. First, we prioritized the counties with missing coordinates for farms (Table A-1). The counties were prioritized in descending order by hog population (total number of head for the sites missing coordinates, by county) and by county ranking from the U.S. Department of Agriculture's (USDA's) 1997 ranking of the six largest counties (in pig population) in North Carolina.

This process identified 168 facilities to be georeferenced, with the highest priority counties being Sampson, Duplin, Bladen, Columbus, Jones, and Edgecomb. All 84 facilities in those six priority counties were geolocated, with the "level of certainty" for each facility also documented. In addition, following the prioritization guidelines described above, all facilities in Wayne, Greene, Nash, Pender, Johnston, Pitt, Washington, Lenoir, and

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Table A-1. Swine Facility Georeferencing Overview

County	Number of Sites Originally without Latitude/Longitude	Design Capacity (pigs)	1997 USDA Inventory (Number of Pigs) for Six Largest North Carolina Counties	Percentage of Inventory without Latitude/Longitude
Sampson	39	164,027	1,776,000	9.24
Duplin	25	121,348	2,034,000	5.97
Wayne	12	48,226		
Bladen	7	42,904	759,000	5.65
Edgecomb	5	29,670	169,000	17.56
Greene	8	29,600		
Pender	10	27,932		
Columbus	6	27,446	258,000	11
Lenoir	5	26,404		
Jones	2	23,643	253,000	9.35
Hoke	2	22,944		
Nash	8	22,867		
Pitt	4	18,026		
Johnston	4	17,536		
Robeson	3	17,440		
Richmond	4	15,100		
Washington	4	11,100		
Harnett	2	6,450		
Hertford	3	5,664		
Brunswick	2	4,322		
Moore	3	4,256		
Cumberland	1	2,400		
Beaufort	1	2,245		
Franklin	1	2,205		
Chatham	1	2,000		
Martin	1	1,900		
Onslow	1	1,776		
Northampton	2	1,700		
Cabarrus	1	1,200		
Halifax	1	280		
Total	**168**	**702,611**	**More than 5,249,000**	**Less than 13.4%**

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Robeson counties were carefully located (an additional 58 facilities), and, because of their importance to this study, three farms owned by Smithfield Carroll's Farms (in Hertford and Northampton counties) were also located and cross-checked. All farms in the remaining counties were located as described below (in Item No. 4).

RTI determined geographic coordinates (latitude and longitude in decimal degrees) for these facilities using the following methods:

1. First, using the table of farms, RTI attempted to use ArcGIS's "geocoding addresses" tool (in conjunction with ArcGIS's StreetMap USA local address geocoding service extension) to obtain geographic coordinates for these farms based on their mailing addresses. The parameters used for selection were spelling sensitivity of 80 percent, a minimum "candidate" score of 10 (out of 100), and a minimum match score of 60. RTI recognizes that the descriptions of the *locations* of the farms are more accurate than a geocoded mailing address, with respect to the actual location of the swine facility; however, in some cases (especially for the lower-priority counties), the geocoded addresses without a spatial cross-check were necessary.
2. After the addresses were geocoded, the descriptions given for the location of each farm in the six priority counties were all checked against 7.5 minute USGS Quad maps (available through ©LandNet Corp.'s *LandViewer*™, using the "interactive maps" option). North Carolina state road numbers were checked and often located using North Carolina county maps, while street names were located and checked using a combination of the *North Carolina Atlas & Gazetteer* (1993) and MapQuest.com's *MapQuest*© (1996-2002). MapQuest's site (http://www.mapquest.com) also gives the viewer the opportunity to cross-check locations with aerial photography (of indeterminate age) at 1 meter or better resolution for most of the study area. This aerial photography service is made possible by MapQuest's partnership with *GlobeXplorer*, Inc. © 2002.
3. The farms in Wayne, Greene, Nash, Pender, Johnston, Pitt, Washington, Lenoir, and Robeson counties were similarly located. In late June 2002, Gary Saunders of the North Carolina Department of Environment and Natural Resources (DENR's) Division of Air Quality provided RTI with an updated spreadsheet, in which he had provided latitudes and longitudes for many of the farms originally missing coordinates. For the counties mentioned above, Mr. Saunders' coordinates were checked against the on-line 7.5 minute quad maps (http://www.landnetusa.com), and adjusted if necessary. Adjustments were made to Mr. Saunders' coordinates if the coordinate recorded did not match the locational descriptions contained in the original

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DWQ database of 209 facilities missing latitudes and longitudes. (RTI also reviewed data provided by Dr. Bailey Norwood of North Carolina State University's Agricultural and Resource Economics [ARE] unit but did not find additional information beyond the above sources to assist with locating missing farms.)

4. The facilities in the remaining counties (Harnett, Hertford, Brunswick, Moore, Cumberland, Beaufort, Franklin, Chatham, Martin, Onslow, Northampton, Cabarrus, and Halifax) were provided with coordinates of varying accuracy, none of which were checked closely against the Internet sources mentioned above. If Mr. Saunders' spreadsheet provided revised coordinates for farms in those counties, his coordinates were almost always used without a cross-check. If no coordinates were provided by Mr. Saunders' table, but ArcGIS had provided a tentative location based on mailing address, that set of geocoded coordinates was used. In all other instances, the Internet resources described above (primarily *LandViewer*™, because it provided latitude and longitude in decimal degrees, based on 7.5 minute USGS quadrangle maps) were used to derive the best estimate of geographic location, given the time and budget constraints of this project.

A.2 NITROGEN AND PHOSPHORUS EDGE-OF-FIELD DELIVERY FROM SWINE OPERATIONS

Nitrogen and phosphorus edge-of-field delivery was calculated using methods described in Schwabe (1996) and Norwood (2003a) and county- and crop-based data provided by Norwood (2003b) and the Conservation Technology Information Center (2002). Nitrogen delivery was estimated as

$$\text{Nitrogen EOFDC} = 1/(1 + \exp(2.33137 - P^{0.984645}) \qquad \text{(A.1)}$$

where P is a county-specific permeability index value.

The phosphorus delivery coefficient was calculated based on the universal soil loss equation (USLE):

$$\text{Phosphorus EOFDC} = 1/(1 + \exp(2.918179191 - \text{USLE}^{-0.623066904})) \qquad \text{(A.2)}$$

For phosphorus delivery, a USLE value was calculated for each county and crop. The USLE value equals

$$\text{USLE} = R * LS * K * C \qquad \text{(A.3)}$$

where

R = rainfall factor,

LS = length/slope,

K = erodibility factor, and

C = cropping factor.

Values for C were based on a crop rotation of corn, soybeans, wheat, and weighting tillage data by the cropland in the county in each type of tillage. The following C values were assumed:

	Conventional Tillage	Conservation Tillage
Corn	0.25	0.15
Soybeans	0.30	0.05
Wheat	0.04	0.03
Bermuda grass	0.007	

In calculating the C factor, it was assumed that 60 percent of the swine waste is applied to row crops and 40 percent to Bermuda grass (Norwood, 2003a).

A.3 LAND USE/COVER

Land use/land cover (LU/LC) data served several purposes in the modeling process. First, the LU/LC data were used to identify/estimate lands on which swine waste is being applied (described below) and to link swine sources to the surface water network. For this use, Advanced Very High Resolution Radiometric (AVHRR) data were used as a 1 km^2 grid.[1] Second, the National Land Cover Dataset was used to estimate land use/cover by 14-digit watershed for nonswine modeling input.

A.4 SURFACE WATER HYDROGRAPHY

A hydrographic/hydrologic database was created based on the River Reach File Version 3 (RF3). With extensive and unique attributes and code embedded in the database, RF3 provided the routing and modeling "engine" for linking sources with surface waters and delivering pollutants through surface water networks. The RF3 database for the study area includes approximately 25,000

[1]This data source was chosen because of historical success in integrating these data with the Reach File.

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networked reaches, terminating at the Tar-Pamlico, Neuse, White Oak, New, and Cape Fear estuaries. Important surface water attributes (e.g., channel characteristics, streamflow statistics) in addition to extensive study area-specific routing features have been incorporated in the RF3 database to support modeling efforts.

RF3 is a hydrologic database of the surface waters of the continental United States. The RF3 network is based on 1:100,000 scale digital line graph hydrographic data and has been designed expressly to establish hydrologic ordering, to perform hydrologic navigation for modeling applications. Recent projects sponsored by the U.S. Environmental Protection Agency (EPA) and the United States Geological Survey (USGS) have resulted in improved ability of the RF3 stream network data to support modeling efforts (RTI, 2001a,b).[2] The RF3 network used for the model includes almost 25,000 reaches accounting for almost 24,000 stream miles. All of the hydrologic, hydraulic, and water quality calculations completed for this study were done for each of these reaches. Model results were reported at the outlet of each 14-digit hydrologic unit (HU) (as defined by federal and state agencies) and also compiled for major river basins. The surface water model network in the study area included 565 HUs.

A.5 FLOW AND HYDRAULIC CHARACTERISTICS

Streamflow was modeled using the methodology described by RTI (2001a). Streamflow statistics integrated into the Reach File database were used to calculate yield (flow per unit area). A land cover grid was linked to RF3 reaches, allowing for drainage area summation by reach. The combination of reach-specific drainage area and yield allowed for the development of a flow routing routine. Annual average flows were used for the analysis described herein, although the analysis could be readily adapted for other flow conditions (e.g., summer low-flow).

The relationship between stream flow and channel width used was

(Keup, 1985)

[2] The National Hydrography Database (NHD), released by the USGS and EPA in 2001, was built with RF3 architecture. Therefore, employing RF3 as the modeling stream network facilitates integration with NHD if warranted for future studies.

$$W = 5.27 * Q\ 0.459 \qquad (A.4)$$

where

W = channel width (ft) and

Q = discharge (stream flow in cubic feet per second [cfs]).

Channel depths were calculated based on the classic Manning's N formulation for channel resistance analysis. Assuming a rectangular channel cross-section, the following formula was used to calculate stream depth:

$$y0 = 0.79(Q * n/(W * (S0)0.5\ )0.6 \qquad (A.5)$$

y0 = channel depth (ft),

Q = discharge (stream flow in cfs),

n = Manning's N roughness coefficient,

W = channel width (ft) calculated above, and

S0 = channel slope (ft/ft)

Manning's N was calculated, based on sinuosity, as

$$\text{Manning's N} = 0.0016 + 0.0234 * S, \qquad (A.6)$$

with a lower limit of Manning's N = 0.025 and an upper limit of Manning's N = 0.040 (Henderson, 1966).

Sinuosity estimates were calculated as

$$S = SEGL/DIST$$

S = sinuosity measure (unitless),

SL = segment length of the reach (mi), and

DIST = straight-line distance between upstream and downstream nodes of the reach (mi).

Stream velocity for each reach, therefore, was calculated as

$$V = Q/(W*y0) \qquad (A.7)$$

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V = velocity (ft/sec),

Q = discharge (streamflow in cubic feet per second, cu ft/sec),

y0 = channel depth (ft) calculated above, and

W = channel width (ft) calculated above.

Time-of-travel along a stream reach was calculated as

$$Tt = SL/(V) \quad (A.8)$$

Tt = time-of-travel along stream reach.

REFERENCES

Conservation Technology Information Center. 2002. "National Crop Residue Management Survey." CD Rom. Available at <http://www.ctic.purdue.edu>.

Norwood, F.B., Oklahoma State University, Department of Agricultural Resource Economics. Email correspondence with Randall Dodd, March 13, 2003a.

Norwood, F.B., Oklahoma State University, Department of Agricultural Resource Economics. Memorandum to Randall Dodd. "Nutrient Balance for Lagoon and Sprayfield System" (summarizing five technical references). January 22, 2003b.

Research Triangle Institute (RTI). 2001a. *National Water Pollution Control Assessment Model (NWPCAM) Version 2.0: Technical Report 1: Hydrology and Hydrodynamics.* Prepared for the U.S. Environmental Protection Agency. Research Triangle Park, NC: RTI.

Research Triangle Institute (RTI). 2001b. *National Water Pollution Control Assessment Model (NWPCAM) Version 2.0: Technical Report 2: Point and Nonpoint Source Loadings.* Prepared for the U.S. Environmental Protection Agency. Research Triangle Park, NC: RTI.

Schwabe, A. Kurt. 1996. "Source Heterogeneity, Resource Characteristics, and the Performance of Marketable Permits." Ph.D. Thesis. Raleigh, NC: Department of Agricultural Resource Economics, North Carolina State University.

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Exhibit 48

Air Pollution, Lung Function, and Physical Symptoms in Communities Near Concentrated Swine Feeding Operations

Leah Schinasi,[a] Rachel Avery Horton,[a] Virginia T. Guidry,[a] Steve Wing,[a] Stephen W. Marshall,[a] and Kimberly B. Morland[b]

Background: Concentrated animal feeding operations emit air pollutants that may affect health. We examined associations of reported hog odor and of monitored air pollutants with physical symptoms and lung function in people living within 1.5 miles of hog operations.

Methods: Between September 2003 and September 2005, we measured hydrogen sulfide (H_2S), endotoxin, and particulate matter (PM_{10}, $PM_{2.5}$, and $PM_{2.5-10}$) for approximately 2-week periods in each of 16 eastern North Carolina communities. During the same time periods, 101 adults sat outside their homes twice a day for 10 minutes, reported hog odor and physical symptoms, and measured their lung function. Conditional fixed-effects logistic and linear regression models were used to derive estimates of associations.

Results: The log odds (ffi1 standard error) of acute eye irritation following 10 minutes outdoors increased by 0.53 (ffi0.06) for every unit increase in odor, by 0.15 (ffi0.06) per 1 ppb of H_2S, and by 0.36 (ffi0.11) per 10 ffig/m^3 of PM_{10}. Odor and H_2S were also associated with irritation and respiratory symptoms in the previous 12 hours. The log odds of difficulty breathing increased by 0.50 (ffi0.15) per unit of odor. A 10 ffig/m^3 increase in mean 12-hour $PM_{2.5}$ was associated with increased log odds of wheezing (0.84 ffi 0.29) and declines in forced expiratory volume in 1 second (ffl0.04 ffi 0.02 L). A 10 EU/mg increase in endotoxin was associated with increased log odds of sore throat (0.10 ffi 0.05), chest tightness (0.09 ffi 0.04), and nausea (0.10 ffi 0.05).

Conclusions: Pollutants measured near hog operations are related to acute physical symptoms in a longitudinal study using analyses that preclude confounding by time-invariant characteristics of individuals.

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Editors' note: *A commentary on this article appears on page 216.*
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Concentrated animal feeding operations contribute to local, regional, and global air pollution.[1] Pollutants of local importance include odor,[2,3] hydrogen sulfide (H_2S),[4] endotoxin,[5] particulate matter (PM),[6,7] and ammonia (NH_3).[8,9]

Several cross-sectional studies have examined the health of people living near concentrated hog operations on the basis of residential proximity to classify exposure. In a population-based survey, neighbors of hog operations reported more episodes of headache, runny nose, sore throat, coughing, diarrhea, and burning eyes compared with demographically similar persons who did not live near a hog operation.[10] Among children, indicators of asthma have been related to measures of residential[11] and school[12,13] exposures to pollution from hog operations. In an area of Germany with a high density of concentrated animal feeding operations, reported odor annoyance was associated with prevalence of wheeze without a cold, and physician-diagnosed asthma and allergic rhinitis. Additionally, the number of operations within 500 meters of participants' homes was associated with increased odds of wheezing without a cold, and with diminished lung function.[14] These symptoms overlap with conditions reported in studies of occupational exposures of animal-confinement-house workers, including decreased lung function,[15–17] chronic cough,[17] excess phlegm production, chest tightness,[18] scratchy throat, eyes and mucous membrane irritation, shortness of breath,[16] and wheezing.[18]

Community Health Effects of Industrial Hog Operations was a longitudinal, community-driven, participatory study of air pollution, health, and quality of life among persons living near hog operations. We have previously described associations between air pollution and hog odor,[19] air pollution and measures of stress and negative mood,[20] and factors associated with data quality and completeness.[21] Here we report relationships between measures of air pollution,

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symptoms, and lung function, focusing on physical symptoms that have been of interest in cross-sectional studies.[22]

METHODS

Between September 2003 and September 2005, residents of 16 eastern North Carolina communities collected health data for approximately 2 weeks while pollutant concentrations were monitored continuously. Communities participated sequentially using the same set of air-monitoring devices.

Nonsmoking volunteers aged at least 18 years residing within 1.5 miles of at least one hog operation were recruited through community-based organizations. The lead community organization for this study was the Concerned Citizens of Tillery.[23] Participants attended a 3-hour training session at which they gave informed consent and practiced completing all data-collection activities. The study design has been described in detail elsewhere.[23]

The Institutional Review Board of the University of North Carolina at Chapel Hill reviewed and approved study activities annually.

Exposure Variables

Odor

Participants spent 10 minutes outdoors at preselected morning and evening times approximately 12 hours apart. While outside, they rated, on a scale of 0 (none) to 8 (very strong), the strength of the hog odor they recalled having smelled during each of the 12 preceding hours. Participants then returned indoors and rated hog odor present during the 10 minutes outside on the same 9-point scale.

We analyzed 2 hog odor variables. Twelve-hour mean odor is the average of the hourly odor levels reported for each of the 12 hours before the morning or evening data collection time. Twice-daily odor is the odor during the 10 minutes outdoors.

Air Monitoring

Continuous air pollution monitors, mounted on a trailer that was centrally located in each community, recorded concentrations of hydrogen sulfide (H_2S), semi-volatile particulate matter less than 10 micrometers in diameter (semivolatile PM_{10}), particulate matter less than 10 micrometers in diameter that excluded the volatile fraction (PM_{10}), coarse PM ($PM_{2.5-10}$), fine PM ($PM_{2.5}$), and endotoxin. An MDA Scientific Single Point Monitor (Honeywell Analytics Inc North America, Lincolnshire, IL) recorded H_2S concentrations every 15 minutes in parts per billion (ppb). Hourly concentrations of PM_{10} and semivolatile PM_{10} were measured in micrograms per cubic meter (ffig/m^3), using a Tapered Element Oscillating Microbalance Series 1400a Ambient Particulate Monitor with a Series 8500 Filter Dynamics Measurement System (Thermo Fisher Scientific, Waltham, MA). In the first 12 of 16 communities, a Dichotomous Partisol-Plus 2025-D Sequential Air Sampler (Thermo Fisher Scientific, Waltham, MA) was used to collect 12-hour samples of $PM_{2.5-10}$ and $PM_{2.5}$ (ffig/m^3) on filters that were assayed for endotoxin in endotoxin units per milligram (EU/mg). Endotoxin levels from $PM_{2.5-10}$ filters were quantified by kinetic chromogenic Limulus amebocyte lysate assay[24,25]; $PM_{2.5-10}$ filters contained approximately 60% of the endotoxin in the PM_{10}.

We calculated the mean concentrations of H_2S, PM_{10}, and semivolatile PM_{10} in the 1- and 12-hour periods that preceded the time at which participants sat outdoors for 10 minutes. Concentrations of $PM_{2.5}$, $PM_{2.5-10}$, and endotoxin were measured on 12-hour filters that typically did not correspond to exposure periods of interest. Thus, we estimated these exposures with a time-weighted average of the concentrations from filters exposed during the 12 hours prior to sitting outdoors. All exposure variables were coded continuously.

Outcome Variables

Given the short follow-up and focus on transient exposures, we analyzed symptoms that could appear and resolve during follow-up.

Physical Symptoms

After sitting outside their homes for 10 minutes and then returning inside, participants noted whether they experienced cough or irritation of the skin, eyes, nose, or throat while outside (Table 1). Symptoms of acute irritation, reported as present or absent, were analyzed in relation to odor levels reported for the same 10 minutes and in relation to averages of PM and H_2S in the hour prior to the time participants returned indoors. After returning indoors, participants rated the extent to which they experienced any of 19 acute physical symptoms in the preceding 12 hours on a scale of 0 (not at all) to 8 (extreme).

We considered the following 12-hour symptoms: respiratory (runny nose, mucus or phlegm, sore throat, cough, wheezing, difficulty breathing, chest tightness), irritation (burning eyes, itching eyes, nasal), gastrointestinal (nausea, diarrhea, poor appetite), neurologic (headache, dizziness), and other (aching joints, difficulty hearing, fever, and backache). Reports of most physical symptoms were uncommon, so we dichotomized them as absent versus present based on the distribution of responses for each symptom such that at least 85% of responses were coded as 0 and no more than 15% were coded as 1. Runny nose, mucus or phlegm, headache, cough, burning eyes, aching joints, nasal irritation, and itching eyes were dichotomized such that a response of 0 or 1 on the original scale was coded as 0 and a response of 2–8 was coded as 1. For the remaining symptoms, a response of 0 on the original scale was coded as 0 and 1–8 was coded as 1.

Lung Function

Participants used an AirWatch personal respiratory monitor (iMetrikus, Inc., Sunnyvale, CA) to measure forced

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TABLE 1. Characteristics of Communities (n ⌋ 16) and Study Participants (n ⌋ 101)

Characteristic	No.
Concentrated swine feeding operations within 2 miles of community	
Median	9
Range	1–16
Permitted no. hogs (in thousands) within 2 miles of community	
Median	42
Range	4–77
Diary entries per participant	
Median	28
Range[a]	7–46
Race and sex	
Black women	57
Black men	28
Nonblack women	9
Nonblack men	7
Exposed to passive smoking[b]	5
Chronic respiratory disease[c]	
Emphysema[d]	0
Asthma[e]	5
Chronic bronchitis[e]	3
Asthma and chronic bronchitis	4
Hay fever allergy[f]	34
Dust, animal, or food allergy[d]	30
Grew up around livestock[g]	76

[a]Some participated for more than 2 weeks.
[b]Eligible participants were nonsmokers.
[c]Based on participant report of diagnosis by a physician at any point in his or her life.
[d]Number missing ⌋ 9.
[e]Number missing ⌋ 10.
[f]Number missing ⌋ 8.
[g]Number missing ⌋ 3.

expiratory volume in the first second (FEV_1) and peak expiratory flow rate (PEF) during each data collection session. The AirWatch internally recorded each of 3 attempts and flagged any that were made with problematic technique. The highest error-free FEV_1 and PEF measurements from each session (sometimes there were none) were included in the analysis as continuous outcome variables.

Statistical Analyses

In this longitudinal study of transient exposures and outcomes, each participant served as her or his own control. The analytic goal was to make valid within-participant comparisons to determine whether increases in air pollutant concentrations or odor ratings were associated with physical symptoms and lung function. Estimates of associations were constructed using conditional fixed-effects linear and logistic regression models. In these models, the within-person correlation due to repeated measures is accounted for by treating each person as a stratum within the model.[26] This approach has good control of measured and unmeasured time-invariant individual level confounders. These models account for the longitudinal nature of the data by modeling differences between individuals' time-specific characteristics and their mean value over the entire period of follow-up.

Time of day was integral to the study design because community members collected data at morning and evening times that were approximately 12 hours apart. Physical symptoms, lung function, and hog odors exhibit diurnal variation,[19] and thus we made an a priori decision to adjust for potential confounding due to time of day by including a term for morning versus evening in all models. There was little variance in community effects; therefore we did not include the community level in our models.

Because of the large number of exposure and outcome variables, we did not restrict analyses to participant records with complete data for all variables. Each analysis excludes only those observations that were missing data for the exposure and outcome being analyzed.

RESULTS

There was a median of 9 hog operations within 2 miles of participating communities, and the median number of hogs within that radius was approximately 42,000 (Table 1). Study participants ranged in age from 19 to 90; their mean age was 53. Over half of participants were women, and most participants described themselves as black. Overall, the study population was healthy, with zero participants reporting emphysema and 12 reporting asthma or chronic bronchitis (Table 1). The participants provided 2949 journal entries. There were approximately 2600 responses about irritation symptoms following the 10-minutes outdoors, 2900 responses about physical symptoms experienced in the last 12 hours, and 1900 error-free measurements of lung function (eAppendix 1, http://links.lww.com/EDE/A453).

Average ambient air pollutant values are presented in eAppendix 2 (http://links.lww.com/EDE/A453). There were approximately 2700 values of H_2S and 2000 values of semivolatile PM_{10} and PM_{10}; the smaller numbers of observations for the latter 2 pollutants were due to equipment malfunction in hot and humid weather. There were approximately 1750 values for $PM_{2.5-10}$, $PM_{2.5}$, and endotoxin in the 12 communities where these pollutants were measured. Overall means, minimum and maximum community means, and between-community variation (as a % of total) are reported in eAppendix 2 (http://links.lww.com/EDE/A453). Two negative minimum community means for semivolatile PM_{10} occurred due to measurement error in the microbalance estimates of mass close to zero. More than half of the total variation in air pollutant measurements occurred between communities for 12-hour odor and 12-hour semivolatile PM_{10}. For the other measured pollutants, the majority of the variation occurred within the communities over time. This was particularly true for 1-hour and 12-hour H_2S and 1-hour and 12-hour PM_{10}, for which the between-community variances were approximately 4%, 6%, 6%, and 15%, respectively.

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TABLE 2. Logistic Fixed Effects Models of Hog Odor, Hydrogen Sulfide, Nonvolatile PM_{10}, and Semivolatile PM_{10} as Predictors of Acute Irritation Symptoms Reported Immediately After Participants Spent 10 Minutes Outdoors[a]

	Twice-daily Odor			1-h Average H_2S per 1 ppb			1-h Average PM_{10} per 10 ffig/m^3			1-h Average Semivolatile PM_{10} per 10 ffig/m^3		
	ffl	SE	⌋2	ffl	SE	⌋2	ffl	SE	⌋2	ffl	SE	⌋2
Eye irritation	0.53	0.06	87.49	0.15	0.06	6.10	0.36	0.11	10.12	0.16	0.27	0.37
Nasal irritation	0.65	0.05	151.68	0.08	0.03	6.83	ffl0.00	0.04	0.00	ffl0.11	0.22	0.23
Throat irritation	0.41	0.06	41.75	0.12	0.07	2.49	ffl0.03	0.05	0.33	0.26	0.33	0.65
Skin irritation	0.37	0.16	5.56	0.13	0.25	0.26	0.56	0.38	2.17	0.47	0.93	0.26
Cough	0.25	0.07	11.89	0.14	0.12	1.34	ffl0.02	0.11	0.05	ffl0.48	0.41	1.32

[a]All models are adjusted for time of day (AM/PM).
SE indicates standard error; PM, particulate matter.

TABLE 3. Linear and Logistic Fixed Effects Models of 12-hour Average Hog Odor, Hydrogen Sulfide, Nonvolatile PM_{10}, and Semivolatile PM_{10} as Predictors of Lung Function and 12-hour Symptoms[a]

	12-h Average Odor			12-h Average H_2S per 1 ppb			12-h Average PM_{10} per 10 ffig/m^3			12-h Average Semivolatile PM_{10} per 10 ffig/m^3		
Lung Function												
Linear Models	ffl	SE	*t*	ffl	SE	*t*	ffl	SE	*t*	ffl	SE	*t*
PEF	ffl0.52	(1.58)	ffl0.33	ffl0.46	(0.71)	ffl0.65	1.29	(1.17)	1.10	ffl7.39	(4.87)	ffl1.52
FEV_1	ffl0.02	(0.01)	ffl1.67	ffl0.01	(0.01)	ffl1.43	ffl0.00	(0.00)	ffl0.22	ffl0.04	(0.04)	ffl1.04
Symptoms												
Logistic Models	ffl	SE	⌋2	ffl	SE	⌋2	ffl	SE	⌋2	ffl	SE	⌋2
Respiratory												
Runny nose	0.27	(0.10)	7.29	0.29	(0.09)	10.00	ffl0.10	(0.10)	1.00	0.35	(0.37)	0.91
Mucus or phlegm	0.19	(0.14)	1.91	0.07	(0.09)	0.65	ffl0.22	(0.13)	2.67	ffl0.44	(0.47)	0.90
Sore throat	0.08	(0.11)	0.56	0.03	(0.04)	0.39	ffl0.25	(0.13)	3.54	ffl0.24	(0.40)	0.38
Cough	0.36	(0.15)	5.50	0.09	(0.10)	0.80	0.02	(0.10)	0.02	ffl0.45	(0.45)	1.01
Wheezing	0.18	(0.16)	1.36	0.09	(0.06)	2.40	0.16	(0.11)	2.33	0.20	(0.56)	0.13
Difficulty breathing	0.50	(0.15)	11.18	0.33	(0.13)	7.06	0.05	(0.08)	0.50	1.22	(0.39)	9.99
Chest tightness	0.12	(0.12)	1.11	ffl0.01	(0.09)	0.02	0.01	(0.09)	0.02	0.53	(0.37)	1.99
Irritation												
Burning eyes	0.32	(0.10)	10.12	0.19	(0.07)	6.29	0.01	(0.09)	0.03	0.10	(0.43)	0.06
Itching eyes	0.17	(0.10)	2.71	0.12	(0.05)	5.15	0.05	(0.10)	0.26	0.01	(0.44)	0.00
Nasal irritation	0.46	(0.13)	13.67	0.12	(0.04)	7.90	0.00	(0.07)	0.00	ffl0.17	(0.39)	0.20
Gastrointestinal												
Nausea	0.21	(0.17)	1.59	0.18	(0.13)	1.82	ffl0.08	(0.17)	0.22	0.02	(0.59)	0.00
Diarrhea	ffl0.10	(0.28)	0.14	ffl0.05	(0.24)	0.04	ffl0.27	(0.30)	0.81	ffl0.46	(0.83)	0.30
Poor appetite	ffl0.03	(0.29)	0.01	ffl0.25	(0.34)	0.54	0.51	(0.20)	6.24	ffl0.05	(0.61)	0.01
Neurological												
Headache	0.12	(0.12)	1.00	ffl0.07	(0.09)	0.60	ffl0.03	(0.11)	0.09	0.32	(0.32)	0.96
Dizziness	0.11	(0.10)	1.25	0.06	(0.07)	0.88	0.15	(0.11)	1.92	ffl0.14	(0.34)	0.17
Other												
Aching joints	ffl0.01	(0.13)	0.01	ffl0.05	(0.13)	0.14	0.09	(0.07)	1.60	ffl0.93	(0.47)	3.84
Difficulty hearing	ffl0.16	(0.23)	0.51	ffl0.91	(0.64)	2.03	0.17	(0.11)	2.62	1.78	(0.65)	7.47
Fever	ffl0.02	(0.53)	0.00	0.65	(0.41)	2.48	ffl0.07	(0.38)	0.03	ffl3.32	(1.91)	3.04
Backache	ffl0.16	(0.14)	1.25	ffl0.04	(0.09)	0.17	0.13	(0.07)	3.03	ffl0.23	(0.39)	0.35

[a]All models are adjusted for time of day (AM/PM).
SE indicates standard error; PEF, peak expiratory flow; FEV_1, forced expiratory volume in the first second; PM, particulate matter.

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Associations of acute irritation symptoms with twice-daily (10-minute) odor reports and 1-hour average pollution levels are presented in Table 2. Irritation symptoms were elevated in association with odor and H_2S, and most coefficients were substantially greater than their standard errors. Estimates of associations between 1-hour PM_{10} and irritation symptoms were near zero for nasal and throat irritation, and cough, whereas associations were positive for eye and skin irritation. Coefficients for semivolatile PM_{10} were both positive and negative and similar in magnitude or smaller than their standard errors.

Estimates of associations of 12-hour average odor, H_2S, PM_{10}, and semivolatile PM_{10} with lung function measures and 12-hour symptom variables are presented in Table 3. Point estimates for PEF and FEV_1 are negative except for the coefficient for PM_{10} and PEF. *T* values indicate that the negative coefficients are less than or equal in value to their standard errors, the largest being for the association between odor and FEV_1.

Point estimates of associations of respiratory symptoms with odor and H_2S were positive except for the coefficient between H_2S and chest tightness (Table 3). The log odds of having experienced 4 of the 7 respiratory symptoms were positive for PM_{10} and semivolatile PM_{10}. However, most of these estimates were close to zero, with the exception of difficulty breathing and 12-hour mean semivolatile PM_{10}. Additionally, sore throat symptom reports were negatively associated with increases in PM_{10}.

We observed positive associations (with high fff values) of irritation symptoms in the past 12 hours with 12-hour mean odor and with 12-hour mean H_2S (Table 3). Twelve-hour irritation symptoms were not associated with 12-hour mean PM_{10} or semivolatile PM_{10} (Table 3). Overall, we found little association between gastrointestinal symptoms and 12-hour mean odor, H_2S, PM_{10}, or semivolatile PM_{10}, with the exception of a positive association between PM_{10} and poor appetite. We found little evidence of associations between neurologic symptoms and 12-hour mean odor, H_2S, PM_{10}, or semivolatile PM_{10}. Point estimates for the symptoms in the "other" category varied in magnitude and direction. Eleven of the 16 point estimates were negative, although most had very small fff values. The highest fff values were for the relationships of aching joints and difficulty hearing with 12-hour mean semivolatile PM_{10}, although the estimates were in opposite directions (ffl0.93 ffi 0.47 and 1.78 ffi 0.65, respectively).

Twelve-hour average concentrations of $PM_{2.5-10}$, $PM_{2.5}$, and endotoxin were modeled as predictors of lung function and 12-hour symptoms in the 12 communities with results from the sequential air sampler (n ¬ 70 participants, Table 4). *T* values for beta coefficients from linear conditional fixed effects models were small except for the association between $PM_{2.5}$ and FEV_1; FEV_1 decreased 0.04 ffi 0.02 L per 10 ffig/m^3 increase in 12 hour mean $PM_{2.5}$.

Associations between symptoms and pollutants measured by the sequential sampler in the 12 communities with these measurements are also presented in Table 4. Most fff values were small, indicating that these exposure measures were poor predictors of symptoms. High fff values were observed for associations between $PM_{2.5-10}$ and 3 symptoms, $PM_{2.5}$ and 5 symptoms, and endotoxin and 3 symptoms. $PM_{2.5-10}$ was negatively associated with chest tightness and nausea and positively associated with aching joints. Symptoms showed more consistently positive associations with $PM_{2.5}$ (wheezing, difficulty breathing, burning eyes, nasal irritation, backache) and endotoxin (sore throat, chest tightness, nausea).

The models reported in Tables 2–4 were also fit using random effects mixed models and produced very similar results.

DISCUSSION

Concerns about air pollution from animal production facilities have grown with the global industrialization of food animal production.[1,10–14,27,28] Concentrated hog feeding operations release air pollutants from confinement buildings, manure holding pits, and land-application of animal wastes.[1,29,30] Although cross-sectional studies have documented relationships of proximity to hog operations with physical symptoms[10–14,31,32] and with reduced FEV_1,[14] they have lacked air pollution measures and most have depended solely on participant recall of symptoms over time periods of 6–12 months. The present study contributes to the literature by linking twice-daily symptom reports and lung function measurements of people residing near hog operations with physical measures of ambient air pollutant concentrations.

Several limitations should be considered in interpreting the results of this study. First, although we have repeated measures for each participant, the number of people in the study is small. The small sample size contributes to imprecision of measures of association and also limits our ability to quantify variability in measures of association between subgroups.

Several factors may limit the external validity of the study findings. The 16 study communities are not a random sample of eastern North Carolina, and we are not able to evaluate the extent to which the characteristics of air pollutants or the volunteers in the study are representative of other populations living near industrial hog operations. Furthermore, participants were nonsmoking volunteers, mostly free of chronic respiratory diseases. Associations between hog operation pollutants and health outcomes may be different among smokers and people with asthma or other conditions that increase responsiveness to pollutants. About three-fourths of the study participants reported growing up around livestock, which has been associated with lower levels of atopy in some studies.[33–35] We did not measure atopy; however, 43% of participants who grew up on a farm reported hay fever compared with 19% of those who did not, suggesting that early exposure to livestock may not have resulted in reduced responsiveness to pollutants in this population.

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TABLE 4. Linear and Logistic Fixed Effects Models of Coarse Particles, Fine Particles, and Endotoxin as Predictors of Lung Function and Symptoms[a]

	12-h $PM_{2.5-10}$ per 10 ffig/m^3			12-h $PM_{2.5}$ per 10 ffig/m^3			12-h Endotoxin per 10 EU/mg		
				Lung Function					
Linear Models	ffl	SE	*t*	ffl	SE	*t*	ffl	SE	*t*
PEF	1.96	(2.08)	0.94	ffl0.19	(2.64)	ffl0.07	0.23	(0.45)	0.53
FEV_1	0.01	(0.02)	0.52	ffl0.04	(0.02)	ffl2.12	0.00	(0.00)	0.37
				Symptoms					
Logistic Models	ffl	SE	┘2	ffl	SE	┘2	ffl	SE	┘2
Respiratory									
Runny nose	ffl0.16	(0.24)	0.46	0.13	(0.20)	0.39	0.02	(0.04)	0.41
Mucus or phlegm	ffl0.02	(0.15)	0.02	ffl0.18	(0.28)	0.40	ffl0.01	(0.05)	0.08
Sore throat	ffl0.50	(0.52)	0.91	ffl0.30	(0.25)	1.45	0.10	(0.05)	3.46
Cough	ffl0.70	(0.51)	1.89	0.01	(0.29)	0.00	0.03	(0.05)	0.33
Wheezing	0.19	(0.26)	0.55	0.84	(0.29)	8.64	ffl0.01	(0.06)	0.02
Difficulty breathing	ffl0.62	(0.42)	2.17	0.50	(0.24)	4.37	0.06	(0.05)	1.47
Chest tightness	ffl0.84	(0.45)	3.56	0.02	(0.24)	0.00	0.09	(0.04)	6.42
Irritation									
Burning eyes	0.15	(0.20)	0.55	0.61	(0.22)	7.78	0.02	(0.04)	0.25
Itching eyes	ffl0.08	(0.18)	0.21	0.38	(0.24)	2.53	0.03	(0.04)	0.72
Nasal irritation	ffl0.03	(0.14)	0.07	0.48	(0.25)	3.66	0.00	(0.04)	0.01
Gastrointestinal									
Nausea	ffl1.43	(0.71)	4.06	ffl0.09	(0.32)	0.07	0.10	(0.05)	3.64
Diarrhea	ffl1.11	(1.21)	0.85	ffl0.07	(0.45)	0.02	0.04	(0.10)	0.12
Poor appetite	0.62	(0.90)	0.47	ffl0.25	(0.62)	0.16	ffl0.03	(0.10)	0.08
Neurological									
Headache	ffl0.31	(0.39)	0.61	ffl0.18	(0.22)	0.63	0.06	(0.05)	1.74
Dizziness	ffl0.54	(0.46)	1.40	ffl0.26	(0.23)	1.29	0.04	(0.05)	0.77
Other									
Aching joints	0.30	(0.15)	3.99	0.02	(0.24)	0.01	0.00	(0.04)	0.01
Difficulty hearing	ffl0.10	(0.43)	0.05	0.53	(0.41)	1.70	0.04	(0.07)	0.41
Fever	0.18	(0.95)	0.04	ffl0.64	(0.79)	0.67	0.19	(0.14)	1.96
Backache	ffl0.02	(0.15)	0.01	0.61	(0.25)	5.86	0.03	(0.04)	0.60

[a]All models are adjusted for time of day (AM/PM).
SE indicates standard error; PEF, peak expiratory flow; FEV_1, forced expiratory volume in the first second; PM, particulate matter.

The air-monitoring equipment for this study was large and difficult to conceal. In some communities, participants reported reductions in hog odor and spraying of hog waste during the study compared with time periods before and after the equipment was in their neighborhoods. Changes in waste management practices could have lowered exposure levels during the study, and consequently our ability to detect effects. In addition, exposure variability within communities could not be quantified by the stationary, centrally located monitors.

Finally, lung function data were of lower quality and were less complete than other outcome data.[21] Lung function assessment depends upon proper technique and is ideally conducted by a laboratory technician.[36] In this study, participants were trained to make 3 measurements to the best of their ability each time they collected data. Given the community-based setting, we did not feel it was appropriate to apply American Thoracic Society/European Respiratory Society standards to these measurements.[37] Instead, we analyzed only error-free readings, further reducing sample size and the precision of estimates of association. Therefore, it is of interest that a 10 ffig/m^3 increase in $PM_{2.5}$ (measured only in 12 of the 16 communities) was associated with a 0.04 ffi 0.02 L decrease in FEV_1 (T┘ f 2.112).

Despite these limitations, most exposure-outcome relationships were in the predicted direction; most of those not in the predicted direction were weak. We observed unexpected negative associations between PM_{10} and sore throat, $PM_{2.5-10}$ and nausea and chest tightness, and semivolatile PM_{10} and aching joints. We are not aware of any biologic mechanisms whereby these air pollutants or unmeasured copollutants

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could protect against development of these symptoms. Although the study design and analytic methods preclude confounding by time-invariant characteristics of participants, these negative associations could reflect uncontrolled time-related confounding, measurement error, or both.

In addition, our findings were generally consistent with prior studies of airborne emissions from industrial hog operations. For example, in a controlled experiment, 48 healthy adult volunteers (mean age ⌋ 26) reported eye irritation and nausea more frequently when exposed to diluted swine air than when exposed to clean air.[38] Radon et al[14] found evidence of decreased FEV_1 and increased wheezing in association with the number of concentrated animal feeding operations near participants' residences, and increased reports of asthma and nasal allergies in association with reported annoyance with odor. Mirabelli et al[12] observed a 23% higher prevalence of wheezing among children who attended schools where staff reported livestock odor inside school buildings twice or more per month, compared with schools where no livestock odor was reported. In a cross-sectional study of rural Iowa children, living on a farm that raised swine and added antibiotics to animal feed was associated with asthma-related outcomes.[11] Finally, endotoxin exposures have been associated with increased respiratory and systemic symptoms and decreased lung function,[39] and working in hog operations has also been associated with respiratory symptoms, reduced lung function, and organic dust toxic syndrome.[15,16,40,41]

Interestingly, in contrast to some other studies, we did not observe an association between hog operation air pollutants and headaches.[10,38,42] It is possible that headaches are more prevalent among individuals living near hog operations, but that the incidence of headaches does not covary with odor and pollutants on the short-time scale used in our study. Although an acute association with headache was observed in a chamber study,[38] that exposure was diluted air from a swine confinement building, and the experimental subjects were naive volunteers who did not live near hog operations.

Among the pollutants we measured, H_2S (which is produced by anaerobic decomposition of sulfur-containing organic matter in hog waste pits[1]) provides a fairly specific measure of hog operation pollution in these rural areas where there are few other industrial sources of H_2S. In contrast to H_2S, PM is a ubiquitous air pollutant with many sources and has been previously associated with lower lung function, heart rate variability, and mortality.[43–46] In addition to solid particle sources, constituents of PM may form indirectly in the atmosphere through reactions of precursor gases such as NH_3[47] to form soluble substances such as ammonium nitrate.[48] These particles may be semivolatile, in equilibrium between gas and particle phases,[49] and may have different effects than nonvolatile fractions of PM. Therefore observed associations between PM, symptoms, and lung function could be due to PM emitted by hog operations, PM from other sources, or both. We were specifically interested in $PM_{2.5-10}$ because of the possibility that hog dander, feed, dried feces, endotoxin, and other microbial matter would be present in the coarse fraction.[30] However, of all the pollution measures, $PM_{2.5-10}$ showed the smallest and least precise associations with symptoms and lung function.

Conclusions

This longitudinal study contributes to evidence obtained from cross-sectional research that suggests that air pollutants near hog operations cause acute physical symptoms, particularly upper respiratory symptoms and irritation of the nose and eyes. Despite limitations of measurements of exposure and outcome, the temporal nature of the analysis eliminates confounding from time-invariant factors and strengthens the evidence. Adjustment for time of day helps reduce any time-related confounding that could be introduced by diurnal covariation in symptoms and air pollutants. Variability in pollutants within morning and evening periods is large enough so that overadjustment is not a concern.

Industrial hog operations in North Carolina are disproportionately located in low-income communities of color[10,29] where there is more potential for exposure to outdoor air pollutants due to older homes that are not air tight and have no air conditioning. Many residents also lack the financial resources to travel and choose activities that could help them avoid high pollution. Exposure to air pollution from hog operations is an environmental injustice in rural areas hosting facilities that supply pork to populations spared the burdens of its production.

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REFERENCES

1. National Research Council Ad Hoc Committee on Air Emissions from Animal Feeding Operations. *Air Emissions from Animal Feeding Operations: Current Knowledge, Future Needs*. Washington, DC: The National Academies Press; 2003.
2. Schiffman SS. Livestock odors: implications for human health and well-being. *J Anim Sci*. 1998;76:1343–1355.
3. Schiffman SS, Walker JM, Dalton P, et al. Potential health effects of

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ED_001369_00043711-00349

odor from animal operations, wastewater treatment, and recycling of byproducts. *J Agromedicine*. 2004;9:397–403.
4. Hoff SJ, Bundy DS, Nelson MA, et al. Emissions of ammonia, hydrogen sulfide, and odor before, during, and after slurry removal from a deep-pit swine finisher. *J Air Waste Manag Assoc*. 2006;56:581–590.
5. Thorne PS, Ansley AC, Perry SS. Concentrations of bioaerosols, odors, and hydrogen sulfide inside and downwind from two types of swine livestock operations. *J Occup Environ Hyg*. 2009;6:211–220.
6. Walker JT, Robarge WP, Shendrikar A, Kimball H. Inorganic PM2.5 at a U.S. agricultural site. *Environ Pollut*. 2006;139:258–271.
7. Goetz S, Aneja VP, Zhang Y. Measurement, analysis, and modeling of fine particulate matter in eastern North Carolina. *J Air Waste Manag Assoc*. 2008;58:1208–1214.
8. Costanza JK, Marcinko SE, Goewert AE, Mitchell CE. Potential geographic distribution of atmospheric nitrogen deposition from intensive livestock production in North Carolina, USA. *Sci Total Environ*. 2008; 398:76–86.
9. Sherlock RR, Sommer SG, Khan RZ, et al. Ammonia, methane, and nitrous oxide emission from pig slurry applied to a pasture in New Zealand. *J Environ Qual*. 2002;31:1491–1501.
10. Wing S, Wolf S. Intensive livestock operations, health, and quality of life among eastern North Carolina residents. *Environ Health Perspect*. 2000;108:233–238.
11. Merchant JA, Naleway AL, Svendsen ER, et al. Asthma and farm exposures in a cohort of rural Iowa children. *Environ Health Perspect*. 2005;113:350–356.
12. Mirabelli MC, Wing S, Marshall SW, Wilcosky TC. Asthma symptoms among adolescents who attend public schools that are located near confined swine feeding operations. *Pediatrics*. 2006;118:e66–e75.
13. Sigurdarson ST, Kline JN. School proximity to concentrated animal feeding operations and prevalence of asthma in students. *Chest*. 2006; 129:1486–1491.
14. Radon K, Schulze A, Ehrenstein V, van Strien RT, Praml G, Nowak D. Environmental exposure to confined animal feeding operations and respiratory health of neighboring residents. *Epidemiology*. 2007;18:300–308.
15. Eduard W, Pearce N, Douwes J. Chronic bronchitis, COPD, and lung function in farmers: the role of biological agents. *Chest*. 2009;136:716–725.
16. Senthilselvan A, Chenard L, Ulmer K, Gibson-Burlinguette N, Leuschen C, Dosman JA. Excess respiratory symptoms in full-time male and female workers in large-scale swine operations. *Chest*. 2007;131:1197–1204.
17. Zejda JE, Hurst TS, Rhodes CS, Barber EM, McDuffie HH, Dosman JA. Respiratory health of swine producers. Focus on young workers. *Chest*. 1993;103:702–709.
18. Andersen CI, Von Essen SG, Smith LM, Spencer J, Jolie R, Donham KJ. Respiratory symptoms and airway obstruction in swine veterinarians: a persistent problem. *Am J Ind Med*. 2004;46:386–392.
19. Wing S, Horton RA, Marshall SW, et al. Air pollution and odor in communities near industrial swine operations. *Environ Health Perspect*. 2008;116:1362–1368.
20. Horton RA, Wing S, Marshall SW, Brownley KA. Malodor as a trigger of stress and negative mood in neighbors of industrial hog operations. *Am J Public Health*. 2009;99:S610–S615.
21. Schinasi L, Horton RA, Wing S. Data completeness and quality in a community-based and participatory epidemiologic study. *Prog Community Health Partnersh*. 2009;3:179–190.
22. Tajik M, Muhammad N, Lowman A, Thu K, Wing S, Grant G. Impact of odor from industrial hog operations on daily living activities. *New Solut*. 2008;18:193–205.
23. Wing S, Horton RA, Muhammad N, Grant GR, Tajik M, Thu K. Integrating epidemiology, education, and organizing for environmental justice: community health effects of industrial hog operations. *Am J Public Health*. 2008;98:1390–1397.
24. Menetrez MY, Foarde KK, Esch RK, et al. An evaluation of indoor and outdoor biological particulate matter. *Atmos Environ*. 2009;43:5476–5483.
25. Foarde K, Berry M. Comparison of biocontaminant levels associated with hard vs. carpet floors in nonproblem schools: results of a year long study. *J Expo Anal Environ Epidemiol*. 2004;14:S41–S48.
26. Allison PD. *Fixed Effects Regression Methods for Longitudinal Data Using SAS*. Cary, NC: SAS Institute; 2005.
27. Pew Commission on Industrial Farm Animal Production. *Putting Meat on the Table: Industrial Farm Animal Production in America*. Baltimore, MD: The Johns Hopkins Bloomberg School of Public Health; 2006.
28. Thorne PS. Environmental health impacts of concentrated animal feeding operations: anticipating hazards—searching for solutions. *Environ Health Perspect*. 2007;115:296–297.
29. Wing S, Cole D, Grant G. Environmental injustice in North Carolina's hog industry. *Environ Health Perspect*. 2000;108:225–231.
30. Iowa State University and the University of Iowa Study Group. *Iowa Concentrated Animal Feeding Operation Air Quality Study*. Iowa City, IA: The University of Iowa College of Public Health, Iowa State University College of Agriculture; 2002.
31. Thu KM. Public health concerns for neighbors of large-scale swine production operations. *J Agric Saf Health*. 2002;8:175–184.
32. Villeneuve PJ, Ali A, Challacombe L, Hebert S. Intensive hog farming operations and self-reported health among nearby rural residents in Ottawa, Canada. *BMC Public Health*. 2009;9:330.
33. Naleway AL. Asthma and atopy in rural children: is farming protective? *Clin Med Res*. 2004;2:5–12.
34. Vedanthan PK, Mahesh PA, Vedanthan R, Holla AD, Liu AH. Effect of animal contact and microbial exposures on the prevalence of atopy and asthma in urban vs rural children in India. *Ann Allergy Asthma Immunol*. 2006;96:571–578.
35. Von Ehrenstein OS, Von Mutius E, Illi S, Baumann L, Bohm O, von Kries R. Reduced risk of hay fever and asthma among children of farmers. *Clin Exp Allergy*. 2000;30:187–193.
36. Miller MR, Crapo R, Hankinson J, et al. General considerations for lung function testing. *Eur Respir J*. 2005;26:153–161.
37. Miller MR, Hankinson J, Brusasco V, et al. ATS/ERS Task Force. Standardisation of spirometry. *Eur Respir J*. 2005;26:319–338.
38. Schiffman SS, Studwell CE, Landerman LR, Berman K, Sundy JS. Symptomatic effects of exposure to diluted air sampled from a swine confinement atmosphere on healthy human subjects. *Environ Health Perspect*. 2005;113:567–576.
39. Heederik D, Sigsgaard T, Thorne PS, et al. Health effects of airborne exposures from concentrated animal feeding operations. *Environ Health Perspect*. 2007;115:298–302.
40. Vogelzang PF, van der Gulden JW, Folgering H, van Schayck CP. Organic dust toxic syndrome in swine confinement farming. *Am J Ind Med*. 1999;35:332–334.
41. Charavaryamath C, Singh B. Pulmonary effects of exposure to pig barn air. *J Occup Med Toxicol*. 2006;1:10.
42. Thu K, Donham KJ, Ziegenhorn R, et al. A control study of the physical and mental health of residents living near a large-scale swine operation. *J Agric Saf Health*. 1997;3:13–26.
43. Downs SH, Schindler C, Liu LJ, et al. Reduced exposure to PM10 and attenuated age-related decline in lung function. *N Engl J Med*. 2007; 357:2338–2347.
44. Lewtas J. Air pollution combustion emissions: characterization of causative agents and mechanisms associated with cancer, reproductive, and cardiovascular effects. *Mutat Res*. 2007;636:95–133.
45. Wheeler A, Zanobetti A, Gold DR, Schwartz J, Stone P, Suh HH. The relationship between ambient air pollution and heart rate variability differs for individuals with heart and pulmonary disease. *Environ Health Perspect*. 2006;114:560–566.
46. Zeka A, Zanobetti A, Schwartz J. Individual-level modifiers of the effects of particulate matter on daily mortality. *Am J Epidemiol*. 2006; 163:849–859.
47. Aneja VP, Schlesinger WH, Erisman JW. Effects of agriculture upon the air quality and climate: research, policy, and regulations. *Environ Sci Technol*. 2009;43:4234–4240.
48. Harrison RM, Yin J. Particulate matter in the atmosphere: which particle properties are important for its effects on health? *Sci Total Environ*. 2000;249:85–101.
49. Grover BD, Eatough NL, Eatough DJ, et al. Measurement of both nonvolatile and semi-volatile fractions of fine particulate matter in Fresno, CA. *Aerosol Sci Technol*. 2006;40:811–826.

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Exhibit 49

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Examination of atmospheric ammonia levels near hog CAFOs, homes, and schools in Eastern North Carolina

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Abstract

Hog concentrated animal feeding operations (CAFOs) release ammonia (NH_3) in Eastern North Carolina (NC) to the atmosphere which is potentially hazardous for nearby human populations at community locations particularly homes and schools. We present NH_3 weekly average concentrations that were collected using passive diffusion tubes from October 2003 to May 2004 (20 sites) and from July 2004 to October 2004 (23 sites) near community locations in close proximity to hog CAFOs. The data for each phase of sampling was stratified by distance from the nearest hog CAFO. The mean Phase I levels were 16, 8, 7 and 5 ppb for distances o 0.5, 0.5–1, 1–2, and 2 km or more, respectively. The mean levels for Phase II were 29, 16, and 11 ppb for distances o 0.5, 0.5–1, and 1 km or more, respectively. The results of the distance stratification are the best results of this study and provide the strongest evidence that distance to one or more CAFOs is the key variable in controlling weekly NH_3 atmospheric concentration at the community level in Eastern NC. Statistical analyses confirmed that source terms such as distance to a hog CAFO and live weight per operation, as well as temperature, wind speed and wind direction were important predictors of atmospheric NH_3 at community locations. The results indicate potential zones of exposure for human populations who live or go to school near hog CAFOs.
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Keywords: Ammonia; Hog; Passive diffusion; CAFOs; Emission; Exposure

1. Introduction

The exposure of rural populations to industrial hog farm pollution including ammonia (NH_3), hydrogen sulfide (H_2S), VOCs, bioaerosols, endotoxins, and particulate matter (National Academy of Sciences (NAS), 2002; Iowa Study Group (ISG), 2002) may lead to adverse health outcomes (e.g., respiratory ailments, immune suppression, stress, mental health problems) (Mirabelli et al., 2006; Merchant et al., 2005; Bullers, 2005; Avery et al., 2004; Hodne, 2001; Wing and Wolf, 2000; Cole et al., 2000; Thu et al., 1997; Schiffman et al., 1995, 2000). In addition, the burden of hog confined agricultural feeding operations (CAFOs) on rural communities can negatively impact quality of life

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including: (1) decreasing the ability of residents to enjoy their property (Thu, 2002), (2) reducing property values (Palmquist et al., 1997), (3) eroding social capital (Wright et al., 2001; Thu, 1996), (4) preventing healthy economic development (Durrenberger and Thu, 1996), and (5) hampering community sustainability.

In recent years, scientists have performed considerable research on industrial hog operations to quantify the emissions of these pollutants from confinement houses, lagoons, sprayfields and reemission from soils (see Iowa Study Group (ISG), 2002 for literature review), while, other researchers have produced studies to assess occupational exposures to hog CAFO pollution and related health effects (Iowa Study Group (ISG), 2002). This work has a limited utility in understanding chronic exposure of rural populations to intermittent levels of NH_3 and other CAFO pollutants and the development of appropriate exposure limits not based on occupational data and a paucity of community-based epidemiology studies.

Researchers have performed a paucity of work to examine the spatiotemporal variation of atmospheric NH_3 near populations at the community level (Reynolds et al., 1997; Secrest, 1999; Walker et al., 2004; Robarge et al., 2002; Phillips et al., 2004). Our lack of knowledge on atmospheric NH_3 at the community level is an important problem, because, without it, we are unable to develop accurate exposure profiles for residents who live near CAFOs and ascertain the burden of CAFOs and negative health responses on exposed populations.

This paper is a part of a larger project that examines spatiotemporal variation of atmospheric ammonia levels in Eastern North Carolina near hog CAFOs, homes and schools (Wilson, 2005). Previous work has demonstrated the importance of source and meteorological parameters in predicting NH_3 levels on the CAFO property or at a limited number of ambient sites. The purpose of this paper is to answer the question: What are the variables that explain NH_3 variation in a region of variable hog CAFO density near homes and schools at the community level? This paper seeks to answer this question by exploring the relationship between distance to emission source and measured NH_3 levels and examining the association between concentration and meteorological parameters across community locations.

2. Methods

2.1. Passive monitoring of atmospheric ammonia in Eastern NC

Passive diffusion tubes were utilized to measure atmospheric ammonia levels near industrial hog CAFOs, homes and schools in Eastern NC. Passive sampling occurred in two phases from 2003 to 2004 across a region of variable CAFO density including Duplin, Greene, and Lenoir (high emission density counties) and Nash, Edgecombe, and Wilson (low emission density counties). Phase I occurred from October 2003 to May 2004 (20 sites) to measure atmospheric NH_3 levels across different seasons and low and high emission density counties. Phase-II sampling occurred from July to October 2004 (23 sites) to measure NH_3 during the warmest months of the year in Duplin, Greene, and Lenoir counties. Passive samplers were placed near homes and schools less than 2 km from the nearest hog CAFO (exposed sites) and near homes and schools greater than 2 km from the nearest hog CAFO (less-exposed sites). Passive samplers were exposed for 1 week at a time, so that the NH_3 data presented in this work correspond to weekly average of atmospheric NH_3 concentration. More information about the passive method, sampling framework, and results can be found in Wilson (2005).

2.2. Calculation of distance

Latitude/longitude coordinates of industrial hog operations were supplied by the North Carolina Department of Environment and Natural Resources (North Carolina Department of Environment and Natural Resources (NCDENR), 2002). Additional information on the location of hog CAFOs was derived from the work presented in Wing et al. (2000). The ArcGIS 8.3 (ESRI, Redlands, CA, USA) find distance tool was employed to find the distance from each passive monitoring station to the closest hog CAFO and these distances were checked in the field. These distances were recorded and placed in an Excel spreadsheet.

2.3. Stratification of distance

NH_3 data were stratified based on distance from the emission source. Four distance categories were established for Phase I: (1) o 0.5 km from a CAFO,

(2) 0.5–1 km from a CAFO, (3) 1–2 km from a CAFO and (4) 4 2 km from a CAFO. Only three distance categories were used o 0.5 km from a CAFO, 0.5–1 km from a CAFO, and 4 1 km from a CAFO for Phase II because sampling occurred at only one site 4 2 km from a CAFO (site #23). The Swine Farm Siting Act requires that swine houses or lagoons holding animal waste shall be located at least 1500 ft from any occupied residence; at least 2500 ft from any school, hospital, or church; and at least 500 ft from any property boundary (North Carolina General Statutes (NCGS), 1995). Distance categories 1 and 2 were comparable to setback distances for livestock operations at 1500 ft (¬ 0.5 km) from a residence and 2500 ft (¬ 0.8 km) from a school. The use of stratification will allow us to ascertain the average NH_3 levels in the mandated buffers between livestock operations and homes and schools at the community level.

2.4. Extraction of weather data from the North Carolina Climate Office database

Meteorological parameters were obtained for nearby weather stations in the Eastern NC study area during Phase I and Phase II sampling. The data were extracted from the North Carolina Climate database administered by the State Climate Office of North Carolina (SCONC) housed at North Carolina State University (State Climate Office of North Carolina (SCONC), 2003; / www.nc-climate.ncsu.eduS. This office maintains the database that collects all of the available meteorological data for the state of NC. The weather stations collect hourly temperature, wind speed and direction, humidity, and precipitation, and barometric pressure data. Fig. 1 shows the location of the weather stations used in this study in relation to the Phase I and II monitoring sites and industrial hog operations.

2.5. Prediction of weather parameter at each passive monitoring station using ArcGIS

Due to the unavailability of weather data at each passive monitoring station, the SCONC data was used. In the ArcGIS 8.3 platform, the Geostatistical Analyst tool (Johnston et al., 2001) was employed to predict unknown weather parameter levels at different locations in the study. Twenty-five stations provided available temperature, wind speed, wind direction, pressure, humidity, temperature and other data. From this data, ordinary kriging was

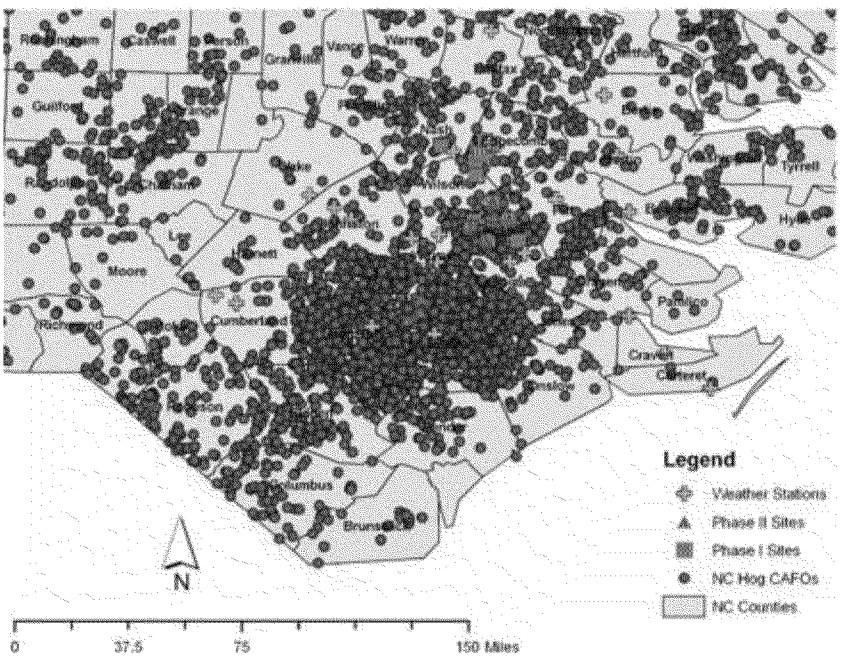

Fig. 1. Location of weather stations in relation to Phase I and II NH_3 sites in Eastern NC. This map shows 25 weather stations in Eastern NC which were used to create weather surfaces.

used to predict and develop a continuous surface map for each weather variable for each sampling period.

A map of the NH_3 sampling stations was overlaid on the continuous surface map for each weather parameter created for each deployment period. A value for each weather parameter was then obtained with the ArcGIS locate tool. For example, the continuous temperature surface showed the kriged predictions of temperature over the entire study area. Using the ArcGIS locate tool, a temperature value was obtained for each of the passive NH_3 stations for Phase-I and Phase-II sampling. These temperature values were recorded and placed in an Excel spreadsheet. This process was repeated for each meteorological parameter for each deployment period.

2.6. Source-related variables obtained using ArcGIS 8.3

Information was obtained from NC DENR on the number of animals and steady state live weight (SSLW) per hog CAFO. ArcGIS 8.3 was used to obtain source-related variables including the distance of each monitoring site to the closest hog CAFO, animals at the nearest CAFO, and SSLW at the nearest CAFO. A spatial calculator was employed to calculate the total and mean number of CAFOs, animals, live weight, and emissions in a 1 km radius around each NH_3-sampling site. These steps were repeated for radial buffers of 2 and 5 km.

2.7. Regression of weather parameters with source variables vs. NH_3 concentration

SPSS 10.0 (SPSS Inc., Chicago, IL) was used to ascertain which weather and source variables were statistically significant predictors of atmospheric ammonia during Phase I and II sampling at community locations. Several regression options were available in SPSS including Forward, Backward and Stepwise. The stepwise procedure was utilized as the primary regression procedure because it allows the user to retain the most statistically significant terms in the model. Mean NH_3 was regressed against meteorological variables (temperature, wind speed, pressure, humidity, average wind direction, maximum wind direction, and precipitation) and source-related variables mentioned previously to obtain the best predictive model for each set of data.

3. Results and discussion

3.1. Location of hog CAFOs in relation to NH_3 passive monitoring sites

Table 1 shows the distance zone of each passive monitoring site employed during Phase I and II sampling in relation to the nearest industrial hog operation regardless of direction.

During Phase-I sampling, the distance from the passive monitoring sites to the nearest hog CAFOs ranged from 0.25 to 4.77 km. Four sites (#6, #8, #10, and #13) were located at distances greater than 2 km from the nearest CAFO in either Edgecombe or Wilson. These sites were designated as ''less-exposed'' sites. Table 1 also shows the distance zone of Phase II monitoring sites to the nearest industrial hog operation. All of these sites were primarily ''exposed sites'' located in high emission density counties as defined by Walker et al. (2004). Phase-II sites were located 0.20–5.94 km from the nearest industrial hog operation.

Table 1
Distance zone of each passive monitoring station to nearest hog CAFO

Phase I station ID	County	Zone[a]	Phase II station ID	County	Zone[b]
1	Nash	1	1	Duplin	3
2	Greene	3	2	Duplin	3
3	Greene	2	3	Duplin	3
4	Greene	3	4	Duplin	2
5	Edgecombe	1	5	Duplin	2
6	Edgecombe	4	6	Duplin	2
7	Edgecombe	3	7	Greene	3
8	Wilson	4	8	Greene	2
9	Greene	2	9	Greene	2
10	Wilson	4	10	Greene	1
11	Greene	3	11	Greene	1
12	Nash	2	12	Greene	2
13	Edgecombe	4	13	Greene	3
14	Greene	1	14	Greene	2
15	Edgecombe	1	15	Greene	3
16	Edgecombe	2	16	Greene	3
17	Greene	3	17	Duplin	1
18	Greene	2	18	Duplin	1
19	Greene	2	19	Duplin	1
20	Greene	3	20	Duplin	1
			21	Duplin	3
			22	Duplin	3
			23	Lenoir	3

[a]For Phase I, Zone 1: 0–0.5 km, Zone 2: 0.5–1 km, Zone 3: 1–2 km, and Zone 4: 2 km or more from nearest hog CAFO.
[b]For Phase II, Zone 1: 0–0.5 km, Zone 2: 0.5–1 km, and Zone 3: 1 km or more from nearest hog CAFO.

3.2. Stratification of distance vs. NH_3 concentration

Walker et al. (2004) reported a mean NH_3 level of 0.58 mg m^{-3} (0.84 ppb) at an agricultural site in Martin County, NC (emission density ¼ 320 kg NH_3-N km^{-1} yr^{-1}). This value is higher than the value reported by Pryor et al. (2001) at an agricultural site in an area of low local emissions (Walker et al., 2004). The mean value at the Martin County site is within the range of values reported for non-agricultural sites and US urban areas (Walker et al., 2004). Walker et al. (2004) also reported a mean value of 2.46 mg m^{-3} (3.50 ppb) at the Kinston site (emission density ¼ 2290 kg NH_3-N km^{-1} yr^{-1}). We report levels in the following section that are higher than the ambient levels mentioned above.

Phase I and II data are considered separately in Figs. 2 and 3. The concentrations are stratified by distance from the nearest hog CAFO. We made the assumption that the closest emission source would be the most dominant emission source near each passive monitoring site. Overall concentrations are lower for Phase-I sampling and concentrations drop off more steeply from o 0.5 to 0.5–1.0 km, but the same declining trend is apparent in both phases. Fig. 2 shows that during Phase-I sampling the mean concentration drops by more than half between sites at 0–0.5 and 0.5–1 km. The mean NH_3 concentration at distances greater than 2 km from a CAFO (5.3 ppb) remained higher than ambient levels

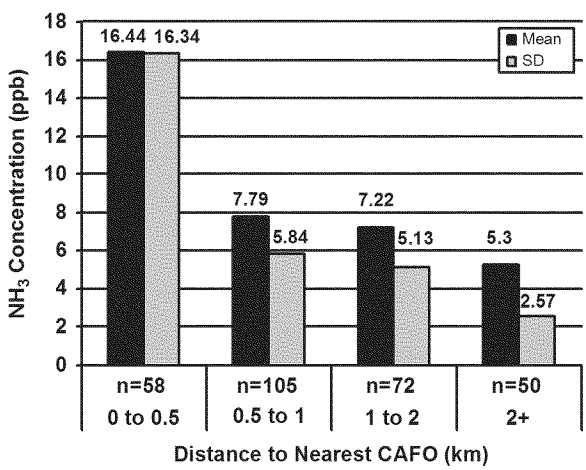

Fig. 2. NH_3 concentrations stratified by distance to nearest hog CAFO (Phase I). The figure shows the mean and standard deviation (SD) of pooled NH_3 averages for four distance zones. Zone 1: 0–0.5 km, Zone 2: 0.5–1 km, Zone 3: 1–2 km, and Zone 4: 2 km or more from nearest hog CAFO.

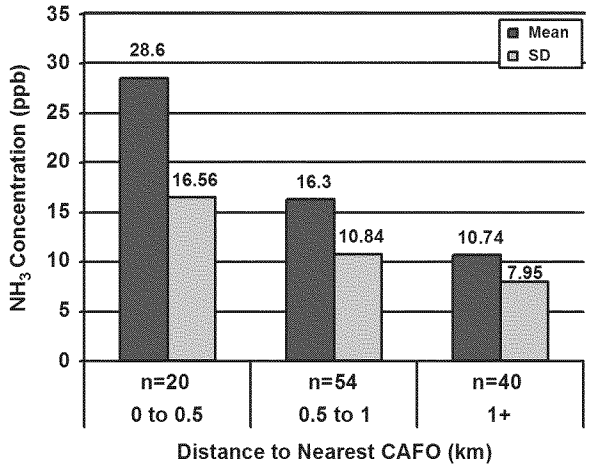

Fig. 3. NH_3 concentrations stratified by distance to nearest hog CAFO (Phase II). The figure shows the mean and standard deviation (SD) of pooled NH_3 averages for three distance zones. Zone 1: 0–0.5 km, Zone 2: 0.5–1 km, and Zone 3: 1 km or more from nearest hog CAFO.

thought to range from less than 1 to 3 ppb for an agricultural region (Pryor et al., 2001; Walker et al., 2004; Warneck, 1988).

Fig. 3 displays the stratified Phase II data. We see that the mean concentration of 29 ppb for sites located in the exposure zone 0.5 km or less from the nearest hog CAFO is two times greater than the mean concentration at sites between 0.5 and 1 km. Additionally, the mean concentration obtained for pooled sites that were 1 km or greater from the nearest CAFO was 10.74 ppb. This figure illustrates the decline in mean NH_3 levels as distance increases between community locations and emission source.

Tables 2 and 3 present data for Phase I and II sampling sites that demonstrate the negative trend that exists between distance to emission source and NH_3 concentration. From these tables, we see that the mean NH_3 levels are generally higher than ambient levels reported in other work (Pryor et al., 2001; Walker et al., 2004). Some of the Phase-I sites located less than 2 km from the nearest hog CAFO had lower than expected mean NH_3 levels. This could be due to their placement in low emission density counties.

We placed all Phase II passive samplers in high emission density counties. This factor in conjunction with their close proximity to not only the nearest CAFO but a cluster of operations within less than 1 km may explain why the mean NH_3 concentrations obtained for each site at distances near or less than 1 km (4–49 ppb) during Phase-II

Table 2
Arithmetic average (mean) of the weekly NH_3 (ppb) concentrations obtained for each site during Phase I

Site	Distance (km)	Mean	Site	Distance (km)	Mean
1	0.71	7.38	11	1.01	7.92
2	1.12	6.28	12	0.9	6.65
3	0.56	10.36	13	3.63	4.23
4	1.93	5.51	14	0.2	19.59
5	0.25	21.09	15	0.46	8.64
6	2.1	5.00	16	0.694	4.80
7	1.18	4.91	17	1.91	11.25
8	4.77	5.20	18	0.644	8.42
9	0.958	9.57	19	0.527	7.34
10	4.92	6.77	20	1.29	7.45

Distance represents distance from each NH_3 monitoring site to nearest hog CAFO.

Table 3
Arithmetic average (mean) of the weekly NH_3 (ppb) concentrations obtained for each site during Phase II

Site	Distance (km)	Mean	Site	Distance (km)	Mean
1	1.01	10.54	13	1.26	4.6
2	1.02	7.91	14	0.53	8.81
3	1.01	9.13	15	1.8	11.56
4	0.79	20.11	16	1.01	4.25
5	0.81	19.48	17	0.44	36.63
6	0.84	21.51	18	0.45	32.12
7	1.12	10.59	19	0.48	48.95
8	0.69	8.56	20	0.48	32.12
9	0.64	18.17	21	1.83	11.57
10	0.2	20.37	22	1.8	12.64
11	0.21	23.2	23	5.94	3.34
12	0.56	9.57			

Distance represents distance from each NH_3 monitoring site to nearest hog CAFO.

sampling were higher than the mean concentrations obtained during Phase-I sampling for the same distance range (7–21 ppb). In addition, Phase-II sampling occurred mainly during the summer when the concentrations at or near animal operations are typically higher than the concentrations in the fall, winter and spring months (Walker et al., 2004; Robarge et al., 2002; Pryor et al., 2001; Lefer et al., 1999; Langford et al., 1992; Asman, 1998).

The mean and maximum concentration (not shown) for each of these sites can be used to infer that human populations in the surrounding area may be exposed to appreciable amounts of ammonia released from nearby hog CAFOs, which creates a relative index of exposure. The relative index of exposure is further influenced by the location of community locations (i.e., homes and schools) proximal to clusters of hog CAFOs at distances less than 2 km. The results from Phase-II sampling demonstrate the strength of the relationship between distance to the nearest hog operation and atmospheric ammonia concentration. The mean atmospheric NH_3 concentrations were generally higher than the concentrations obtained for sites during Phase I-sampling because of the placement of the monitoring stations in high emission density counties such as Greene and Duplin.

Sites 10–11 (Greene) (Table 2) and 17–20 (Duplin) (Table 3) were located at distances less than 0.5 km from the nearest operation. Sites 10 and 11 both located approximately 200 m from the nearest hog CAFO had mean concentrations of 20 and 23 ppb, respectively, and a combined concentration range between 12 and 47 ppb. These sites had elevated concentration levels that were appreciably above ambient background levels. The location of multiple hog operations in close proximity to sites 17–20 resulted in the highest levels of atmospheric ammonia observed during data collection. Sites 17–20 were placed at a residential location with multiple hog operations less than 0.5 km from the collocated passive samplers. The mean concentration for the pooled data of these sites was 28 ppb and the concentration range fell between 4 and 81 ppb.

Conversely, Phase-I sites located at distances greater than 2 km from an industrial hog operation (sites #6, #8, #10, and #13) (Table 2) were designated as ''less-exposed'' sites. Due to their distance from an emission source, these sites were located in low emission density counties with lower numbers of hogs raised in a confined environment than in Duplin and Greene counties. The NH_3 data for these ''less-exposed'' sites indicate on average there are lower NH_3 levels at community sites located at greater distances from industrial hog operations. Moreover, human populations that reside at distances greater than 2 km from an industrial hog operation may have a lower risk or frequency of exposure to atmospheric ammonia when they reside in communities, attend school or travel to receptor locations in counties with a low density of operations (i.e. sparse hog population). Even though ammonia emissions released to the atmosphere undergo dry or wet deposition, as well as transformation processes, these processes do not completely eliminate atmospheric concentration of

ammonia down to ambient levels (1–3 ppb) for sites that are more than 2 km from the CAFO source in counties with low emission density as expected.

Figs. 2 and 3 reveal that the distance-to-the-closest-farm curve does not decline quickly either for Phase-I or Phase-II data. This result leads us to believe that in areas similar to Eastern NC, the presence of a high density of CAFOs in a region will have a cumulative effect and result in higher background levels of atmospheric NH_3 than agricultural regions with few operations. Therefore, we believe the density of hog CAFOs is equally or a more important determinant of atmospheric NH_3 levels than distance to the nearest CAFO. This supposition is further validated by the fact that we found a high background level even at sites that we located far from hog CAFOs. The implication of these findings (see Section 4) is that we expect a regional increase of atmospheric NH_3 across high emission density counties where no resident is far from any hog operation, so that the density of hog operations is a critical component of any intervention to minimize community exposure to NH_3.

However, in states like Iowa, Oklahoma and Minnesota, where ammonia emissions are reduced by the use of deep pit building systems and alternative waste management techniques instead of the uncovered lagoons used at most NC operations (Iowa Study Group (ISG), 2002), this supposition may not hold true. Therefore, the results in Eastern NC may have limited generalizability to areas in hog production states that use alternative waste management systems.

3.3. Regression of weather variables and source data vs. NH_3 concentration

Stepwise regression was used to examine the relationship between meteorological, source-related terms, and measured ammonia concentration for Phases I and II. The deployment averages collected for 40 weeks were pooled for each variable and analyses were run in SPSS 10.0. Tables 4a, 4b, 5a and 5b show the stepwise regression models and coefficients for Phases I and II.

The Phase-I model only explained a small portion (21%) of the variation of the NH_3 concentration. This model was an improvement over the regression of NH_3 using only Phase I meteorological variables which only explained 3% of the variation (not shown). The source-related variables provide information on the major source of ammonia near the passive monitoring stations which was assumed in this work to be industrial hog operations. The inclusion of the source variables greatly improved the regression models. For example, the R^2 increased from Phase I to Phase II (21–43%) because during Phase II most of the sites were located less than 1.5 km from the nearest CAFO and sampling occurred only in high emission density counties during the summer when NH_3 levels should be the highest. Many of the Phase-I sites were located greater than 1.5 km from the nearest hog operation in low emission density counties. Less ammonia was available for sampling and lower mean NH_3 levels were obtained.

Live weight acts as an important predictor of NH_3 (Walker et al., 2004, 2000a, b; Dragosits et al., 2002) and has similar Beta coefficients for Phase I and II data. However, the distance to closest farm variable is only present in the Phase-I model and not

Table 4a
Stepwise regression coefficients for Phase I

Model	R^2	R^2 change
1	0.062	0.062
2	0.099	0.037
3	0.187	0.088
4	0.211	0.024

Model 1: Constant + DISCLOSF.
Model 2: Constant + DISCLOSF + LIVEWT.
Model 3: Constant + DISCLOSF + LIVEWT + SUMAN2KM.
Model 4: Constant + DISCLOSF + LIVEWT + SUMAN2KM + AVGTEMP.
R^2: Amount of NH_3 variation accounted for by the model.

Table 4b
Final regression model coefficients for Phase I

Variable	Beta coefficient
Constant (B_0)	11.6
Distance from each NH_3 monitoring station to the nearest industrial hog farm (DISCLOSF)	-6.20
Steady state live weight of nearest hog CAFO to NH_3 monitoring station (LIVEWT)	1.40×10^{-5}
Sum of the number of hogs on all of the industrial operations located within a 2 km radius of each NH_3 monitoring station (SUMAN2KM)	-7.20×10^{-4}
Average temperature (AVGTEMP)	0.30

Table 5a
Stepwise regression for Phase II

Model	R^2	R^2 change
1	0.300	0.308
2	0.381	0.087
3	0.411	0.036

Model 1: Constant + LIVEWT.
Model 2: Constant + LIVEWT + WDMAXWS.
Model 3: Constant + LIVEWT + WDMAXWS + AWS.
R^2: Amount of NH_3 variation accounted for by the model.

Table 5b
Final regression model coefficients for Phase II

Variable	Beta coefficient
Constant (B_0)	15.3
Steady state live weight of nearest hog CAFO to NH_3 monitoring station (LIVEWT)	1.20×10^{-5}
Wind direction of maximum wind speed (WDMAXWS)	6.70×10^{-2}
Average wind speed (AWS)	-7.00

the Phase-II model. This may be explained by a spatial gradient during Phase-I sampling (several sites located 2 or more km from the nearest CAFO) while only one site was located 2 or more km from the nearest CAFO during Phase-II sampling resulting in no spatial gradient. Monitoring sites located in close proximity to hog CAFOs during Phase II indirectly controlled for distance and helped to exclude it from the final model.

Temperature, which was previously demonstrated to control atmospheric NH_3 levels (Robarge et al., 2002; Walker et al., 2004, 2000a, b; Aneja et al., 2000; Asman, 1998; Lefer et al., 1999) was included in the Phase-I model and not the Phase-II model because passive sampling occurred during fall, winter and spring months. Phase-II sampling only occurred during the summer months, giving no appreciable temperature gradient and the variable was dropped from the model. If Phase II-sampling occurred from summer 2004 to spring 2005, we believe the temperature variable would have had a greater chance of inclusion in the final model. In addition, Phase II regression model shows that wind speed is an important variable. The model indicates as wind speed increases, there is more mixing and dispersion and less ammonia at the community level. This relationship between wind speed and pollutant level has been established previously (Tate, 2002; Brown, 2000; Thijsse et al., 1998; Robarge et al., 2002; Rabaud et al., 2001).

In the Phase I regression model, SUMAN2KM (sum of animals within 2 km) has a negative value for its regression coefficient. Since we controlled for live weight (which has a positive regression coefficient), this means that for a given live weight more animals produce less NH_3, or put in other words, that smaller animals produce less NH_3 per unit weight. This does not necessarily follow the usual wisdom, and therefore this observation will have to be studied in more detail. It could be that the number of animals captures some confounding effect not accounted for in our model (i.e. this relationship could be more representative of variation at the farm level when animals are present on the operation vs. when they are not present on the operation or type of operation (i.e., farrowing, feeding, finishing). Unfortunately, the inclusion of both live weight and number of animals may limit the generalizability of this model to other hog production regions.

The regression analyses indicate that there is a positive relationship between wind direction and NH_3. An explanation is NH_3 sampling occurred in an area with multiple sources. While the nearest source does have an impact, we cannot ignore the overall elevation of ammonia in the sampling area due to the contribution of multiple sources. Robarge et al. (2002) used loess regression to develop model for a site surrounded by several CAFOs and found NH_3 would be highest when wind direction was near 278° (blowing from the northwest). These results emphasize the importance of wind direction in relation to source strength (one or more sources) and highlight the potential use of NH_3 as a tracer for CAFO pollution based on relative wind direction.

The regression analyses reiterate the importance of hog CAFOs as the primary source of NH_3 emissions released to the local environment in Eastern NC. Walker et al. (2000a, b) support the role of animal population in determining NH_3 variation and therefore supports the inclusion of LIVEWT in the regression model. The distance, direction, and population of an industrial hog operation contribute to potential exposure including frequency and duration for humans at community locations contiguous to the operation or a hog-densified area.

4. Conclusions

The purpose of this paper was to answer the question: What are the variables that explain NH_3 variation at the community level? The distance stratification results (Figs. 2 and 3) demonstrate how concentration changes over space as a function of distance. These results are the best results of this study and provide the strongest evidence that answers the above question: distance to one or more CAFOs is the key variable in controlling atmospheric NH_3 at the community level in Eastern NC. The results also show that the passive diffusion method was successful at measuring NH_3 at the community level.

The results suggest that maximally exposed populations in Eastern NC (average exposure levels X 10 ppb) will live in environments characterized by one or more hog CAFOs (o 1–5 km away) and above-average levels of hogs measured by either CAFO density, hog population density, etc. at the county level. These conclusions are supported by the regression results. Distance to the nearest CAFO and SSLW were shown to be strong predictors of NH_3 concentration. Meteorological parameters such as temperature, wind speed and direction were found to be good predictors of ammonia as well. The low reported R^2s for Phase I (21%) and Phase II (43%) could be an effect of geographic or temporal differences in the weather variables, measurement variability, or an increase in the regional background levels of atmospheric NH_3. High baseline levels limit the effect that individual variables such as wind speed and direction, temperature, humidity, etc. have on NH_3 levels at the regional scale. However, these findings are consistent with other studies that have examined or discussed the influence of source terms (Walker et al., 2004, 2000a, b; Fowler et al., 1998; Robarge et al., 2002) and weather variables (Robarge et al., 2002; Aneja et al., 2000).

The results also support the theory that zones of exposure exist for human populations who live near industrial hog operations in Eastern NC. These zones are a function of distance from the emission source where frequency of exposure over time increases the closer a community location is to the source (as shown in Figs. 2 and 3). Human populations residing at locations with a density of operations within close proximity (2 km) could be exposed to very high levels of ammonia, up to 40 times higher than normal ambient levels (1–3 ppb). As started earlier, we believe that the density of hog CAFOs is a critical emission factor belying the effectiveness of nuisance and public health policies focusing on individual facility setback distances from homes and schools. Furthermore, this finding may indicate the potential ineffectiveness of setback distances even where hog facilities are low density, but clustered.

These findings are crucial for the development of an exposure zone theory to model hog CAFO pollution in low and high emission density counties. The challenge of developing such a model is to identify variables controlling important fate and transport mechanisms for which data is currently available or attainable through more research. Our findings indicate that currently available data exists for (a) distance to the location of CAFOs, (b) live weight, (c) wind speed and wind direction, and (d) temperature. We recommend that future modeling approaches combine both mechanistic modeling of key fate and transport mechanisms (e.g. additive plumes arising from each CAFO, etc.) to account for the general characteristics of the spatiotemporal distribution of NH_3 in regions with high emission density, as well as geostatistical processing of NH_3 monitoring data to account for other random space/time processes for which data is lacking. The aim of such future work will be to model the effect of the density of CAFOs and their emissions, which this work points to as being a critical concern for chronic community exposure to hog CAFO air pollution. It is not just how far CAFOs are from a residence, but also what is the density of CAFOs in that community.

We expect this paper and additional work on the spatiotemporal variation of human exposure to atmospheric ammonia to help fill the gap between the work to monitor NH_3 and related odors at or near the CAFO property and limited number of environmental epidemiology studies performed in exposed communities. The linkages between the two are obvious for populations negatively affected by chronic exposure to intermittent levels of NH_3 and other hog CAFO pollutants. It is important that rigorous scientific inquiry examines this chronic exposure and the efficaciousness of buffers between CAFOs and residences and schools to improve quality of life and protect public health. Data from these studies will provide a clearer picture of the burden that hog CAFOs have on nearby communities and support legislation needed to redress the health and quality of life

burdens that hog CAFOs have on exposed human populations.

Acknowledgments

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References

Aneja, V.P., Chauhan, J.P., Walker, J.T., 2000. Characterization of atmospheric ammonia emissions from swine waste storage and treatment lagoons. Journal of Geophysical Research—Atmospheres 105 (D9), 11535–11545.

Asman, W.A.H., 1998. Factors influencing local dry deposition of gases with special reference to ammonia. Atmospheric Environment 32 (3), 415–421.

Avery, R., Wing, S., Marshall, S., Schiffman, S., 2004. Perceived odor from industrial hog operations and suppression of mucosal immune function in nearby residents. Archives of Environmental Health 59, 101–108.

Brown, R.H., 2000. Monitoring the ambient environment with diffusive samplers: theory and practical considerations. Journal of Environmental Monitoring 2, 1–9.

Bullers, S., 2005. Environmental stressors, perceived control, and health: the case of residents near large-scale hog farms in eastern North Carolina. Human Ecology 33, 1–16.

Cole, D., Todd, L., Wing, S., 2000. Concentrated swine feeding operations and public health: a review of occupational and community health effects. Environmental Health Perspectives 108, 685–699.

Dragosits, U., Theobald, M.R., Place, C.J., Lord, E., Webb, J., Hill, J., Apsimon, H.M., Sutton, M.A., 2002. Ammonia emission, deposition and impact assessment at the field scale: a case study of sub-grid spatial variability. Environmental Pollution 117, 147–158.

Durrenberger, P., Thu, K.M., 1996. The expansion of large scale hog farming in Iowa: the applicability of Goldschmidt's findings fifty years later. Human Organization 55 (4), 409–415.

Fowler, D., Pitcairn, C.E.R., Sutton, M.A., Flechard, C., Louber, B., Coyle, M., Munro, RC., 1998. The mass budget of atmospheric ammonia in woodland within 1 km of livestock buildings. Environmental Pollution 102 (S1), 337–342.

Hodne, C.J., 2001. Posttraumatic stress disorder: causes, symptoms, and prevention. In: Proceedings of the ICASH Annual Meeting, West Des Moines, Iowa, 8–9 November 2001.

Iowa Study Group (ISG), 2002. Iowa Concentrated Animal Feeding Operations Air Quality Study. The University of Iowa College of Public Health, Iowa City. Available: / http://www.ehsrc.orgS (accessed 2 November 2002).

Langford, A.O., Fehsenfeld, F.C., Zachariassen, J., Schimel, D.S., 1992. Gaseous ammonia fluxes and background concentrations in terrestrial ecosystems of the United States. Global Biogeochemical Cycles 6, 459–483.

Lefer, B.L., Talbot, R.W., Munger, J.W., 1999. Nitric acid and ammonia at a rural northeastern US site. Journal of Geophysical Research 104 (D1), 1645–1661.

Merchant, J.A., Naleway, A.L., Svendsen, E.R., Kelly, K.M., Burmeister, L.F., Stromquist, A.M., et al., 2005. Asthma and farm exposures in a cohort of rural Iowa children. Environmental Health Perspectives 113 (3), 350–356.

Mirabelli, M.C., Wing, S., Marshall, S., Wilcosky, T., 2006. Asthma symptoms among adolescents who attend public schools that are located near confined swine feeding operations. Pediatrics 118 (1), 66–75.

National Academy of Sciences (NAS), 2002. The Scientific Basis for Estimating Air Emissions from Animal Feeding Operations. National Academy Press, Washington, D.C.

North Carolina Department of Environment and Natural Resources (NCDENR), 2002. Hog CAFO Inventory. Raleigh, NC.

North Carolina General Statutes (NCGS), 1995. Swine Farm Siting Act. (1995, c. 420, s. 1; 1995 (Regular Session, 1996), c. 626, s. 7(a); 1997-458, s. 4.1).

Palmquist, R.B., Roka, F.M., Vukina, T., 1997. Hog operations, environmental effects and residential property values. Land Economics 73, 114–124.

Phillips, S.B., Arya, S.P., Aneja, V.P., 2004. Ammonia flux and dry deposition velocity from near-surface concentration gradient measurements over a grass surface in North Carolina. Atmospheric Environment 38, 3469–3480.

Pryor, S.C., Barthelmie, R.J., Sorenson, L.L., Jensen, B., 2001. Ammonia concentrations and fluxes over a forest in the midwestern USA. Atmospheric Environment 35, 5645–5656.

Rabaud, N.E., James, T.A., Ashbaugh, L.L., Flochini, R.G., 2001. A passive sampler for the determination of airborne ammonia concentrations near large-scale animal facilities. Environment Science and Technology 35, 1190–1196.

Reynolds, S., Donham, K., Stooksberry, J., Thorne, P.S., Subramanian, P., Thu, K., et al., 1997. Air quality assessments in the vicinity of swine production facilities. Agricultural Health and Safety: Recent Advances 4, 45–57.

Robarge, W.P., Walker, J.T., McCullock, R.B., Murray, G., 2002. Atmospheric concentrations of ammonia and ammonium at an agricultural site in the southeast United States. Atmospheric Environment 36, 1661–1674.

Schiffman, S., Miller, E.A., Suggs, M.S., 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.

Schiffman, S., Walker, J., Dalton, P., Lorig, T., Raymer, J., Shusterman, D., et al., 2000. Potential health effects of odor from animal operations, wastewater treatment, and recycling of byproducts. Journal of Agromedicine 7, 7–81.

Secrest, C., 1999. Field measurement of air pollutants near swine confined animal feeding operations using UV DOAS and FTIR. In: Proceedings of SPIE—The International Society of Optical Engineering, vol. 4199, pp. 98–104.

State Climate Office of North Carolina (SCONC), 2003. State Climate Office of North Carolina (SCONC), North Carolina State University, Raleigh, NC, / www.nc-climate.ncsu.eduS.

Tate, P., 2002. Ammonia sampling using Ogawa passive samplers. MS Thesis, University of South Florida, Tampa, FL.

Thijsse, T.H.R., Duyzer, J.H., Verhagen, H.L.M., Wyers, G.P., Wayers, A., Mols, J.J., 1998. Measurement of ambient ammonia with diffusion tube samplers. Atmospheric Environment 32, 333–337.

Thu, K. (Ed.), 1996. Understanding the Impacts of Large-Scale Swine Production: Proceedings from an Interdisciplinary Scientific Workshop. The University of Iowa, Iowa City, Iowa.

Thu, K., 2002. Public health concerns for neighbors of large-scale swine production. Journal of Agricultural Safety and Health 8 (2), 175–184.

Thu, K., Donham, K., Ziegenhorn, R., Reynolds, S., Thorne, P.S., Subramanian, P., et al., 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.

Walker, J.T., Aneja, V.P., Dickey, D., 2000a. Atmospheric transport and wet deposition of ammonia in North Carolina. Atmospheric Environment 34, 3407–3418.

Walker, J.T., Nelson, D., Aneja, V.P., 2000b. Trends in ammonium concentration in precipitation and atmospheric ammonia emissions at a coastal plain site in North Carolina, USA. Environmental Science and Technology 34, 3527–3534.

Walker, J.T., Whitall, D.R., Robarge, W., Paerl, H.W., 2004. Ambient ammonia and ammonium aerosol across a region of variable ammonia emission density. Atmospheric Environment 38, 1235–1246.

Warneck, P., 1988. Chemistry of the Natural Atmosphere. Academic Press, San Diego, CA.

Wilson, S.M., 2005. Monitoring and spatiotemporal mapping and estimation of atmospheric ammonia levels near hog CAFOs and human receptor sites in eastern NC. Doctoral Dissertation, Department of Environmental Sciences and Engineering, University of North Carolina, Chapel Hill, NC.

Wing, S., Wolf, S., 2000. Intensive livestock operations, health, and quality of life among eastern North Carolina residents. Environmental Health Perspectives 108, 233–238.

Wing, S., Grant, G., Cole, D., 2000. Environmental injustice in North Carolina's hog industry. Environmental Health Perspectives 108, 225–231.

Wright, W., Flora, C.B., Kremer, K.S., Goudy, W., Hinrichs, C., Lasley, P., et al., 2001. Technical work paper on social and community impacts. Prepared for the Generic Environmental Impact Statement on Animal Agriculture and the Minnesota Environmental Quality Board.

Exhibit 50

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ED_001369_00043711-00366

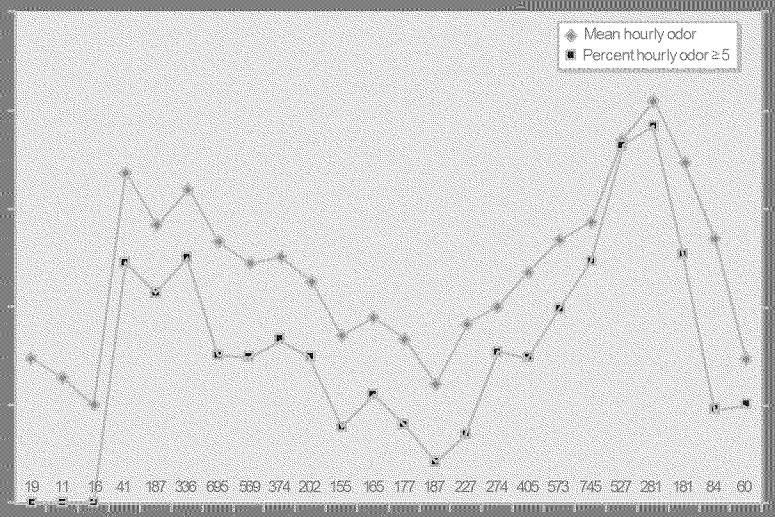

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Exhibit 51

Air Pollution from Industrial Swine Operations and Blood Pressure of Neighboring Residents

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BACKGROUND: Industrial swine operations emit odorant chemicals including ammonia, hydrogen sulfide (H_2S), and volatile organic compounds. Malodor and pollutant concentrations have been associated with self-reported stress and altered mood in prior studies.

OBJECTIVES: We conducted a repeated-measures study of air pollution, stress, and blood pressure in neighbors of swine operations.

METHODS: For approximately 2 weeks, 101 nonsmoking adult volunteers living near industrial swine operations in 16 neighborhoods in eastern North Carolina sat outdoors for 10 min twice daily at preselected times. Afterward, they reported levels of hog odor on a 9-point scale and measured their blood pressure twice using an automated oscillometric device. During the same 2- to 3-week period, we measured ambient levels of H_2S and PM_{10} at a central location in each neighborhood. Associations between systolic and diastolic blood pressure (SBP and DBP, respectively) and pollutant measures were estimated using fixed-effects (conditional) linear regression with adjustment for time of day.

RESULTS: PM_{10} showed little association with blood pressure. DBP [β (SE)] increased 0.23 (0.08) mmHg per unit of reported hog odor during the 10 min outdoors and 0.12 (0.08) mmHg per 1-ppb increase of H_2S concentration in the same hour. SBP increased 0.10 (0.12) mmHg per odor unit and 0.29 (0.12) mmHg per 1-ppb increase of H_2S in the same hour. Reported stress was strongly associated with BP; adjustment for stress reduced the odor–DBP association, but the H_2S–SBP association changed little.

CONCLUSIONS: Like noise and other repetitive environmental stressors, malodors may be associated with acute blood pressure increases that could contribute to development of chronic hypertension.

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The rapid global expansion of confined animal feeding operations (CAFOs) has created environmental health concerns at local, regional, and global scales, including infectious and respiratory diseases, reduced quality of life, impacts on the built environment, and environmental injustice (Pew Commission on Industrial Food Animal Production 2008). CAFO airborne emissions, including ammonia, hydrogen sulfide (H_2S), volatile organic compounds, and endotoxins, originate from confinement buildings, waste storage areas, and land application of animal waste (National Research Council 2003).

North Carolina experienced a rapid transformation of swine production during the 1980s and 1990s. The number of producers declined, the size of operations grew, the swine population increased from approximately 2.5 million to 10 million, and production shifted to the eastern coastal plain region of the state (Furuseth 1997). In North Carolina, swine CAFOs are concentrated in low-income communities of color (mostly African American), where older housing and lack of central air conditioning could increase human exposure to air pollutants (Wing et al. 2000). Studies conducted in Germany and the United States reported that neighbors describe odors from swine CAFOs as annoying and offensive (Schiffman 1998; Tajik et al. 2008; Thu 2002, 2003; Thu and Durrneberger 1998; Radon et al. 2007). In a previous study of communities neighboring North Carolina CAFOs (Schinasi et al. 2011), we found that self-reported hog odor and H_2S are associated with acute irritation of the eyes, nose, and throat, and also that particulate matter ≤ 10 µm in aerodynamic diameter (PM_{10}) is associated with eye irritation. In addition to physical symptoms and negative mood (Bullers 2005; Horton et al. 2009; Schiffman et al. 1995), CAFO neighbors have reported that because of frequent and unpredictable episodes of malodor, they were unable to engage in valued traditions of rural life, including gardening, family gatherings, cookouts, visiting neighbors, and drying laundry (Tajik et al. 2008; Thu 2002, 2003; Thu and Durrneberger 1998).

Several studies have found relationships between malodor from swine CAFOs and chronic (Schiffman et al. 1995) or acute (Horton et al. 2009) stress in neighbors. Other studies have reported that environmental stressors are associated with increased blood pressure (BP) (Attarchi et al. 2012; Belojevic and Evans 2012; Djindjic et al. 2012) and that odorant compounds perceived as pleasant attenuated exercise-related increases in BP (Nagai et al. 2000). African Americans and low-income people experience an excess prevalence of chronic hypertension (Carson et al. 2011; Keenan and Rosendorf 2011; Liao et al. 2011), as well as hypertension-related morbidity (Liao et al. 2011) and mortality (Fiscella and Holt 2008). Identification of environmental factors that contribute to BP elevations could inform efforts to prevent upward shifts of BP in populations.

In this study we evaluated whether measures of swine CAFO air pollution were associated with acute changes in BP among neighbors during follow-up of approximately 2 weeks. We did not compare BPs of CAFO neighbors and other people; rather, we compared each participant's BP during times of more and less exposure to swine CAFO air pollution. In this design each participant served as her or his own control. Characteristics that were essentially constant during the short follow-up (e.g., age, socioeconomic status,

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medical history, body mass, occupation, personality) could not cause bias in estimates of the exposure–outcome relationship. Chronic effects of exposure, however, could not be evaluated.

Methods

Setting and data collection. The study was conducted in partnership with the Concerned Citizens of Tillery (CCT), a community-based organization in Halifax County that promotes the health, environmental, and political interests of predominantly African-American communities in eastern North Carolina (Wing et al. 1996). CCT has partnered with universities to provide medical care through the Tillery People's Clinic and to conduct research on health and environmental justice (Tajik and Minkler 2006). For this study, the CCT staff organized community meetings in areas with a high density of swine CAFOs and provided information about our ongoing study to attendees, who were invited to contact CCT or University of North Carolina–Chapel Hill researchers if they were interested in participating in the study (Wing et al. 2008a). We sequentially enrolled between 4 and 10 volunteers in each of 16 rural communities from 2003 to 2005, and participants began data collection within 24–36 hr. Enrollment did not take place between mid-December and mid-February because of holidays and cold weather. Numbers of nearby swine CAFOs, participants, and other community-specific characteristics have been reported previously (Wing et al. 2008b).

To be eligible, participants had to be ≥ 18 years of age and nonsmokers, and live within 1.5 miles of at least one swine CAFO (Wing et al. 2008a), defined as a facility housing > 250 animals and using a liquid waste management system (Wing et al. 2000). At an initial training session, participants chose morning and evening times when they would sit outside each day for approximately 2 weeks (in three neighborhoods participants chose to continue up to 1 more week). They provided information about regular use of medications, and each participant's odor sensitivity was tested using a standard set of butanol dilutions to evaluate the lowest concentration that could be distinguished from zero (e.g., Croy et al. 2009). Participants completed the John Henryism Active Coping (JHAC) scale, which measures the pre disposition to respond behaviorally to psychosocial environmental stressors (James et al. 1987); higher values indicate a greater predisposition to cope actively. Participants were classified by reported use (yes/no) of antihypertensive medications (e.g., drugs classified as beta blockers, calcium channel blockers, angiotensin-converting-enzyme inhibitors, diuretics). They learned how to use a structured diary to record levels of swine odor, stress, and symptoms, and they practiced measuring their BP with an automated oscillometric device. Time spent outdoors and times of diary completion were tracked using a digital clock provided and set by researchers. Informed consent was obtained at the training session using a procedure approved by the University of North Carolina Institutional Review Board, which reviewed the study annually. We obtained a Certificate of Confidentiality from the National Institutes of Health (Wing et al. 2008a) because of prior attempts by the pork industry to obtain confidential records (Wing 2002).

Each morning and evening, participants sat outside for 10 min and completed the first of four pages of a data-collection diary. They then returned indoors to complete the remaining pages and measure their BP (Wing et al. 2008a). They rated the strength of swine odor during the 10-min period outdoors on a nine-level Likert-type scale [0 (none) to 8 (very strong)], and evaluated perceived stress ("How do you feel now … stressed or annoyed?) on a nine-level scale [0 (none) to 8 (extremely)]. Participants measured their BP twice in a seated position. They were instructed to wait 1 min between readings, raising their right arm above their head for the first 30 sec and then resting for the remaining time before taking their BP again. They printed the results and taped the printout with the systolic (SBP) and diastolic (DBP) values and current time into the diary. We treated the average of the two readings as dependent variables.

While participants collected data, we monitored air pollution at a central location in each neighborhood. The mean and median distance from air monitors to participant homes was 0.2 miles and 0.1 miles, respectively (Wing et al. 2008a). Swine CAFOs release many odorant chemicals including ammonia, H_2S, and hundreds of volatile organic compounds (Schiffman et al. 2001). Odorant chemicals may occur as gases or particles. We quantified H_2S, which is produced by the anaerobic decomposition of fecal waste, as a marker of this complex mixture that is related to hog odor intensity (Wing et al. 2008b; Schiffman et al. 2005). H_2S is a specific marker of swine CAFO pollution in the study areas because other H_2S-emitting industries such as waste water treatment plants, petrochemical plants, and paper mills, were not present. Average ambient H_2S concentrations measured every 15 min with an MDA Scientific Single Point Monitor (Zellweger Analytics Inc., Lincolnshire, IL) were used to calculate hourly averages; 15-min values below the detection limit of 2 ppb were treated as zero. We considered average concentrations during the 1 hr before BP measurements as predictors of SBP and DBP.

We measured hourly levels of PM_{10} using a Series 1400a tapered element oscillating microbalance Ambient Particulate Monitor (Rupprecht and Patashnick Co. Inc., East Greenbush, NY). A Series 8500 FDMS Filter Dynamics Measurement System (Rupprecht and Patashnick Co. Inc.) was used to quantify semivolatile PM_{10}. Semivolatile particles consist of compounds that are present in both vapor and condensed phases. Airborne PM is ubiquitous; although CAFOs are one source, particles are not a specific marker of CAFO pollutants. We reported previously that semivolatile PM_{10} showed little association with hog odor in the study neighborhoods and that PM_{10} was related to hog odor only when wind speeds were high (Wing et al. 2008b).

Statistical analysis. In this repeated-measures design, each participant served as her or his own control. The sample size is a function of the number of participants and the number of observations (records) per person. We used linear fixed-effects regression to model repeated measures for individuals (Allison 2005). This approach estimates the average within-person associations between exposure measures and BP by conditioning on person, and eliminates bias from any measured or unmeasured confounding factors that do not change during follow-up. Relationships between SBP and DBP and air pollution appeared linear across categories of exposure (data not shown), so they were modeled as continuous variables. BP varies diurnally, as do hog odor and H_2S (Wing et al. 2008b); therefore, time of day (AM vs. PM) was included as a covariate in all models. In separate analyses, we also adjusted for self-reported stress, a potential mediator of associations between pollutants and BP. Sex and odor detection threshold (dichotomized at the median) were considered potential modifiers related to odor perception, whereas JHAC score (dichotomized at the median) and use of antihypertensive medication (yes/no) were considered potential modifiers of BP reactivity to environmental stressors. We also considered modification by age (dichotomized at the median) because it could influence either odor perception or BP reactivity.

Observations (records) with missing values for a variable were dropped from models including that variable. Model coefficients represent the average within-person change in BP for each unit increase in pollution. In nonrandomized studies, confidence limits and *p*-values do not quantify the confidence or probability that a point estimate would occur within a specified interval due to chance; therefore, we report standard errors of the regression coefficients as a measure of precision and *t*-values as indicators of the improvement in the fit of the model associated with the exposure variable. Degrees of freedom for *t*-tests, *n*-1, are large and can be considered equivalent for comparing *t* values.

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Results

Descriptive characteristics of the 101 participants are given in Table 1. Half of the participants were > 53 years of age, and two-thirds were women. Among the 97 participants whose odor detection threshold was determined, 55 had a butanol odor detection threshold of ≤ 40 ppm. Forty-two participants reported taking one or more BP medications. Among the 96 participants who completed the JHAC, 46 had a score > 52. Most participants (85) identified themselves as black.

Table 2 presents distributions of reported hog odor intensity during the 10 min outdoors, average pollutant concentrations in the hour before BP measurement, SBP, and DBP. Odor ratings were missing in 6% of the records, and no odor was reported in 48% of the records. Very strong odor (a rating of 6, 7, or 8) was reported 6% of the time. Hourly H_2S measurements were missing in approximately 9% of the records, and most (88%) were below the limit of detection (2 ppb). PM measures were missing in 32.2% of the records, primarily because of equipment malfunction during periods of high temperature and humidity (Wing et al. 2008b). For 12.4% of records, semivolatile particle concentrations were < 0; this occurs when concentrations are low because microbalance estimates are derived by subtraction of sequential mass values that are measured with error (Wing et al. 2008b). BP was missing in 1.4% of the records. SBP readings were < 120 mmHg in approximately 30% of the records and > 140 mmHg in approximately 25% of the records. DBP was < 80 mmHg in 61% of the records and ≥ 90 mmHg in 11% of the records. No participants were missing data for all their records.

Associations between air pollutants and BP adjusted for time of day (AM or PM) are presented in Table 3. Each unit increase in reported hog odor on the 0–8 intensity scale was associated with average estimated increases [β (SE)] of 0.10 (0.12) and 0.23 (0.08) mmHg for SBP and DBP, respectively. A 1-ppb increase in H_2S was associated with increases of 0.29 (0.12) mmHg for SBP and 0.12 (0.08) mmHg for DBP. PM_{10} was not associated with BP. Semivolatile PM_{10} was not associated with SBP but had a small negative association with DBP [–0.06 (0.03)].

Table 4 provides beta coefficients for hog odor and H_2S according to potential modifying variables. Coefficients for PM_{10} and semivolatile PM_{10} are not shown because their main effect estimates were small, they are not specific markers of swine CAFO air pollution, and data are missing for almost one-third of the records. Hog odor coefficients for SBP were all positive, but none had t-values > 1.17. Coefficients for DBP were positive and all had t-values near or above 2 except for participants ≤ 53.7 years of age, for whom the β (SE) is 0.08 (0.12). Coefficients for both SBP and DBP were larger for older participants than younger participants [0.14 (0.15) and 0.33 (0.10) vs. 0.04 (0.18) and 0.08 (0.12), respectively] and for men than women [0.20 (0.23) and 0.36 (0.15) vs. 0.07 (0.13) and 0.19 (0.09), respectively]. Associations between hog odor and SBP were larger for participants with JHAC scores ≤ 52 compared with those for persons with JHAC scores > 52 [0.18 (0.17) compared with 0.01 (0.16)] and for participants who reported no use of antihypertensive drugs compared with those with regular use [0.19 (0.16) compared with 0.01 (0.17)]. For H_2S, coefficients for both SBP and DBP were larger for men than women [0.56 (0.30) and 0.48 (0.19) compared with 0.24 (0.13) and 0.05 (0.08), respectively]; participants with butanol odor sensitivity thresholds > 40 ppm than for those with thresholds ≤ 40 ppm [0.33 (0.14) and 0.13 (0.09) compared with 0.17 (0.22) and 0.07 (0.14), respectively]; and participants with JHAC scores of ≤ 52 than those with scores > 52 [0.36 (0.14) and 0.17 (0.09) compared with 0.02 (0.24) and –0.07 (0.15), respectively]. The SBP coefficient was larger for participants who did not report taking BP medications compared with those who did [0.38 (0.14) compared with 0.07 (0.22)].

SBP and DBP were strongly associated with reported stress, increasing on average 0.82 (0.21; t = 3.98) and 0.57 (0.13 mmHg; t = 4.28), respectively, for every unit increase on the 0–8 scale. We included stress in models reported above (in addition to time of day) to evaluate whether associations of BP with hog odor and H_2S change after adjustment for this potential mediator. With adjustment for reported stress, coefficients for the association between hog odor and DBP declined from 0.23 (0.08) to 0.15 (0.08), whereas the coefficient for SBP decreased from 0.10 (0.12) to –0.04 (0.12). With adjustment for reported stress, there was little change in the coefficient for the association between H_2S and DBP [0.15 (0.08) vs. 0.12 (0.08) before adjustment] or SBP [0.26 (0.12) vs. 0.29 (0.12) before adjustment].

Table 1. Characteristics of participants [n (%) of nonmissing observations], Community Health Effects of Industrial Hog Operations study.

Variable	Participants (N = 101)	Records (N = 2,949)
Age (years)		
≤ 53.7	51 (50.5)	1,410 (47.9)
> 53.7	50 (49.5)	1,539 (52.2)
Gender		
Women	66 (65.3)	1,945 (66.0)
Men	35 (34.7)	1,004 (34.0)
Odor threshold		
Missing[a]	4 (4.0)	91 (3.1)
Butanol ≤ 40ppm	55 (56.7)	1,559 (54.5)
Butanol > 40ppm	42 (43.3)	1,299 (45.5)
BP medication used		
No	59 (58.4)	1,680 (57.0)
Yes	42 (41.6)	1,269 (43.0)
JHAC score[b]		
Missing[a]	5 (5.0)	117 (4.0)
≤ 52	50 (52.1)	1,480 (52.3)
> 52	46 (47.9)	1,352 (47.7)

[a]Percent of all observations. [b]Higher JHAC score indicates higher active coping with psycho social stressors.

Discussion

In this community-based participatory repeated-measures study we found that, on average, BP of participants living near swine CAFOs increased in association with increases in markers of transient plumes of odorant air pollution. Because each participant served as her or his own control, factors that did not change during the 2-week study—including body mass, race, socioeconomic position, medical and dietary history, and prior BP—could not

Table 2. Distributions of odor, H_2S, and BP from the total of non missing records (N = 2,949), Community Health Effects of Industrial Hog Operations study.

Variable (scale)	n (%)
Odor (0–8)	
Missing[a]	177 (6.0)
None	1,419 (48.1)
1–2	779 (26.4)
3–5	407 (13.8)
6–8	167 (5.7)
Stress (0–8)	
Missing[a]	58 (2.0)
None	2,331 (80.6)
1–2	436 (15.1)
3–5	91 (3.2)
6–8	33 (1.2)
H_2S (ppb)	
Missing[a]	255 (8.6)
0	2,412 89.5
0–2	170 (6.3)
2–4.99	77 (2.9)
5–47.5	35 (1.3)
PM_{10} (μg/m³)	
Missing[a]	948 (32.1)
< 10	415 (20.7)
10–19.9	783 (39.1)
20–29.9	528 (26.4)
30–502.0	275 (13.7)
Semivolatile PM_{10} (μg/m³)	
Missing[a]	948 (32.2)
< 0	366 (18.3)
0–2.99	638 (31.9)
3–7.99	767 (38.3)
> 8	230 (11.5)
SBP (mmHg)	
Missing[a]	41 (1.4)
< 120	897 (30.8)
120–139	1,257 (43.2)
140–159	510 (17.5)
> 160	244 (8.4)
DBP (mmHg)	
Missing[a]	41 (1.4)
< 80	1,804 (62.0)
80–89	781 (26.9)
90–99	221 (7.6)
> 100	102 (3.5)

[a]Percent of all records.

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confound these associations. Estimated DBP was almost 2 mmHg higher during periods of very strong odor (a rating of 8) compared to none, and estimated SBP was almost 3 mmHg higher when H_2S concentrations were 10 ppb compared with times when H_2S was zero (below the limit of detection). This magnitude of effect could have public health importance because of the frequency and duration of odor episodes near CAFOs. The 101 people who participated in this study for approximately 2 weeks reported 1,655 episodes of outdoor hog odor, 38% of which lasted > 1 hr, and 17% of which had a mean odor ≥ 5 (on the scale of 0–8); participants also reported 500 episodes of indoor odor (Wing et al. 2008b). If the associations were causal and if malodors from other sources such as sewage, landfills, and chemical refineries produce similar effects, then control of environmental malodor might help prevent repeated acute elevations of BP that could contribute to development of chronic hypertension.

With approximately 29 measures per person, the sample size for this study was primarily suited to examining within-person covariation in exposures and outcomes. Although estimates within subgroups defined by non–time-varying factors are imprecise, some interactions are of interest. Associations between H_2S and SPB were similar for both older and younger participants, whereas the odor–DBP association was observed primarily among older participants. Beta coefficients for both odor and H_2S were larger for men than women. The magnitude of the association between BP and hog odor was not related to the butanol odor sensitivity threshold. Because the effectiveness of peoples' active coping is reduced by lack of resources, persons with high JHAC scores and low socioeconomic position are expected to be more physiologically reactive to psychosocial stressors than people with high JHAC scores and high socioeconomic position, or people with low JHAC scores (James et al. 1987). Contrary to our expectation, even though all participants in this study lived in low-income areas, associations between hog air pollution markers and BP were not stronger among participants with high JHAC scores. Associations for SBP were generally weaker among participants who were taking BP medications, which may reduce responses to environ mental stimuli.

Table 3. Linear fixed effects beta coefficients (SEs) and *t*-values for associations of one-unit increases in pollutants with SBP and DBP, adjusted for time-of-day (AM or PM), Community Health Effects of Industrial Hog Operations study.

	SBP		DBP	
Pollutant	β (SE)	*t*-Value	β (SE)	*t*-Value
Odor (0–8)	0.10 (0.12)	0.86	0.23 (0.08)	3.02
H_2S (ppb)	0.29 (0.12)	2.45	0.12 (0.08)	1.52
PM_{10} (μg/m^3)	–0.01 (0.01)	–0.78	–0.00 (0.01)	–0.41
Semivolatile PM_{10} (μg/m^3)	–0.02 (0.05)	–0.45	–0.06 (0.03)	–1.66

Table 4. Linear fixed effects beta coefficients (SEs) and *t*-values for potential modifiers of associations of BP with one-unit increases in hog odor and H_2S, adjusted for time-of-day (AM or PM), Community Health Effects of Industrial Hog Operations study.

	SBP		DBP	
Modifier	β (SE)	*t*-Value	β (SE)	*t*-Value
Hog odor (0–8)				
Age ≤ 53.7 years	0.04 (0.18)	0.23	0.08 (0.12)	0.68
Age > 53.7 years	0.14 (0.15)	0.93	0.33 (0.10)	3.34
Women	0.07 (0.13)	0.50	0.19 (0.09)	2.11
Men	0.20 (0.23)	0.85	0.36 (0.15)	2.37
Butanol threshold ≤ 40 ppm	0.10 (0.15)	0.67	0.21 (0.10)	2.17
Butanol threshold > 40 ppm	0.10 (0.19)	0.54	0.24 (0.12)	2.03
JHAC score ≤ 52	0.18 (0.17)	1.07	0.22 (0.11)	2.05
JHAC score > 52	0.01 (0.16)	0.06	0.20 (0.11)	1.92
No BP meds	0.19 (0.16)	1.17	0.25 (0.11)	2.31
Any BP meds	0.01 (0.17)	0.04	0.21 (0.11)	1.96
H_2S (ppb)				
Age ≤ 53.7 years	0.30 (0.15)	1.97	0.13 (0.10)	1.32
Age > 53.7 years	0.28 (0.19)	1.45	0.10 (0.12)	0.78
Women	0.24 (0.13)	1.85	0.05 (0.08)	0.58
Men	0.56 (0.30)	1.90	0.48 (0.19)	2.51
Butanol threshold ≤ 40 ppm	0.17 (0.22)	0.78	0.07 (0.14)	0.48
Butanol threshold > 40 ppm	0.33 (0.14)	2.40	0.13 (0.09)	1.49
JHAC score ≤ 52	0.36 (0.14)	2.67	0.17 (0.09)	1.90
JHAC score > 52	0.02 (0.24)	0.08	–0.07 (0.15)	–0.45
No BP medication	0.38 (0.14)	2.70	0.10 (0.09)	1.12
Any BP medication	0.07 (0.22)	0.34	0.15 (0.14)	1.07

Although the repeated-measures design and fixed-effects analysis precludes confounding from time-independent factors that differ between people, time-related factors associated with both air pollution and BP could have either attenuated or exaggerated associations. Time of day (AM vs. PM) was included in all models; therefore, potential time-related factors would need to be associated with pollution and BP within times of day in order to act as confounders. Time-related confounding could occur if a cause of acute BP change that is not a consequence of CAFO air pollution covaried with the CAFO air pollutants in participants' neighborhoods.

Measurement errors could also impact estimates of association between odorant pollutants and BP. In a clinical or experimental setting, BP is typically measured by a trained technician in a standardized manner. In contrast, in the present study, each participant measured her or his own BP twice each day at home, which could reduce the precision of the effect estimates. Use of a portable printer with a time stamp to record BP values in the diaries prevented transcription errors that could have introduced systematic errors related to odor intensity. The temporal sequence of sitting outside prior to BP measurement was reversed in < 2% of records (Schinasi et al. 2009).

Although participants recognized hog odor and could rate it on the 0–8 scale from "none" to "very strong," we did not evaluate the reproducibility of their ratings, which could be affected by physical and social context. For example, participants might rate an odor as more intense on a day that they expected company if they were ashamed of their expected guests' reactions to the presence of fecal odor at their home. More precise measures of odor can be made in units of dilution to threshold using an olfactometer (Lambert et al. 2000); however, it was not feasible to use such a device in this participatory study. We evaluated participants' odor sensitivity threshold using a butanol standard and expected that associations between hog odor and BP might be attenuated among participants with poorer odor sensitivity; however, associations with hog odor differed little by odor sensitivity. In an experiment including 44 volunteers, van Thriel et al. (2008) reported that butanol odor threshold was not related to ratings of environmental odorants.

H_2S was the chemical marker of odorant swine CAFO air pollution that we could quantify over short time period; these measures cannot be affected by response bias. Because there are no other major industrial sources of H_2S in the study communities, it is a specific marker of swine CAFO emissions; however, this marker is not sensitive, in part, because of the detection threshold of the instrument (~ 2 ppb/15 min). Hog

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odor, which has a distinctive character due to a complex mixture of volatile organic compounds (Schiffman et al. 2001; Karageorgos et al. 2010), was often reported when H_2S levels were below the detection limit. Another source of measurement error comes from the placement of the H_2S monitor at a central location in rural neighborhoods, which was as far as approximately 1 mile from some participants' residences (median, 0.1 mile). Narrow plumes of odorant compounds from swine CAFOs could be present at participants' homes but not at the monitor, or vice versa. We expect this type of exposure misclassification would attenuate any real associations between H_2S and BP.

Relationships between odorant air pollutants and BP could be produced by psychophysiological or pharmacological mechanisms (Shusterman 1992). Our findings that odor and H_2S, but not PM, were associated with BP increases are consistent with a psychophysiological mechanism. The lack of an association with PM could also be related to the lower levels or different composition of PM in rural communities compared with urban areas typically studied. Furthermore, many observations were missing for PM. We evaluated BP in this study because environmental exposure to swine odor in this population has been associated with self-reported stress (Horton et al. 2009), and acute stress is associated with transient BP elevation (Sparrenberger et al. 2009). Odorant pollution could also produce other changes in a person's environment that cause acute changes in BP, for example, irritability of a household member.

The pharmacological actions of swine CAFO air emissions on BP are unknown and difficult to predict because emissions include many chemical compounds and fine particles (Schiffman et al. 2001). Although we measured H_2S as an indicator of the odorant component of this mixture, growing evidence suggests that H_2S, an endogenous gasotransmitter, acts as a vasodilator (Wagner 2009). To the extent that exogenous H_2S plays a similar role, its presence in odorant plumes could therefore attenuate associations between swine odor and BP.

The setting for our study, the coastal plain of eastern North Carolina, has one of the highest densities of swine production in the world (Pew Commission on Industrial Food Animal Production 2008). Historically, it is part of both the Black Belt (home to a majority of rural African Americans) and the stroke belt (an area of high mortality from cerebrovascular and cardiovascular diseases) (Casper et al. 1995). Swine CAFOs in the state are highly disproportionately located in low-income communities of color (Wing et al. 2000). If swine CAFO air pollution contributes to high BP in this region, the associated cardiovascular morbidity and mortality would be among the consequences of environmental injustice.

Malodors are produced by other types of CAFOs, waste disposal sites, refineries, chemical plants, waste water treatment plants, and land application of sewage sludge. These facilities and activities expose communities that lack political power to environmental malodors while benefiting consumers and producers in nonimpacted areas. Therefore, the generalizability of findings reported here is relevant to public health protection. Communities with low levels of political influence are less able to prevent siting of such facilities than are communities with political power, and they are less able to demand the best technologies for reducing resulting pollutants. Repeated acute physical environmental stressors, such as malodor and noise, may be aspects of the built environment that contribute to racial and economic disparities in high BP and its sequelae.

References

Allison PD. 2005. Fixed Effects Regression Methods for Longitudinal Data Using SAS. Cary, NC:SAS Institute Inc.

Attarchi M, Golabadi M, Labbafinejad Y, Mohammadi S. 2012. Combined effects of exposure to occupational noise and mixed organic solvents on blood pressure in car manufacturing company workers. Am J Ind Med; doi:10.1002/ajim.22086 [Online 19 June 2012].

Belojevic G, Evans GW. 2012. Traffic noise and blood pressure in low-socioeconomic status, African-American urban schoolchildren. J Acoust Soc Am 132:1403–1406.

Bullers S. 2005. Environmental stressors, perceived control, and health: the case of residents near large-scale hog farms in eastern North Carolina. Hum Ecol 33:1–16.

Carson AP, Howard G, Burke GL, Shea S, Levitan EB, Muntner P. 2011. Ethnic differences in hypertension incidence among middle-aged and older adults: the multi-ethnic study of atherosclerosis. Hypertension 57:1101–1107.

Casper M, Wing S, Anda R, Knowles M, Pollard R. 1995. The shifting stroke belt: changes in the geographic pattern of stroke mortality in the United States. Stroke 26:755–760.

Croy I, Lange K, Krone F, Negoias S, Seo HS, Hummel T. 2009. Comparison between odor thresholds for phenyl ethyl alcohol and butanol. Chem Senses 34:523–527.

Djindjic N, Jovanovic J, Djindjic B, Jovanovic M, Jovanovic JJ. 2012. Associations between the occupational stress index and hypertension, type 2 diabetes mellitus, and lipid disorders in middle-aged men and women. Ann Occup Hyg 56:1051–1062.

Fiscella K, Holt K. 2008. Racial disparity in hypertension control: tallying the death toll. Ann Fam Med 6:497–502.

Furuseth O. 1997. Restructuring of hog farming in North Carolina: explosion and implosion. Prof Geogr 49:391–403.

Horton RA, Wing S, Marshall SW, Brownley KA. 2009. Malodor as a trigger of stress and negative mood in neighbors of industrial hog operations. Am J Public Health 99(suppl 3):S610–S615.

James SA, Strogatz DS, Wing SB, Ramsey DL. 1987. Socioeconomic status, John Henryism, and hypertension in blacks and whites. Am J Epidemiol 126:664–673.

Karageorgos P, Latos M, Mpasiakos C, Chalarakis E, Dimitrakakis E, Daskalakis C, et al. 2010. Characterization and dispersion modeling of odors from a piggery facility. J Environ Qual 39:2170–2178.

Keenan NL, Rosendorf KA. 2011. Prevalence of hypertension and controlled hypertension—United States, 2005–2008. MMWR Surveill Summ 60(suppl):94–97.

Lambert S, Beaman A, Winter P. 2000. Olfactometric characterisation of sludge odours. Water Sci Technol 41(6):49–55.

Liao Y, Bang D, Cosgrove S, Dulin R, Harris Z, Taylor A, et al. 2011. Surveillance of health status in minority communities—Racial and Ethnic Approaches to Community Health Across the U.S. (REACH U.S.) risk factor survey, United States, 2009. MMWR Surveil Summ 60:1–44.

Nagai M, Wada M, Usui N, Tanaka A, Hasebe Y. 2000. Pleasant odors attenuate the blood pressure increase during rhythmic handgrip in humans. Neurosci Lett 289:227–229.

National Research Council. 2003. Air Emissions from Animal Feeding Operations: Current Knowledge, Future Needs. Washington, DC:National Academies Press.

Pew Commission on Industrial Food Animal Production. 2008. Putting Meat on the Table: Industrial Farm Animal Production in America. Available: http://www.ncifap.org/ [accessed 23 March 2009].

Radon K, Schulze A, Ehrenstein V, van Strien RT, Praml G, Nowak D. 2007. Environmental exposure to confined animal feeding operations and respiratory health of neighboring residents. Epidemiology 18:300–308.

Schiffman SS. 1998. Livestock odors: implications for human health and well-being. J Anim Sci 76:1343–1355.

Schiffman S, Bennett J, Raymer J. 2001. Quantification of odors and odorants from swine operations in North Carolina. Agric Forest Meteorol 108:213–240.

Schiffman SS, Sattely Miller EA, Suggs MS, Graham BG. 1995. The effect of environmental odors emanating from commercial swine operations on the mood of nearby residents. Brain Res Bull 17:369–375.

Schiffman SS, Studwell CE, Landerman LR, Berman K, Sundy JS. 2005. Symptomatic effects of exposure to diluted air sampled from a swine confinement atmosphere on healthy human subjects. Environ Health Perspect 113:567–576.

Schinasi L, Horton RA, Guidry VT, Wing S, Marshall SW, Morland KB. 2011. Air pollution, lung function, and physical symptoms in communities near concentrated swine feeding operations. Epidemiology 22:208–215.

Schinasi L, Horton RA, Wing S. 2009. Data completeness and quality in a community-based and participatory epidemiologic study. Prog Community Health Partnersh 3:179–190.

Shusterman D. 1992. Critical review: the health significance of environmental odor pollution. Arch Environ Health 47:76–87.

Sparrenberger F, Cichelero FT, Ascoli AM, Fonseca FP, Weiss G, Berwanger O, et al. 2009. Does psychosocial stress cause hypertension? A systematic review of observational studies. J Hum Hypertens 23:12–19.

Tajik M, Minkler M. 2006. Environmental justice research and action: a case study in political economy and community-academic collaboration. Int Q Community Health Educ 26:213–231.

Tajik M, Muhammad N, Lowman A, Thu K, Wing S, Grant G. 2008. Impact of odor from industrial hog operations on daily living activities. New Solut 18:193–205.

Thu K. 2002. Public health concerns for neighbors of large-scale swine production operations. J Agric Saf Health 8:175–184.

Thu K. 2003. Industrial agriculture, democracy, and the future. In: Beyond Factory Farming: Corporate Hog Barns and the Threat to Public Health, the Evironment, and Rural Communities (Ervin A, Holtslander C, Qualman D, Sawa R, eds). Saskatoon, Saskatchewan, Canada:Canadian Centre for Policy Alternatives, 9–28.

Thu K, Durrneberger E, eds. 1998. Pigs, Profits, and Rural Communities. Albany, NY:State University of New York Press.

van Thriel C, Kiesswetter E, Schaper M, Juran SA, Blaszkewicz M, Kleinbeck S. 2008. Odor annoyance of environmental chemicals: sensory and cognitive influences. J Toxicol Environ Health A 71:776–785.

Wagner CA. 2009. Hydrogen sulfide: a new gaseous signal molecule and blood pressure regulator. J Nephrol 22:173–176.

Wing S. 2002. Social responsibility and research ethics in community-driven studies of industrialized hog production. Environ Health Perspect 110:437–444.

Wing S, Cole D, Grant G. 2000. Environmental injustice in North Carolina's hog industry. Environ Health Perspect 108:225–231.

Wing S, Grant G, Green M, Stewart C. 1996. Community based collaboration for environmental justice: South-east Halifax environmental reawakening. Environ Urban 8:129–140.

Wing S, Horton RA, Marshall SW, Thu K, Tajik M, Schinasi L, et al. 2008a. Air pollution and odor in communities near industrial swine operations. Environ Health Perspect 116:1362–1368.

Wing S, Horton RA, Muhammad N, Grant GR, Tajik M, Thu K. 2008b. Integrating epidemiology, education, and organizing for environmental justice: community health effects of industrial hog operations. Am J Public Health 98:1390–1397.

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Exhibit 52

Environmental Injustice in North Carolina's Hog Industry

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Rapid growth and the concentration of hog production in North Carolina have raised concerns of a disproportionate impact of pollution and offensive odors on poor and nonwhite communities. We analyzed the location and characteristics of 2,514 intensive hog operations in relation to racial, economic, and water source characteristics of census block groups, neighborhoods with an average of approximately 500 households each. We used Poisson regression to evaluate the extent to which relationships between environmental justice variables and the number of hog operations persisted after consideration of population density. There are 18.9 times as many hog operations in the highest quintile of poverty as compared to the lowest; however, adjustment for population density reduces the excess to 7.2. Hog operations are approximately 5 times as common in the highest three quintiles of the percentage nonwhite population as compared to the lowest, adjusted for population density. The excess of hog operations is greatest in areas with both high poverty and high percentage nonwhites. Operations run by corporate integrators are more concentrated in poor and nonwhite areas than are operations run by independent growers. Most hog operations, which use waste pits that can contaminate groundwater, are located in areas with high dependence on well water for drinking. Disproportionate impacts of intensive hog production on people of color and on the poor may impede improvements in economic and environmental conditions that are needed to address public health in areas which have high disease rates and low access to medical care as compared to other areas of the state. *Key words:* African Americans, environmental health, environmental justice, epidemiology, geographic information systems, rural health. *Environ Health Perspect* 108:225–231 (2000). [Online 8 February 2000]
http://ehpnet1.niehs.nih.gov/docs/2000/108p225-231wing/abstract.html

Environmental injustice refers to the disproportionate burden of pollution on people of color and the poor (*1–3*). In contrast to rural America's traditional image of unspoiled territory free of industrial pollution, poor rural communities have been targeted in recent years for urban, industrial, and military wastes that are unwanted by communities with larger populations and more political power (*4–6*). Other threats of environmental injustice in rural areas have come about because of the industrialization of agricultural activities (*7,8*). In this work we consider the environmental justice implications of the transformation of hog production in North Carolina from a system dominated by small independent farmers to large vertically integrated agribusiness production.

Between 1985 and 1998 North Carolina moved from fifteenth to second in hog production among U.S. states, with approximately 10 million head outnumbering the state's human population of approximately 7.5 million (*7,9*). The expansion of production has been accompanied by a declining number of operations and an increasing average size of operations (*10*). In 1998, market prices for hogs dropped to their lowest levels since the 1920s, which accelerated the demise of smaller independent producers. Most hogs are now produced by operators who work under contract to corporate integrators, which provide the management plan and own the animals, feed, and transportation; the operators own the land, buildings, and waste (*11*). In the past, hog production was dispersed throughout the state, but it has become consolidated in the coastal plain region, which concentrates waste and the potential for environmental damage in a region that is sensitive because of low-lying flood plains and high water tables (*10*).

Intensive swine production may pose environmental health dangers because of the high volume of waste, the chemical and microbial content of the waste, and the practice of using liquid waste management systems that are not isolated from the environment (*12*). In intensive hog production facilities, referred to as confined animal feeding operations (CAFOs), thousands of hogs are housed in large buildings. Waste is collected in cesspools for anaerobic decomposition and is subsequently sprayed on fields. Airborne emissions from confinement houses, cesspools, and spray fields contain ammonia, hydrogen sulfide, hundreds of volatile organic compounds, dusts, and endotoxins. These mixtures, which cause respiratory dysfunction in hog confinement-house workers (*13–28*) and possibly lower level symptoms in nearby residents (*29,30*), are highly obnoxious odorants that affect quality of life (*29–31*) and may be associated with mood disorders and lowered immune function (*32,33*).

Leaking cesspools and waste sprayed on fields can contaminate groundwater with nitrates and pathogens. The North Carolina State Health Department's (Raleigh, NC) well-testing program for the neighbors of intensive hog operations has documented elevated nitrates from hog operations (*34*). Groundwater contamination is a particular problem in eastern North Carolina because the water tables are high and many wells are shallow and unlined. No active population-based surveillance data are available to document pathogen contamination or the incidence of infections. Hog operations also contaminate surface waters, which may lead to high pathogen loads, eutrophication, and the promotion of algae and dinoflagellate growth (*35–39*).

The coastal plain region of North Carolina is also part of the southern Black Belt, a region where the agricultural economy was first built on the basis of slave labor and where a majority of rural African Americans in the United States still reside. The concentration of hog production in this poor region of the state has therefore raised the issue of environmental injustice (*40*). As in the case of other environmental justice problems, the presence of this polluting industry is a threat to public health because it may lower land values and quality of life and impede healthier economic developments that are needed in communities which suffer from low wages, lack of access to medical care, and poor nutritional options. Environmental injustice in the North Carolina hog industry has previously been investigated for counties (*7,9*) and U.S. Census Bureau (Suitland, MD) block groups (*41*). Using data for census block groups (areas of approximately 500 households), we

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examined the extent to which hog CAFOs are located disproportionately in communities with high levels of poverty, high proportions of nonwhite persons, and high percentages of households dependent on well water. In addition, because agricultural activities are located in rural areas where land is inexpensive, and because many rural areas are poor and nonwhite, we also considered whether relationships between the locations of hog CAFOs and poverty, race, and well use can be explained by the rural nature of these areas.

Materials and Methods

We obtained a list of all animal operations registered with the North Carolina Division of Water Quality (DWQ; Raleigh, NC) as of February 1998. Animal operators report information on the number of head, species and type of animals, aspects of the liquid waste management system, the latitude and longitude coordinates of the facility, and the name of the corporate integrator, if any, with whom the operator has a contract. Swine operations are required to register with the DWQ if they have > 250 head and if they use a liquid waste management system. The steady state live weight (SSLW) of the herd was calculated by the DWQ as a function of the number of head of each type (breeding sows, farrow to wean pigs, wean to feeder pigs, feeder to finish hogs, boars, and gilts) and the average weight for each type hog. Finished hogs, ready for market, weigh approximately 240 lb.

Of the 3,039 animal operations in the database, 2,585 were swine operations (Figure 1). Facilities with missing data or head counts < 250 were excluded. We located the facilities within the state using latitude and longitude data. For 257 facilities, geographic coordinates placed the facility outside of the county of operation, outside the state, or the coordinates were missing. Missing and incorrect geocoordinates were corrected using local maps, geographic information systems software, and the driving instructions provided to state inspectors. The DWQ was contacted to provide information for operations that were missing road instructions or had incomplete instructions, and on those that were out of business. Operations with coordinates inside the correct county were not examined further. Three university-owned operations, which are not subject to the same commercial location considerations as other facilities, were excluded from the analysis. The remaining 2,514 swine CAFOs were included in the analysis (Figure 1).

We used geographic coordinates for the swine operations to locate the facilities within the boundaries of block groups. The number of facilities in each block group was the dependent variable in analyses quantifying the association between number of hog CAFOs and the characteristics of block groups. Because airborne emissions from hog CAFOs may affect the environment well beyond their boundaries, we also conducted analyses considering buffer zones of 1 and 2 miles, in which the count of operations for a block group consisted of the number of hog CAFOs that were within 1 or 2 miles of the block group's boundaries.

Information on race, poverty, and water source was obtained for 1990 census block groups, the smallest geographical unit for which economic and demographic data can be obtained and the unit most closely approximating neighborhoods or communities. The 1990 census provided the most recent block group level geographic information available, and corresponded to the time during which hog production in North Carolina began to accelerate rapidly. Three environmental justice variables of interest were defined as the percentage nonwhite population, the percent of persons in poverty, and the percent of households that used well water. We also obtained the total number of persons, land area in square miles, and population density for each block group.

Some areas of the state, including metropolitan areas, have no presence of the commercial swine production industry. These areas, including mostly white Appalachia and some largely African American areas in central cities of the Piedmont, could have skewed the evaluation of the relationship between hog operations and the environmental justice variables. Therefore, we excluded from the analysis 14 of the state's 100 counties that did not border a county with a hog CAFO and the state's five cities with 1990 populations > 100,000. The remainder of the state considered in the analysis included 4,177 block groups with a population of approximately 4.9 million persons.

Relationships between the environmental justice variables (poverty, race, and water source) and the presence of hog CAFOs were first evaluated by summing the total number of hog CAFOs in quintiles of the distribution of each environmental justice variable. Because quintiles have the same number of block groups by definition, the ratio of the number of hog CAFOs in each higher quintile as compared to the lowest quintile of the variable is equal to the prevalence ratio of the number of operations per block group at higher levels as compared to the lowest level. This unadjusted measure is referred to as a crude ratio.

We prepared maps to show the spatial distribution of the major study variables. Chloropleth maps of poverty, race, and population density are keyed to bar graphs indicating the numbers of block groups in each category. Because block groups vary greatly in land area and because the visual impact of the chloropleth map is influenced by land area, categories based on quintiles of block groups are not sensitive to the spatial distribution of the variables. Therefore, we chose category boundaries for maps to reflect the distribution of each variable.

Agricultural operations of all types are located in rural areas, where population density is low and land is inexpensive. Rural areas have higher poverty rates, much of the southern Black Belt is rural, and rural areas are often not served by municipal water systems.

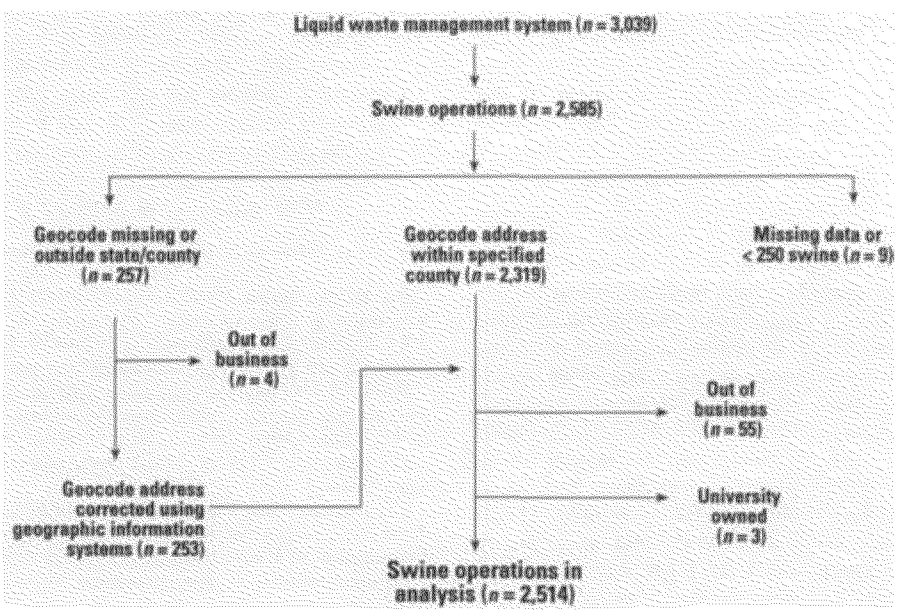

Figure 1. The identification of swine CAFOs from the DWQ data, February 1998.

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It was therefore of interest to determine the extent to which excess numbers of hog operations in poor, nonwhite, and well-water-dependent communities could be considered a function of their low population density. We used Poisson regression to model the relationship between the natural log of population density and the number of hog operations per block group. We used linear, quadratic, and cubic terms for the log of population density to obtain an adequate fit of the model to the data. Higher order terms did little to improve the fit of the model.

Because Poisson models were overdispersed (model deviance/degrees of freedom > 1), we set the scale parameters for the models equal to the overdispersion values, which ranged from 1.6 to 1.8. We included indicator variables to represent each of the higher quintiles and we calculated the ratios of the number of hog CAFOs in block groups in each higher quintile of the environmental justice variables as compared to the lowest. We adjusted these ratios for population density using the cubic polynomial regression. Models were fit separately for operations under contract to corporate integrators and for those that were independent.

Results

Figure 2 shows the locations of hog CAFOs in North Carolina and the areas of the state excluded from the analysis. Each red dot represents one hog operation. The dense area of operations in the southeastern part of the state is centered on Duplin and Sampson Counties, the two largest hog-producing counties in the United States.

The size distribution of the 2,514 North Carolina hog CAFOs is shown in Table 1. The smallest 277 operations had an SSLW of < 100,000 lb each, which accounted for 11.0% of the operations and 1.4% of the state's SSLW. The SSLW of the largest 369 operations was ≥ 1 million pounds, which accounted for 14.7% of the operations and 44.4% of the SSLW in the state.

The geographic distribution of poverty is shown in Figure 3. Figure 3B shows the number of block groups in each category of poverty. For example, the categories with 0–5 and 5–10% persons in poverty each include approximately 1,000 block groups. Low-poverty areas predominate in the central Piedmont region of the state, whereas the higher poverty areas are located in the eastern coastal plain and in the northwest region (the edge of Appalachia).

Figure 4 shows the percentage nonwhite population. Most of the approximately 1,800 block groups with < 10% nonwhite population are located in the western part of the study area. These include 454 block groups that are 100% white. Areas with larger proportions of nonwhite population (mostly African Americans) are primarily in the eastern part of the state. An exception to the primarily African American makeup of the state's nonwhite population is Robeson County, located just southeast of the angle formed by the two straight lines along the central southern boundary of state. Robeson County is home to the Lumbee Indians and its population is approximately one-third Native American.

Table 2 presents the characteristics of block groups in relation to the environmental justice variables. Larger numbers of persons in the lowest categories of poverty live in a smaller land area, which results in higher population densities in areas with less poverty. Block groups in the lowest quintile of poverty contained only 43 hog CAFOs with 17.5 million lb of hogs, an average of 406.8 thousand lb/operation. In comparison, there are 225 hog operations in the second quintile

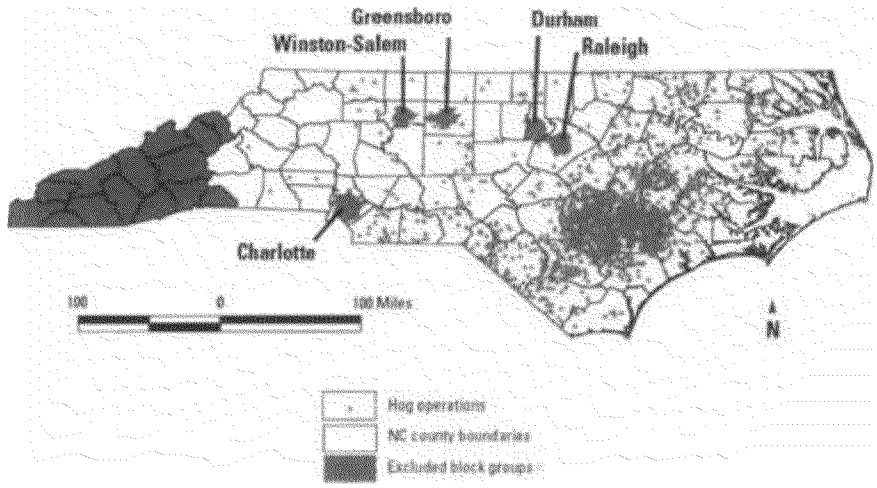

Figure 2. North Carolina study areas and locations of intensive hog operations, 1998.

Table 1. SSLW of North Carolina hog CAFOs, 1998.

SSLW (millions of pounds)	Operations (*n*)	Operations (%)	Cumulative SSLW (millions of pounds)	SSLW (%)
0.02 to < 0.10	277	11.0	20.8	1.4
0.10 to < 0.25	583	23.2	97.6	6.8
0.25 to < 0.50	708	28.2	268.2	18.6
0.50 to < 1.0	577	23.0	414.5	28.8
1.0 to < 10.1	369	14.7	639.7	44.4
Total	2,514	100	1,440.8	100

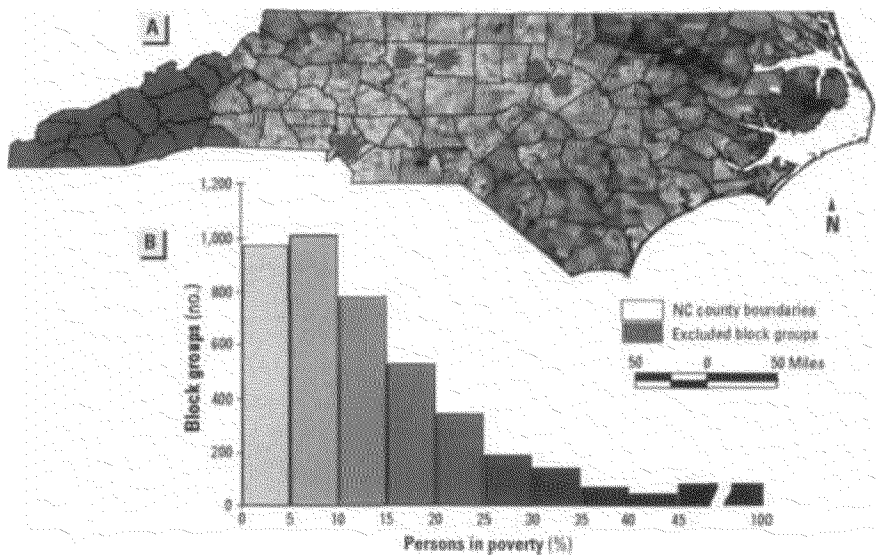

Figure 3. (*A*) The percent of persons in poverty in North Carolina, 1990. (*B*) The number of block groups in each category of poverty.

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of poverty, 585 in the third, and > 800 in the fourth and fifth quintiles. Increases in total SSLW in areas with higher poverty levels are due to both larger numbers of operations and higher SSLW per operation.

Table 2 also shows the distribution of persons, land area, and hog operations for categories of the percentage nonwhite population. Population densities are lowest in the fourth and fifth quintiles of the percentage nonwhite variable. The 123 hog CAFOs in the lowest quintile have an SSLW of 48 million lb. The number of hog CAFOs in higher quintiles of the percentage nonwhite population increases to a maximum of 820 in the fourth quintile. The largest SSLW is in the highest quintile, 513 million lb, and the average size of operations increases with increases in the percentage nonwhite population.

Table 2 also presents information for block groups in quintiles of percentage of households using well water. This variable is most clearly related to population density, which declines from 1,315.4 persons/square mile in areas where < 1% of households have well water to 53.9/square mile in areas where > 85% of households have well water. Only five hog CAFOs, with a total SSLW of 1.2 million lb, are found in the lowest quintile of well-water use. Almost half of all hog CAFOs are located in block groups where > 85% of households have well water.

Although Table 2 shows clearly that there are more hog CAFOs in areas with higher percentages of persons in poverty, nonwhite persons, and households that use wells, it also shows that areas with the highest levels of these characteristics have lower population density, indicating that they are more rural areas. Population density is generally low throughout the eastern part of the state as compared to much of the Piedmont (Figure 5). Figure 6 shows that the number of hog operations per block group is strongly related to population density and that the observed number of operations per block group is predicted well by a cubic polynomial on a log–log scale. The number of operations per block group is lowest at the highest density, reaches a peak at approximately 20 persons/square mile, and declines somewhat at the lowest levels of density. The total number of operations in each category, shown in Figure 6 beside the observed values for the number of operations per block group, shows that the vast majority of operations are in block groups with fewer than 100 persons/square mile.

Table 3 summarizes the relationship between environmental justice variables and the presence of hog CAFOs in terms of the ratio of the number of operations per block group among block groups in the higher quintiles as compared to the lowest quintiles. The crude ratio of the number of operations per block group can be calculated from the data in Table 2. The ratio, adjusted for population density, is shown in the second column under each variable in Table 3. The large ratios for the higher levels of poverty, which vary from 5 to 20, are substantially reduced with adjustment for the rural nature of those areas. Adjusted ratios increase in a stepwise fashion with higher levels of poverty, from 3.0 in the second quintile to 7.2 in the highest.

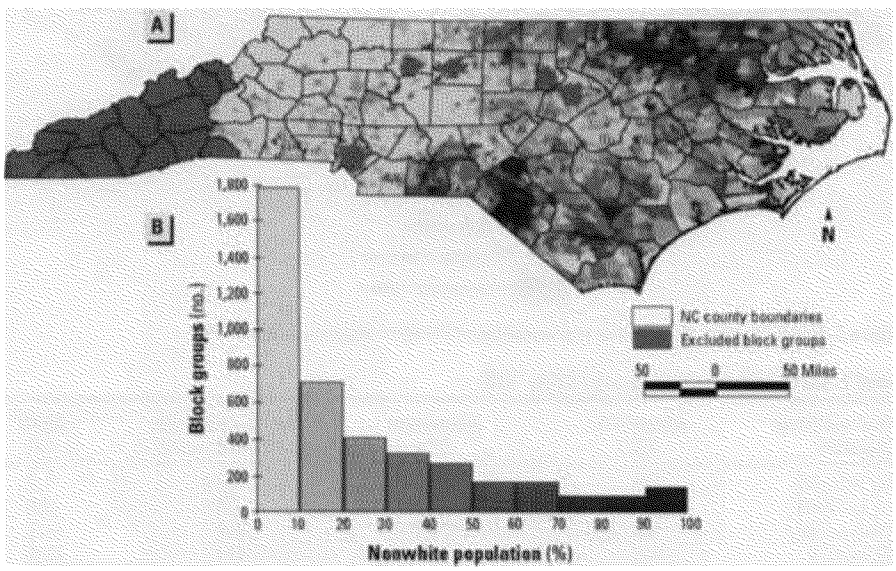

Figure 4. (*A*) The percentage nonwhite population in North Carolina, 1990. (*B*) The number of block groups in each category of the percentage nonwhite population.

Table 2. Characteristics of block groups in relation to poverty, race, and water source.

Characteristic	Block groups (*n*)	No. persons (thousands)	Land area (thousands of square miles)	Population density (people per square mile)	Total operations	Pounds of hogs (millions)	SSLW per operation (thousands)
Poverty (%)							
0 to < 4.9	835	1,118	4.7	238.0	43	17.5	406.8
4.9 to < 8.8	835	1,069	7.2	148.0	225	100.6	447.0
8.8 to < 13.6	836	966	9.4	103.0	585	284.9	486.9
13.6 to < 21.0	835	930	11.3	82.1	850	503.6	592.5
21.0 to 100	836	853	9.4	90.5	811	534.3	658.8
Nonwhite (%)							
0 to < 2.3	835	840	7.3	114.5	123	48.0	390.2
2.3 to < 9.3	835	1,048	6.3	165.2	165	78.1	473.6
9.3 to < 20.8	836	1,039	8.0	129.5	623	306.2	491.5
20.8 to < 44.2	835	1,103	10.5	105.5	820	495.5	604.3
44.2 to 100	836	907	9.9	91.7	783	513.0	655.1
Well water (%)							
0 to < 1.0	835	897	0.7	1,315.4	5	1.2	246.0
1.0 to < 16.4	835	1,068	3.4	314.4	185	91.6	495.1
16.4 to < 46.1	836	1,039	8.3	124.5	386	205.9	533.4
46.1 to < 85.5	835	1,020	12.7	80.5	734	450.5	613.7
85.5 to 100	836	914	17.0	53.9	1,204	691.6	574.4
Total[a]	4,177	4,937	42.1	117.4	2,514	1,440.8	573.1

[a]Sum for each variable.

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Crude ratios for the percentage nonwhite population are smaller than the crude ratios for the percent of persons in poverty, ranging from 1.3 in the second quintile to 6.7 in the fourth quintile. Furthermore, the ratios are less affected by adjustment for population density. The ratio for the second quintile increases to 1.9, whereas ratios in the fourth and fifth quintiles are somewhat decreased. Adjusting for population density, the third, fourth, and fifth quintiles of the percentage nonwhite population have approximately 5 times as many hog CAFOs as those in the lowest quintile.

Hog CAFOs show a strong and monotonically increasing relationship to the percent of households using well water, with prevalence ratios ranging from 37.0 in the second to 240.8 in the fifth quintile. Most of this strong relationship, however, can be explained by the lower population density of areas with a high dependence on wells. Adjusted ratios in higher quintiles as compared to the lowest range between 4 and 5.

Table 4 shows the prevalence ratios for hog CAFOs in block groups cross-classified by poverty and the percentage nonwhite population, adjusted for population density. Block groups in the 0–5% poverty and 0–2% nonwhite population category are considered the referent group. Table 4 shows that increases in the percentage nonwhite population have little effect on number of hog operations among block groups in the lowest poverty group. Similarly, only modest increases in the numbers of operations are seen with increasing poverty levels among block groups in the lowest percent nonwhite category. However, prevalence ratios increase dramatically in areas with higher proportions of poor and nonwhite persons, reaching a ratio of 9 times as many operations in block groups with ≥ 12% poverty and ≥ 10% nonwhite population, adjusted for population density.

Most of the growth in NC pork production during the 1990s has been in large operations managed for corporate integrators rather than in independent operations. Therefore, we repeated the analyses for poverty and race separately for operations that listed corporate integrators on their permit applications (n = 1,603) and those that did not (n = 911). Prevalence ratios for integrator and independent CAFOs, adjusted for population density, are shown in Table 5. Although there is an excess of both types of operations in areas with greater percentages of poor and nonwhite populations, the excess is substantially larger for integrator operations at every level of poverty and race. Among the areas in the poorest quintile of block groups there are 20 times more integrator CAFOs than in the least-poor quintile, adjusted for differences in population density, whereas the excess of independent CAFOs in those areas is only 3.5 times. Similarly, block groups in the highest three quintiles of the percentage nonwhite population show an excess of integrator operations of 7 to 8 times, whereas the excess of independent operations is approximately 3 times.

Our analyses reported above consider only populations within the block groups containing hog CAFOs as potentially affected. However, airborne emissions and water pollution from CAFOs may travel some distance. Therefore, we reclassified the number of hog CAFOs in each block group considering 1- and 2-mile buffers around each operation. In these analyses, the number of hog operations in a block group is considered the number within the block group's boundaries plus the number within 1 or 2 miles of the block group, under the assumption that CAFOs located within 1 or 2 miles may impact the populations of neighboring block groups. We conducted analyses for the percent of persons in poverty and the percentage nonwhite population using the cubic polynomial model to adjust for population density. The ratios for the percent of persons in poverty were somewhat reduced, ranging between 2.2 and 5.9 under 1 and 2-mile buffers, as compared to a range of 3.0–7.2 with no buffer (Table 3). The ratios for the percentage nonwhite population were similar to ratios using a zero buffer, ranging from 1.9 to 5.3.

Discussion

We examined the locations of North Carolina's approximately 2,500 intensive hog confinement facilities in relation to poverty levels, race, and household water source of neighboring populations. These facilities are located disproportionately in communities with higher levels of poverty, higher proportions of nonwhite persons, and higher dependence on wells for household water supply. The disproportionate location of hog CAFOs in these areas raises numerous public health and social justice issues (*7,9,42,43*). Intensive swine production and its attendant pollution are concentrated in areas of North Carolina that have the highest disease rates (*44,45*), the least access to medical care, and the greatest need for positive economic development and better educational systems (*46*). The adverse effects of hog CAFOs on the quality of life and on community aesthetics (*29–31*) threaten the community economic and social developments that are fundamental to improved public health (*47*).

This study did not address siting decisions for particular hog operations. The reasons why a facility is located in a specific place are, in some ways, particular to the historical situation, business climate, local culture, and personal or family decision making. However, the pattern of location of industries reflects institutional factors and the political and economic power of local populations.

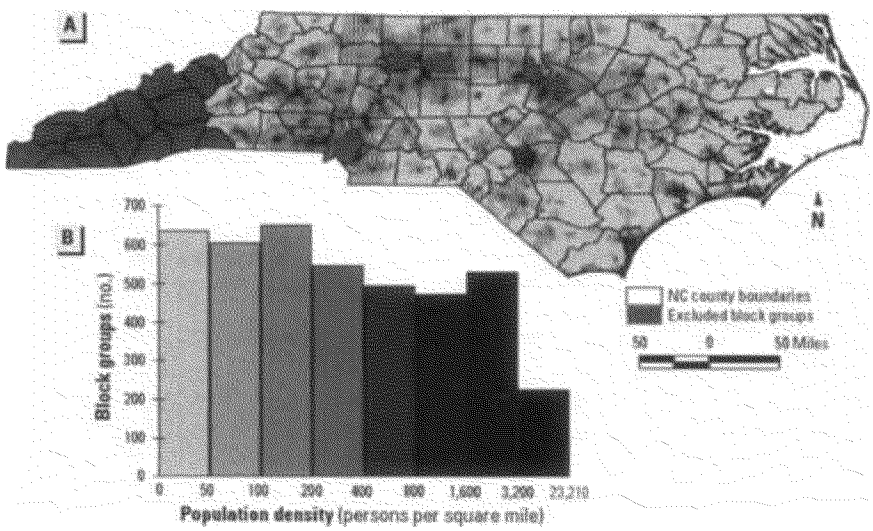

Figure 5. (*A*) North Carolina population density, 1990. (*B*) The number of block groups in each category of population density.

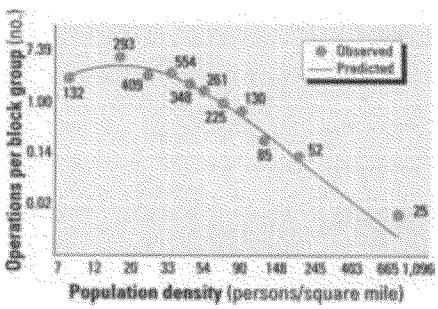

Figure 6. Number of operations per block group in relation to population density.

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Table 3. Crude and adjusted prevalence ratios of numbers of hog CAFOs per block group for quintiles of poverty, nonwhite population, and well-water source.

	Poverty (%)		Nonwhite (%)		Well water (%)	
Quintile	Crude ratio[a]	Adjusted ratio[b]	Crude ratio[a]	Adjusted ratio[b]	Crude ratio[a]	Adjusted ratio[b]
I	1.0	1.0	1.0	1.0	1.0	1.0
II	5.2	3.0	1.3	1.9	37.0	4.9
III	13.6	5.5	5.1	5.1	77.2	4.2
IV	19.8	6.4	6.7	5.1	146.8	4.2
V	18.9	7.2	6.4	4.7	240.8	4.7

[a]Unadjusted ratio of number of operations, higher quintile as compared to the first quintile. [b]Adjusted for population density, cubic polynomial.

These institutional inequalities are critically important issues to consider in addressing the public health problem of the disproportionate burden of polluting industries among poor and nonwhite populations (*1,2,5,40,48*).

Both poverty and race are strongly related to the location of hog operations, as shown in Tables 2 and 3. However, the combination of the two characteristics is of particular interest (Table 4). Increasing levels of poverty have only a modest effect in block groups with < 2% nonwhite populations. Similarly, increasing levels of nonwhite populations have little effect on the prevalence of hog operations among the block groups with < 5% poverty. It is the combination of a high percentage nonwhite populations and high poverty levels that is associated with the greatest excess of hog CAFOs, reaching a prevalence ratio of almost 10 for block groups with ≥ 12% poverty and ≥ 10% nonwhite population as compared to block groups with < 5% poverty and < 2% nonwhite population.

The industrialization of agriculture has brought about not only changes in size, but also in ownership. All of the hog operations considered in this research are large and fall under state regulations for intensive livestock operations. However, among these large operations, some are owned and operated by independent farmers who make their own management decisions. Other operations are owned by or are operated under contract with large agribusiness integrators that own and control the animals, feed, veterinary supplies, transportation, financing, and marketing of the product. Although both types of operations are large and industrialized, integrator operations have been responsible for most of the recent expansion of the industry (*7*). Because of their corporate structures, they may be in the best position to locate facilities based on economic considerations such as proximity to other operations, transportation routes, and slaughterhouses, as well as low land prices and the low local political power of host communities. Furthermore, there is a net decrease in jobs in regions where hog production has been industrialized because of the displacement of the independent producers who purchased locally (*49*). The concentration of hog CAFOs in poor and nonwhite areas is much greater for integrator than for independent operations (Table 5). Because the industry is moving rapidly toward greater economic concentration while family-owned businesses are in decline (*9,10,50*), the evidence of greater environmental injustice for integrator operations suggests that this problem may increase in the future.

This study was conducted using census block groups as the units of analysis. These areas, averaging approximately 500 households, are the smallest unit for which population data are available from the U.S. census and should provide better sensitivity and specificity to the characteristics of populations in greatest proximity to hog operations than would larger geographic units. The most recent block group data available are from 1990; more recent economic data from other sources are not available with this level of geographic detail. In any case, 1990 is an appropriate year for which to measure socioeconomic characteristics in our study of the location of hog operations because the period of rapid growth in the industry began in the late 1980s.

We depended on data from the DWQ for information on the locations and characteristics of intensive livestock operations in February 1998. Because a moratorium on the construction of new industrial operations was imposed by the North Carolina General Assembly in March 1997 (*7*) and has not yet been lifted (as of 1999), information from 1998 remains relevant. However, the validity of analyses reported here depend on the quality of information recorded by the state. We detected and corrected hundreds of errors in latitude/longitude coordinates for North Carolina hog CAFOs that were not located in the correct county according to the database (Figure 1). The extent of within-county errors in the data is unknown. Information on the size of the operation depends on the quality of data provided by the operator. The database contains information on a number of other characteristics of interest, such as the start date of the operation, the size and number of cesspools, and the acreage of spray fields. Unfortunately, these data were too incomplete to use in our analyses. Future studies of environmental justice and public health impacts of this industry would benefit from more complete and accurate data.

The public health implications of environmental injustice in the North Carolina hog industry are of special concern. Exposures in the environment of confinement houses are clearly related to impaired respiratory function, occupational asthma, and organic dust syndrome (*51*). This is an occupational health concern in areas with a large industry presence. In addition, environmental exposures to airborne emissions from hog CAFOs may be associated with respiratory effects (*29,30*) and impaired mood (*32,33*) in neighboring populations. Groundwater from hog CAFOs has been contaminated by nitrates in North Carolina (*34*). This is a special concern considering the findings presented here, which show that approximately half of the hog CAFOs are located in block groups of the state where > 85% of households depend on well water for drinking (Table 2). The eastern coastal plain of the state where most operations are located (Figure 1) has sandy soils and high water tables that facilitate the movement of water pollution from cesspools and

Table 4. Adjusted prevalence ratios[a] of the numbers of hog CAFOs per block group for block groups classified by poverty and nonwhite population.

	Nonwhite (%)		
Poverty (%)	0 to < 2	2 to < 10	10 to 100
0 to <5	1.0[b] (264)[c]	1.4 (335)	1.1 (254)
5 to < 12	1.8 (341)	3.6 (419)	7.0 (635)
12 to 100	1.7 (186)	3.1 (202)	9.6 (1,541)

[a]Adjusted for population density, cubic polynomial. [b]Referent group. [c]Number of block groups in parentheses.

Table 5. Adjusted prevalence ratios[a] of the numbers of hog CAFOs per block group for quintiles of poverty and nonwhite population: integrators and independents.

	Poverty (%)		Nonwhite (%)	
Quintile	Integrators	Independents	Integrators	Independents
I	1.0[b]	1.0[b]	1.0[b]	1.0[b]
II	7.2	1.9	2.4	1.5
III	16.2	2.7	7.5	3.4
IV	17.7	3.5	8.0	2.9
V	20.7	3.5	7.0	3.0

[a]Adjusted for population density, cubic polynomial. [b]Referent group.

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spray fields into groundwater, and older rural homes occupied by the poor and people of color often have shallow wells with less protection from contamination. Surface water pollution is a concern because of the spread of microbial contamination and the nutrient loading of rivers and estuaries.

Community concerns about environmental injustice in the distribution of hog operations in North Carolina are real. Predominantly poor and nonwhite communities that host a disproportionate number of hog CAFOs have a great need for positive economic development, environmentally sound industry, and better schools and medical care. Such community resources are important to public health (*47*). However, future prospects for these communities are threatened by an industry that produces highly obnoxious odors and reduces the quality of life for neighbors (*29–31*), which can hamper the growth of cleaner industries, reduce land values, and contribute to loss of locally owned land (*9,40*). Our findings should be taken into consideration as growth, technological change, and environmental remediation in the industry are considered.

References and Notes

1. Bryant B. Environmental Justice: Issues, Policies and Solutions. Washington, DC:Island Press, 1995.
2. Bullard RD, Wright BH. Environmental justice for all: community perspectives. Toxicol Ind Health 9:821–841 (1993).
3. United Church of Christ Commission for Racial Justice. Toxic Waste and Race: A National Report on the Racial and Socioeconomic Characteristics of Communities with Hazardous Waste Facilities. New York:United Church of Christ, 1987.
4. Goldtooth T. Indigenous nations: summary of sovereignty and its implications for environmental protection. In: Environmental Justice: Issues, Policies and Solutions (Bryant B, ed). New York:Island Press, 1995;138–148.
5. Bullard R. Dumping in Dixie: Race, Class, and Environmental Quality. Boulder, CO:Westview Press, 1990.
6. Geiser K, Waneck G. PCBs and Warren County. In: Unequal Protection: Environmental Justice and Communities of Color (Bullard R, ed). San Francisco, CA:Sierra Club Books, 1994;43–52.
7. Ladd A, Edwards B. Swine before pearls: environmental justice and public opposition to corporate pork production in North Carolina. In: Race, Gender, Class and Environmentalism (Bullard R, Johnson G, Taylor D, Belkhir J, eds). New York:Roman and Littlefield, in press.
8. Jackson L. Large-scale swine production and water quality. In: Pigs, Profits, and Rural Communities (Thu K, Durrenberger E, eds). Albany, NY:State University of New York Press, 1998;103–119.
9. Edwards B, Ladd A. Environmental justice, swine production and farm loss in North Carolina. Sociol Spectrum (in press).
10. Furuseth O. Restructuring of hog farming in North Carolina: explosion and implosion. Prof Geogr 49:391–403 (1997).
11. Braun J, Braun P. Inside the industry from a family hog farmer. In: Pigs, Profits, and Rural Communities (Thu K, Durrneberger E, eds). Albany, NY:State University of New York Press, 1998;39–56.
12. Taylor D. Fresh from the Farm. Environ Health Perspect 107:A154–A157 (1999).
13. Donham KJ. Health effects from work in swine confinement buildings. Am J Ind Med 17:17–25 (1990).
14. Donham K, Haglind P, Peterson Y, Rylander R, Belin L. Environmental and health studies of farm workers in Swedish swine confinement buildings. Br J Ind Med 46:31–37 (1989).
15. Donham K, Rubino M, Thedell T, Kammermeyer J. Potential health hazards to agricultural workers in swine confinement buildings. J Occup Med 19:383–387 (1977).
16. Cormier Y, Duchaine C, Israel-Assayag E, Bedard G, Laviolette M, Dosman J. Effects of repeated swine building exposures on normal naive subjects. Eur Resp J 10:1516–1522 (1997).
17. Donham K, Reynolds S, Whitten P, Merchant J, Burmeister L, Popendorf W. Respiratory dysfunction in swine production facility workers: dose-response relationships of environmental exposures and pulmonary function. Am J Ind Med 27:405–418 (1995).
18. Haglind P, Rylander R. Occupational exposure and lung function measurements among workers in swine confinement buildings. J Occup Med 29:904–907 (1987).
19. Heederik D, Brouwer R, Biersteker K, Boleij JSM. Relationship of airborne endotoxin and bacteria levels in pig farms with the lung function and respiratory symptoms of farmers. Int Arch Occup Environ Health 62:595–601 (1991).
20. Holness DL, O'Blenis EL, Sass-Kortsak A, Pilger C, Nethercott JR. Respiratory effects and dust exposures in hog confinement farming. Am J Ind Med 11:571–580 (1987).
21. Iversen M. Predictors of long-term decline of lung function in farmers. Monaldi Arch Chest Dis 52:474–478 (1997).
22. Larsson K, Eklund A, Hansson L, Isaksson B, Malmberg P. Swine dust causes intense airways inflammation in healthy subjects. Am J Resp Crit Care Med 150:973–977 (1994).
23. Olson D, Bark S. Health hazards affecting the animal confinement farm worker. AAOHN J 44:198–204 (1996).
24. Pickrell J. Hazards in confinement housing—gases and dusts in confined animal houses for swine, poultry, horses, and humans. Vet Hum Toxicol 33:32–39 (1991).
25. Schwartz DA, Landas SK, Lassise DL, Burmeister LF, Hunninghake GW, Merchant JA. Airway injury in swine confinement workers. Ann Int Med 116:630–635 (1992).
26. Vogelzang PFJ, van der Gulden JWJ, Preller L, Heederik D, Tielen MJM, van Schayck CP. Respiratory morbidity in relationship to farm characteristics in swine confinement work: possible preventive measures. Am J Ind Med 30:212–218 (1995).
27. Von Essen S, Scheppers L, Robbins R, Donham K. Respiratory tract inflammation in swine confinement workers studied using induced sputum and exhaled nitric oxide. Clin Toxicol 36:557–565 (1998).
28. Zejda JE, Barber E, Dosman JA, Olenchock SA, McDuffie HH, Rhodes C, Hurst T. Respiratory health status in swine producers relates to endotoxin exposure in the presence of low dust levels. J Occup Med 36:49–56 (1994).
29. Wing S, Wolf S. Intensive livestock operations, health, and quality of life among eastern North Carolina residents. Environ Health Perspect 108:233–238 (2000).
30. Thu K, Donham K, Ziegenhorn R, Reynolds S, Thorne P, Subramanian P, Whitten P, Stookesberry J. A control study of the physical and mental health of residents living near a large-scale swine operation. J Agric Saf Health 3:13–26 (1997).
31. Swinker M. Human health effects of hog waste. N C Med J 59:16–18 (1998).
32. Schiffman SS, Sattely Miller EA, Suggs MS, Graham BG. The effect of environmental odors emanating from commercial swine operations on the mood of nearby residents. Brain Res Bull 17:369–375 (1995).
33. Schiffman SS. Livestock odors: implications for human health and well-being. J Anim Sci 76:1343–1355 (1998).
34. CDC. The Confinement Animal Feeding Operation Workshop. Washington, DC:Centers for Disease Control and Prevention, National Center for Environmental Health, 1998.
35. Crane S, Moore J, Grismer M, Miner J. Bacterial pollution from agricultural sources: a review. Trans Am Soc Agric Eng 72:858–866 (1983).
36. Baxter-Potter W, Gilliland M. Bacterial pollution in runoff from agricultural lands. J Environ Qual 17:27–34 (1988).
37. Hallegraeff G. A review of harmful algal blooms and their apparent global increase. Phycologia 32:79–99 (1993).
38. Mallin M. Phytoplankton ecology of North Carolina estuaries. Estuaries 17:561–574 (1994).
39. Glasgow H, Burkholder J. Insidious effects of a toxic estuarine dinoflagellate on fish survival and human health. J Toxicol Environ Health 46:501–522 (1995).
40. Wing S, Grant G, Green M, Stewart C. Community based collaboration for environmental justice: south-east Halifax environmental reawakening. Environ Urbanization 8:129–140 (1996).
41. Raine J. Environmental Justice Issues of the North Carolina Swine Industry [Masters thesis]. Durham, NC:Duke University, Nicholas School of the Environment, 1998.
42. Morgan R. Legal and political injustices of industrial swine production in North Carolina. In: Pigs, Profits, and Rural Communities (Thu K, Durrenberger E, eds). Albany, NY:State University of New York Press, 1998;138–144.
43. Wing S. Whose epidemiology, whose health? Int J Health Serv 28:241–252 (1998).
44. Wing S, Casper M, Davis W, Pellom A, Riggan W, Tyroler H. Stroke mortality maps: United States whites aged 35-74, 1962–1982. Stroke 19:1507–1513 (1988).
45. Weber D, Rutala W, Samsa G, Sarubbi F, King L. Epidemiology of tuberculosis in North Carolina, 1966 to 1986: analysis of demographic features, geographic variation, AIDS, migrant workers, and site of infection. South Med J 92:1204–1214 (1989).
46. Falk W, Lyson T. High Tech, Low Tech, No Tech: Recent Industrial and Occupational Change in the South. Albany, NY:State University of New York Press, 1988.
47. Sclar ED. Community economic structure and individual well-being: a look behind the statistics. Int J Health Serv 10:563–579 (1980).
48. Brown P. Race, class, and environmental health: a review and systematization of the literature. Environ Res 69:15–30 (1995).
49. Ikerd J. Sustainable agriculture, rural economic development, and large-scale swine production. In: Pigs, Profits, and Rural Communities (Thu K, Durrenberger E, eds). Albany, NY:State University of New York Press, 1988;157–164.
50. Morrison J. The poultry industry: a view of the swine industry's future? In: Pigs, Profits, and Rural Communities (Thu K, Durrenberger E, eds). Albany, NY:State University of New York Press, 1998;145–153.
51. Donham K. The impact of industrial swine production on human health. In: Pigs, Profits, and Rural Communities (Thu K, Durrenberger E, eds). Albany, NY:State University of New York Press, 1998;73–83.

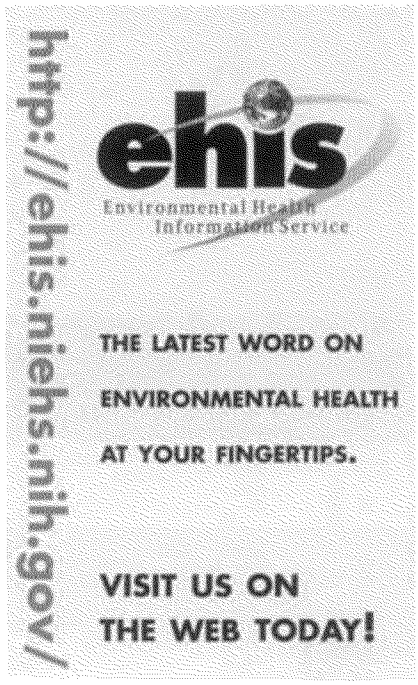

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Exhibit 53

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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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)

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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

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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.

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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?"

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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.

References and Notes

1. Furuseth O. Restructuring of hog farming in North Carolina: explosion and implosion. Prof Geogr 49:391–403 (1997).
2. Edwards B, Ladd A. Environmental justice, swine production and farm loss in North Carolina. Sociol Spectrum (in press).
3. Ladd A, Edwards B. Swine before pearls: environmental justice and public opposition to corporate pork production in North Carolina. In: Race, Gender, Class and Environmentalism (Bullard R, Johnson G, Taylor D, Belkhir J, eds). New York:Roman and Littlefield, in press.
4. Taylor D. Fresh from the farm. Environ Health Perspect 107:A154–A157 (1999).
5. Schiffman SS. Livestock odors: implications for human health and well-being. J Anim Sci 76:1343–1355 (1998).
6. Reynolds SJ, Donham KJ, Stookesberry J, Thorne PS, Subramanian P, Thu K, Whitten P. Air quality assessments in the vicinity of swine production facilities. In: Agricultural Health and Safety: Recent Advances (Donham KJ, ed). Binghamton, NY:Haworth Press, Inc., 1997;37–45.
7. Thu K, Donham K, Ziegenhorn R, Reynolds S, Thorne P, Subramanian P, Whitten P, Stookesberry J. A control study of the physical and mental health of residents living near a large-scale swine operation. J Agric Saf Health 3:13–26 (1997).
8. Swinker M. Human health effects of hog waste. N C Med J 59:16–18 (1998).
9. Donham KJ. Health effects from work in swine confinement buildings. Am J Ind Med 17:17–25 (1990).
10. Donham K, Haglind P, Peterson Y, Rylander R, Belin L. Environmental and health studies of farm workers in Swedish swine confinement buildings. Br J Ind Med 46:31–37 (1989).
11. Donham K, Rubino M, Thedell T, Kammermeyer J. Potential health hazards to agricultural workers in swine confinement Buildings. J Occup Med 19:383–387 (1977).
12. Cormier Y, Duchaine C, Israel-Assayag E, Bedard G, Laviolette M, Dosman J. Effects of repeated swine building exposures on normal naive subjects. Eur Respir J 10:1516–1522 (1997).
13. Donham K, Reynolds S, Whitten P, Merchant J, Burmeister L, Popendorf W. Respiratory dysfunction in swine production facility workers: dose-response relationships of environmental exposures and pulmonary function. Am J Ind Medicine 27:405–418 (1995).
14. Haglind P, Rylander R. Occupational exposure and lung function measurements among workers in swine confinement buildings. J Occup Med 29:904–907 (1987).
15. Heederik D, Brouwer R, Biersteker K, Boleij JSM. Relationship of airborne endotoxin and bacteria levels in pig farms with the lung function and respiratory symptoms of farmers. Int Arch Occup Environ Health 62:595–601 (1991).
16. Holness DL, O'Blenis EL, Sass-Kortsak A, Pilger C, Nethercott JR. Respiratory effects and dust exposures in hog confinement farming. Am J Ind Med 11:571–580 (1987).
17. Iversen M. Predictors of long-term decline of lung function in farmers. Monaldi Arch Chest Dis 52:474–478 (1997).
18. Larsson K, Eklund A, Hansson L, Isaksson B, Malmberg P. Swine dust causes intense airways inflammation in healthy subjects. Am J Respir Crit Care Med 150:973–977 (1994).
19. Olson D, Bark S. Health Hazards affecting the animal confinement farm worker. AAOHN J 44:198–204 (1996).
20. Pickrell J. Hazards in confinement housing—gases and dusts in confined animal houses for swine, poultry, horses, and humans. Vet Hum Toxicol 33:32–39 (1991).
21. Schwartz DA, Landas SK, Lassise DL, Burmeister LF, Hunninghake GW, Merchant JA. Airway injury in swine confinement workers. Ann Intern Med 116:630–635 (1992).
22. Vogelzang PFJ, van der Gulden JWJ, Preller L, Heederik D, Tielen MJM, van Schayck CP. Respiratory morbidity in relationship to farm characteristics in swine confinement work: possible preventive measures. Am J Ind Med 30:212–218 (1995).
23. Von Essen S, Scheppers L, Robbins R, Donham K. Respiratory tract inflammation in swine confinement workers studied using induced sputum and exhaled nitric oxide. Clin Toxicol 36:557–565 (1998).
24. Zejda JE, Barber E, Dosman JA, Olenchock SA, McDuffie HH, Rhodes C, Hurst T. Respiratory health status in swine producers relates to endotoxin exposure in the presence of low dust levels. J Occup Med 36:49–56 (1994).
25. Dunham K. The impact of industrial swine production on human health. In: Pigs, Profits, and Rural Communities (Thu K, Durrenberger E, eds). Albany, NY:State University of New York Press, 1998.
26. Schiffman SS, Sattely Miller EA, Suggs MS, Graham BG. The effect of environmental odors emanating from commercial swine operations on the mood of nearby residents. Brain Res Bull 17:369–375 (1995).
27. Wing S, Cole D, Grant G. Environmental injustice in North Carolina's hog industry. Environ Health Perspect 108:225–231 (2000).
28. Thomas S, Quinn S. The Tuskegee syphilis study, 1932 to 1972: implications for HIV education and AIDS risk reduction programs in the Black community. Am J Public Health 81:1498–1504 (1991).
29. CDC. The Confinement Animal Feeding Operation Workshop. Washington, DC:Centers for Disease Control and Prevention, National Center for Environmental Health, 1998.
30. Sclar ED. Community economic structure and individual well-being: a look behind the statistics. Int J Health Serv 10:563–579 (1980).
31. Thu K, Durrenberger E, eds. Pigs, Profits, and Rural Communities. Albany, NY:State University of New York Press, 1998.
32. Wing S, Casper M, Davis W, Pellom A, Riggan W, Tyroler H. Stroke mortality maps: United States whites aged 35–74, 1962–1982. Stroke 19:1507–1513 (1988).
33. Weber D, Rutala W, Samsa G, Sarubbi F, King L. Epidemiology of tuberculosis in North Carolina, 1966 to 1986: analysis of demographic features, geographic variation, AIDS, migrant workers, and site of infection. South Med J 92:1204–1214 (1989).

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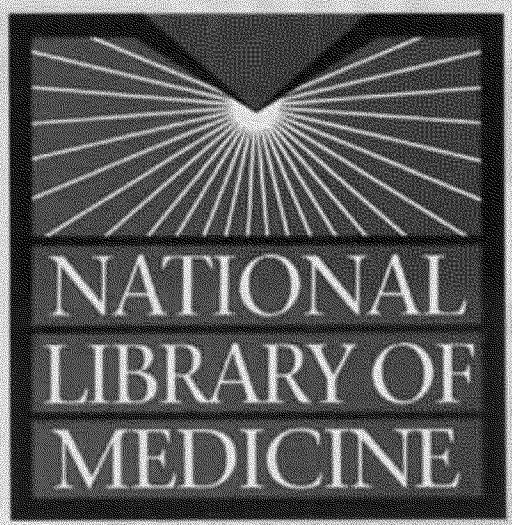

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To: 'We Act'[jalonne@weact.org]
Cc: Lisa Garcia[lgarcia@earthjustice.org]; Tejada, Matthew[Tejada.Matthew@epa.gov]; Jon Jacobs (jjacobs@jacobsstotsky.com) (jjacobs@jacobsstotsky.com)[jjacobs@jacobsstotsky.com]; Benjamin F. Wilson (BWilson@bdlaw.com)[BWilson@bdlaw.com]
From: Neil Gormley
Sent: Tue 12/9/2014 8:23:06 PM
Subject: RE: December 11, 2014: Climate Justice: Overburdened Communities, Climate Change, and EPA's Clean Power Plan
DC bar release form.pdf

Hi Jalonne,

As far as I know, the event information has not gone out on the listserves you mention. Please do go ahead and share!

I think you're right that our hour will go quickly. I promise to keep my own participation very limited and keep the focus on the experts – all of you! We can be flexible and see where the discussion takes us, but how about we plan on approximately 6-8 minutes each for your presentations/remarks, followed by 10-20 minutes for discussion of the Clean Power Plan or other examples, and then 10-20 minutes for questions? Let me know how that sounds to you.

Based on conversations we've already had, the following is my understanding of what each of you is planning to cover in your initial presentations/remarks. If I'm way off, please let me know!

Lisa: introduction to the idea of environmental justice

Ben: the role of regulated industries

Jalonne: environmental justice implications of climate change and climate change regulations

Matthew: the work of EPA's Office of Environmental Justice

Also, please remember to send back the DC Bar consent and release form if you haven't already done so! I've attached it again.

Neil Gormley

Senior Associate Attorney

Earthjustice DC

1625 Massachusetts Ave., NW, Ste. 702

Washington, DC 20036

T: 202.797.5239

F: 202.667.2356

earthjustice.org

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From: Jalonne White-Newsome [mailto:jalonne.weact@gmail.com] **On Behalf Of** We Act
Sent: Tuesday, December 09, 2014 10:21 AM
To: Neil Gormley
Cc: Lisa Garcia; Jalonne White-Newsome (jalonne@weact.org); Matthew Tejada (tejada.matthew@epa.gov) (tejada.matthew@epa.gov); Jon Jacobs (jjacobs@jacobsstotsky.com) (jjacobs@jacobsstotsky.com)
Subject: Re: December 11, 2014: Climate Justice: Overburdened Communities, Climate Change, and EPA's Clean Power Plan

Hello Neil,

Hope all is well and looking forward to the

Panel. I will be sending it out to the EPOC

Listserv and our dMV coalition listserve ...

I assume you might have sent it to the

Mainstream lobbyists listserve? If not, I'll share

It as well

Also, how long would you like our comments

To be since I'm sure the hour will go

Pretty quickly!

Thanks!

Dr. Jalonne L. White-Newsome

Please disregard any typos or errors due to texting

Sent from my iPhone

On Dec 1, 2014, at 2:11 PM, Neil Gormley <ngormley@earthjustice.org> wrote:

> Lisa and Jalonne,
>
> Matt informs me that only free events can be shared over the NEJAC listserve. Can anyone think of other lists or groups we could use to get the word out?

> Neil Gormley
>
> Associate Attorney
>
> Earthjustice DC
>
> 1625 Massachusetts Ave., NW, Ste. 702

Washington, DC 20036

T: 202.797.5239

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From: Tejada, Matthew [mailto:Tejada.Matthew@epa.gov]
Sent: Monday, December 01, 2014 1:57 PM
To: Neil Gormley
Cc: Jon Jacobs (jjacobs@jacobsstotsky.com) (jjacobs@jacobsstotsky.com)
Subject: RE: December 11, 2014: Climate Justice: Overburdened Communities, Climate Change, and EPA's Clean Power Plan

Thanks Neil, but since there is a charge associated I cannot send it out.

Matthew Tejada

Director - Office of Environmental Justice

Environmental Protection Agency

202-564-8047

From: Neil Gormley [mailto:ngormley@earthjustice.org]
Sent: Monday, December 01, 2014 12:39 PM

To: Tejada, Matthew
Cc: Jon Jacobs (jjacobs@jacobsstotsky.com) (jjacobs@jacobsstotsky.com)
Subject: FW: December 11, 2014: Climate Justice: Overburdened Communities, Climate Change, and EPA's Clean Power Plan

Hey Matt,

Could you share the details for our climate justice event on the NEJAC listserve? Link to the full description below.

Neil Gormley

Associate Attorney

Earthjustice DC

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From: Lisa Garcia
Sent: Monday, December 01, 2014 12:25 PM
To: Neil Gormley; Jalonne White-Newsome (jalonne@weact.org)
Subject: RE: December 11, 2014: Climate Justice: Overburdened Communities, Climate Change, and EPA's Clean Power Plan

Neil- you can ask Matt Tejada to send out to NEJAC.. he runs the listserve.

Thanks

From: Neil Gormley
Sent: Monday, December 01, 2014 12:20 PM
To: Jalonne White-Newsome (jalonne@weact.org); Lisa Garcia
Subject: December 11, 2014: Climate Justice: Overburdened Communities, Climate Change, and EPA's Clean Power Plan

Hi Jalonne and Lisa,

I'm working on getting the word out about our event next week. I think it would be great to draw a wide and diverse audience. Could one of you post this event to the NEJAC listserve? Any other lists or groups we should use to get the word out?

Neil Gormley

Associate Attorney

Earthjustice DC

1625 Massachusetts Ave., NW, Ste. 702

Washington, DC 20036

T: 202.797.5239

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From: D.C. Bar Sections [mailto:sectionsannouncement@dcbar.org]
Sent: Wednesday, November 12, 2014 5:10 PM
To: Neil Gormley
Subject: December 11, 2014: Climate Justice: Overburdened Communities, Climate Change, and EPA's Clean Power Plan

<image002.jpg>

Climate Justice: Overburdened Communities, Climate Change, and EPA's Clean Power Plan

Join us for a fresh take on the most prominent environmental issue of our day, as our panel of environmental justice experts explore how climate issues disproportionately affect overburdened communities, and assess EPA's Clean Power Plan.

Thursday, December 11, 2014 from 12:30pm to 1:30pm

CLE Credit: No

<image003.gif>

Please visit us at www.dcbar.org/sections *for more information.*

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<image004.png><image005.png><image006.png>

<image007.gif>

To: Tejada, Matthew[Tejada.Matthew@epa.gov]; Emma Cheuse[echeuse@earthjustice.org]; Ali, Mustafa[Ali.Mustafa@epa.gov]
From: Stephanie Maddin
Sent: Fri 4/10/2015 8:35:50 PM
Subject: RE: EJSCREEN

Hi Matt and Ali!!!

From: Tejada, Matthew [mailto:Tejada.Matthew@epa.gov]
Sent: Friday, April 10, 2015 4:32 PM
To: Emma Cheuse; Ali, Mustafa
Cc: Stephanie Maddin
Subject: RE: EJSCREEN

Thanks Emma.

Hey Stephanie!

Matthew Tejada

Director - Office of Environmental Justice

Environmental Protection Agency

202-564-8047

From: Emma Cheuse [mailto:echeuse@earthjustice.org]
Sent: Friday, April 10, 2015 4:30 PM
To: Tejada, Matthew; Ali, Mustafa
Cc: Stephanie Maddin
Subject: FW: EJSCREEN

Dear Mr. Tejada and Mr. Ali, a courtesy copy of a letter sent today to Administrator McCarthy on EJSCREEN is attached. All the best, Emma

From: Emma Cheuse
Sent: Friday, April 10, 2015 4:23 PM
To: McCarthy.Gina@epa.gov
Cc: Stephanie Maddin
Subject: EJSCREEN

Dear Administrator McCarthy,

Please accept the attached letter, respectfully requesting that EPA publicly release EJSCREEN as soon as possible this year.

Earthjustice's President Trip Van Noppen and leaders from 45 other national and local organizations have signed this letter.

We appreciate your leadership on this important issue.

Very best regards,

Emma Cheuse and Stephanie Maddin

Earthjustice

1625 Massachusetts Avenue, N.W., Suite 702

Washington, DC 20036-2243

T: 202.667.4500

F: 202.667.2356

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EARTHJUSTICE

To: Tejada, Matthew[Tejada.Matthew@epa.gov]
From: Emma Cheuse
Sent: Wed 6/17/2015 3:26:12 PM
Subject: RE: letters for your signature

Thanks. (Just an FYI re minor typo -- Refinery Rule letter page 2 at the top says Clean Power Plan Rule).

- Emma

Emma Cheuse

Staff Attorney

Earthjustice

1625 Massachusetts Avenue, N.W., Suite 702

Washington, DC 20036-2243

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From: Tejada, Matthew [mailto:Tejada.Matthew@epa.gov]

Sent: Wednesday, June 17, 2015 10:02 AM
To: Emma Cheuse
Subject: Re: letters for your signature

These are final so feel free to use as you see fit.

Best

M

Matthew S. Tejada

Director

EPA Office of Environmental Justice

(202) 564-8047

On Jun 17, 2015, at 8:57 AM, Emma Cheuse <echeuse@earthjustice.org> wrote:

> Thanks, Matt. When will they be posted publicly? Can we share them with our clients/partners? Can we share with press? I don't know if people will want to -- but wanted to ask before I forward. Best, Emma
>
> ---
>
> Emma Cheuse
>
> Staff Attorney
>
> Earthjustice
>
> 1625 Massachusetts Avenue, N.W., Suite 702
>
> Washington, DC 20036-2243
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> T: 202.745.5220 or 202.667.4500 Ext. 5220
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From: Tejada, Matthew [mailto:Tejada.Matthew@epa.gov]
Sent: Tuesday, June 16, 2015 6:41 PM
To: Emma Cheuse
Subject: FW: letters for your signature
Importance: High

Hey Emma

These are now signed and public documents, though we have not as yet posted them anywhere publicly. Sharing them with you as a courtesy based upon your past requests for them.

M

Matthew Tejada

Director - Office of Environmental Justice

Environmental Protection Agency

202-564-8047

To: Tejada, Matthew[Tejada.Matthew@epa.gov]
From: Emma Cheuse
Sent: Wed 6/17/2015 1:57:41 PM
Subject: RE: letters for your signature

Thanks, Matt. When will they be posted publicly? Can we share them with our clients/partners? Can we share with press? I don't know if people will want to -- but wanted to ask before I forward. Best, Emma

---

Emma Cheuse

Staff Attorney

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From: Tejada, Matthew [mailto:Tejada.Matthew@epa.gov]
Sent: Tuesday, June 16, 2015 6:41 PM
To: Emma Cheuse
Subject: FW: letters for your signature

Importance: High

Hey Emma

These are now signed and public documents, though we have not as yet posted them anywhere publicly. Sharing them with you as a courtesy based upon your past requests for them.

M

Matthew Tejada

Director - Office of Environmental Justice

Environmental Protection Agency

202-564-8047

To: Mccarthy, Gina[McCarthy.Gina@epa.gov]; Title VI Complaints[Title_VI_Complaints@epa.gov]
Cc: Jocelyn D'Ambrosio[jdambrosio@earthjustice.org]; Marianne Engelman Lado[mengelmanlado@earthjustice.org]; Ex. 6 - Personal Privacy
Ex. 6 - Personal Privacy 'lbaldwin@waterkeeper.org'[lbaldwin@waterkeeper.org]; Wooden-Aguilar, Helena[Wooden-Aguilar.Helena@epa.gov]; Tejada, Matthew[Tejada.Matthew@epa.gov]; HALIM-CHESTNUT, NAIMA[Halim-Chestnut.Naima@epa.gov]; 'Daria.Neal@usdoj.gov'[Daria.Neal@usdoj.gov]; 'tom.reeder@ncdenr.gov'[tom.reeder@ncdenr.gov]; 'christine.lawson@ncdenr.gov'[christine.lawson@ncdenr.gov]
From: Alok Disa
Sent: Wed 9/3/2014 11:57:28 PM
Subject: Exhibits to 09 03 14 DENR Complaint: Exhibits 39 - 45
09 03 14 DENR Complaint - Exhibit Vol 2 Part B_Exs. 39-45.pdf

Dear Administrator McCarthy and Ms. Golightly-Howell,

Attached please find Exhibits 39-45, which represent the second part of the second set of Exhibits to the Complaint submitted earlier today by Earthjustice on behalf of North Carolina Environmental Justice Network, Rural Empowerment Association for Community Help, and Waterkeeper Alliance, Inc. We apologize for forwarding these exhibits in batches and are forwarding hard copy versions by overnight mail for your convenience.

Please feel free to let us know if these materials raise any question or if you have trouble downloading them.

Sincerely,

Alok Disa, on behalf of Marianne Engelman Lado and Jocelyn D'Ambrosio

---

Alok Disa

Litigation Assistant

Earthjustice Northeast Office

48 Wall Street, 19th Floor

New York, NY 10005

T: 212-845-7386 (direct)

F: 212-918-1556

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Exhibit 39

Concentrated Swine Feeding Operations and Public Health: A Review of Occupational and Community Health Effects

Dana Cole,[1] Lori Todd,[2] and Steve Wing[1]

[1]Department of Epidemiology, [2]Department of Environmental Sciences and Engineering, School of Public Health, University of North Carolina, Chapel Hill, North Carolina, USA

Recent industry changes in swine management practices have resulted in a growing controversy surrounding the environmental and public health effects of modern swine production. The numerous wastes produced by intensive swine production not only pose a significant challenge to effective environmental management but also are associated with decreased air quality in confinement houses, potentially detectable antimicrobial resistance patterns, and several infectious agents that can be pathogenic to humans. Published studies have documented a variety of contaminants, microbial agents, and health effects in those occupationally exposed to swine, and these have provided the groundwork for an increasing body of research to evaluate possible community health effects. Nonetheless, several factors limit our ability to define and quantify the potential role of intensive swine rearing facilities in occupational and community health. Our incomplete understanding and ability to detect specific exposures, the complicated nature of disease etiology, pathogenesis, and surveillance, and the inherent difficulties associated with study design all contribute to the inadequate level of knowledge that currently prevails. However, an evaluation of the published literature, and a recognition of the elements that may be compromising these studies, provides the foundation from which future studies may develop. *Key words:* air quality, air sampling, CAFOs, community health, occupational health, hygiene, industrial wastes, swine production. *Environ Health Perspect* 108:685–694 (2000). [Online 21 June 2000]
http://ehpnet1.niehs.nih.gov/docs/2000/108p685-694wingabstract.html

During the last several years most animal husbandry practices in the United States have been industrialized, resulting in an increased number of large corporate and contract livestock operations raising thousands of animals in a single facility. Industrialized farms achieve economies of scale through specialization, increased size, and close confinement that allows high animal densities on relatively small land areas (*1–3*). These changes in animal production systems, combined with changing community demographics, have considerably narrowed the farm–urban interface and have resulted in growing public concern over the potential occupational, environmental, and community hazards posed by these large concentrated animal feeding operations (CAFOs). Numerous debates and related legislation over this controversial topic have brought to the public forefront several health issues related to modern swine husbandry.

Swine CAFOs

Most modern swine operations raise thousands of animals in closed confinement buildings. Among other things, closed confinement facilitates climate control and automation of some tasks such as feeding and watering. However, the large number of animals raised in swine CAFOs generate significant amounts of dusts, dander, and waste materials. Within the confinement buildings, dust particles consisting of swine skin cells, feces, feed, bacteria, and fungi become airborne and contribute to poor indoor air quality (*3*). The manure and urine produced in these buildings also generate numerous gases that may further decrease the quality of the indoor air. Thousands of gases, particles, and bioaerosol emissions have been documented in swine facilities. Many pollutants present at these facilities do not have occupational exposure limits (OELs).

Swine CAFOs must deal with a substantial amount of waste materials on-site that are associated with significant odors and contain antimicrobials, nutrients, organics, and pathogenic microbes. Raw swine manure can contain 100 million fecal coliform bacteria per gram (*4–7*). It is estimated that 100 million tons of feces and urine are produced annually by the 60 million hogs raised in the United States (*8*). Storage and treatment of this waste is typically in wastewater lagoons. Lagoons became popular for the storage and management of swine wastes as production facilities increased in size and efficient storage and treatment of wastes became necessary. The majority of swine lagoons rely principally on anaerobic bacteria (bacteria that do not use oxygen) to decompose the organic matter because more organic matter per unit lagoon volume can be handled by anaerobic bacteria than by aerobic processes (*9,10*). In addition, anaerobic lagoons can be deeper, requiring less land area than aerobic lagoons.

Lagoon management has become a significant environmental concern. Contamination of the environment can result from lagoon breaks and the subsequent release of millions of gallons of animal wastes directly into surface water at one time (*11*) or from seepage losses of lagoon wastewater into the surrounding soil and groundwater (*11–13*). In addition, land application of liquefied wastes may result in wastes leaching into groundwater or reaching streams as a result of overland flow (*14,14*). When sprayfields are used to distribute the wastes, aerosolization of particulates may result in contamination over a wide geographic range (*15,16*).

The widespread application of antimicrobial agents at therapeutic and subtherapeutic levels allows the livestock industry to increase animal densities and feed conversion rates. With greater opportunities for horizontal spread of infectious agents among closely confined animals, antimicrobials are useful to decrease the spread of infectious disease between animals (*17,18*). The broad application of antimicrobials to farm animals can apply selective pressure to their normal and pathogenic microflora (*17–20*), resulting in the evolution of groups of resistant organisms that may survive in the environment or pass their resistance properties to other human-associated microbes.

Identification of Potential Human Health Effects

Historically, human disease resulting from the exposure to gases, aerosols, and infectious

Address correspondence to D.J. Cole, Department of Epidemiology, School of Public Health, University of North Carolina, CB#7400 McGavran-Greenberg Hall, Chapel Hill, NC 27599-7400. Telephone: (919) 966-7516. Fax: (919) 966-2089. E-mail: dcole@unc.edu

We thank K. Minnis for assistance in preparing this manuscript.

This research was supported by grant R25-ES08206-09 under the Environmental Justice Partnerships for Communication program of the NIEHS.

Received 10 January 2000; accepted 10 April 2000.

ED_001369_00043779-00002

agents generated or carried by animals and their wastes has been largely limited to those in agricultural occupations (e.g., farmers, food processors, and veterinarians). Consequently, most reports of human-acquired disease from animal husbandry practices focus on occupational exposures. However, even in these high-risk groups, elucidating potential causative agents, dose–response relationships, disease mechanisms, and methods of control is problematic.

In health-effect studies of gases and particulates, it is difficult to identify the cause of occupational illnesses in the absence of specific biomarkers. Similarly, determining which chemicals to sample to evaluate occupational exposures is complicated because it still is not clear which specific contaminants or complex mixtures are responsible for reported symptoms, or even whether all the potentially harmful substances have been evaluated.

Studies of occupational exposure to infectious agents associated with swine production are complicated by the natural history of disease caused by agents of animal origin (zoonoses). The majority of zoonotic diseases that occur in people resolve without specific medical therapy and are not transmitted between people (*21*). Consequently, large outbreaks or epidemics of disease do not usually occur with zoonoses. Even diseases that do require medical attention can be difficult to diagnose because the symptoms are vague and nonspecific and because traditional human and veterinary surveillance systems are not equipped to detect many of them (*22*). Consequently, many diagnoses of this type are made only when there is increased suspicion on the part of the medical provider and when special requests are made of the diagnostic laboratory. Even when these requests are made, laboratory technicians unfamiliar with animal diseases may be unprepared for the diagnosis of zoonotic diseases.

Detection of specific exposures and diseases in the communities surrounding swine CAFOs is even more challenging because of the additional complexities of environmental dispersion of agents and human exposure pathways. Furthermore, the susceptibility of community members to contaminants and pathogens may be substantially different from that of workers.

To address some of these issues, we evaluate the evidence related to the adverse exposures and health effects found in occupational studies. Although more susceptible workers may leave their jobs because of adverse health effects, an assessment of the occupational exposures and associated symptoms may provide a template for the approach that studies of potential community problems should take. We discuss the most likely routes of community exposure to these hazards and the limitations of the published research.

Identified Hazards of Swine CAFOs

Air-Associated Contaminants

In the 1970s, researchers described respiratory hazards for workers in swine confinement operations (*23,24*). Since that time many researchers from the United States, the Netherlands, Sweden, Denmark, Yugoslavia, and Canada have documented symptoms and begun to identify the contaminants and contaminant concentrations associated with the symptoms (*25–40*). Industrial hygiene studies have measured the concentration of contaminants in the air of swine houses, epidemiologic studies have documented symptoms in workers and contaminant concentrations in air, mechanistic studies have exposed human volunteers to swine dust, and community studies have documented symptoms in residents who live adjacent to swine CAFOs.

The primary airborne contaminants in swine operations can be grouped into three categories: gases and vapors, nonbiologic aerosols, and bioaerosols (*24,41,42*). Early occupational health studies focused on the gases and nonbiologic aerosols in the indoor air because their adverse health effects generally were well documented and because there were recommended occupational exposure limits for these agents. However, bioaerosols, particularly endotoxins, have emerged as important agents in causing adverse respiratory health effects in swine CAFO workers.

Although the variety of adverse health effects associated with working at a swine CAFO is well documented, it is not clear which agents or mixtures are responsible for the symptoms. For example, health effects have been positively correlated with individual contaminants such as ammonia, dust, and endotoxins, as well as combinations of these (*38,43–45*). Work practices have also been associated with symptoms seen in workers, such as the types and methods of feeding the animals, the use of wood shavings for animal bedding, and the use of disinfectants (*39,46,47*). Holness and Nethercott (*46*) found that nasal irritation, coughing, wheezing, and dyspnea were frequently associated with floor feeding of hogs and that dizziness was frequently associated with working with liquid manure. The researchers suggested that the high dust levels in their study were because of floor scatter feeding, indoor feed grinding, and the use of high-moisture corn feed.

Epidemiologic studies of workers in swine-production facilities have documented increases in morning phlegm, coughing, scratchy throat, burning eyes, wheezing, shortness of breath, and chronic bronchitis compared to individuals who do not work in these facilities (*38,41,42,48*).

Gases and vapors. The primary gases and vapors of interest to health researchers include ammonia, carbon monoxide, hydrogen sulfide, and methane. The major source of gases and vapors detected in confinement buildings is the manure contained in the storage pits beneath the flooring. The concentrations of specific gases inside swine houses are not usually high enough to be toxic by themselves based on the OELs mandated by the Occupational Safety and Health Administration (OSHA) and recommended by the American Conference of Governmental Industrial Hygienists (ACGIH) and the National Institute for Occupational Safety and Health (NIOSH) (Table 1). However, these guidelines take into account economic as well as health-based considerations (*49,50*).

Ammonia's effects on the respiratory system include irritation to the eyes, skin, mucous membranes, and upper respiratory system. Ammonia is water-soluble and is absorbed in the upper respiratory tract; however, if there are aerosols and high humidity present in the air, ammonia and other gases can adsorb onto the aerosols and be carried deeper into the lungs. At high concentrations hydrogen sulfide is an eye and respiratory tract irritant. Other chemicals used in swine

Table 1. OELs for several agents that are found in swine house air and dust.

Agent	OSHA (*249*)	ACGIH (*250*)	NIOSH (*251*)
Ammonia	50 ppm TWA	25 ppm TWA 35 ppm STEL	25 ppm TWA 35 ppm STEL
Carbon monoxide	35 ppm TWA	25 ppm TWA	35 ppm TWA 200 ppm ceiling
Hydrogen sulfide	20 ppm ceiling	10 ppm TWA 15 ppm STEL 5 ppm TWA[a]	10 ppm ceiling
Particulates			
Inhalable dust	15 mg/m^3 TWA	10 mg/m^3 TWA	—
Respirable dust	5 mg/m^3 TWA	3 mg/m^3 TWA	—
Endotoxins	None	None	—

Abbreviations: STEL, short-term exposure limit; TWA, time-weighted average.
[a]OEL proposed in 1999.

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CAFOs that have been implicated in adverse respiratory effects and asthma include quaternary ammonium disinfectants and disinfectants containing aldehydes (glutaraldehyde and formaldehyde) or chloramine (*47,51*).

In addition to these gases and vapors, thousands of vapors have been identified as being responsible for the odors characteristic of swine CAFOs. Often the odors increase as the animal manure decomposes. Anaerobic processes can release volatile fatty acids that may be more offensive odorants than ammonia or hydrogen sulfide. Studies show that the odorous compounds in swine CAFOs are adsorbed onto dust particles < 10 microns in size (*52*). In fact, the odorous air inside swine CAFO buildings was odorless when a respirator equipped with a dust filter was used. When the small dust particles are inhaled they impinge on the moist warm mucous membranes in the nose and the volatile compounds are released—enabling the perception of odor. Researchers have proposed that the most critical factors involved in the release of odorous volatile organic chemicals from the dust particles are the sizes and concentrations of the particles. Table 2 shows characteristic odors for many of the compounds and presents concentrations that have been measured at swine CAFOs. The quantified concentrations of specific contaminants in air are considered low, and it is difficult to evaluate their significance because there are few OELs and associated health effect studies for most chemicals at the level of odor detection.

Table 2. Odorous chemicals detected in swine house air and dust.

Odor compound	Odor characteristic	Concentrations found	Reference
Organic acids			
3-phenyl-propionic	Cinnamon	Not quantified	(*52,228–230*)
Acetic	Pungent, sharp, vinegar	3.94–39.81 μg/m^3	(*231*)
		267 μg/g dust	(*232*)
		189 μg/m^3	(*233*)
		Not quantified	(*52,229,230,234,235*)
Butyric	Sweaty, rancid, sharp, dairy, cheese, butter, fruit nuance	80 μg/m^3	(*236*)
		0.26–11.02 μg/m^3	(*231*)
		73 μg/g dust	(*232*)
		318 μg/m^3	(*233*)
		Not quantified	(*52,229,230,234,235*)
Caproic	Goatlike, mild, sour, fatty	0.15–0.47 μg/m^3	(*231*)
		10 μg/m^3	(*233*)
		Not quantified	(*229,230,235*)
Isobutyric	Pungent, rancid butter	47 μg/g dust	(*232*)
		40 μg/m^3	(*233*)
		Not quantified	(*229,230,235*)
Isovaleric	Disagreeable, rancid cheese, sour, stinky feet, sweaty	62 μg/g dust	(*232*)
		49 μg/m^3	(*233*)
		Not quantified	(*229,230,235*)
Lauric acid	Heavy, stale	Not quantified	(*52,230*)
Phenylacetic	Sweet, floral, swine	0.22–0.45 μg/m^3	(*231*)
		Not quantified	(*52,228,230*)
Propionic	Pungent, disagreeable, rancid	0.12–13.08 μg/m^3	(*231*)
		140 μg/g dust	(*232*)
		156 μg/m^3	(*233*)
		Not quantified	(*229,230,234*)
Valeric (pentanoic)	Unpleasant, sickening, putrid, fecal, sweaty, rancid	0.21–3.06 μg/m^3	(*231*)
		38 μg/m^3	(*232*)
		35 μg/m^3	(*233*)
		Not quantified	(*229,230,235,237*)
Phenolics			
Cresols	Medicinal, sweet, tarry	7.3 μg/m^3	(*236*)
		1.17–2.09 μg/m^3	(*231*)
		145 μg/g dust	(*232*)
		39 μg/m^3	(*233*)
		Not quantified	(*52,228,230,234,237,238*)
Ethylphenols	Sweet, burned	1.97 μg/m^3	(*231*)
		13 μg/g dust	(*232*)
		Not quantified	(*52,229,235,237,240*)
Phenol	Sweet, tarry, burned	92 μg/g dust	(*232*)
		23 μg/m^3	(*233*)
		Not quantified	(*52,229,230,234,235,237*)
Nitrogen-containing compounds			
Ammonia	Pungent	Not quantified	(*229,230,235*)
Dimethyl amine	Pungent, fishy, ammoniacal	2,000 μg/m^3	(*233*)
		Not quantified	(*237*)
Skatole (3-methyl indole)	Fecal odor, nauseating	Not quantified	(*52,228–230,235,237*)
Trimethyl amine	Ammoniacal, fishy, pungent	2,000 μg/m^3	(*233*)
		Not quantified	(*229,230,235,240*)
Trimethyl-pyrazine	Nutty, musty earthy, powdery cocoa, roasted peanut	0.45 μg/m^3	(*236*)
		Not quantified	(*230,234*)
Tetramethyl-pyrazine	Sweet, musty chocolate, coffee, cocoa, soybean, lard, burnt	0.09 μg/m^3	(*236*)
		Not quantified	(*230,234*)
Indole	Strong moth ball, naphthelene, intense fecal, nauseating	Not quantified	(*228–230,235*)
Sulfur-containing compounds			
Dimethyl sulfide	Decayed vegetables, putrid	Not quantified	(*235,237*)
Hydrogen sulfide	Rotten eggs	Not quantified	(*229,230,235,241*)
Other compounds			
Hexanal	Horseradish, green, fruity, aldehydic, fatty, sweaty	Not quantified	(*52*)
		0.40–2.41 μg/m^3	(*231*)
2-Hexenal	Green plant	0.29–2.58 μg/m^3	(*231*)
		Not quantified	(*235*)

Organically derived aerosols. Nonbiologic aerosols generally consist of dust particles generated from feed, skin cells, hair, and dried feces. Acute exposures to high levels of dust may result in increased phlegm production and pulmonary inflammation 4–10 hr after exposure; these symptoms can last up to 24 hr. Chronic exposures may result in bronchitis and asthma. For industrial hygiene sampling, dust is separated into fractions (total, inspirable, thoracic, and respirable) based on particle size and site of deposition in the lung. Total dust refers to all of the dust particles in the air that can be inhaled or captured on a filter. The inspirable dust fraction is a newer term that refers primarily to materials that are hazardous anywhere in the respiratory tract, particularly in the head airway region. The thoracic fraction is dust that can reach the thoracic airways (past the larynx) or the gas exchange region. The respirable fraction refers only to the size fraction of aerosols that reach deep into the lungs into the gas exchange region—past the terminal bronchioles. Current occupational exposure limits for dust are presented in Table 1.

Pickrell et al. (*53*) examined the size distribution of aerosols in a swine confinement facility and found that when a certified dust mask was exposed to silica dust, 1% of the dust with an aerodynamic diameter of 0.6–1.0 μm penetrated the mask. However, when the same masks were exposed to swine confinement aerosols, there was 3–25% penetration of the sealed masks. The authors concluded that swine confinement aerosols may have a considerable size distribution

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< 1.0 µm in diameter. Therefore, respirable aerosols may be an important size fraction for study in swine CAFOs. A cross-sectional study on respiratory health in swine producers suggested that when workers used dust masks to prevent illness, there was a lower prevalence of chronic and work-related respiratory symptoms (*54*). Workers who used dust masks preventatively had better lung function indices than those who did not wear masks. However, if workers used dust masks because they were already experiencing symptoms, their lung function was comparable to workers who did not wear dust masks.

Bioaerosols. Bioaerosols are particles that contain endotoxins, bacteria, and fungi. Endotoxins are present in dusts as a part of a bacterial cell wall or as fragments of whole bacteria. Endotoxins are fragments of the gram-negative bacterial cell wall that contain lipopolysaccharide as well as the other naturally occurring compounds in the cell wall. In the laboratory, the control standard for endotoxin is chemically pure lipopolysaccharide. When endotoxin is inhaled it can potentially cause chronic respiratory symptoms (cough, phlegm production, and wheezing), pulmonary impairment, malaise, and fever (*55–57*).

Bioaerosols from swine facilities contain several microbial agents but humidity, temperature, and oxygen content all affect their viability (*58,59*). Gram-positive bacteria are in the greatest concentration; *Enterococcus* accounts for 68–96% of the total bacteria (*60*). Total bacteria typically include 7–53% gram-negative bacteria (*28,60,61*), with only 12–40% of the gram-negative bacteria being adsorbed to respirable particulates (*28,60*). These gram-negative bacteria are the most susceptible to inactivation by oxygen; therefore they are likely not viable in the environment. Evidence suggests that viruses are more stable on bioaerosols, and it has been proposed that influenza transmission may be attributable, in part, to bioaerosol deposition (*58*).

Waste-Associated Contaminants

Infectious agents. Swine-associated wastes such as manure, urine, and tissues are associated with numerous microbial pathogens that can be potentially transmissible to humans. These wastes contain bacteria, viruses, and protozoa capable of causing illness in humans even in the absence of physical signs of disease in the swine. Organisms associated with the gastrointestinal tract of swine, such as *Erysipelothrix rhusiopathiae*, *Yersinia enterocolitica*, *Salmonella* species, *Streptococcus suis*, and hepatitis E virus, may be passed to humans by direct contact with either saliva or fecal wastes or by media contaminated with these materials. Alternatively, contact with infected urine or tissues can result in transmission of organisms such as *Leptospira* or *Brucella* bacteria between animals and humans. Some organisms, such as *S. suis*, influenza virus, and hepatitis E virus, have strains with varying infectivity to human hosts—some strains are species specific and are not capable of infecting humans whereas others do not have such a limited host range. This complicates detection and control of these diseases in humans.

Antimicrobial resistance. Some bacteria are naturally resistant to certain antibiotics and others develop resistance by mutation or acquisition from other resistant bacteria when subjected to the selective pressures exerted by antimicrobials (*17–19,62*). Before 1950 bacteria were largely susceptible to antibiotics (*19*) but resistance to tetracycline began to be reported in bacterial isolates from market pigs in the United Kingdom starting in 1956 (*63*). Since then single- and multiple-resistance patterns to virtually every antibiotic have been found in bacteria, including *Escherichia coli*, *Salmonella*, *Campylobacter*, *Enterococcus*, and *Staphylococcus* (*18,20,63–76*).

Antimicrobial resistance patterns can be transferred between bacteria, and disease does not have to occur in the host to transfer resistance (*19,62*). The development of resistant strains of bacteria can result in increased infectivity and virulence of pathogens and reduced effectiveness of appropriate therapy. An example is the recently emerged multiply-resistant bacteria, *Salmonella typhimurium* DT104. This strain of *Salmonella*, which emerged in livestock in the United States and the United Kingdom in the 1980s, is resistant to five antimicrobials and is associated with higher morbidity and mortality than antimicrobial-susceptible strains of *Sa. typhimurium* (*64,77,78*). Direct transmission of this organism from infected animals to their caretakers has been documented (*78*).

Nutrients. Wastes also contain high quantities of many nutrients such as nitrogen and phosphorous. In public health the most notable of these nutrients is nitrogen. Excessive nitrates in water continue to be a cause of methemoglobinemia (blue-baby syndrome)—an underrecognized cause of illness and death in infants (*79,80*). Some evidence suggests that methemoglobinemia is more likely when nitrate-containing water is also contaminated with bacterial species (as might be expected when groundwater is contaminated with fecal wastes), because the bacteria convert the nitrate to nitrite, causing diarrhea in infants (*79*). In addition, animal studies and some human studies suggest that reproductive health effects such as central nervous system developmental defects and miscarriages may occur with excessive intake of nitrates (*79,81*).

Occupational Health Effect and Exposure Studies of Swine CAFOs

Air-Associated Contaminants

Epidemiologic studies to evaluate respiratory and other symptoms in swine confinement workers usually compare swine workers with nonfarming control subjects and use questionnaires, lung function tests, and occasionally sputum sample analyses of immune cells. Bacteria and endotoxins have been the primary contaminants measured when symptoms are compared with exposures to air contaminants, total and respirable dust, carbon dioxide, ammonia, hydrogen sulfide, and carbon monoxide. Table 3 lists the levels of contaminants found in the studies cited in this article. The OELs for gases and vapors (Table 1) were rarely exceeded in the studies, and slightly less than half of the studies exceeded the limits for dust. Furthermore, the nuisance dust standard may not be appropriate to apply to swine confinement workers because the dust in these houses is highly biologically active (*44*). Donham et al. (*43*) suggested that exposure guidelines should be reduced for total dust and ammonia—to 2.8 mg/m^3 and 7.5 ppm, respectively. It is difficult to evaluate endotoxin levels because there is no established OEL. Various groups have calculated no-effect levels for endotoxins in several ranges: 170–180 (*43,55*), 33 (*82*), and < 1–20 ng/m^3 (*83–87*). These no-effect endotoxin levels are similar to the levels observed in nonagricultural and industrial buildings (*88*), but 12 studies in Table 3 exceeded the highest no-effect level calculated (170–180 ng/m^3).

Swine confinement workers have significantly more symptoms of chronic bronchitis and asthma (*35,38,39,89*) and more missed work days (*43*) than controls. Documented symptoms include wheezing, coughing, sinusitis, fever, chest tightness, nasal irritation, phlegm, throat irritation, and sneezing. Some farmers also reported headaches and joint and muscle pain (*61*). Lung function indices of airflow are significantly lower (*35,38,43,44*) or no different (*89*) than nonfarming controls. Swine workers had a significant elevation in macrophages in sputum samples, indicating signs of lower respiratory tract inflammation (*89*).

Healthy, nonsmoking, previously unexposed volunteers exposed to several hours of swine dust in a swine CAFO experience a variety of symptoms, including cough and nasal stuffiness (*90–92*), moderate chills (*90–94*), headaches (*90–94*), muscle pain (*91,92,94,95*), mental fatigue (*91,95*), malaise (*93,97*), and nausea (*93*). Third-year veterinary students who visited a swine farm for 3 hr reported eye irritation, headache,

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tiredness, cough, nasal and throat irritation, sinus trouble, and flulike symptoms (98). Symptoms generally developed the same day and disappeared within 3 days of the exposure. Thorn and Rylander (99) exposed healthy subjects to bacterial endotoxin. 24 hr after exposure the subjects reported breathlessness, irritation in the throat, dry cough, headache, heaviness in the head, and unusual tiredness.

When comparing health effects to exposures, most studies found a correlation between one or more contaminants and lung function indices and/or respiratory, irritation, and flulike symptoms (Table 4). Endotoxin and ammonia were most often correlated with lung function and symptoms followed by dust.

Donham et al. (43) found that the correlation between exposure and pulmonary function decrements was highest after 6 years of cumulative exposure, with total dust and ammonia being the strongest predictors of response. In a follow-up study with the same cohort, Reynolds et al. (44) found the strongest correlations for workers who had 0–6 years or 10–13 years of exposure. Based on years of exposure, total and respirable endotoxins and ammonia were strongly correlated with response in the 0- to 6-year group, total dust, respirable dust, and ammonia with those in the 10- to 13-year group, and total dust with the > 13-year group. The researchers suggested that although total dust may be an important factor for chronic changes in pulmonary function, endotoxins may be most important for acute health effects. Zejda et al. (45) found a significant relationship among symptoms, lung function, and the number of hours worked. When a subset of young workers (26–35 years of age) was evaluated, Zejda et al. (35) found that chronic respiratory symptoms were associated with the number of hours worked each day and the number of pigs per barn. The adverse health effects of working in intensive swine operations seen in the subset of workers may be because younger workers spend more time in the barns than older workers. On the other hand, older workers who are symptomatic may have a tendency to leave the industry. Several studies found a positive correlation between lung function and/or symptoms with duration of the use of

Table 3. Levels of contaminants found in swine confinement houses [illegible]

Total inhalable dust (mg/m³)	Dust fraction (mg/m³)	Ammonia (mg/m³)	Hydrogen sulfide (ppm)	Carbon monoxide (ppm)	Endotoxin (ng/m³ or EU/m³)	Total bacteria (10⁶ CFU/m³)	Bacterial fraction (10⁶ CFU/m³)	References
[illegible]	—	—	—	—	[illegible]	—	—	[illegible]
[illegible]	—	—	—	—	—	[illegible]	[illegible]	[illegible]
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[illegible]	—	[illegible]	—	—	[illegible]	—	—	[illegible]
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[illegible]		[illegible]	—	—	[illegible]	—	[illegible]	[illegible]
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[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	—	—	[illegible]
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[illegible]	—	—	—	—	[illegible]	—	—	[illegible]
[illegible]	—	—	—	—	[illegible]	—	—	[illegible]
[illegible]	—	—	—	—	[illegible]	—	—	[illegible]

Abbreviations: IQR, [illegible]; NR, not reported.
[illegible] Ammonia dust. [illegible] Endotoxin extracted from airborne dust. [illegible] Total dust. [illegible] Endotoxin extracted from total dust. [illegible] Endotoxin measured at 25°C. [illegible] Endotoxin measured at 37°C. [illegible] Respiratory dust. [illegible] Endotoxin extracted from respiratory dust. [illegible] Geometric mean. [illegible] Inhalable dust. [illegible] Endotoxin measured from inhalable dust. [illegible] Thoracic dust. [illegible] Endotoxin extracted from thoracic dust. [illegible] Gram-negative bacteria.

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disinfection (*47,51*). These studies associated the decline in lung function over the years with quaternary ammonium compounds used as disinfectants and with the use of automated dry feeding systems.

Mechanistic studies. Although air contaminants have been correlated with lung function indices, changes in traditional lung function tests taken by swine confinement workers are usually only modest compared to the widespread presence of subjective symptoms. Historically, these tests have been used in the field and in volunteer research to evaluate airway obstructions caused by organic dust. However, it is possible that the swine contaminants operate using a different mechanism and the very modest changes in the lung indices are caused by an inflammatory response that would be uncovered using other test methods.

Larsson et al. (*100*) evaluated lung function, bronchial reactivity (methacholine challenge), and inflammatory cells in bronchoalveolar lavage (BAL) fluid. Although the lung function and bronchial reactivity tests were similar between farmers and controls, the BAL fluid of the farmers showed elevations in total cell concentrations and in the concentration of neutrophils, granulocytes, albumin, hyaluronnan, and fibronectin. These changes are indicative of an inflammatory reaction in the alveoli. These farmers had signs of airway inflammation reaction and activation of the immune system without alteration in lung function or bronchial reactivity (*100*).

Schwartz et al. (*101*) reported that swine confinement work is associated with asthma and bronchitis and that the work-related respiratory symptoms are indicative of airway or lung disease. The authors found that swine confinement workers had evidence of early airway injury that may not always be apparent using lung function tests. Although the lung function tests were normal, symptomatic swine workers tended to have enhanced airway response to inhaled methacholine and had a thickening of the epithelial basement membrane of the lobar bronchi when compared to asymptomatic controls (*101*). Thickening of the basement membrane is an early and consistent feature of asthma. Carvalheiro et al. (*102*) also found that swine CAFO workers had enhanced airway response to inhaled methacholine and had symptoms of chronic bronchitis.

Mechanistic studies have evaluated the upper and lower airway inflammation in swine farmers by exposing healthy, nonsmoking, previously unexposed volunteers to pure endotoxin (lipopolysaccharide) or to several hours of swine dust in a swine CAFO and then assessing nasal lavage and BAL or sputum analysis. The lavage fluids are analyzed for cells involved with inflammatory responses (total count, macrophages, lymphocytes,

Table 4. Association of symptoms and lung function with occupational exposures.

S or L	Variable type[a]	Dust	Respirable dust	Ammonia	Carbon dioxide	Endotoxin	Airborne organisms	Exposure (years)	Work/day (hr)	Farming (months)[b]	Disinfectant usage	References
S	Individual	+	+			+	+	+	+			(*38*)
							+					
L	Individual	+		+	+	+	+		+			
						+						
L	Individual	+	+	+		+						(*41*)
L	Multiple	+										
L	Individual			+								(*103*)
L	Individual			+		+	+					(*61*)
L	Individual					+						
L	Individual		+							+		(*38*)
L	Individual											
L	Multiple											(*40*)
L	Multiple											
L	Individual											(*61*)
L	Individual			+		+						
L	Individual	+	+	+		+						(*44*)
L	Multiple	+						+				
L	Multiple							+				
L	Multiple	+										
L	Individual					+				+	+	(*43*)
L	Individual									+	+	(*104*)
L	Individual							+				(*39*)
L	Multiple											
L	Individual								+			
L	Individual		+	+	+		+					(*40*)
L	Multiple		+									
L	Multiple		+	+								
L	Multiple											
L	Multiple								+			
L	Multiple				+				+			
L	Multiple								+			
L	Multiple		+	+		+						
L	Multiple		+	+					+			
L	Multiple		+			+			+			
L	Individual		+			+			+			
L	Multiple		+			+						
L	Multiple			+		+						
L	Multiple		+						+			
L	Multiple			+					+			
L	Multiple				+				+			
L	Multiple					+			+			

[a]S, multiple factors; L, outcome that varies by two factors, one factor negative. [b]Is associated or changed than each factor tested individually. [c]Variables that affect the two factors are various negative. [d]Is associated or not changed than other factor tested individually. Abbreviations: L, lung function; S, respiratory symptoms.
[e]Of factors. [f]In specific tasks. [g]Main source. [h]Total bacteria. [i]Time spent. [j]Farmer and family. [k]Farmer's health. [l]Dust and respiratory tract mass. [m]Sputum.

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granulocytes, neutrophils, and eosinophils) (*89–91,93,94,97,99,100,103*) and/or the proinflammatory cytokines (tumor necrosis factor-α) (*94*), interleukins (*90,91,103*), and other soluble indicators of inflammation (*94,97,100*). An increase in these cells represents an influx of inflammatory cells in the upper or lower airways. The release of cytokines may be associated with some of the peripheral effects in workers; for example, headaches, malaise, fever, and fatigue. In addition to lavages, blood can be analyzed for inflammatory cells, cytokines, and other soluble factors (*90,92–95,97,99,103–106*). Methacholine challenge can be used to evaluate bronchial responsiveness. Studies show significant increases in inflammatory cells and cytokines in the lavage fluids and blood and increases in bronchial responsiveness. Tables 5 and 6 show the inflammatory markers in these studies.

Infectious Agents

Published reports of occupational disease from zoonoses are largely limited to case series and individual case reports. Because of the long history of known transmission of disease between humans and their domesticated animals, numerous accounts are anecdotal and do not appear in the published literature outside of textbook descriptions. A recent study estimated the risk of zoonotic illness among farmers and found an association between increased reported illness and level of contact with different livestock animals (*107*). Assisting sows with farrowing, for example, was associated with a relative risk of 6.61 for developing pneumonia compared to nonfarmer controls. As is typical of studies of this kind, the report could not confirm animal sources of infection.

Seroprevalence studies are used most commonly in epidemiology to document occupational exposures to zoonoses. Although some of the studies described here have not specifically included swine farmers, the organisms have either been isolated from swine, or swine are considered the main reservoirs of infection.

Y. enterocolitica. Porcine and human strains of *Y. enterocolitica* cannot be distinguished from each other (*108*). In swine, *Y. enterocolitica* is isolated from the tonsils, oral cavity, intestines and feces of 1–83.3% of healthy swine (*108–112*). Although yersiniosis is primarily considered a foodborne disease associated with the consumption of pork products (*108–110,113–115*), it has also been recovered from the floors and viscera tables in slaughterhouses and is considered by some researchers to be an occupationally acquired disease (*111,112*). A study in Finland compared the presence of antibodies to several serotypes of *Y. enterocolitica* in swine farmers and slaughterhouse workers to grain and berry farmers; swine farmers had an elevated risk of positive serology compared to the other two groups (*116*). Another study of slaughterhouse workers in Finland reported a higher prevalence of *Y. enterocolitica* antibodies in workers compared to blood donors from the same geographic region (*111*), and also found a higher rate of enteric disease symptoms among the occupationally exposed compared to the blood donor controls. There are no published reports of direct transmission of *Y. enterocolitica* from pigs to humans (*108*); however, seroepidemiologic data suggest that transmission does occur in the occupational setting (*111,116*).

Salmonella *species.* *Salmonella* has been called the universal pathogen because it has been isolated from all tested vertebrates (*117*). Swine may represent a significant reservoir of *Salmonella* infection for humans (*118*). Pigs can shed *Salmonella* into the environment without showing signs of disease, or they might display display signs of moderate to severe illness (*119–121*). Four of the most common *Salmonella* serotypes isolated from swine are on the Centers for Disease Control and Prevention (CDC) list of top 10 human isolates (*122*).

The risk of salmonellosis in occupational settings may be significant considering the presence of published reports of disease after occupational contacts (*78,123,124*), the prevalence of the organism in swine wastes (84% in some herds) (*122,125–127*), and the ability of this organism to survive in liquid slurry systems for months (*128*). Of the estimated 4 million yearly cases of human salmonellosis, however, roughly 1–10% are confirmed and reported to the CDC (*123*). Consequently, quantifying the risks of disease represented by specific exposures is problematic. Improved surveillance and detection in recent years, however, has resulted in increased success in tracing human infections directly obtained from livestock species other than swine (*129–131*), and it is anticipated that recognition of this route of transmission will increase in multiple livestock species.

The emergence of *Sa. typhimurium* DT104 as a significant cause of severe diarrheal disease in animals and humans is of particular concern to public health agencies. This organism has been successfully recovered from several livestock species, including swine (*132,133*), and there is evidence that this strain may have a competitive advantage over other strains of *Sa. typhimurium* (*133*). Consequently, swine populations may become increasingly infected.

Leptospira *species.* Several human diseases are due to Leptospire organisms. Weil disease (*Leptospira icterohaemorrhagiae*), canicola fever (*Leptospira canicola*), dairy-worker fever (*Leptospira hardjo*), and swineherds disease (*Leptospira pomona*) are all zoonotic diseases associated with occupational exposures (*134*). Of these, contact with pigs has been most commonly associated with Weil disease and swineherds disease, and direct transmission has been reported (*134,135*). It is not unusual for detectable antibodies to multiple serovars to be present within an individual animal (*136*), and the reported prevalence of leptospire antibodies in pigs range from 10 to 46% (*135,137*).

Human studies of leptospirosis include an epidemiologic study in the United States which found that 58% of sporadic cases could be attributed to meat processing (*138*). A similar study in Trinidad reported that approximately 6% of human clinical cases were people working on pig farms (*137*), and several seroprevalence studies confirmed elevated antibody prevalences in farmers and slaughterhouse workers (*136,139,140*). In addition, there is a positive association between seroprevalence and the number of years of employment as a meat inspector (*139*). Farmers are considered at the highest risk of leptospirosis (*140*).

E. rhusiopathiae. Disease associated with the pathogen *E. rhusiopathiae* has been recognized in swine occupations since the

Table 5. Markers of inflammation in lavage fluids that have been altered after exposure to swine confinement house dust.

Markers in lavage	Reference
Total white blood cell count	(*90,91,97,100,103*)
Monocytes	(*94*)
Macrophages	(*89–91,93,97*)
Lymphocytes	(*90,91,93,94,97,99*)
Granulocytes	(*93,94*)
Eosinophils	(*93,97*)
Neutrophils	(*90,91,93,97,99,100*)
T-cell markers	(*93*)
IL-1α	(*94*)
IL-1β	(*94,103*)
IL-6	(*94,103*)
IL-8	(*90,91,103*)
Tumor necrosis factor-α	(*94*)
Albumin	(*94,97,100*)
Fibronectin	(*100*)
Hyaluronan	(*100*)

Table 6. Markers of inflammation in blood that have been altered after exposure to swine confinement house dust.

Markers in blood	Reference
Total white blood cell count	(*90,92,95,97,103–105*)
Monocytes	(*90,92,99*)
Lymphocytes	(*93,103*)
Granulocytes	(*92,93,95*)
Neutrophils	(*90,99,103,104*)
IL-1 receptor antagonist	(*105*)
IL-1β	(*105*)
IL-6	(*92,94,95,103,105,106*)
Tumor necrosis factor-α	(*92,105*)
Oroscomucoid	(*97*)
C-reactive protein	(*97,104*)
Fibrinogen	(*106*)

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19th century (*141–143*). There are three human disease syndromes associated with this pathogen: a cutaneous form (erysipeloid), an acute or septicemic form, and a chronic form (*141,143,144*). *Erysipelothrix* can be isolated from the tonsils, intestines, lymph nodes, gall bladder, joints, and bone marrow of swine (*144*). This organism is stable in the environment and is associated with pig carcasses and swine fecal slurry (*142,143*).

Citing the number of reported cases of systemic erysipelas infection in the last 15 years, a recently published case report suggested that the growth of the swine industry in the southern United States was associated with an increase in human infections with *Erysipelothrix* because this number was already equal to the number reported in the precee-ding 60 years (*141*). Studies of the seroprevalence of *Erysipelothrix* antibodies in slaughterhouse workers found rates of 16–17% (*142*). Because erysipeloid is the most common form and usually heals spontaneously after a few weeks, this disease may be an underrecognized occupational disease (*141,143*).

Brucella suis. Brucellosis has long been recognized as a serious occupational disease of livestock producers, slaughterhouse workers, and veterinarians. Consequently, it has been the focus of a stringent eradication program in U.S. swine since 1961 (*145,146*). Estimates vary, but because of the vague clinical signs of disease, the prevalence of subclinical disease, and the difficulty associated with its diagnosis, only 4–50% of cases in the United States are probably reported (*146–148*). Swine-associated *B. suis* was responsible for most human cases of brucellosis in the 1960s and early 1970s; surprisingly, it continues to be reported as an abbatoir-associated disease into the 1990s in spite of its nearly successful eradication in the United States (*145,148*).

S. suis. Since 1968, adult meningitis caused by *S. suis* has been recognized as an occupational disease in those working with swine and swine carcasses (*149,150*). It has been most commonly reported in Asia and Northern Europe, but recent case reports have come from Canada and New Zealand (*149–153*). In a study of *S. suis* meningitis in Hong Kong, a crude incidence rate of 0.17 per 100,000 population was calculated, and the majority of human cases were associated with occupational exposures to swine or pork (*150*). Although it has never been reported in the United States, some researchers assume this is due to the difficulty of bacteriologic diagnosis in human cases and the lack of surveillance for this disease in the United States, because it is found in other countries with intensive pork production and consumption (*149,150,152*).

There are 35 identified serotypes of *S. suis* in pigs, but not all are associated with disease in swine or humans (*149,150,152,154*). Only Group R serotype 2 has been isolated in cases of human meningitis (*149–153*). The organism can cause disease in pigs or can be found in healthy carriers, and many serotypes may be isolated from a single animal (*154*). Consequently, the risk of infection to workers is difficult to estimate from prevalence studies of the organism in U.S. swine herds.

Hepatitis E virus. Historically, there have been two or three strains of human hepatitis E virus (HEV) in the human population—a Mexican strain and one or two Asian/African strains (*155*). Most U.S. cases of HEV are associated with travel to countries where this virus is endemic, but epidemiologic studies of blood donors have found a seroprevalence rate of 1–2% (up to 28% in some regions of the United States), suggesting a possible unidentified reservoir in this country (*156,157*). Commercial swine have a high prevalence of HEV antibodies and carry an HEV strain that is similar to the human-isolated HEV (*156*). Cross-species infection with the human strain and the swine strain of HEV has been successful under experimental conditions (*155,156*). Recently, a new human strain of HEV has been isolated in the United States from a man with no history of travel, and the strain is molecularly more similar to the swine HEV strain than to the previously identified human strains (*155,156,158,159*). Together, this new human U.S. strain and the swine HEV are considered a molecularly distinct genotype (*155*). Consequently, the possibility of zoonotic transmission of this infectious agent between swine and humans is being explored.

Influenza. The most widely recognized example of a virus passed between species is the influenza virus. Influenza viruses are usually species specific, but mutation and reassortment of genetic material can allow them to cross species barriers and infect new hosts. Swine are most important in the epidemiology of influenza as the mixing vessel for several viral strains, and simultaneous infection of pigs with avian viruses and swine or human viruses can result in mutation or reassortment of viral genetic material (*160–162*). Serologic studies of influenza in pigs suggest that pigs may become infected during outbreaks of human disease (*163,164*). The famous Spanish flu pandemic of 1918 was generated in pigs, and it is anticipated that the next major human pandemic of influenza may again come from swine (*160,162,165*).

Influenza disease in human hosts, however, is not entirely limited to the human-derived and swine "mixed" strains of virus. Serology in humans in contact with pigs indicate exposure prevalences to the swine-adapted influenza virus, H1N1, as 8.8–10% (*166,167*). Although uncommon, the swine-specific influenza virus does cause disease in human hosts and may be more fatal to people than human-adapted strains (*165,168–171*).

Cryptosporidium parvum. *C. parvum* is a coccidian enteric pathogen of mammals that causes clinical disease in numerous species, including swine and humans (*172*). The prevalence of fecal shedding of *Cryptosporidium* varies significantly among farms, animal species, and animal ages (*173–176*). Differences in prevalence on swine farms have been related to management practices, with higher shedding and infection rates associated with poor hygienic practices and incomplete waste removal from animal pens (*177*). In contrast with other livestock species, shedding of *Cryptosporidium* by pigs does not seem to be predominantly restricted to young animals. Prevalence rates in tested swine populations have ranged from 0 to 34.4% (*174,175,177*). Infected individuals can shed more than 108 oocysts daily for extended periods of time (*178,179*), and the human infective dose may be as low as 30 oocysts with some strains (*180*). Direct transmission to humans from animals has been documented, but these reports have not included swine (*181–183*).

Antimicrobial Resistance

The role of pigs as reservoirs of bacterial strains with transferable antimicrobial resistance patterns has been studied for many years. A U.K. study of market pigs documented the evolution of antimicrobial resistance to some common antibiotics in *Es. coli* isolates between 1956 and 1979 (*63*). This study not only documented increasing patterns of resistance in swine isolates, but also reported that up to 95% of some isolated strains of bacteria contained transferable resistance patterns. Since then, numerous studies have isolated transferable single- and multiple-resistant patterns from the bacteria of pigs, some with ribotypes indistinguishable from those found in human isolates (*68,72–75,184,185*). The percentage of resistant isolates among swine increases with increasing antimicrobial use on farms (*69–71,184*).

Several studies have demonstrated the potential for transfer of antimicrobial-resistant properties between livestock animals and workers. Exposure to antimicrobial-containing feed and animal wastes and contaminated animal tissues can result in either selective pressure on human bacterial strains or direct transmission of genetic codes for antimicrobial resistance from animals to humans. In 1978 Levy (*66*) reported the emergence of tetracycline-resistant bacteria

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in poultry within 36 hr of the introduction of a tetracycline-containing feed, and within farm personnel between 4 and 6 months after the introduction of antimicrobial-supplemented feed. In 1989 a similar study of poultry and farm personnel (*186*) documented increased antimicrobial resistance in commercially reared birds compared to free-range village poultry. In this study, similar resistance patterns were isolated among poultry personnel and birds but not in village controls (*186*). Nijsten et al. (*187*) demonstrated the ability of fecal *Es. coli* isolated from pigs to directly transfer their resistance patterns to human fecal *Es. coli* strains. In addition, Marshall et al. (*188*) reported on the stability of resistant strains of bacteria in the environment after experimental inoculation of pigs with a resistant strain of swine *Es. coli* and the subsequent isolation of this strain from water, bedding materials, mice, flies, and a human caretaker within the 4-month test period.

Furthermore, epidemiologic studies have shown that farmers and abattoir workers have higher incidences of antimicrobial-resistant bacteria than other occupational cohorts. A study of pig farmers, slaughterhouse workers, and suburban residents within the same geographic region found that pig farmers have the highest prevalences of antimicrobial resistance in fecal isolates compared to the other cohorts (*67*). Slaughterhouse workers and pig breeders in Japan have higher prevalences of antimicrobial resistance in fecal microbes than urban controls, and the human patterns were similar to the sampled pigs (*65*). Ozanne et al. (*76*) reported that slaughterhouse workers had a higher prevalence ratio of resistance (1.22–1.36) in isolated enteric bacteria than controls when previous antimicrobial exposure was controlled in the study (*76*). The patterns of resistance in the swine and slaughterhouse workers also indicated circulation of bacterial genetic material between the animals and workers.

Potential Routes and Effects of Community Exposure to Swine CAFO Hazards

People residing near swine CAFOs may be exposed to hazardous agents through a number of pathways. Airborne contaminants and small microbe-bearing particulates can be distributed into the outdoor air by building ventilation fans and spray application of slurried wastes. In addition, soil transport of microbes and nutrients from land-applied wastes, leaking lagoons, and pit-buried carcasses, as well as overland flow of microbes and nutrients from land-applied wastes, can potentially contaminate ground- and surface water sources and become sources of waterborne disease. Although there is a paucity of research in this area, there is a potential for, and some evidence of, community health effects.

Environmental Dispersion of Swine CAFO Hazards

Airborne. A limited number of studies have evaluated gases, dusts, bioaerosols, and odors outside swine CAFOs. Particles can be carried in the air long distances from their source (*189*), and can cause health concerns in the neighboring communities (*190,191*). If endotoxins are absorbed on particles < 1 µm in diameter, these particles can stay airborne for long distances and periods of time. Mixtures of volatile organic chemicals can also be transported off-site; however, the concentrations are usually orders of magnitude lower than those measured inside a swine house. Furthermore, OELs are not appropriate to use for the community because they assume the exposed population is healthy, exclude children and the elderly, and are based on a limited exposure duration.

Recently, it has been suggested that the unpleasant odors produced by inhalation of volatile organic chemicals can adversely affect the health status of people living near swine CAFOs (*191*). Shiffman (*192*) described how airborne emissions can affect health through direct irritant and psychophysiologic mechanisms. Odorous mixtures can cause sensory irritation in the eye, nose, and throat by activating at least five cranial nerves that have receptors in the nasal cavity, oral cavity, and eyes. Irritants can affect respiratory volume (*193,194*) and can induce inflammatory responses (*195,196*). People who have preexisting respiratory problems may be particularly vulnerable to the adverse effects of irritants, and can experience an increase in nasal resistance, respiration rates, and heart rates after exposures (*197,198*). Odorants positively or adversely affect mood and stress depending on whether the odor is perceived as pleasant or unpleasant (*191,199,200*).

To determine how far bioaerosols are transported through the air, they were measured inside and outside a swine facility, to a maximum distance of 300 m (*59*). Air samples were obtained within 1 m of the ground and most air samples contained viable bacteria. At 300 m from the houses, detected bacteria concentrations were approximately 4–10 times lower than concentrations at a distance of 5 m from the houses. There was a dramatic decrease in concentrations at distances > 300 m, although there were several limitations to the study. First, the measurements were taken on a dry and sunny day that could have resulted in low survival of the bacteria. Second, the process of air sampling bioaerosols can kill bacteria by desiccation and result in underestimation of concentrations. Third, the sampling height may not have been optimal for measuring the plume centerline.

Air samples were obtained 60 m away from four swine facilities and one control (nonlivestock) farm at a height of 2 m. The samples were analyzed for ammonia, hydrogen sulfide, total dust, and endotoxin (*201*). Outdoor mean ammonia concentrations ranged from 0.086 to 0.214 ppm at the swine facilities compared to nondetected at the control farm. Concentrations of ammonia were always greater downwind of sources than upwind and were significantly higher than concentrations at the control farm. Outdoors, in most cases, concentrations of total dust, endotoxins, and hydrogen sulfide were below detectable levels.

Waterborne. Lagoon breaks have resulted in the release of millions of gallons of animal wastes directly into surface water at one time, resulting in eutrophication, fish kills, and high environmental pathogen loads (*1*). However, the environmental impacts of land application of liquefied wastes, pit burial of carcasses, and chronic lagoon leakage are less documented. Historically, most of the concern and research regarding water pollution from CAFOs has focused on the impact of land application of wastes (*4,202*). However, a small body of research has also found seepage losses from waste lagoons in several states and excessive nutrient and microbial loading on regional ground and surface waters.

Before the land application of human waste materials, the microbial content of the material must not exceed federally mandated concentrations. No similar regulations apply to the land application of animal wastes, and the microbial content of water runoff from agricultural lands frequently exceeds the standards for recreational water (*4,202*). In a study of land application of swine wastes on silty clay soil with subsurface drainage, up to 3% of the microbes applied to the land were drained from the soil (*4*). Periods of rainfall can increase the microbial loading of environmental waters from CAFOs (*202*). Several of the previously discussed infectious organisms are stable in the environment and can contribute to the contamination of ground and surface waters. One study attributed enteroviral contamination of a major Canadian river to swine-farming activities (*203*).

Studies in Iowa and North Carolina (*11,14,204–206*) revealed groundwater contamination resulting from agricultural practices. Moderate to severe seepage losses from lagoons and groundwater pollution with nitrates and microbes, resulting in contamination in excess of drinking water standards, have been documented (*11,14,204–206*). A voluntary well-testing program conducted by the North Carolina Department of Environmental Health and Natural Resources

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(Raleigh, NC) found that 22% of the tested wells in one county had nitrate levels which exceed the no-observed-adverse-effect level (*79,207*).

Community Health Effects

There have been few health effect studies to evaluate the physical and mental health of residents living near swine CAFOs. Although outbreaks of *E. coli*, Leptospirosis, and cryptosporidiosis have been traced to contaminated water sources, specific sources of contamination are rarely identified (*81*). Evidence for the putative role of livestock production in the environmental spread of infectious agents has been limited to reports of increased infection rates in human populations after periods of high rainfall or flooding, and regional animal events such as calving or lambing (*139,208,209*). Unfortunately, this evidence does not implicate specific exposures. HEV is a waterborne disease in countries where it is endemic, but contamination sources are not clearly defined. Consequently, there is no direct evidence of community outbreaks of infectious disease resulting from microbial contamination from swine facilities.

Antibiotic residues have been found in wastewater specimens (*205*), and discriminant analysis has identified resistance patterns in bacteria isolated from environmental waters that are distinct from human patterns and have been attributed to agricultural sources (*210*). However, it is not known whether exposure to antibiotics or resistant bacteria in contaminated waters has any health impacts on surrounding communities.

The incidence of nitrate poisoning in the United States is not known because is not a reportable disease. In addition, in some areas, infant deaths due to nitrate-induced methemoglobinemia are sometimes misdiagnosed as congenital heart disease or sudden infant death syndrome (*80*). Long associated with well-water usage, nitrate intoxication is considered a disease of rural areas where livestock production, septic systems, and fertilized fields predominate (*80,211*). Recently, studies have associated excessive nitrate ingestion with developmental abnormalities and miscarriages, and the CDC blamed water contaminated with nitrates from a swine farm for several miscarriages occurring in 1993 and 1994 (*79,81*).

Several epidemiologic studies have investigated differential reporting of adverse symptoms between communities closely associated with swine CAFOs and other rural communities. One study evaluated the effect of odors from swine facilities on the mental health of people living near the facility (*200*). Forty-four persons living near the facilities filled out a Profile of Mood States questionnaire on 4 days when the hog odors could be smelled; an equal number of controls completed the questionnaires for 2 days. Those who lived near the facility and experienced odors had significantly more depression, tension, anger, fatigue, and confusion than controls.

In a study to evaluate both physical and mental health, Thu et al. (*212*) interviewed 18 people who lived within a 2-mile radius of a swine facility and comparable controls. The subjects near the facility had significantly higher rates of four clusters of physical symptoms compared to controls. These symptoms are consistent with symptoms reported in swine CAFO workers, and include *a*) respiratory effects such as inflammation of the bronchi or bronchioles, wheezing, and cough (associated with air pollution, chronic agricultural dust inhalation, endotoxins, and smoking); *b*) nausea, weakness, dizziness, and fainting (associated with endotoxin exposure); *c*) headaches and plugged ears (25% of swine workers have chronic sinusitis); and *d*) runny nose, scratchy throat, and burning eyes (associated with exposure to irritant gases such as ammonia). There was no significant difference for anxiety or depression between the study and control groups.

A study in North Carolina compared reported physical symptoms and quality-of-life perceptions among 155 individuals from three rural communities: a rural community with no livestock facilities within 2 miles; a similar group of households within 2 miles of a dairy facility; and another group within 2 miles of a swine CAFO (*213*). The frequencies of reported symptoms in the three groups were compared with adjustment for sex, age, smoking status, and employment. Those living within 2 miles of the swine CAFO reported a significantly greater frequency of headaches, runny nose, sore throat, excessive coughing, burning eyes, and diarrhea than the other two groups. In addition, compared to the other two groups, the residents near the swine CAFO reported significantly more episodes during which they could not open their windows or enjoy the outdoor environment.

Limitations of Current Evidence

Occupational Studies

Exposure assessment. One of the limitations of occupational health studies is successfully linking exposures to symptoms and lung function indices. Usually, the environmental measurements are obtained on 1 day, and these limited measurements are then used to compare with symptoms or lung function tests. Air contaminant concentrations vary spatially and by shift, day, week, and season. Therefore, isolated short-term contaminant measurements are being compared with health effects that may result from long-term exposures. These short-term measurements are probably not representative of the actual exposures over time. Some of the studies obtain personal measurements and some use area samples. Area samples may be poor estimators of personal exposures. One concern when evaluating dose response using these data is the poor ability of area samples to discriminate between workers with lower and higher levels of exposure.

When sampling for endotoxin in particular, the results may not reflect accurate concentrations in air. The conditions under which the endotoxins are collected, extracted, and stored can all affect the accuracy of the analytical results (*56,87,214*). In a study by Douwes et al. (*215*), a series of parallel air samples was collected and different methods of collecting and processing the samples were compared. Investigators found a difference of up to 17-fold in endotoxin yield using the different methods of processing the samples. The types of filter and water dramatically impacted the recovery of endotoxin. Freezing and thawing of the samples significantly reduced the activity of endotoxins up to 25%. Additionally, dust samples appeared to be more stable than extracted endotoxins (*87*).

There are a number of sources of variation and interferences that affect the quantification of endotoxin in the widely used Limulus amebocyte lysate assay (LAL) (*216,217*). Historically, endotoxin results from this test have been reported in weight/volume or weight/weight units. More recently, standard endotoxin preparations have been developed, and by using these standards, data can be reported in endotoxin units (EUs). The use of EUs allows for comparisons between laboratories and takes into account the variance in biologic activities between endotoxins from different sources. Milton et al. (*216*) investigated various interferences in the LAL and found that interferences could result in a 136-fold underestimation to a 34-fold overestimation of endotoxin concentration. Preventing the underestimation of concentrations due to endotoxin collection procedures, storage of samples, assay conditions, or interferants present in the sample is particularly important when evaluating community exposures where the levels may be very low.

In epidemiologic studies, exposure misclassification and confounding can reduce the sensitivity of studies to find effects. Exposure misclassification may result from the use of general air rather than personal sampling, failure to characterize specific chemicals or dusts that are most relevant to health outcomes, and inability to characterize temporal

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patterns of exposure. Confounding can occur if workers with higher exposures are more exposed to other causes of adverse outcomes, resulting in the observance of an exposure–outcome relationship that may not exist. The opposite problem may also occur. For example, smokers have poorer respiratory function than nonsmokers. Higher smoking among the unexposed group could dilute differences in respiratory function between exposed and unexposed workers. This could happen if smokers are less tolerant of work in confinement operations than nonsmokers.

Disease detection. Characterization of human infectious disease depends on the recognition of the pathogenic agents. Most diseases of swine CAFO origin that potentially affect populations at risk cannot be distinguished from more common human-source diseases. In addition, even relatively common zoonoses and intoxications may be significantly underdiagnosed. It has been estimated that only 50% of *Salmonella* cases seek medical attention, and of these only 20% are diagnosed. For parasitic diseases such as cryptosporidiosis clinicians often misunderstand the laboratory protocols that do not include this organism on routine tests, and fail to specifically request it (*218*). Methemoglobinemia may be misdiagnosed as congenital heart defects or sudden infant death syndrome (*79,80*). The lack of routine screening for *Yersinia* in U.S. laboratories has been attributed to its low detection rate in this country (*114*).

In addition, selection factors may decrease disease detection in occupational studies and limit their application to other cohorts. Two types of selection are relevant. First, workers tend to be a generally healthy group compared to the general population, in that they do not include children, the elderly, or persons with chronic diseases who are too ill to work. This is often referred to as the healthy worker effect. Thus, although workers are studied because their exposures are higher, their lower sensitivity to exposure must be considered when adverse health effects are monitored. The second selection issue of concern occurs within the workplace and affects studies that compare exposure levels among workers according to personal monitoring results and/or length of employment [e.g., Reynolds et al. (*45*)]. In such populations, a healthy worker survivor effect may occur, in which workers who are more sensitive to the adverse effects of occupational exposures leave the workplace at a higher rate than workers who are less sensitive. In this situation, not only is disease detection compromised, but the length of employment (and magnitude of cumulative exposure) is inversely related to health-effect sensitivity. Greater exposure of less-susceptible individuals tends to dampen dose–response relationships in occupational studies (*219,220*).

Community-Based Studies

Study design. Community-based health studies suffer from some of the same methodologic problems. Exposure assessment is often very difficult or nonexistent in community-based studies. For example, Thu et al. (*212*) did not measure exposure but assumed that residents living near hog operations were more exposed then residents further away. Schiffman et al. (*200*) asked respondents to record survey responses when they smelled odor but there was no independent evaluation of airborne emissions.

Although health symptoms are important outcomes, the responses of participants may be influenced by feelings about the industry created by loss of home values, quality of life, and other adverse social experiences. Experiences of anger or depression may on the one hand influence health outcomes directly, and on the other influence recall in response to survey items, introducing ambiguity in interpretation of results.

Furthermore, community-level disease detection resulting from surveillance systems is probably insufficient to detect changes in disease rates. First, poor access to health care in rural communities limits the ability to detect changes in incidence observed by passive surveillance systems. Second, regional statistics combining urban and rural populations are not sensitive to changes in disease trends in sparse rural populations. Finally, the index of suspicion for diseases possibly associated with swine CAFO exposure must be higher in the regional health care system to detect zoonotic diseases. Consequently, in the absence of specific population-based surveillance, disease trends in rural communities are difficult to measure.

Community-based studies also suffer from small sample sizes, small number of facilities evaluated, and lack of comparability of the evaluated exposures. Thu et al. (*212*) and Wing and Wolf (*213*) examined relatively small clusters of individuals in close proximity to a facility of interest, and persons near only one exposure unit were evaluated (i.e., one swine CAFO). Health effects may differ as a function of management systems, facility size, and local factors affecting exposure pathways.

Environmental injustice. A disproportionate presence of polluting industries and environmental exposures in communities of poor and people of color has been referred to as environmental injustice. Environmental injustice is not only a concern with regard to specific health effects, but also with regard to general community health, economic development, and disease surveillance. The presence of intensive swine operations may reduce land values and limit the attractiveness of those locations for other types of economic and social improvements that positively impact both individual and public health.

Environmental injustice has specifically been considered in the North Carolina swine industry. Two N.C. studies showed that in recent years hog production became concentrated in economically distressed counties with high proportions of African Americans (*221,222*). Another study examined the distribution of intensive hog operations with respect to the economic and racial characteristics of census block groups (areas of approximately 500 households each) and found strong support for the contention that intensive hog operations in North Carolina are located disproportionately in communities where people of color, the poor, and households that use well water are concentrated (*223*).

Environmental injustice in these regions of swine CAFO concentration further complicates disease detection and public health surveillance. The accumulation of epidemiologic data may be compromised by a lower rate of physician visits by those most affected. For example, a recent study of outpatient visit trends for infectious diseases showed that the visit rate for white populations was 25% higher than the rate for nonwhite populations (*224*). This difference cannot be explained by differential disease rates: Morbidity and mortality from infectious diseases such as influenza, *Y. enterocolitica*, and *Salmonella* are significantly higher in African-American populations than in white populations (*225,226*). Clearly, the surveillance of disease trends is compromised by the many economic and social factors that prevent opportunities for physician diagnoses in the populations at risk from CAFOs.

The Future of Occupational and Community Studies of Swine CAFO Impacts

Although theory and preliminary studies tell us that gases, vapors, aerosols, microbial pathogens, antimicrobial residues and resistance, and nutrients generated at a swine CAFO might reach the community, exposure assessment and disease surveillance are problematic. Future studies in this area need to focus on appropriate exposure measurements, exposure pathways, and the unique characteristics and impacts on the populations at risk.

Future community-based studies should utilize environmental exposure assessment methods and clinical or physiologic measures of health outcomes to improve their sensitivity and specificity. Considering the similarity between the symptoms observed in workers at

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swine CAFOs and in community (*212,213*) studies, endotoxins and ammonia on particles would be candidates for community-level monitoring. One complication with evaluating endotoxins in the home is determining the source or sources (outdoor or indoor). Based on the literature on odors, it would be valuable to use real-time instrumentation that can detect multiple contaminants simultaneously to capture milligram-per-cubic-meter levels of contaminants in air for the signature compounds emanating from nearby swine CAFO facilities.

Exposure pathways need to be identified and contaminants traced through these pathways from the sources of contamination. For microbial pathogens, molecular techniques may prove invaluable in source tracing. The body of literature evaluating molecular technologies that discriminate animal and human sources of microbes is increasing, and may be of particular relevance in environmental epidemiology studies of this kind.

Finally, special attention must be paid to the unique population impacted by the swine industry. Large-scale CAFOs have impacts on the quality of life of neighbors as well as the larger communities in which they are located (*227*). Although the impacts of reduced quality of life on long-term mental health could be specifically addressed by further research, neighbors are more concerned about immediate threats to their health and well being. The presence of swine CAFOs, especially in poor and underdeveloped regions, may preclude other types of economic development and industrialization and may impact local land ownership, which are critical to keeping profits in local communities. Research in North Carolina suggests that the loss of African-American-owned land is related to the expansion of vertically integrated swine operations in the state (*221*). There are extensive opportunities for further research into the impacts of swine CAFOs on land values, land ownership, and the ability of communities to attract and maintain educational, industrial, and medical facilities—community resources that are essential to positive public health developments (*96*).

References and Notes

1. Swine Odor Task Force. Options for Managing Odor. Available: http://www.ces.ncsu.edu/whpaper/SwineOdor.html [cited 1 April 1998].
2. Purdy BM, Langemeier MR, Featherstone AM. Financial performance, risk, and specialization. J Agric Appl Econ 29:149–161 (1997).
3. Robertson JF. Ammonia, dust and air quality: quantifying the problem. Pig J 33:113–125 (1994).
4. Crane SR, Moore JA, Grismer ME, Miner JR. Bacterial pollution from agricultural sources: a review. Trans ASAE 26:858–866 (1983).
5. Hill VR, Sobsey MD. Microbial indicator reductions in alternative treatment systems for swine wastewater. Water Sci Tech 38:119–122 (1998).
6. Kearney TE, Larkin MJ, Frost JP, Levett PN. Survival of pathogenic bacteria during mesophilic anaerobic digestion of animal waste. J Appl Bacteriol 75:215–219 (1993).
7. Smallbeck DR, Bromel MC. Bacterial analysis and land disposal of farm waste lagoon waters. In: Third International Symposium on Livestock Wastes, 21–24 April 1975, University of Illinois, Urbana, Illinois. St. Joseph, MI:American Society of Agricultural Engineers, 1975;318–321.
8. Meadows R. Livestock legacy. Environ Health Perspect 103:1096–1100 (1995).
9. Overcash MR, Humenik FJ, Miner JR. Livestock Waste Management. Boca Raton, FL:CRC Press, 1983.
10. Barker J. Lagoon Design and Management for Livestock Waste Treatment and Storage. Raleigh, NC:North Carolina Cooperative Extension Service, North Carolina State University, 1996.
11. Ciravolo TG, Martens DC, Hallock DL, Collins ER, Kornegay ET, Thomas HR. Pollutant movement to shallow ground water tables from anaerobic swine waste lagoons. J Environ Qual 8:126–130 (1979).
12. Huffman RL, Westerman PW. Seepage and electromagnetic terrain conductivity around new swine lagoons. In: Conference Proceedings of the Meeting of the American Society of Agricultural Engineers, Albuquerque, New Mexico, 23–26 June 1991. St. Joseph, MI:American Society of Agricultural Engineers, 1991;paper 914016.
13. Westerman PW, Huffman RL, Feng JS. Swine-lagoon seepage in sandy soil. Trans ASAE 38:1749–1760 (1995).
14. Krider J. Assessing animal waste systems impacts on groundwater: occurrences and potential problems. In: Rural Groundwater Contamination (D'Itri FM, Wolfson LG, eds). Chelsea, MI:Lewis Publishers, Inc, 1987;115–128.
15. Brenner KP, Scarpino PV, Clark CS. Animal viruses, coliphages, and bacteria in aerosols and wastewater at a spray irrigation site. Appl Environ Microbiol 54:409–415 (1988).
16. Camann DE, Moore BE, Harding HJ, Sorber CA. Microorganism levels in air near spray irrigation of municipal wastewater: the Lubbock infection surveillance study. J WPCF 60:1960–1970 (1988).
17. Gustafson RH, Bowen RE. Antibiotic use in animal agriculture. J Appl Microbiol 83:531–541 (1997).
18. Rao G. Risk factors for the spread of antibiotic-resistant bacteria. Drugs 55:323–330 (1998).
19. Hawkey P. The origins and molecular basis of antibiotic resistance. Br Med J 317:657–660 (1998).
20. Moore JE, Madden RH, Kerr JR, Wilson TS, Murphy PG. Erythromycin-resistant thermophilic *Campylobacter* species isolated from pigs. Vet Rec 138:306–307 (1996).
21. Donham K. Zoonotic diseases of occupational significance in agriculture: a review. Int J Zoonoses 12:163–191 (1985).
22. Orriss G. Animal diseases of public health importance. Emerg Infect Dis 3:497–502 (1997).
23. Preuschen G. Air pollution and human work capacity. In: Proceedings of the International Livestock Environment Symposium, University of Nebraska, Lincoln, Nebraska, 17–19 April 1974. St. Joseph, MI:American Society of Agricultural Engineers, 1974;195–198.
24. Donham K, Rubino M, Thedell T, Kammermeyer J. Potential health hazards to agricultural workers in swine confinement buildings. J Occup Med 19:383–387 (1977).
25. Zuskin E, Zagar Z, Schachter EN, Mustajbegovic J, Kern J. Respiratory symptoms and ventilatory capacity in swine confinement workers. Br J Ind Med 49:435–440 (1992).
26. Attwood P, Brower R, Ruigewaard P, Versloot P, Dewit R, Heederik D, Boleij JSM. A study of the relationship between airborne contaminants and environmental factors in Dutch swine confinement buildings. Am Ind Hyg Assoc J 48:745–751 (1987).
27. Bongers P, Houthuijs D, Remijn B, Brower R, Biersteker K. Lung function and respiratory symptoms in pig farmers. Br J Ind Med 44:819–823 (1987).
28. Cormier Y, Tremblay G, Meriaux A, Brochu G, Lavoie J. Airborne microbial contents in two types of swine confinement buildings in Quebec. Am Ind Hyg Assoc J 51:304–309 (1990).
29. Crook B, Robertson J, Travers Glass S, Botheroyd E, Lacey J, Topping M. Airborne dust, ammonia, microorganisms, and antigens in pig confinement houses and the respiratory health of exposed farm workers. Am Ind Hyg Assoc J 52:271–279 (1991).
30. Donham K. Health effects from work in livestock confinement buildings. In: Organic Dust Handbook (Rylander R Jr, ed). Boca Raton, FL:CRC Press, 1993;219–232.
31. Dosman JA, Graham BL, Hall D, Pahwa P, McDuffie HH, Lucewicz M, To T. Respiratory symptoms and alterations in pulmonary function tests in swine producers in Saskatchewan: results of a survey of farmers. J Occup Med 30:715–720 (1988).
32. Haglind P, Rylander R. Occupational exposure and lung function measurements among workers in swine confinement buildings. J Occup Med 29:904–907 (1987).
33. Mackiewicz B. Study on exposure of pig farm workers to bioaerosols, immunologic reactivity and health effects. Ann Agric Environ Med 5:169–175 (1998).
34. Rylander R, Bake B, Fischer JJ, Helander IM. Pulmonary function and symptoms after inhalation of endotoxin. Am Rev Respir Dis 140:981–986 (1989).
35. Zejda JE, Hurst TS, Rhodes CS, Barber EM, McDuffie HH, Dosman JA. Respiratory health of swine producers: focus on young workers. Chest 103:702–709 (1993).
36. Zuskin E, Kanceljak B, Schachter EN, Mustajbegovic J, Goswami S, Maayani S, Marom Z, Rienzi N. Immunological and respiratory findings in swine workers. Environ Res 56:120–130 (1991).
37. Choudat D, Goehen M, Korobaeff M, Boulet A, Dewitte JD, Martin MH. Respiratory symptoms and bronchial reactivity among pig and dairy farmers. Scand J Work Environ Health 20:48–54 (1994).
38. Donham K, Haglind P, Peterson Y, Rylander R, Belin L. Environmental and health studies of farm workers in Swedish swine confinement buildings. Br J Ind Med 46:31–37 (1989).
39. Holness DL, O'Blenis EL, Sass-Kortsak A, Pilger C, Nethercott JR. Respiratory effects and dust exposures in hog confinement farming. Am J Ind Med 11:571–580 (1987).
40. Wilhelmsson J, Bryngelsson IL, Ohlson CG. Respiratory symptoms among Swedish swine producers. Am J Ind Med 15:311–318 (1989).
41. Olson DK, Bark SM. Health hazards affecting the animal confinement farm worker. AAOHN J 44:198–204 (1996).
42. Pickrell J. Hazards in confinement housing—gases and dusts in confined animal houses for swine, poultry, horses, and humans. Vet Hum Toxicol 33:32–39 (1991).
43. Donham K, Reynolds S, Whitten P, Merchant J, Burmeister L, Popendorf W. Respiratory dysfunction in swine production facility workers: dose-response relationships of environmental exposures and pulmonary function. Am J Ind Med 27:405–418 (1995).
44. Reynolds SJ, Donham KJ, Whitten P, Merchant JA, Burmeister LF, Popendorf WJ. Longitudinal evaluation of dose-response relationships for environmental exposures and pulmonary function in swine production workers. Am J Ind Med 29:33–40 (1996).
45. Zejda JE, Barber E, Dosman JA, Olenchock SA, McDuffie HH, Rhodes C, Hurst T. Respiratory health status in swine producers relates to endotoxin exposure in the presence of low dust levels. J Occup Med 36:49–56 (1994).
46. Holness DL, Nethercott JR. Respiratory status and environmental exposure of hog confinement and control farmers in Ontario. In: Principles of Health and Safety in Agriculture (Dosman JA, Cockroft DW, eds). Boca Raton, FL:CRC Press, 1989;69–71.
47. Vogelzang P, van der Gulden J, Preller L, Tielen M, van Schayck C, Folgering H. Bronchial hyperresponsiveness and exposure in pig farmers. Int Arch Occup Environ Health 70:327–333 (1997).
48. Donham KJ. Health effects from work in swine confinement buildings. Am J Ind Med 17:17–25 (1990).
49. Rappaport SM. Threshold limit values, permissible exposure limits, and feasibility: the bases for exposure limits in the United States. Am J Ind Med 23:683–694 (1993).
50. Roach SA, Rappaport SM. But they are not thresholds: a critical analysis of the documentation of threshold limit values. Am J Ind Med 17:727–753 (1990).
51. Preller L, Heederik D, Boleij JSM, Vogelzang PFJ, Tielen MJM. Lung funtion and chronic respiratory symptoms of pig farmers: focus on exposure to endotoxins and ammonia and use of disinfectants. Occup Environ Med 52:654–660 (1995).
52. Hammond E, Fedler C, Junk G. Identification of dust-borne odors in swine confinement facilities. Trans ASAE 22:1186–1192 (1979).

ED_001369_00043779-00013

53. Pickrell JA, Heber AJ, Murphy JP, Henry SC, May MM, Nolan D, Gearhart SK, Cederber BL, Oehme FW, Schonewels D. Total and respirable dust in swine confinement buildings: the benefit of respiratory protective masks and effect of recirculated air. Vet Hum Toxicol 37:430–435 (1995).
54. Zejda JE, Hurst TS, Barber EM, Rhodes C, Dosman JA. Respiratory health status in swine producers using respiratory protective devices. Am J Ind Med 23:743–750 (1993).
55. Haglind P, Rylander R. Exposure to cotton dust in an experimental cardroom. Br J Ind Med 41:340–345 (1984).
56. Douwes J, Heederick D. Epidemiologic investigations of endotoxins. Int J Occup Environ Health 3(suppl):S26–S31 (1997).
57. Michel O. Human challenge studies with endotoxins. Int J Occup Environ Health 3(suppl):S18–S25 (1997).
58. Cox C. Stability of airborne microbes and allergens. In: Bioaerosols Handbook (Cox CS, Wathes CM, eds). London:Lewis Publishers, 1995;77–99.
59. Homes MJ, Heber AJ, Wu CC, Clark LK, Grant RH, Zimmerman NJ, Hill MA, Strobel BR, Peugh MW, Jones DD. Viability of bioaerosols produced from a swine facility. In: Proceedings of the International Conference on Air Pollution from Agricultural Operations, 7–9 February 1996, Kansas City, Missouri. Ames, IA:Iowa State University, 1996;127–131.
60. Clark S, Rylander R, Larsson L. Airborne bacteria, endotoxin and fungi in dust in poultry and swine confinement buildings. Am Ind Hyg Assoc J 44:537–541 (1983).
61. Heederik D, Brouwer R, Biersteker K, Boleij JSM. Relationship of airborne endotoxin and bacteria levels in pig farms with the lung function and respiratory symptoms of farmers. Int Arch Occup Environ Health 62:595–601 (1991).
62. Tenover F. Reasons for the emergence of antibiotic resistance. Am J Med Sci 311:9–16 (1996).
63. Smith H. Antibiotic-resistant *Escherichia coli* in market pigs in 1956–1979: the emergence of organisms with plasmid-borne trimethoprim resistance. J Hyg Camb 84:467–477 (1980).
64. Glynn MK, Bopp C, Dewitt W, Dabney P, Mokhtar M, Angulo F. Emergence of multidrug-resistant *Salmonella enterica* serotype typhimurium DT104 infections in the United States. N Engl Med 338:1333–1338 (1998).
65. Saida K, Ike Y, Mitsuhashi S. Drug resistance and R plasmids of *Escherichia coli* strains isolated from pigs, slaughterers, and breeders of pigs in Japan. Antimicrob Agents Chemother 19:1032–1036 (1981).
66. Levy S. Emergence of antibiotic-resistant bacteria in the intestinal flora of farm inhabitants. J Infect Dis 137:688–690 (1978).
67. Nijsten R, London N, Van Den Bogaard A, Stobberingh E. Resistance in faecal *Escherichia coli* isolated from pig-farmers and abattoir workers. Epidemiol Infect 113:45–52 (1994).
68. Aalbaek B RJ, Nielsen B, Olsen JE. Prevalence of antibiotic-resistant *Escherichia coli* in Danish pigs and cattle. APMIS 99:1103–1110 (1991).
69. Mathew AG, Saxton AM, Upchurch WG, Chattin SE. Multiple antibiotic resistance patterns of *Escherichia coli* isolates from swine farms. Appl Environ Microbiol 65:2770–2772 (1999).
70. Mathew AG, Upchurch WG, Chattin SE. Incidence of antibiotic resistance in fecal *Escherichia coli* isolated from commercial swine farms. J Anim Sci 76:429–434 (1998).
71. Langlois BE, Cromwell GL, Hays VW. Influence of type of antibiotic and length of antibiotic feeding period on performance and persistence of antibiotic resistant enteric bacteria in growing-finishing swine. J Anim Sci 46:1383–1396 (1978).
72. Wise PJ, Towner KJ, Webster CA, Slack RCB, Jones TO. Trimethoprim resistance plasmids in *Escherichia coli* isolated from cases of diarrhoea in cattle, pigs and sheep. J Appl Bacteriol 58:555–561 (1985).
73. Bates J, Jordens JZ, Griffiths DT. Farm animals as a putative reservoir for vancomycin-resistant enterococcal infection in man. J Antimicrob Chemother 34:507–516 (1994).
74. Jansson C, Franklin A, Skold O. Spread of a newly found trimethoprim resistance gene, dhfrIX, among porcine isolates and human pathogens. Antimicrob Agents Chemother 36:2704–2708 (1992).
75. Mee BJ, Nikoletti SM. Plasmids encoding trimethoprim resistance in bacterial isolates from man and pigs. J Appl Bacteriol 54:225–235 (1983).
76. Ozanne G, Bedard P, Ducic S, Panisset J. Antibiotic multiresistance among coliforms isolated from the gut of swine and abattoir workers: evidence of transfer from animal to man. Can J Public Health 78:340–344 (1987).
77. Evans S, Davies R. Case control study of multiple-resistant *Salmonella typhimurium* DT104 infection of cattle in Great Britain. Vet Rec 139:557–558 (1996).
78. Hogue A, Akkina J, Angulo F, Johnson R, Peterson K, Saini P, Schlosser W. Situation Assessment: *Salmonella Typhimurium* DT104. Washington, DC:Food Safety and Inspection Service, U.S. Department of Agriculture, 1997.
79. Fan AM, Steinberg VE. Health implications of nitrate and nitrite in drinking water: an update on methemoglobinemia occurrence and reproductive and developmental toxicity. Regul Toxicol Pharmacol 23:35–43 (1996).
80. Johnson CJ, Kross BC. Continuing importance of nitrate contamination of groundwater and wells in rural areas. Am J Ind Med 18:449–456 (1990).
81. Kramer MH, Herwaldt BL, Craun GF, Calderon RL, Juranek DD. Surveillance for waterborne-disease outbreaks—United States, 1993–1994. Morb Mortal Wkly Rep 45:1–33 (1996).
82. Rylander R, Haglind P, Lundholm M. Endotoxin in cotton dust and respiratory-function decrement among cotton workers in an experimental cardroom. Am Rev Respir Dis 131:209–213 (1985).
83. Smid T. Exposure to organic dust and respiratory disorders: an epidemiological study in the animal feed industry [PhD thesis]. Wageningen, The Netherlands:Agricultural University, 1993.
84. Smid T, Heederik D, Houba R, Quanjer PH. Dust-related and endotoxin-related respiratory effects in the animal-feed industry. Am Rev Respir Dis 146:1474–1479 (1992).
85. Castellan RM, Olenchock SA, Kinsley KB, Hankinson JL. Inhaled endotoxin and decreased spirometric values: an exposure-response relation for cotton dust. N Engl J Med 317:605–610 (1987).
86. Kennedy SM, Christiani DC, Eisen EA, Wegman DH, Greaves IA, Olenchock SA, Ye TT, Lu PL. Cotton dust and endotoxin exposure-response relationships in cotton textile workers. Am Rev Respir Dis 135:194–200 (1987).
87. Milton DK, Wypij D, Kriebel D, Walters MD, Hammond SK, Evans JS. Endotoxin exposure-response in a fiberglass manufacturing facility. Am J Ind Med 29:3–13 (1996).
88. Teeuw KB, Vandenbroucke-Grauls CM, Verhoef J. Airborne gram-negative bacteria and endotoxin in sick building syndrome: a study in Dutch governmental office buildings. Arch Intern Med 154:2339–2345 (1994).
89. Von Essen S, Scheppers L, Robbins R, Donham K. Respiratory tract inflammation in swine confinement workers studied using induced sputum and exhaled nitric oxide. Clin Toxicol 36:557–565 (1998).
90. Cormier Y, Duchaine C, Israel-Assayag E, Bedard G, Laviolette M, Dosman J. Effects of repeated swine building exposures on normal naive subjects. Eur Respir J 10:1516–1522 (1997).
91. Larsson B, Palmberg L, Malmberg P, Larsson K. Effect of exposure to swine dust on levels of IL-8 in airway lavage fluid. Thorax 52:638–642 (1997).
92. Wang Z, Malmberg P, Larsson P, Larsson BM, Larsson K. Time course of interleukin-6 and tumor necrosis factor-alpha increase in serum following inhalation of swine dust. Am J Respir Crit Care Med 153:147–152 (1996).
93. Muller-Suur C, Larsson K, Malmberg P, Larsson PH. Increased number of activated lymphocytes in human lung following swine dust inhalation. Eur Respir J 10:376–380 (1997).
94. Wang Z, Larsson K, Palmberg L, Malmberg P, Larsson P, Larsson L. Inhalation of swine dust induces cytokine release in the upper and lower airways. Eur Respir J 10:381–387 (1997).
95. Wang Z, Malmberg P, Larsson B, Larsson K, Larsson L, Saraf A. Exposure to bacteria in swine-house dust and acute inflammatory reactions in humans. Am J Respir Crit Care Med 154:1261–1266 (1996).
96. Sclar ED. Community economic structure and individual well-being: a look behind the statistics. Int J Health Serv 10:563–579 (1980).
97. Larsson K, Eklund A, Hansson L, Isaksson B, Malmberg P. Swine dust causes intense airways inflammation in healthy subjects. Am J Respir Crit Care Med 150:973–977 (1994).
98. Jolie R, Backstrom L, Thomas C. Health problems in veterinary students after visiting a commercial swine farm. Can J Vet Res 62:44–48 (1998).
99. Thorne J, Rylander R. Inflammatory response after inhalation of bacterial endotoxin assessed by the induced sputum technique. Thorax 53:1047–1052 (1998).
100. Larsson K, Eklund A, Malmberg P, Belins L. Alterations in bronchoalveolar lavage fluid but not in lung function and bronchial responsiveness in swine confinement workers. Chest 101:767–774 (1992).
101. Schwartz DA, Landas SK, Lassise DL, Burmeister LF, Hunninghake GW, Merchant JA. Airway injury in swine confinement workers. Ann Intern Med 116:630–635 (1992).
102. Carvalheiro MF, Peterson Y, Rubenowitz E, Rylander R. Bronchial reactivity and work-related symptoms in farmers. Am J Ind Med 27:65–74 (1995).
103. Senthilselvan A, Zhang Y, Dosman JA, Barber EM, Holefeld LE, Kirychuck SP, Cormier Y, Hurst TS, Rhodes CS. Positive human health effects of dust suppression with canola oil in swine barns. Am J Respir Crit Care Med 156:410–417 (1997).
104. Michel O, Duchateau J, Plat G, Cantinieaux B, Hotimsky A, Gerain J, Sergysels R. Blood inflammatory response to inhaled endotoxin in normal subjects. Clin Exp Allergy 25:73–79 (1995).
105. Wang Z, Manninen A, Malmberg P, Larsson K. Inhalation of swine-house dust increases the concentrations of interleukin-1 beta and interleukin-1 receptor antagonist in peripheral blood. Respir Med 92:1022–1027 (1998).
106. Sjogren B, Wang ZP, Larsson BM, Larsson K, Larsson PH, Westerholm P. Increase in interleukin-6 and fibrinogen in peripheral blood after swine dust inhalation. Scand J Work Environ Health 25:39–41 (1999).
107. Thomas DR, Salmon RL, Kench SM, Meadows D, Coleman TJ, Morgan-Capner P, Morgan KL. Zoonotic illness-determining risks and measuring effects: association between current animal exposure and a history of illness in a well characterised rural population in the UK. J Epidemiol Community Health 48:151–155 (1994).
108. Anderson JK, Sorensen R, Glensbjerg M. Aspects of the epidemiology of *Yersinia enterocolitica*: a review. Int J Food Microbiol 13:231–238 (1991).
109. De Boer E, Nouws JFM. Slaughter pigs and pork as a source of human pathogenic *Yersinia enterocolitica*. Int J Food Microbiol 12:375–378 (1991).
110. Hariharan H, Giles JS, Heaney SB, Leclere SM, Schurman RD. Isolation, serotypes, and virulence associated properties of *Yersinia enterocolitica* from the tonsils of slaughter hogs. Can J Vet Res 59:161–166 (1995).
111. Merilahti-Palo R, Lahesmaa R, Granfors K, Gripenberg-Lerche C, Toivanen. Risk of *Yersinia* infection among butchers. Scand J Infect Dis 23:55–61 (1991).
112. Nesbakken T. Enumeration of *Yersinia enterocolitica* O:3 from the porcine oral cavity, and its occurrence on cut surfaces of pig carcasses and the environment in a slaughterhouse. Int J Food Microbiol 6:287–293 (1988).
113. Miller MA, Paige JC. Other food borne infections. In: The Veterinary Clinics of North America (Tollefson L, ed). Philadelphia:W.B. Saunders, 1998;71–89.
114. Ostroff S. *Yersinia* as an emerging infection: epidemiologic aspects of yersiniosis. In: Yersiniosis: Present and Future (Ravagnan G, Chiesa C, eds). New York:Karger, 1994;5–10.
115. Tauxe RV, Wauters G, Goossens V, Van Noyen R, Vandepitte J, Martin SM, De Mol P, Thiers G. *Yersinia enterocolitica* infections and pork: the missing link. Lancet 1:1129–1132 (1987).
116. Seuri M, Granfors K. Antibodies against *Yersinia* among farmers and slaughterhouse workers. Scand J Work Environ Health 18:128–132 (1992).
117. Roof M. Porcine salmonellosis: characterization, immunity, and potential vaccines. In: The Compendium Collection. Trenton, NJ:Veterinary Learning Systems, 1993;191–201.
118. Isaacson RE, Bane D, Hungerford L, Troutt HF. Detection and epidemiology of *Salmonella* in swine - Year 02, vol 1995. Available: http://www.nppc.org/Research/researchmain.html [cited 25 August 1998]. Select "Research Investment Report 1995."
119. Ekperigin HE, Nagaraja KV. *Salmonella*. In: The Veterinary Clinics of North America: Food Animal Practice, Vol 14 (Tollefson L, ed). Philadelphia:W.B. Saunders Company, 1998;17–29.
120. House JK, Smith BP. Current strategies for managing

ED_001369_00043779-00014

Salmonella infections in cattle. Vet Med 93:756–764 (1998).
121. Schwartz K. Salmonellosis in swine. In: The Compendium Collection. Trenton, NJ:Veterinary Learning Systems, 1993;202–209.
122. U.S. Department of Agriculture Animal and Plant Inspection Service. Information Sheet: Shedding of *Salmonella* by Finisher Hogs in the U.S. Available: http://www.aphis.usda.gov/vs/ceah/cahm/Swine/swine.htm [cited 2 February 1999]. Scroll down to the information sheet.
123. Cohen ML, Tauxe RV. Drug-Resistant *Salmonella* in the United States: an epidemiologic perspective. Science 234:964–969 (1986).
124. Holmberg SD, Osterholm MT, Snger KA, Cohen ML. Drug-resistant *Salmonella* from animals fed antimicrobials. N Engl J Med 311:617-622 (1984).
125. Davies PR, Bovee FGEM, Funk JA, Morrow WEM, Jones FT, Deen J. Isolation of *Salmonella* serotypes from feces of pigs raised in a multiple-site production system. J Am Vet Med Assoc 212:1925–1929 (1998).
126. Davies PR, Morrow WEM, Jones FT, Deen J, Fedorka-Cray PJ, Harris IT. Prevalence of *Salmonella* in finishing swine raised in different production systems in North Carolina, USA. Epidemiol Infect 119:237–244 (1997).
127. Davies PR, Morrow WEM, Jones FT, Deen J, Fedorka-Cray PJ, Gray JT. Risk of shedding *Salmonella* organisms by market-age hogs in a barn with open-flush gutters. J Am Vet Med Assoc 210:386–389 (1997).
128. Forshell LP, Ekesbo I. Survival of Salmonellas in composted and not composted solid animal manures. J Vet Med 40:654–658 (1993).
129. Bender JB, Hedberg CW, Besser JM, Boxrud DJ, Wicklund JH, Osterholm MT. Surveillance for *Salmonella typhimurium* infections in Minnesota by molecular subtype [Abstract]. In: International Conference on Emerging Infectious Diseases, 8–11 March 1998, Atlanta, Georgia. Atlanta, GA:Centers for Disease Control and Prevention, 1998;116.
130. Friedman CR, Brady RC, Celotti MJ, Schoenfeld SE, Johnson RH, Galbraith PD, Carney JK, Robbins K, Slutsker L. An outbreak of multidrug-resistant *Salmonella* serotype typhimurium definitive type 104 (DT104) infections in humans and cattle in Vermont [Abstract]. In: International Conference on Emerging Infectious Diseases, 8–11 March 1998, Atlanta, Georgia. Atlanta, GA:Centers for Disease Control and Prevention, 1998;68.
131. Khakhria R, Mulvey MR, Ahmed R, Woodward D, Johnson W. Emergence of multi-resistant strain of *Salmonella typhimurium* phage type 104 (DT104) in Canada [Abstract]. In: International Conference on Emerging Infectious Diseases, 8–11 March 1998, Atlanta, GA. Atlanta, GA:Centers for Disease Control and Prevention, 1998;141.
132. Besser TE, Gay CC, Gay JM, Hancock DD, Rice D, Pritchett LC, Erickson ED. Salmonellosis associated with *S typhimurium* DT104 in the USA [Letter]. Vet Rec 140:75 (1997).
133. Petersen K, Akkina J, Angulo F, Hogue A, Johnson R, Saini P, Schlosser W. Situation report on *Salmonella typhimurium* DT104. Available: http://www.usaha.org/speeches/sal10497.html [cited 24 August 1998].
134. Penny R. Old diseases, new arrivals: leptospirosis and brucellosis. Pig J 33:30–37 (1994).
135. Perea A, Garcia R, Maldonado A, Tarradas MC, Luque I, Astorga R, Arenas A. Prevalence of antibodies to different *Leptospira interrogans* serovars in pigs on large ferms. J Vet Med B 41:512–516 (1994).
136. Stanford CF, Connolly JH, Ellis WA, Smyth ETM, Coyle PV, Montgomery WI, Simpson DIH. Zoonotic infections in northern Ireland farmers. Epidemiol Infect 105:565–570 (1990).
137. Everard COR, Ferdinand GA, Butcher LV, Everard JD. Leptospirosis in piggery workers in Trinidad. J Trop Med Hyg 92:253–258 (1989).
138. Crawford RP, McCulloch WF, Top FH, Diesch SL. Epidemiologic studies of sporadic human cases of leptospirosis in Iowa, 1965–1968. J Am Vet Med Assoc 155:2084–2090 (1969).
139. Heath SE, Johnson R. Leptospirosis. J Am Vet Med Assoc 205:1518–1523 (1994).
140. Skilbeck NW, Miller GT. A serological survey of leptospirosis in Gippsland dairy farmers. Med J Aust 144:565–569 (1986).
141. Hill DC, Ghassemian JN. *Erysipelothrix rhusiopathiae* endocarditis: clinical features of an occupational disease. South Med J 90:1147–1148 (1997).
142. Molin G, Soderlind O, Ursing J, Norrung V, Ternstrom A, Lowenhielm C. Occurrence of *Erysipelothrix rhusiopathiae* on pork and in pig slurry, and the distribution of specific antibodies in abattoir workers. J Appl Bacteriol 67:347–352 (1989).
143. Reboli AC, Farrar WE. *Erysipelothrix rhusiopathiae*: an occupational pathogen. Clin Microbiol Rev 2:354–359 (1989).
144. Takahashi T, Sewada T, Muramatsu M, Tamura Y, Fujisawa T, Benno Y, Mitsuoka T. Serotype, antimicrobial susceptibility, and pathogenicity of *Erysipelothrix rhusiopathiae* isolates from tonsils of apparently healthy slaughter pigs. J Clin Microbiol 25:536–539 (1987).
145. Buchanan TM, Hendricks SL, Patton CM, Feldman RA. Brucellosis in the United States, 1960–1972. Medicine 53:427–439 (1974).
146. Centers for Disease Control and Prevention. Brucellosis outbreak at a pork processing plant—North Carolina, 1992. JAMA 271:1734–1735 (1994).
147. Abramson O, Rosenvasser Z, Block C, Dagan R. Detection and treatment of brucellosis by screening a population at risk. Pediatr Infect Dis J 10:434–438 (1991).
148. Trout D, Gomez TM, Bernard BP, Mueller CA, Smith CA, Smith CG, Hunter L, Kiefer M. Outbreak of brucellosis at a United States pork packing plant. J Occup Environ Med 37:697–703 (1995).
149. Dupas D, Vignon M, Geraut C. *Streptococcus suis* meningitis: a severe noncompensated occupational disease. J Occup Med 34:1102–1105 (1992).
140. Kay R, Chang AF, Tse CY. *Streptococcus suis* infection in Hong Kong. Q J Med 88:39–47 (1995).
151. Bartelink AKM, van Kretgen E. *Streptococcus suis* as threat to pig-farmers and abattoir workers. Lancet 346:1707 (1995).
152. Zanen HC, Engel HWB. Porcine streptococci causing meningitis and septicaemia in man. Lancet i:1286–1288 (1975).
153. Michaud S, Duperval R, Higgins R. *Streptococcus suis* meningitis: first case reported in Quebec. Can J Infect Dis 7:329–331 (1996).
154. Amass S, Stevenson G, Knox K, Reed A. Efficacy of an autogenous vaccine for preventing streptococcosis in piglets. Vet Med 94:480–484 (1999).
155. Meng XJ, Halbur PG, Shapiro MS, Govindarajan S, Bruna JD, Mushahwar IK, Purcell RH, Emerson SU. Genetic and experimental evidence for cross-species infection by swine hepatitis E virus. J Virol 72:9714–9721 (1998).
156. Meng XJ, Purcell RH, Halbur PG, Lehman JR, Webb DM, Tsareva TS, Haynes JS, Thacker BJ, Emerson SU. A novel virus in swine is closely related to the human hepatitis E virus. Proc Natl Acad Sci USA 94:9860–9865 (1997).
157. Groen P. Hepatitis E in the United States: a case of hog fever? Mayo Clin Proc 72:1197–1198 (1997).
158. Kwo P, Schlauder GG, Carpenter HA, Murphy PJ, Rosenblatt JE, Dawson GJ, Mast EE, Krawczynski K, Balan V. Acute hepatitis E by a new isolate acquired in the United States. Mayo Clin Proc 72:1133–1136 (1997).
159. Schlauder GG, Dawson GJ, Erker JC, Kwo PY, Knigge MF, Smalley DL, Rosenblatt JE, Desai SM, Mushahwar IK. The sequence and phylogenetic analysis of a novel hepatitis E virus isolated from a patient with acute hepatitis reported in the United States. J Gen Virol 79:447–456 (1998).
160. Ito T, Couceiro JN, Kelm S, Baum LG, Krauss S, Castrucci MR, Donatelli I, Kida H, Peulson JC, Webster RG, et al. Molecular basis for the generation in pigs of influenza A viruses with pandemic potential. J Virol 72:7367–7373 (1998).
161. Scholtissek C. Molecular evolution of influenza viruses. Virus Genes 11:209–215 (1996).
162. Webster RG, Shortridge KF, Kawaoka Y. Influenza: interspecies trensmission and emergence of new pandemics. FEMS Immun Med Microbiol 18:275–279 (1997).
163. Brown I. Recent changes in the epizootiology of swine influenza. Pig J 36:150–158 (1996).
164. Katsuda K, Seto S, Imai M, Shirahata T, Goto H. Prevalence of antibodies to type A influenza viruses in swine sera 1990–1994. J Vet Med Sci 57:773–775 (1995).
165. Teubenberger JK, Reid AH, Krafft AE, Bijwaard KE, Fanning TG. Initial genetic characterization of the 1918 Spanish influenza virus. Science 275:1793–1796 (1997).
166. Webster RG. Influenza: an emerging diseese. Emerg Infect Dis 4:436–441 (1998).
167. Nowotny N, Deutz A, Fuchs K, Schuller W, Hinterdorfer F, Auer H, Aspock H. Prevalence of swine influenza and other viral, bacterial, and parasitic zoonoses in veterinarians. J Infect Dis 176:1414–1415 (1997).
168. Dowdle W. The 1976 experience. J Infect Dis 176:S69–S72 (1997).
169. Kimura K, Adlakha A, Simon PM. Fatal case of swine influenza virus in an immunocompetent host. Mayo Clin Proc 73:243–245 (1998).
170. Wells DL, Hopfensperger DJ, Arden NH, Harmon MW, Davis JP, Tipple MA, Schonberger LB. Swine influenza virus infections. Transmission from ill pigs to humans at a Wisconsin agricultural fair and subsequent probable person-to-person transmission. JAMA 265:478–481 (1991).
171. Wentworth DE, McGregor MM, Macklin MD, Neumann V, Hinshaw VS. Transmission of swine influenza virus to humans after exposure to experimentally infected pigs. J Infect Dis 175:7–15 (1997).
172. O'Donoghue P. *Cryptosporidium* and cryptosporidiosis in man and animals. Int J Parasitol 25:139–195 (1995).
173. Garber LP, Salman MD, Hurd HS, Keefe T, Schlater JL. Potential risk factors for *Cryptosporidium* infection in dairy calves. J Am Vet Med Assoc 205:86–91 (1994).
174. Olson ME, Thorlakson CL, Deselliers, Morck DW, McAllister TA. Giardia and *Cryptosporidium* in Canadian farm animals. Vet Parasitol 68:375–381 (1997).
175. Quilez J, Ares-Mazas E, Sanchez-Acedo C, del Cacho E, Clavel A, Causape AC. Comparison of oocyst shedding and the serum immune response to *Cryptosporidium parvum* in cattle and pigs. Parasitol Res 82:529–534 (1996).
176. Scott CA, Smith HV, Mtambo MMA, Gibbs HA. An epidemiological study of *Cryptosporidium parvum* in two herds of adult beef cattle. Vet Parasit 57:277–288 (1995).
177. Xiao L, Herd RP, Bowman GL. Prevalence of *Cryptosporidium* and *Giardia* infections on two Ohio pig farms with different management systems. Vet Parasitol 52:331–336 (1994).
178. Chappell CL, Okhuysen PC, Sterling CR, DuPont HL. *Cryptosporidium parvum*: intensity of infection and oocyst excretion patterns in healthy volunteers. J Infect Dis 173:232–236 (1996).
179. Ortega-Mora L, Wright SE. Age-related resistance in ovine cryptosporidiosis: patterns of infection and humoral response. Infect Immun 62:5003–5009 (1994).
180. Dupont HL, Chappell CL, Sterling CR, Okhuysen PC, Rose JB, Jakubowski W. The infectivity of *Cryptosporidium parvum* in healthy volunteers. N Engl J Med 332:855–859 (1995).
181. Konkle DM, Nelson KM, Lunn DP. Nosocomial transmission of *Cryptosporidium* in a veterinary hospital. J Vet Intern Med 11:340–343 (1997).
182. Miron D, Kenes J, Dagan R. Calves as a source of an outbreak of cryptosporidiosis among young children in an agricultural closed community. Pediat Infect Dis J 10:438–441 (1991).
183. Reif JS, Wimmer L, Smith JA, Dargatz DA, Cheney JM. Human cryptosporidiosis associated with an epizootic in calves. Am J Public Health 79:1528–1530 (1989).
184. Gellin G, Langlois BE, Dawson KA, Aaron DK. Antibiotic resistance of gram-negative enteric bacteria from pigs in three herds with different histories of antibiotic exposure. Appl Environ Microbiol 55:2287–2292 (1989).
185. Towner KJ, Wise PJ, Lewis MJ. Molecular relationships between trimethoprim R plasmids obtained from human and animal sources. J Appl Bacteriol 61:535–540 (1986).
186. Ojeniyi AA. Direct transmission of Escherichie coli from poultry to humens. Epidemiol Infect 103:513–522 (1989).
187. Nijsten R, London N, van den Bogaard A, Stobberingh E. In-vitro transfer of antibiotic resistance between faecal *Escherichia coli* strains isolated from pig farmers and pigs. J Antimicrob Chemother 37:1141–1154 (1996).
188. Mershall B, Petrowski D, Levy SB. Inter- and intraspecies spread of *Escherichia coli* in a farm environment in the absence of antibiotic usage. Proc Nal Acad Sci 87:6609–6613 (1990).
189. Cox C. Airborne bacteria and viruses. Sci Prog 73:469–500 (1989).
190. Schusterman D. Critical review: the health significance of environmental odor pollution. Arch Environ Health 47:76–87 (1992).
191. Schusterman D, Lipscomb J, Neutra R, Satin K. Symptom

ED_001369_00043779-00015

prevalence and odor severity emissions near incinerator waste sites. Environ Health Perspect 94:35–39 (1992).
192. Schiffman SS. Livestock odors: implications for human health and well-being. J Anim Sci 76:1343–1355 (1998).
193. Wiesner G, Walker J, Duke A, Lutz K. Assessing the effects of odorants on nasal airway and lung function. Physiol Behav 51:425–430 (1992).
194. Wark J, Zwerdler J, Niesz L, Samet J, Weggner G, Cauthen S, Gokavarak H, Schwartz M. Respiratory and irritant health effects of ambient volatile organic compounds. Am J Epidemiol 131:1296–1301 (1990).
195. Lewis A, Byers V. Environmental illness: a disorder of airways regulation. Stanf Art Rev Occup Med 2:669–681 (1987).
196. Marshall J, Shamsuddin J. The role of mast cells in inflammatory reactions of the airways, skin and intestine. Curr Opin Immunol 6:893–899 (1994).
197. Horwath K. The role of odors and vapors in allergic disease. J Asthma Res 4:125–130 (1966).
198. Doty RL, Shaman DA, Frye WE, Pellegrino R, Chapman A. Olfactory sensitivity, nasal resistance, and autonomic function in patients with multiple chemical sensitivities. Arch Otolaryngol Head Neck Surg 114:1422–1427 (1988).
199. Schiffman S. Physicochemical correlates of olfactory qualities. Science 185:112–117 (1974).
200. Schiffman SS, Sattely-Miller EA, Suggs MS, Graham BG. The effect of environmental odors emanating from commercial swine operations on the mood of nearby residents. Brain Res Bull 37:369–375 (1995).
201. Reynolds SJ, Clonniger KJ, Sonnenberg J, Thorne PS, Subramanian P, Thu K, Whitten P. Air quality assessments in the vicinity of swine production facilities. J Agromed 4:37–46 (1997).
202. Hunter-Filatovitch WR, Gilliland MW. Bacterial pollution in runoff from agricultural lands. J Environ Qual 17:27–34 (1988).
203. Peyton P. Presence of bacterial and animal viruses in surface and ground waters. Water Sci Tech 31:203–208 (1995).
204. Huffman RL, Shipitalo JW, Mooney AE, Daniels RB. Potential for pesticide contamination from agricultural chemicals in 1994 International Summer Meeting of the American Society of Agricultural Engineers, Kansas City, Missouri, 20–23 June 1994. St. Joseph, MI: American Society of Agricultural Engineers, 1994 paper 94-2093.
205. Campagnolo ER, Rubin CS. Leptospirosis.
206. CDC. National Center for Environmental Health. The Contemporary Animal Feeding Operation Workshop, 23–24 June 1998, Washington, DC. Atlanta: GA: Centers for Disease Control and Prevention, 1998.
207. Sweeney M. Human health effects of hog waste. NZ Med J 99:19–19 (1986).
208. Ashford DA, Bragg SL, Wiswell RE, Sanders EJ, Bunnell LR, Smotte L, Shah WJ, Zell ER, Perkins BA, Spiegel RA. Leptospirosis and rodents: recent experience at the National Center for Infectious Diseases [Abstract]. In: International Conference on Emerging Infectious Diseases, 8–11 March 1998, Atlanta, Georgia. Atlanta: GA: Centers for Disease Control and Prevention, 1998:135.
209. Mawdsley PL, Cassemore DP, Miller KB. Epidemiological aspects of human cryptosporidiosis and the role of waterborne transmission. Epidemiol Rev 16:116–136 (1994).
210. Wiggins B. Environmental analysis of antibiotic resistance patterns in fecal streptococci, a method to differentiate human and animal sources of fecal pollution in national waters. Appl Environ Microbiol 62:3997–4000 (1996).
211. Crosby H. Outbreak in Walkerton caused by nitrates in well water. JAMA 139:113–116 (1999).
212. Thu K, Donham K, Ziegenhorn R, Reynolds S, Thorne P, Subramanian P, Whitten P, Stookesberry J. A control study of the physical and mental health of residents living near a large-scale swine operation. J Agric Safety and Health 3:13–26 (1997).
213. Wing S, Wolf S. Intensive livestock operations, health and quality of life among African North Carolina neighbors. Environ Health Perspect 108:233–238 (2000).
214. Jacobs R. Environmental monitoring of antibiotics. Int J Occup Environ Health 3:S27–S41 (1997).
215. Hoewel J, Weisskopf P, Weilenmann A, Wegmann S, Gujer W. Influence of animal dust sampling and measurement methods on the measurement of endotoxin emissions. Appl Environ Microbiol 67:1353–1360 (1999).
216. Mason CA, Jenkins DA, Pyle JW. Environmental endotoxin measurement: interference and sources of variation in the Limulus assay of house dust. Am Ind Hyg Assoc J 56:901–907 (1995).
217. Jacobs R. Analysis of endotoxins. Int J Occup Environ Health 3:S42–S49 (1997).
218. Abbey DE, Arrowood MJ, Burkett WS, Colby DD, Jamison DD, Kaplan JE. Assessing the public health threat associated with ammonia cryptosporidium report of a workshop. Morbid Mortal Wkly Rep 44:1–19 (1995).
219. Antglis HM, Horn-Ricciotto I. The nursing concept of the healthy worker: summer effect. Epidemiology 5:169–196 (1994).
220. Checkoway H, Pearce NE, Crawford-Brown DJ. Research Methods in Occupational Epidemiology. New York: Oxfordd University Press, 1989.
221. Edwards B, Ludd A. Environmental justice, swine production and farm loss in North Carolina. Social Spectrum 20:1–24 (2000).
222. Ludd A, Edwards B. Swine before sparks: environmental justice and white opposition to corporate pork production in North Carolina. In: Race, Ethnicity, Class and Environmentalism (Bullard R, Johnson G, Taylor D, Halkin J, eds). New York: Rowman and Littlefield, in press.
223. Wing S, Cole D, Grant G. Environmental injustice in North Carolina's hog industry. Environ Health Perspect 108:225–231 (2000).
224. Avirbucrg GL, Porter RW. Trends in outpatient visits for infectious disease in the United States [Abstract]. In: International Conference on Emerging Infectious Diseases, 8–11 March 1998, Atlanta, Georgia. Atlanta: GA: Centers for Disease Control and Prevention, 1998:110.
225. Vugia DJ, Shallow S, Farley M, Marcus R, Shallow B, Angulo F. FOODNET: Salmonella incidence trends and characteristics, FoodNet 1996 [Abstract]. In: International Conference on Emerging Infectious Diseases, 8–11 March 1998, Atlanta, Georgia. Atlanta: GA: Centers for Disease Control and Prevention, 1998:83.
226. Ray S, Vugia D, Segler S, Kassa J, Shi F, Fiorentino T, Wickliffe J, Tenney J, Farley M. FOODNET: FoodNet active surveillance for foodborne parasitic infection [Abstract]. In: International Conference on Emerging Infectious Diseases, 8–11 March 1998, Atlanta, Georgia. Atlanta: GA: Centers for Disease Control and Prevention, 1998:83.
227. Thu K, Donnelsberger E, eds. Pigs, Profits, and Rural Communities. Albany, NY: State University of New York Press, 1998.
228. Hammerli EE, Heggener C, Stoll A. Odors of swine animal housing. Agric Ecosyst Environ 25:123–133 (1989).
229. Nenner W. Odor control of livestock wastes: state-of-the-art in North America. J Agric Eng Res 42:31–42 (1989).
230. O'Neill DH, Phillips VR. A review of the control of odor nuisance from livestock buildings: 3 properties of the odorous substances which have been identified in livestock wastes or the air around them. J Agric Eng Res 53:23–50 (1992).
231. Hammond EC, Fedler C, Smith RJ. Analysis of parameters affecting swine house odors. Agric Environ 5:235–251 (1981).
232. Hartung J. Chromatographic analysis of volatile fatty acids and phenolic/indolic compounds in pig house dust after ultrasonic extraction. Grunner Tierarztl Lett 9:21–28 (1983).
233. Hartung J. Tentative calculations of gaseous emissions from pig houses by way of the exhaust air. In: Odours Emissions from Livestock Farming and Sewage Operations (Nielsen VC, Voorburg JH, L'Hermite P, eds). New York: Elsevier Applied Science, 1988:54–58.
234. Hammond EG, Burcham P, Junk G, Kiorl J. Conditioning of swine house odors. In: Proceedings of the International Livestock Environment Symposium, 17–19 April 1994, University of Nebraska, Lincoln, Nebraska. St. Joseph, MI: American Society of Agricultural Engineers, 1994:364–375.
235. Sweeney S. Origin of objectionable odorous components in piggery wastes and the possibility of applying indicator components for studying odor development. Agric Environ 5:241–252 (1980).
236. Hammond EG, Smith RJ. Survey of some molecularly dispersed odorous constituents in swine house air. Iowa State J Res 55:387–399 (1981).
237. Moser JW, Kirk MD, Anderson AM. Identification and measurement of volatile components within a swine building and measurement of ammonia emission rates from manure covered surfaces. In: Third International Symposium on Livestock Wastes, 25–28 April 1971, University of Illinois, Urbana, Illinois. St. Joseph, MI: American Society of Agricultural Engineers, 1971:301–303.
238. Schaefer J. Sampling, characterization and analysis of emissions. Agric Environ 2:121–137 (1977).
239. Schaefer J, Wanner C. Emissionen von flüchtigen fettsäuren und anderen geruchsrelevanten komponenten. KTBL 4253. Zeist: The Netherlands: Centraal Instituut voor Landbouwpublicatie, 1991.
240. Mukhtar JA, Hassan TE, Mosier AR. Introduction of gases in a swine confinement atmosphere. Trans Am Soc Agric Eng 15:519–523 (1972).
241. Ramanathan L, Brenner JM. Microbiomass of odor gases evolved from animal manures. J Environ Qual 4:493–499 (1975).
242. Bertine KJ, Papendorf WJ. Ammonia levels of selected poultry industry confinement buildings. Am Ind Hyg Assoc J 46:698–661 (1985).
243. Hendrick D, van Zwieten R, Brouwer A. Acute shift lung function changes among pig farmers. Am J Ind Med 11:87–98 (1987).
244. Lindahlstjer K, Wittmann F, Kangas J, Tunia ED. Dust exposure in piggeries. Eur J Respir Dis 71:86–90 (1987).
245. Rosenstock W, Meinchen JA, Jannard G, Rommelaere JP, Dieterlen SA. Respiratory protection and acceptability among agricultural workers. Appl Occup Environ Hyg 13:809–820 (1998).
246. Preiser L, Rendbert, D, Kronmuller H, Bunzy J, Tomm MJM. Determinants of dust and endotoxin exposure of pig farmers: development of a control strategy using empirical modeling. Ann Occup Hyg 39:845–857 (1995).
247. Heinzow P, Wahlen BM. Endotoxin in exposures to dust and endotoxin in farmer piggeries. Am Ind Hyg Assoc J 53:237–241 (1992).
248. Impellitteri F, van der Schoor J, Folgering H, van Dijmerijk E. Longitudinal changes in lung function associated with aspects of swine confinement exposure. J Occup Environ Med 40:1000–1005 (1998).
249. Occupational Safety and Health Standards, 29 CFR Part 1910, Subpart Z. Toxic and Hazardous Substances. 1989.
250. American Conference of Governmental Industrial Hygienists. 1999 Threshold Limit Values for Chemical Substances and Physical Agents. Cincinnati: ISBN 1882416-1999.
251. NIOSH. NIOSH Pocket Guide to Chemical Hazards. Cincinnati, OH: National Institute for Occupational Safety and Health, 1997.

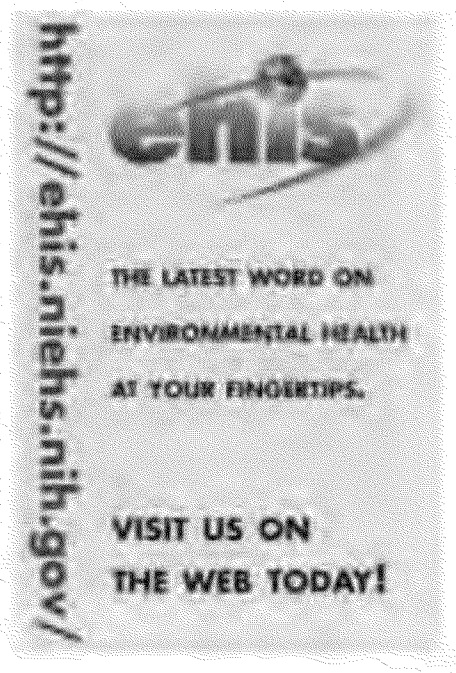

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Exhibit 40

environmental health

Understanding Concentrated Animal Feeding Operations and Their Impact on Communities

NALBOH

National Association of Local Boards of Health

Understanding Concentrated Animal Feeding Operations and Their Impact on Communities

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Foreword

The National Association of Local Boards of Health (NALBOH) is pleased to provide *Understanding Concentrated Animal Feeding Operations and Their Impact on Communities* to assist local boards of health who have concerns about concentrated animal feeding operations (CAFOs) or large industrial animal farms in their communities. The Environmental Health Services Branch of the Centers for Disease Control and Prevention (CDC), National Center for Environmental Health (NCEH) encouraged the development of this product and provided technical oversight and financial support. This publication was supported by Cooperative Agreement Number 5U38HM000512. Its contents are solely the responsibility of the authors and do not necessarily represent the official views of the CDC.

The mission of NALBOH is to strengthen boards of health, enabling them to promote and protect the health of their communities, through education, technical assistance, and advocacy. Boards of health are responsible for fulfilling three public health core functions: assessment, policy development, and assurance. For a health agency, this includes overseeing and ensuring that there are sufficient resources, effective policies and procedures, partnerships with other organizations and agencies, and regular evaluation of an agency's services.

NALBOH is confident that *Understanding Concentrated Animal Feeding Operations and Their Impact on Communities* will help local board of health members understand their role in developing ways to mitigate potential problems associated with CAFOs. We trust that the information provided in this guide will enable board of health members to develop and sustain monitoring programs, investigate developing policy related to CAFOs, and create partnerships with other local and state agencies and officials to improve the health and well-being of communities everywhere.

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Introduction

Livestock farming has undergone a significant transformation in the past few decades. Production has shifted from smaller, family-owned farms to large farms that often have corporate contracts. Most meat and dairy products now are produced on large farms with single species buildings or open-air pens (MacDonald & McBride, 2009). Modern farms have also become much more efficient. Since 1960, milk production has doubled, meat production has tripled, and egg production has quadrupled (Pew Commission on Industrial Animal Farm Production, 2009). Improvements to animal breeding, mechanical innovations, and the introduction of specially formulated feeds and animal pharmaceuticals have all increased the efficiency and productivity of animal agriculture. It also takes much less time to raise a fully grown animal. For example, in 1920, a chicken took approximately 16 weeks to reach 2.2 lbs., whereas now they can reach 5 lbs. in 7 weeks (Pew, 2009).

New technologies have allowed farmers to reduce costs, which mean bigger profits on less land and capital. The current agricultural system rewards larger farms with lower costs, which results in greater profit and more incentive to increase farm size.

AFO vs. CAFO

A CAFO is a specific type of large-scale industrial agricultural facility that raises animals, usually at high-density, for the consumption of meat, eggs, or milk. To be considered a CAFO, a farm must first be categorized as an animal feeding operation (AFO). An AFO is a lot or facility where animals are kept confined and fed or maintained for 45 or more days per year, and crops, vegetation, or forage growth are not sustained over a normal growing period (Environmental Protection Agency [EPA], 2009). CAFOs are classified by the type and number of animals they contain, and the way they discharge waste into the water supply. CAFOs are AFOs that contain at least a certain number of animals, or have a number of animals that fall within a range and have waste materials that come into contact with the water supply. This contact can either be through a pipe that carries manure or wastewater to surface water, or by animal contact with surface water that runs through their confined area. (See Appendix A)

History

AFOs were first identified as potential pollutants in the 1972 Clean Water Act. Section 502 identified “feedlots” as “point sources” for pollution along with other industries, such as fertilizer manufacturing. Consequently, a permit program entitled the National Pollutant Discharge Elimination System (NPDES) was created which set effluent limitation guidelines and standards (ELGs) for CAFOs. CAFOs have since been regulated by NPDES or a state equivalent since the mid-1970s. The definitions of what was considered an AFO or CAFO were created by the EPA for the NPDES process in 1976. These regulations remained in effect for more than 25 years, but increases and changes to farm size and production methods required an update to the permit system.

The regulations guiding CAFO permits and operations were revised in 2003. New inclusions in the 2003 regulations were that all CAFOs had to apply for a NPDES permit even if they only discharged in the event of a large storm. Large poultry operations were included in the regulations, regardless of their waste disposal system, and all CAFOs that held a NPDES permit were required to develop and implement a nutrient management plan. These plans had CAFOs identify ways to treat or process waste in a way that maintained nutrient levels at the appropriate amount.

The 2003 CAFO rule was subsequently challenged in court. A Second Circuit Court of Appeals decision required alteration to the CAFO permitting system. In *Water Keeper et al. vs. the EPA*, the court directed the EPA to remove the requirement for all CAFOs to apply for NPDES. Instead, the court required that nutrient management plans be submitted with the permit application, reviewed by officials and the public, and the terms of the plan be incorporated into the permit.

As a result of this court decision, the CAFO rule was again updated. The current final CAFO rule, which was revised in 2008, requires that only CAFOs which discharge or propose to discharge waste apply for permits. The EPA has also provided clarification in the discussion surrounding the rule on how CAFOs should assess whether they discharge or propose to discharge. There is also the opportunity to receive a no discharge certification for CAFOs that do not discharge or propose to discharge. This certification demonstrates that the CAFO is not required to acquire a permit. And while CAFOs were required to create nutrient management plans under the 2003 rule, these plans were now included with permit applications, and had a built-in time period for public review and comment.

Benefits of CAFOs

When properly managed, located, and monitored, CAFOs can provide a low-cost source of meat, milk, and eggs, due to efficient feeding and housing of animals, increased facility size, and animal specialization. When CAFOs are proposed in a local area, it is usually argued that they will enhance the local economy and increase employment. The effects of using local materials, feed, and livestock are argued to ripple throughout the economy, and increased tax expenditures will lead to increase funds for schools and infrastructure.

Environmental Health Effects

The most pressing public health issue associated with CAFOs stems from the amount of manure they produce. CAFO manure contains a variety of potential contaminants. It can contain plant nutrients such as nitrogen and phosphorus, pathogens such as *E. coli*, growth hormones, antibiotics, chemicals used as additives to the manure or to clean equipment, animal blood, silage leachate from corn feed, or copper sulfate used in footbaths for cows.

Depending on the type and number of animals in the farm, manure production can range between 2,800 tons and 1.6 million tons a year (Government Accountability Office [GAO], 2008). Large farms can produce more waste than some U.S. cities—a feeding operation with 800,000 pigs could produce over 1.6 million tons of waste a year. That amount is one and a half times more than the annual sanitary waste produced by the city of Philadelphia, Pennsylvania (GAO, 2008). Annually, it is estimated that livestock animals in the U.S. produce each year somewhere between 3 and 20 times more manure than people in the U.S. produce, or as much as 1.2–1.37 billion tons of waste (EPA, 2005). Though sewage treatment plants are required for human waste, no such treatment facility exists for livestock waste.

While manure is valuable to the farming industry, in quantities this large it becomes problematic. Many farms no longer grow their own feed, so they cannot use all the manure they produce as fertilizer. CAFOs must find a way to manage the amount of manure produced by their animals. Ground application of untreated manure is one of the most common disposal methods due to its low cost. It has limitations, however, such as the inability to apply manure while the ground is frozen. There are also limits as to how many nutrients from manure a land area can handle. Over application of livestock wastes can overload

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soil with macronutrients like nitrogen and phosphorous and micronutrients that have been added to animal feed like heavy metals (Burkholder et al., 2007). Other manure management strategies include pumping liquefied manure onto spray fields, trucking it off-site, or storing it until it can be used or treated. Manure can be stored in deep pits under the buildings that hold animals, in clay or concrete pits, treatment lagoons, or holding ponds.

Animal feeding operations are developing in close proximity in some states, and fields where manure is applied have become clustered. When manure is applied too frequently or in too large a quantity to an area, nutrients overwhelm the absorptive capacity of the soil, and either run off or are leached into the groundwater. Storage units can break or become faulty, or rainwater can cause holding lagoons to overflow. While CAFOs are required to have permits that limit the levels of manure discharge, handling the large amounts of manure inevitably causes accidental releases which have the ability to potentially impact humans.

The increased clustering and growth of CAFOs has led to growing environmental problems in many communities. The excess production of manure and problems with storage or manure management can affect ground and surface water quality. Emissions from degrading manure and livestock digestive processes produce air pollutants that often affect ambient air quality in communities surrounding CAFOs. CAFOs can also be the source of greenhouse gases, which contribute to global climate change.

All of the environmental problems with CAFOs have direct impact on human health and welfare for communities that contain large industrial farms. As the following sections demonstrate, human health can suffer because of contaminated air and degraded water quality, or from diseases spread from farms. Quality of life can suffer because of odors or insect vectors surrounding farms, and property values can drop, affecting the financial stability of a community. One study found that 82.8% of those living near and 89.5% of those living far from CAFOs believed that their property values decreased, and 92.2% of those living near and 78.9% of those living far from CAFOs believed the odor from manure was a problem. The study found that real estate values had not dropped and odor infestations were not validated by local governmental staff in the areas. However, the concerns show that CAFOs remain contentious in communities (Schmalzried and Fallon, 2007). CAFOs are an excellent example of how environmental problems can directly impact human and community well-being.

Groundwater

Groundwater can be contaminated by CAFOs through runoff from land application of manure, leaching from manure that has been improperly spread on land, or through leaks or breaks in storage or containment units. The EPA's 2000 National Water Quality Inventory found that 29 states specifically identified animal feeding operations, not just concentrated animal feeding operations, as contributing to water quality impairment (Congressional Research Service, 2008). A study of private water wells in Idaho detected levels of veterinary antibiotics, as well as elevated levels of nitrates (Batt, Snow, & Alga, 2006). Groundwater is a major source of drinking water in the United States. The EPA estimates that 53% of the population relies on groundwater for drinking water, often at much higher rates in rural areas (EPA, 2004). Unlike surface water, groundwater contamination sources are more difficult to monitor. The extent and source of contamination are often harder to pinpoint in groundwater than surface water contamination. Regular testing of household water wells for total and fecal coliform bacteria is a crucial element in monitoring groundwater quality, and can be the first step in discovering contamination issues related to CAFO discharge. Groundwater contamination can also affect surface water (Spellman &

Whiting, 2007). Contaminated groundwater can move laterally and eventually enter surface water, such as rivers or streams.

When groundwater is contaminated by pathogenic organisms, a serious threat to drinking water can occur. Pathogens survive longer in groundwater than surface water due to lower temperatures and protection from the sun. Even if the contamination appears to be a single episode, viruses could become attached to sediment near groundwater and continue to leach slowly into groundwater. One pollution event by a CAFO could become a lingering source of viral contamination for groundwater (EPA, 2005).

Groundwater can still be at risk for contamination after a CAFO has closed and its lagoons are empty. When given increased air exposure, ammonia in soil transforms into nitrates. Nitrates are highly mobile in soil, and will reach groundwater quicker than ammonia. It can be dangerous to ignore contaminated soil. The amount of pollution found in groundwater after contamination depends on the proximity of the aquifer to the CAFO, the size of the CAFO, whether storage units or pits are lined, the type of subsoil, and the depth of the groundwater.

If a CAFO has contaminated a water system, community members should be concerned about nitrates and nitrate poisoning. Elevated nitrates in drinking water can be especially harmful to infants, leading to blue baby syndrome and possible death. Nitrates oxidize iron in hemoglobin in red blood cells to methemoglobin. Most people convert methemoglobin back to hemoglobin fairly quickly, but infants do not convert back as fast. This hinders the ability of the infant's blood to carry oxygen, leading to a blue or purple appearance in affected infants. However, infants are not the only ones who can be affected by excess nitrates in water. Low blood oxygen in adults can lead to birth defects, miscarriages, and poor general health. Nitrates have also been speculated to be linked to higher rates of stomach and esophageal cancer (Bowman, Mueller, & Smith, 2000). In general, private water wells are at higher risk of nitrate contamination than public water supplies.

Surface Water

The agriculture sector, including CAFOs, is the leading contributor of pollutants to lakes, rivers, and reservoirs. It has been found that states with high concentrations of CAFOs experience on average 20 to 30 serious water quality problems per year as a result of manure management problems (EPA, 2001). This pollution can be caused by surface discharges or other types of discharges. Surface discharges can be caused by heavy storms or floods that cause storage lagoons to overfill, running off into nearby bodies of water. Pollutants can also travel over land or through surface drainage systems to nearby bodies of water, be discharged through manmade ditches or flushing systems found in CAFOs, or come into contact with surface water that passes directly through the farming area. Soil erosion can contribute to water pollution, as some pollutants can bond to eroded soil and travel to watersheds (EPA, 2001). Other types of discharges occur when pollutants travel to surface water through other mediums, such as groundwater or air.

Contamination in surface water can cause nitrates and other nutrients to build up. Ammonia is often found in surface waters surrounding CAFOs. Ammonia causes oxygen depletion from water, which itself can kill aquatic life. Ammonia also converts into nitrates, which can cause nutrient overloads in surface waters (EPA, 1998). Excessive nutrient concentrations, such as nitrogen or phosphorus, can lead to eutrophication and make water inhabitable to fish or indigenous aquatic life (Sierra Club Michigan Chapter, n.d.). Nutrient over-enrichment causes algal blooms, or a rapid increase of algae growth in an aquatic environment (Science Daily, n.d.). Algal blooms can cause a spiral of environmental problems to an aquatic system. Large groups of algae can block sunlight from underwater plant life, which are

habitats for much aquatic life. When algae growth increases in surface water, it can also dominate other resources and cause plants to die. The dead plants provide fuel for bacteria to grow and increased bacteria use more of the water's oxygen supply. Oxygen depletion once again causes indigenous aquatic life to die. Some algal blooms can contain toxic algae and other microorganisms, including *Pfiesteria*, which has caused large fish kills in North Carolina, Maryland, and the Chesapeake Bay area (Spellman & Whiting, 2007). Eutrophication can cause serious problems in surface waters and disrupt the ecological balance.

Water tests have also uncovered hormones in surface waters around CAFOs (Burkholder et al., 2007). Studies show that these hormones alter the reproductive habits of aquatic species living in these waters, including a significant decrease in the fertility of female fish. CAFO runoff can also lead to the presence of fecal bacteria or pathogens in surface water. One study showed that protozoa such as *Cryptosporidium parvum* and *Giardia* were found in over 80% of surface water sites tested (Spellman & Whiting, 2007). Fecal bacteria pollution in water from manure land application is also responsible for many beach closures and shellfish restrictions.

Air Quality

In addition to polluting ground and surface water, CAFOs also contribute to the reduction of air quality in areas surrounding industrial farms. Animal feeding operations produce several types of air emissions, including gaseous and particulate substances, and CAFOs produce even more emissions due to their size. The primary cause of gaseous emissions is the decomposition of animal manure, while particulate substances are caused by the movement of animals. The type, amount, and rate of emissions created depends on what state the manure is in (solid, slurry, or liquid), and how it is treated or contained after it is excreted. Sometimes manure is "stabilized" in anaerobic lagoons, which reduces volatile solids and controls odor before land application.

The most typical pollutants found in air surrounding CAFOs are ammonia, hydrogen sulfide, methane, and particulate matter, all of which have varying human health risks. Table 1 on page 6 provides information on these pollutants.

Most manure produced by CAFOs is applied to land eventually and this land application can result in air emissions (Merkel, 2002). The primary cause of emission through land application is the volatilization of ammonia when the manure is applied to land. However, nitrous oxide is also created when nitrogen that has been applied to land undergoes nitrification and denitrification. Emissions caused by land application occur in two phases: one immediately following land application and one that occurs later and over a longer period as substances in the soil break down. Land application is not the only way CAFOs can emit harmful air emissions—ventilation systems in CAFO buildings can also release dangerous contaminants. A study by Iowa State University, which was a result of a lawsuit settlement between the Sierra Club and Tyson Chicken, found that two chicken houses in western Kentucky emitted over 10 tons of ammonia in the year they were monitored (Burns et al., 2007).

Most studies that examine the health effects of CAFO air emissions focus on farm workers, however some have studied the effect on area schools and children. While all community members are at risk from lowered air quality, children take in 20-50% more air than adults, making them more susceptible to lung disease and health effects (Kleinman, 2000). Researchers in North Carolina found that the closer children live to a CAFO, the greater the risk of asthma symptoms (Barrett, 2006). Of the 226 schools that were included in the study, 26% stated that there were noticeable odors from CAFOs outdoors, while 8% stated

Table 1 Typical pollutants found in air surrounding CAFOs.

CAFO Emissions	Source	Traits	Health Risks
Ammonia	Formed when microbes decompose undigested organic nitrogen compounds in manure	Colorless, sharp pungent odor	Respiratory irritant, chemical burns to the respiratory tract, skin, and eyes, severe cough, chronic lung disease
Hydrogen Sulfide	Anaerobic bacterial decomposition of protein and other sulfur containing organic matter	Odor of rotten eggs	Inflammation of the moist membranes of eye and respiratory tract, olfactory neuron loss, death
Methane	Microbial degradation of organic matter under anaerobic conditions	Colorless, odorless, highly flammable	No health risks. Is a greenhouse gas and contributes to climate change.
Particulate Matter	Feed, bedding materials, dry manure, unpaved soil surfaces, animal dander, poultry feathers	Comprised of fecal matter, feed materials, pollen, bacteria, fungi, skin cells, silicates	Chronic bronchitis, chronic respiratory symptoms, declines in lung function, organic dust toxic syndrome

they experience odors from CAFOs inside the schools. Schools that were closer to CAFOs were often attended by students of lower socioeconomic status (Mirabelli, Wing, Marshall, & Wilcosky, 2006).

There is consistent evidence suggesting that factory farms increase asthma in neighboring communities, as indicated by children having higher rates of asthma (Sigurdarson & Kline, 2006; Mirabelli et al., 2006). CAFOs emit particulate matter and suspended dust, which is linked to asthma and bronchitis. Smaller particles can actually be absorbed by the body and can have systemic effects, including cardiac arrest. If people are exposed to particulate matter over a long time, it can lead to decreased lung function (Michigan Department of Environmental Quality [MDEQ] Toxics Steering Group [TSG], 2006). CAFOs also emit ammonia, which is rapidly absorbed by the upper airways in the body. This can cause severe coughing and mucous build-up, and if severe enough, scarring of the airways. Particulate matter may lead to more severe health consequences for those exposed by their occupation. Farm workers can develop acute and chronic bronchitis, chronic obstructive airways disease, and interstitial lung disease. Repeated exposure to CAFO emissions can increase the likelihood of respiratory diseases. Occupational asthma, acute and chronic bronchitis, and organic dust toxic syndrome can be as high as 30% in factory farm workers

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(Horrigan, Lawrence, & Walker, 2002). Other health effects of CAFO air emissions can be headaches, respiratory problems, eye irritation, nausea, weakness, and chest tightness.

There is evidence that CAFOs affect the ambient air quality of a community. There are three laws that potentially govern CAFO air emissions—the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA, also known as the Superfund Act), the Emergency Planning & Community Right to Know Act (EPCRA), and the Clean Air Act (CAA). However, the EPA passed a rule that exempts all CAFOs from reporting emissions under CERCLA. Only CAFOs that are classified as large are required to report any emission event of 100 pounds of ammonia or hydrogen sulfide or more during a 24-hour period locally or to the state under EPCRA (Michigan State University Extension, n.d.). The EPA has also instituted a voluntary Air Quality Compliance Agreement in which they will monitor some CAFO air emissions, and will not sue offenders but instead charge a small civil penalty. These changes have attracted criticism from environmental and community leaders who state that the EPA has yielded to influence from the livestock industry. The changes also leave ambiguity as to whether emission standards and air quality near CAFOs are being monitored.

Greenhouse Gas and Climate Change

Aside from the possibility of lowering air quality in the areas around them, CAFOs also emit greenhouse gases, and therefore contribute to climate change. Globally, livestock operations are responsible for approximately 18% of greenhouse gas production and over 7% of U.S. greenhouse gas emissions (Massey & Ulmer, 2008). While carbon dioxide is often considered the primary greenhouse gas of concern, manure emits methane and nitrous oxide which are 23 and 300 times more potent as greenhouse gases than carbon dioxide, respectively. The EPA attributes manure management as the fourth leading source of nitrous oxide emissions and the fifth leading source of methane emissions (EPA, 2009).

The type of manure storage system used contributes to the production of greenhouse gases. Many CAFOs store their excess manure in lagoons or pits, where they break down anaerobically (in the absence of oxygen), which exacerbates methane production. Manure that is applied to land or soil has more exposure to oxygen and therefore does not produce as much methane. Ruminant livestock, such as cows, sheep, or goats, also contribute to methane production through their digestive processes. These livestock have a special stomach called a rumen that allows them to digest tough grains or plants that would otherwise be unusable. It is during this process, called enteric fermentation, that methane is produced. The U.S. cattle industry is one of the primary methane producers. Livestock production and meat and dairy consumption has been increasing in the United States, so it can only be assumed that these greenhouse gas emissions will also rise and continue to contribute to climate change.

Odors

One of the most common complaints associated with CAFOs are the odors produced. The odors that CAFOs emit are a complex mixture of ammonia, hydrogen sulfide, and carbon dioxide, as well as volatile and semi-volatile organic compounds (Heederik et al., 2007). These odors are worse than smells formerly associated with smaller livestock farms. The anaerobic reaction that occurs when manure is stored in pits or lagoons for long amounts of time is the primary cause of the smells. Odors from waste are carried away from farm areas on dust and other air particles. Depending on things like weather conditions and farming techniques, CAFO odors can be smelled from as much as 5 or 6 miles away, although 3 miles is a more common distance (State Environmental Resource Center, 2004).

Because CAFOs typically produce malodors, many communities want to monitor emissions and odors. Quantifying odor from industrial farming can be challenging because it is a mixture of free and particle-bound compounds, which can make it hard to identify what specifically is causing the odor. Collecting data on specific gases, such as hydrogen sulfide, can be used as a proxy for odor levels.

CAFO odors can cause severe lifestyle changes for individuals in the surrounding communities and can alter many daily activities. When odors are severe, people may choose to keep their windows closed, even in high temperatures when there is no air conditioning. People also may choose to not let their children play outside and may even keep them home from school. Mental health deterioration and an increased sensitization to smells can also result from living in close proximity to odors from CAFOs. Odor can cause negative mood states, such as tension, depression, or anger, and possibly neurophysciatric abnormalities, such as impaired balance or memory. People who live close to factory farms can develop CAFO-related post traumatic stress disorder, including anxiety about declining quality of life (Donham et al., 2007).

Ten states use direct regulations to control odors emitted by CAFOs. They prohibit odor emissions greater than a set standard. States with direct regulations use scentometers, which measure how many times an odor has to be doused with clean air before the smell is undetectable. An additional 34 states have indirect methods to reduce CAFO odors. These include: setbacks, which specify how far CAFO structures have to be from other buildings; permits, which are the most typical way of regulating CAFOs; public comment or involvement periods; and operator or manure placement training.

Insect Vectors

CAFOs and their waste can be breeding grounds for insect vectors. Houseflies, stable flies, and mosquitoes are the most common insects associated with CAFOs. Houseflies breed in manure, while stable and other flies breed in decaying organic material, such as livestock bedding. Mosquitoes breed in standing water, and water on the edges of manure lagoons can cause mosquito infestations to rise. Flies can change from eggs to adults in only 10 days, which means that substances in which flies breed need to be cleaned up regularly.

Flies are typically considered only nuisances, although insects can agitate livestock and decrease animal health. The John Hopkins Bloomberg School of Public Health found evidence that houseflies near poultry operations may contribute to the dispersion of drug-resistant bacteria (Center for Livable Future, 2009). Since flies are attracted to and eat human food, there is a potential for spreading bacteria or pathogens to humans, including microbes that can cause dysentery and diarrhea (Bowman et al., 2000). Mosquitoes spread zoonotic diseases, such as West Nile virus, St. Louis encephalitis, and equine encephalitis.

Residences closest to the feeding operations experience a much higher fly population than average homes. To lower the rates of insects and any accompanying disease threats, standing water should we cleaned or emptied weekly, and manure or decaying organic matter should be removed twice weekly (Purdue Extension, 2007). For more specific insect vector information, please refer to NALBOH's vector guide (*Vector Control Strategies for Local Boards of Health*).

Pathogens

Pathogens are parasites, bacterium, or viruses that are capable of causing disease or infection in animals or humans. The major source of pathogens from CAFOs is in animal manure. There are over 150 pathogens in manure that could impact human health. Many of these pathogens are concerning because

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they can cause severe diarrhea. Healthy people who are exposed to pathogens can generally recover quickly, but those who have weakened immune systems are at increased risk for severe illness or death. Those at higher risk include infants or young children, pregnant women, the elderly, and those who are immunosuppressed, HIV positive, or have had chemotherapy. This risk group now roughly compromises 20% of the U.S. population.

Table 2 Select pathogens found in animal manure.

Pathogen	Disease	Symptoms
Bacillus anthracis	Anthrax	Skin sores, headache, fever, chills, nausea, vomiting
Escherichia coli	Colibacilosis, Coliform mastitis-metris	Diarrhea, abdominal gas
Leptospira pomona	Leptospirosis	Abdominal pain, muscle pain, vomiting, fever
Listeria monocytogenes	Listerosis	Fever, fatigue, nausea, vomiting, diarrhea
Salmonella species	Salmonellosis	Abdominal pain, diarrhea, nausea, chills, fever, headache
Clostirdum tetani	Tetanus	Violent muscle spasms, lockjaw, difficulty breathing
Histoplasma capsulatum	Histoplasmosis	Fever, chills, muscle ache, cough rash, joint pain and stiffness
Microsporum and *Trichophyton*	Ringworm	Itching, rash
Giardia lamblia	Giardiasis	Diarrhea, abdominal pain, abdominal gas, nausea, vomiting, fever
Cryptosporidium species	Cryptosporidosis	Diarrhea, dehydration, weakness, abdominal cramping

Sources of infection from pathogens include fecal-oral transmission, inhalation, drinking water, or incidental water consumption during recreational water activities. The potential for transfer of pathogens among animals is higher in confinement, as there are more animals in a smaller amount of space. Healthy or asymptomatic animals may carry microbial agents that can infect humans, who can then spread that infection throughout a community, before the infection is discovered among animals.

When water is contaminated by pathogens, it can lead to widespread outbreaks of illness. Salmonellosis, cryptosporidiosis, and giardiasis can cause nausea, vomiting, fever, diarrhea, muscle pain, and death, among other symptoms. *E.coli* is another serious pathogen, and can be life-threatening for the young, elderly, and immunocompromised. It can cause bloody diarrhea and kidney failure. Since many CAFO use sub-therapeutic antibiotics with their animals, there is also the possibility that disease-resistant bacteria can emerge in areas surrounding CAFOs. Bacteria that cannot be treated by antibiotics can have very serious effects on human health, potentially even causing death (Pew Charitable Trusts, n.d.).

There is also the possibility of novel (or new) viruses developing. These viruses generate through mutation or recombinant events that can result in more efficient human-to-human transmission. There has been some speculation that the novel H1N1 virus outbreak in 2009 originated in swine CAFOs in Mexico. However, that claim has never been substantiated. CAFOs are not required to test for novel viruses, since they are not on the list of mandatory reportable illness to the World Organization for Animal Health.

Antibiotics

Antibiotics are commonly administered in animal feed in the United States. Antibiotics are included at low levels in animal feed to reduce the chance for infection and to eliminate the need for animals to expend energy fighting off bacteria, with the assumption that saved energy will be translated into growth. The main purposes of using non-therapeutic doses of antimicrobials in animal feed is so that animals will grow faster, produce more meat, and avoid illnesses. Supporters of antibiotic use say that it allows animals to digest their food more efficiently, get the most benefit from it, and grow into strong and healthy animals.

The trend of using antibiotics in feed has increased with the greater numbers of animals held in confinement. The more animals that are kept in close quarters, the more likely it is that infection or bacteria can spread among the animals. Seventy percent of all antibiotics and related drugs used in the U.S. each year are given to beef cattle, hogs, and chickens as feed additives. Nearly half of the antibiotics used are nearly identical to ones given to humans (Kaufman, 2000).

There is strong evidence that the use of antibiotics in animal feed is contributing to an increase in antibiotic-resistant microbes and causing antibiotics to be less effective for humans (Kaufman, 2000). Resistant strains of pathogenic bacteria in animals, which can be transferred to humans thought the handling or eating of meat, have increased recently. This is a serious threat to human health because fewer options exist to help people overcome disease when infected with antibiotic-resistant pathogens. The antibiotics often are not fully metabolized by animals, and can be present in their manure. If manure pollutes a water supply, antibiotics can also leech into groundwater or surface water.

Because of this concern for human health, there is a growing movement to eliminate the non-therapeutic use of antibiotics with animals. In 2001, the American Medical Association approved a resolution to ban all low-level use of antibiotics. The USDA has developed guidelines to limit low-level use, and some major meat buyers (such as McDonald's) have stopped using meat that was given antibiotics that are also used for humans. The World Health Organization is also widely opposed to the use of antibiotics, calling for a cease of their low-level use in 2003. Some U.S. legislators are seeking to ban the routine use of antibiotics with livestock, and there has been legislation proposed to solidify a ban. The Preservation of Antibiotics for Medical Treatment Act (PAMTA), which was introduced in 2009, has the support of over 350 health,

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consumer, and environmental groups (H.R. 1549/S. 619). The act, if passed, would ban seven classes of antibiotics important to human health from being used in animals, and would restrict other antibiotics to therapeutic and some preventive uses.

Other Effects – Property Values

Most landowners fear that when CAFOs move into their community their property values will drop significantly. There is evidence that CAFOs do affect property values. The reasons for this are many: the fear of loss of amenities, the risk of air or water pollution, and the increased possibility of nuisances related to odors or insects. CAFOs are typically viewed as a negative externality that can't be solved or cured. There may be stigma that is attached to living by a CAFO.

The most certain fact regarding CAFOs and property values are that the closer a property is to a CAFO, the more likely it will be that the value of the property will drop. The exact impact of CAFOs fluctuates depending on location and local specifics. Studies have found differing results of rates of property value decrease. One study shows that property value declines can range from a decrease of 6.6% within a 3-mile radius of a CAFO to an 88% decrease within 1/10 of a mile from a CAFO (Dakota Rural Action, 2006). Another study found that property value decreases are negligible beyond 2 miles away from a CAFO (Purdue Extension, 2008). A third study found that negative effects are largest for properties that are downwind and closest to livestock (Herriges, Secchi, & Babcock, 2005). The size and type of the feeding operation can affect property value as well. Decreases in property values can also cause property tax rates to drop, which can place stress on local government budgets.

Considerations for Boards of Health

Right-to-Farm Laws

With all of the potential environmental and public health effects from CAFOs, community members and health officials often resort to taking legal action against these industrial animal farms. However, there are some protections for farms in place that can make lawsuits hard to navigate. Right-to-farm laws were created to address conflicts between farmers and non-farming neighbors. They seek to override common laws of nuisance, which forbid people to use their property in ways that are harmful to others, and protect farmers from unreasonable controls on farming.

All 50 states have some form of right-to-farm laws, but most only offer legal protections to farms if they meet certain specifications. Generally, they must be in compliance with all environmental regulations, be properly run, and be present in a region first before suburban developments, often a year before the plaintiff moves to that area. These right-to-farm laws were originally created in the late 1970s and early 1980s to protect family farms from suburban sprawl, at a time when large industrial farms were not the norm. As industrial farms grew in size and number, the agribusiness industry lobbied for and achieved the passage of stricter laws in the 1990s, many of which are now being challenged in court by homeowners and small family farmers. Opponents to these laws argue that they deprive them of their use of property and therefore violate the Fifth Amendment to the Constitution.

Some state courts have overturned their strict right-to-farm laws, such as Iowa, Michigan, Minnesota, and Kansas. Others such as Vermont have rewritten their laws. Vermont's updated right-to-farm bill

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protects established farm practices as long as there is not a substantial adverse effect on health, safety, or welfare.

Boards of health need to be aware of what legal protection their state offers farms. Right-to-farm laws can hinder nuisance complaints brought about by community members. State laws can prevent local government or health officials from regulating industrial farms.

Board of Health Involvement with CAFOs

Boards of health are responsible for fulfilling the three public health core functions: assessment, policy development, and assurance. Boards of health can fulfill these functions through addressing problems stemming from CAFOs in their communities. Specific public health services that can tackled regarding CAFOs include monitoring health status, investigating health problems, developing policies, enforcing regulations, informing and educating people about CAFOs, and mobilizing community partnerships to spread awareness about environmental health issues related to CAFOs.

Assessment: Board of health members should ensure that there is an effective method in place for collecting and tracking public complaints about CAFOs and large animal farms. Since environmental health specialists at local health departments are often responsible for investigating complaints, the board of health must take measures to ensure that they are properly trained and educated about CAFOs. It is possible that the board of health may be responsible or choose to do some investigations itself. Schmalzried and Fallon (2008) advocate that local health districts adopt a proactive approach for addressing public concerns about CAFOs, stating that health districts can offer some services that may help ease public frustration with CAFOs. A fly trapping program can establish a baseline for the average number of flies present prior to the start-up of CAFOs or large animal farms, which can then establish if a fly nuisance exists in the area. Testing for water quality and quantity can provide evidence if CAFOs are suspected of affecting private water supplies. Boards of health can also monitor exposure incidences that occur in emergency rooms to determine if migrant or farm workers are developing any adverse health conditions as a result of their work environments. Establishing these programs benefit both members of the community and provide information to future animal farm operators, and local boards of health should recommend them if they've been receiving complaints about CAFOs.

Policy Development: Boards of health in many states can adopt health-based regulations about CAFOs, however, they may be met with some resistance. Humbolt County, Iowa, adopted four health-based ordinances concerning CAFOs that became models for regulations in other states, but the Iowa Supreme Court ruled the ordinances were irreconcilable with state laws. Boards of health that choose to regulate CAFOs can also be subject to pressure from outside forces, including possible lawsuits or withdrawal of funding. Boards of health should also consider working with other local officials to institute regulations on CAFOs, such as zoning ordinances.

Assurance: Boards of health can execute the assurance function by advocating for or educating about better environmental practices with CAFOs. Board members may receive complaints from the public about CAFOs, and boards can hold public meetings to receive complaints and hear public testimony about farms. If boards of health are not capable of regulating industrial farms in their communities, they can still try to collaborate with other local agencies that have jurisdiction. Board of health members can educate other local agencies and public officials about CAFOs and spread awareness about the environmental and health hazards. They can request a public hearing with the permitting agency of the

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CAFO to express their concerns about the potential health effects. They can also work with agricultural and farm representatives to teach better environmental practices and pollution reduction techniques.

In many states, boards of health are empowered to adopt more stringent rules than the state law if it is necessary to protect public health. Board of health members should examine their state laws before they take any action regarding CAFOs to determine the most appropriate course of action. Any process should include an investigative period to gather evidence, public hearings, and a time for public review of draft policies.

Board of Health Case Studies

Tewksbury Board of Health, Massachusetts

Locals have complained about Krochmal Farms, a pig farm, for many years, but complaints have increased recently. The addition of a hog finishing facility to the farm coincided with the time that community member complaints grew. Most complaints are centered on the odor coming from the farm. The complaints were originally just logged when phone calls were received; however, the health department added a data tracking system as the number of complaints increased. After a complaint is received, the sanitarian or health director does a site visit to investigate.

The health director in Tewksbury filed an order of prohibition against the farm, which is allowed under Massachusetts law 111, section 143, for anything that threatens public health. The order of prohibition was appealed and the matter was taken to the board of health for a grievance hearing. The board of health hearing included months of testimony about the pig farm. The board of health is also doing a site assignment, which determines if a location is appropriate for treating, storing, or disposing of waste, including agricultural waste. The site assignment process includes both the Department of Environmental Protection (DEP) and the local board of health. The board of health holds a public hearing process, while the DEP reviews the site assignment application. The board of health grants the site assignment only if it is concurrently approved by the DEP.

The health director in Tewksbury points out that the only laws the board of health is able to regulate the farm under are nuisance laws. There have been efforts by the community to do a home rule petition to address the air quality and pest management complaints. The home rule petition is currently working its way through the Massachusetts state house. The status of the petition is unknown.

The board of health has tried to work directly with the pig farm to manage complaints. The farm contains manure composting facilities and the health district has requested advance notice to warn the community before manure is treated or applied to the soil. The farm has adopted a new manure management system. This system uses Rapp technology to control odors and reduce ammonia and hydrogen sulfide levels. However, questions still remain as to whether this addition will fully solve the odor issue. Typically, systems using Rapp technology include an oil cap that floats on manure holding pools and helps seal odors inside. These techniques have been researched and proven to reduce odors. However, the Tewksbury farm did not install the oil cap, and it is unknown whether the exclusion of the cap will hinder the technology's ability to reduce odors.

The complaints about the farm primarily concern the odor that emanates from the farm. The complaints do include mention of health side effects, including nausea and burning eyes. The health director has also heard concerns about potential environmental effects from the pig manure. Community members are

worried the manure runoff is entering and contaminating Sutton Brook, since there has been flooding in that area. There has been no confirmation of this occurring. The board of health is aware that the farm has a nutrient management plan, but they are not allowed to request and find out what is incorporated in that plan.

The Tewksbury piggery is technically not classified as a CAFO, though it is believed to be the largest pig farm in the commonwealth of Massachusetts. The area around it has become densely populated and the community members state that they just want to live peacefully with the farm. The board of health has submitted multiple grant applications to study the health effects associated with the farm. After the site assignment process is complete, the board of health will decide how it will regulate the farm. At the beginning of 2010, the board of health was still working on drafting regulations for the pig farms.

Wood County Board of Health, Ohio

Wood County, Ohio, contains two existing large dairy farms, both of which were proposed in 2001 to be expanded to over 1500 cows each. It is also the site for three other proposed dairy farms. There is a large community effort that supports restricting the operation and expansion of these farms, mainly represented by the community group Wood County Citizens Opposed to Factory Farms. The Wood County Board of Health became involved in investigating these dairy farms through this community group and other local officials. The Trustees of Liberty Township requested assistance from the Wood County Board of Health in supporting a moratorium on factory farm operations until local regulations were in effect. The trustees believed that manure runoff from the farms could contaminate local waterways, lower the ground water table, increase the presence of insect vectors, and devalue local properties.

The Wood County Health Director, in cooperation with the board of health, contacted nearby counties to determine what actions they had taken against farms in their communities. While the health director and board of health investigated action in the form of a nuisance regulation against the farms, they were advised that nuisance lawsuits filed against farms in Ohio were held to a tough standard, and they would be forced to demonstrate with scientific proof that the farms have a substantial adverse effect on health. They found that no other board of health in Ohio had opted to regulate farming operations and relied on the enforcement of existing state laws.

The board of health held a public forum to hear public opinion regarding the industrial farms. Ultimately, the Wood County Board of Health took actions other than regulations to help protect the health and environment of its community. They helped community members protect the safety of their water wells by offering free and low cost water well testing and inspections. They tested area ditch and water ways for fecal coliform bacteria, phosphorous, and nitrates to monitor the impact of farm runoff. They also purchased fly traps to monitor and count fly types to determine if the farms have caused an increase in insect vectors. Board of health members also met with state officials from the Ohio EPA in an effort to facilitate cooperation regarding the factory farms. While the Wood County Board of Health and Health Department chose not to institute any local regulations, they continue to monitor the situation and respond to community complaints.

Cerro Gordo County Board of Health, Iowa

Officials in Cerro Gordo County, Iowa, began looking into regulating animal feeding operations after the number of hog farms in Iowa started to grow. Floods in North Carolina and new regulations in Colorado meant that many hog farms began relocating to Iowa. Many citizens had concerns over the effects of

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CAFOs, and the Iowa State Association of Counties wanted to review air quality issues. Officials in Cerro Gordo County originally began working on a regulation that required inspections and was based on public health concerns, since farms were already exempt from any regulations related to zoning. However, Iowa state senators soon introduced legislation that passed and prevented any animal feeding operations from being regulated from a public health angle as well.

As Iowans were now prevented from regulating animal feeding operations in terms of zoning or public health, officials in Cerro Gordo County decided to place a moratorium on the construction of new animal feeding operations in that county. They wanted to temporarily stop the growth of animal feeding operations until they could get better science about their effects. Cerro Gordo County Ordinance #40, the "Animal Confinement Moratorium Ordinance," went into effect on May 14, 2002. Since the moratorium did not address public health or zoning, officials were able to get around the rules and still have a way to temporarily control animal feeding operation growth in their county. The ordinance placed "a 1-year moratorium on any new construction, expansion, or activity occurring on land used for the production, care, feeding, or housing of animals." The ordinance also afforded "local public health officials adequate time to appropriately assess health and environmental concerns that may be related to confined animal feeding operations and concentration of animals; establish objective measurable standards of enforcement; exercise the Board of Health's responsibility to protect and improve the health of the public; refrain from impacting farm operators unfairly; and provide penalties for violations of the provisions hereof pursuant to Chapter 137, Code of Iowa" (Cerro Gordo County, 2002).

The moratorium was first adopted by the Cerro Gordo County Board of Health. It was then presented to the county board of supervisors by the health director on behalf of the board of health. Before the board of health adopted the moratorium, they held an investigative meeting in which representatives from the Iowa Farm Bureau and other industry spokespeople exchanged opinions on the issue of animal feeding operations. The moratorium was created through a collaboration between local and county officials—health department staff, the board of health, and the board of supervisors. The moratorium did not receive any help or backing from state officials, who were concerned about the political nature of the ordinance. However it did receive backing from a *Globe Gazette* editorial.

The moratorium was immediately met with resistance from state officials. The Cerro Gordo County Board of Supervisors was contacted by a local legislator, and the Iowa Farm Bureau stated they would challenge the county budget. The Iowa Farm Bureau threatened to take the county to court. There were concerns over the cost of a court trial, which was estimated to be as high as $60,000. The county attorney doubted the legality of the moratorium and ultimately recommended removing it. The moratorium was in effect until June of 2005, when it was repealed by the county board of supervisors.

Since the moratorium was repealed there have been a few hog farms built in Cerro Gordo County, but the decline in pork prices has prevented any large growth of hog farms. Health officials believe that if the county had not implemented the animal confinement moratorium, there would have been many more farms built in their county, since many hog farms were built in counties south of Cerro Gordo County. There is now a process for siting new animal confinement operations in Iowa that uses a Master Matrix scoring system. The Cerro Gordo County Board of Supervisors tracks the Master Matrix system, but so far no animal feeding operations in Iowa who have applied using this system have been denied the right to build.

Conclusion

Concentrated animal feeding operations or large industrial animal farms can cause a myriad of environmental and public health problems. While they can be maintained and operated properly, it is important to ensure that they are routinely monitored to avoid harm to the surrounding community. While states have differing abilities to regulate CAFOs, there are still actions that boards of health can and should take. These actions can be as complex as passing ordinances or regulations directed at CAFOs or can be simply increasing water and air quality testing in the areas surrounding CAFOs. Since CAFOs have such an impact locally, boards of health are an appropriate means for action. Boards of health should take an active role with CAFOs, including collaboration with other state and local agencies, to mitigate the impact that CAFOs or large industrial farms have on the public health of their communities.

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Appendix A: Regulatory Definitions of Large CAFOs, Medium CAFOs, and Small CAFOs

Animal Sector	Size Thresholds (number of animals)		
	Large CAFOs	Medium CAFOs[1]	Small CAFOs[2]
Cattle or cow/calf pairs	1,000 or more	300-999	Less than 300
Mature dairy cattle	700 or more	200-699	Less than 200
Veal calves	1,000 or more	300-999	Less than 300
Swine (over 55 pounds)	2,500 or more	750-2,500	Less than 750
Swine (under 55 pounds)	10,000 or more	3,000-9,999	Less than 3,000
Horses	500 or more	150-499	Less than 150
Sheep or lambs	10,000 or more	3,000-9,999	Less than 3,000
Turkeys	55,000 or more	16,500-54,999	Less than 16,500
Laying hens or broilers[3]	30,000 or more	9,000-29,999	Less than 9,000
Chickens other than laying hens[4]	125,000 or more	37.500-124,999	Less than 37,500
Laying hens[4]	82,000 or more	25,000-81,999	Less than 25,000
Ducks[4]	30,000 or more	10,000-29,999	Less than 10,000
Ducks[3]	5,000 or more	1,500-4,999	Less than 1,500

Data: Environmental Protection Agency

1 Must also meet one of two “method of discharge” criteria to be defined as a CAFO or must be designated.

2 Never a CAFO by regulatory definition, but may be designated as a CAFO on a case-by-case basis.

3 Liquid manure handling system

4 Other than a liquid manure handling system

Appendix B: Additional Resources

American Public Health Association. *Precautionary moratorium on new concentrated animal feed operations*. http://www.apha.org/advocacy/policy/policysearch/default.htm?id=1243

Center for a Livable Future. http://www.livablefutureblog.com/

Environmental Health Sciences Research Center. *Iowa concentrated animal feeding operation air quality study*. http://www.public-health.uiowa.edu/ehsrc/CAFOstudy.htm

Environmental Protection Agency. *Animal feeding operations*. http://cfpub.epa.gov/npdes/home.cfm?program_id=7

Food and Water Watch. http://www.foodandwaterwatch.org/

Impacts of CAFOs on Rural Communities. http://web.missouri.edu/ikerdj/papers/Indiana%20--%20CAFOs%20%20Communities.htm#_ftn1

Land Stewardship Project. http://www.landstewardshipproject.org/index.html

Midwest Environmental Advocates. http://www.midwestadvocates.org/

National Agriculture Law Center. *Animal feeding operations reading room*. http://www.nationalaglawcenter.org/readingrooms/afos

National Association of Local Boards of Health. *Vector control strategies for local boards of health*. http://www.nalboh.org/publications.htm

Pew Charitable Trusts. *Human health and industrial farming*. http://www.saveantibiotics.org/index.html

Pew Commission on Industrial Animal Farm Production. http://www.ncifap.org/

Purdue Extension. *Concentrated animal feeding operations*. http://www.ansc.purdue.edu/CAFO/

State Environmental Resource Center. http://serconline.org

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References

Barrett, J.R. (2006). Hogging the air: CAFO emissions reach into schools. *Environmental Health Perspectives 114*(4), A241. Retrieved from http://ehp03.niehs.nih.gov/article/info%3Adoi%2F10.1289%2Fehp.114-a241a

Batt, A.L., Snow, D.D., & Aga, D.S. (2006). Occurrence of sulfonamide antimicrobials in private water wells in Washington County, Idaho, USA. *Chemosphere, 64*(11), 1963–1971. Retrieved from http://digitalcommons.unl.edu/cgi/viewcontent.cgi?article=1017&context=watercenterpubs

Bowman, A., Mueller, K., & Smith, M. (2000). *Increased animal waste production from concentrated animal feeding operations (CAFOs): Potential implications for public and environmental health*. Nebraska Center for Rural Health Research. Retrieved from http://www.unmc.edu/rural/documents/cafo-report.pdf

Burkholder, J., Libra, B., Weyer, P., Heathcote, S., Kolpin, D., Thorne, P., et al. (2007). Impacts of waste from concentrated animal feeding operations on water quality. *Environmental Health Perspectives, 11*(2), 308–312. Retrieved from http://www.ncbi.nlm.nih.gov/pmc/articles/PMC1817674/pdf/ehp0115-000308.pdf

Burns, R., Xin, H., Gates, R., Li, H., Hoff, S., Moody, L., et al. (2007). *Tyson broiler ammonia emission monitoring project: Final report*. Retrieved from http://www.sierraclub.org/environmentallaw/lawsuits/docs/ky-tysonreport.pdf

Center for Livable Future. (2009). *Flies may spread drug-resistant bacteria from poultry operations*. Retrieved from http://www.livablefutureblog.com/2009/03/flies-may-spread-drug-resistant-bacteria-from-poultry-operations/

Cerro Gordo County, Iowa. (2002). *Ordinance #40: Animal confinement moratorium ordinance*. Retrieved from http://www.cghealth.net/pdf/AnimalConfinementMoratoriumOrdinance.pdf

Congressional Research Service. (2008). *Animal waste and water quality: EPA regulation of concentrated animal feeding operations (CAFOs)*. Retrieved from http://www.nationalaglawcenter.org/assets/crs/RL31851.pdf

Dakota Rural Action. (2006). *CAFO economic impact*. Retrieved from http://www.dakotarural.org/index.php?option=com_content&view=article&id=17&Itemid=30

Donham, K.J., Wing, S., Osterberg, D., Flora, J.L., Hodne, C., Thu, K.M., et al. (2007). Community health and socioeconomic issues surrounding CAFOs. *Environmental Health Perspectives 115*(2), 317–320. Retrieved from http://www.ncbi.nlm.nih.gov/pmc/articles/PMC1817697/pdf/ehp0115-000317.pdf

Environmental Protection Agency. (1998). *Environmental impacts of animal feeding operations*. Retrieved from http://www.epa.gov/waterscience/guide/feedlots/envimpct.pdf

ED_001369_00043779-00043

Environmental Protection Agency. (2001). *Environmental assessment of proposed revisions to the national pollutant discharge elimination system regulation and the effluent guidelines for concentrated animal feeding operations*. Available from http://cfpub.epa.gov/npdes/docs.cfm?view=archivedprog&program_id=7&sort=name

Environmental Protection Agency. (2004). *Water on tap: A consumer's guide to the nation's drinking water*. Retrieved from http://permanent.access.gpo.gov/lps21800/www.epa.gov/safewater/wot/wheredoes.html

Environmental Protection Agency. (2005). *Detecting and mitigating the environmental impact of fecal pathogens originating from confined animal feeding operations: Review*. Retrieved from http://www.farmweb.org/Articles/Detecting%20and%20Mitigating%20the%20Environmental%20Impact%20of%20Fecal%20Pathogens%20Originating%20from%20Confined%20Animal%20Feeding%20Operations.pdf

Environmental Protection Agency. (2009). *Animal feeding operations*. Retrieved from http://cfpub.epa.gov/npdes/home.cfm?program_id=7

Environmental Protection Agency. (2009). *Inventory of U.S. greenhouse gas emissions and sinks: 1990-2007*. Retrieved from http://epa.gov/climatechange/emissions/usinventoryreport.html

Government Accountability Office. (2008). *Concentrated animal feeding operations: EPA needs more information and a clearly defined strategy to protect air and water quality from pollutants of concern*. Retrieved from http://www.gao.gov/new.items/d08944.pdf

Heederik, D., Sigsgaard, T., Thorne, P.S., Kline, J.N., Avery, R., Bønløkke, et al. (2007). Health effects of airborne exposures from concentrated animal feeding operations. *Environmental Health Perspectives, 115*(2), 298–302. Retrieved from http://www.ncbi.nlm.nih.gov/pmc/articles/PMC1817709/pdf/ehp0115-000298.pdf

Herriges, J.A., Secchi, S., & Babcock, B.A. (2005). Living with hogs in Iowa: The impact of livestock facilities on rural residential property values. *Land Economics*, 81, 530–545.

Horrigan, L., Lawrence, R.S., & Walker, P. (2002). How sustainable agriculture can address the environmental and human health harms of industrial agriculture. *Environmental Health Perspectives, 110*(5), 445–456. Retrieved from http://ehpnet1.niehs.nih.gov/members/2002/110p445-456horrigan/EHP110p445PDF.PDF

Kaufman, M. (2000). Worries rise over effect of antibiotics in animal feed; Humans seen vulnerable to drug-resistant germs. *Washington Post*, p. A01. Retrieved from http://www.upc-online.org/000317wpost_animal_feed.html

Kleinman, M. (2000). *The health effects of air pollution on children*. Retrieved from http://www.aqmd.gov/forstudents/health_effects_on_children.pdf

MacDonald, J.M. and McBride, W.D. (2009). *The transformation of U.S. livestock agriculture: Scale, efficiency, and risks*. United States Department of Agriculture. Retrieved from http://www.ers.usda.gov/Publications/EIB43/EIB43.pdf

Massey, R. and Ulmer, A. (2008). *Agriculture and greenhouse gas emission*. University of Missouri Extension. Retrieved from http://extension.missouri.edu/publications/DisplayPub.aspx?P=G310

Merkel, M. (2002). *Raising a stink: Air emissions from factory farms*. Environmental Integrity Project. Retrieved from http://www.environmentalintegrity.org/pdf/publications/CAFOAirEmissions_white_paper.pdf

Michigan Department of Environmental Quality (MDEQ) Toxics Steering Group (TSG). (2006). *Concentrated animal feedlot operations (CAFOs) chemicals associated with air emissions*. Retrieved from http://www.michigan.gov/documents/CAFOs Chemicals_Associated_with_Air_Emissions_5-10-06_158862_7.pdf

Michigan State University Extension. (n.d.) *Air emission reporting under EPCRA for CAFOs*. Retrieved from http://www.animalagteam.msu.edu/Portals/0/MSUE%20EPCRA%20REPORTING%20FACT%20SHEET.pdf

Mirabelli, M.C., Wing, S., Marshall, S.W., & Wilcosky, T.C. (2006). Race, poverty, and potential exposure of middle-school students to air emissions from confined swine feeding operations. *Environmental Health Perspectives, 114*(4), 591–596. Retrieved from http://ehp.niehs.nih.gov/realfiles/members/2005/8586/8586.pdf

Pew Charitable Trusts. (n.d.) *Antibiotic-resistant bacteria in animals and unnecessary human health risks*. Retrieved from http://www.saveantibiotics.org/resources/PewHumanHealthEvidencefactsheet7-14FINAL.pdf

Pew Commission on Industrial Animal Farm Production. (2009). *Putting meat on the table: Industrial farm animal production in America*. Retrieved from http://www.ncifap.org/_images/PCIFAPFin.pdf

Purdue Extension. (2007). *Contained animal feeding operations—Insect considerations*. Retrieved from http://www.ces.purdue.edu/extmedia/ID/cafo/ID-353.pdf

Purdue Extension. (2008). *Community impacts of CAFOs: Property value*. Retrieved from http://www.ces.purdue.edu/extmedia/ID/ID-363-W.pdf

Schmalzried, H.D. & Fallon, L.F., Jr. (2007). Large-scale dairy operations: Assessing concerns of neighbors about quality-of-life issues. *Journal of Dairy Science, 90*(4), 2047-2051. Retrieved from http://jds.fass.org/cgi/reprint/90/4/2047?maxtoshow=&hits=10&RESULTFORMAT=&fulltext=large-scale&searchid=1&FIRSTINDEX=0&volume=90&issue=4&resourcetype=HWCIT

Schmalzried, H.D. & Fallon, L.F., Jr. (2008). A proactive approach for local public health districts to address concerns about proposed large-scale dairy operations. *Ohio Journal of Environmental Health, Fall/Winter 2008*, 20-25.

Science Daily. (n.d.) *Algal bloom*. Retrieved from http://www.sciencedaily.com/articles/a/algal_bloom.htm

Sierra Club Michigan Chapter. (n.d.) *Glossary of CAFO terms*. Retrieved from http://michigan.sierraclub.org/issues/greatlakes/articles/cafoglossary.html#E

Sigurdarson,S.T. & Kline, J.N. (2006). School proximity to concentrated animal feeding operations and prevelance of asthma in students. *Chest, 129*, 1486–1491. Retrieved from http://chestjournal.chestpubs.org/content/129/6/1486.full.pdf

Spellman, F.R. & Whiting, N.E. (2007). *Environmental management of concentrated animal feeding operations (CAFOs)*. Boca Raton, FL: CRC Press.

State Environmental Resource Center. (2004). *Issue: Regulating air emissions from CAFOs*. Retrieved from http://www.serconline.org/cafoAirEmissions.html

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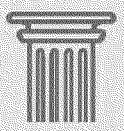
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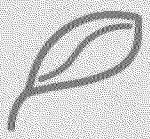
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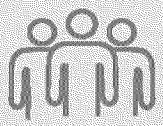
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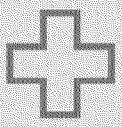
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Exhibit 41

Industrialized Animal Production—A Major Source of Nutrient and Microbial Pollution to Aquatic Ecosystems

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University of North Carolina at Wilmington

Livestock production has undergone massive industrialization in recent decades. Nationwide, millions of swine, poultry, and cattle are raised and fed in concentrated animal feeding operations (CAFOs) owned by large, vertically integrated producer corporations. The amount of nutrients (nitrogen and phosphorus) in animal manure produced by CAFOs is enormous. For example, on the North Carolina Coastal Plain alone an estimated 124,000 metric tons of nitrogen and 29,000 metric tons of phosphorus are generated annually by livestock. CAFO wastes are largely either spread on fields as dry litter or pumped into waste lagoons and sprayed as liquid onto fields. Large amounts of nitrogen and phosphorus enter the environment through runoff, percolation into groundwater, and volatilization of ammonia. Many CAFOs are located in nutrient-sensitive watersheds where the wastes contribute to the eutrophication of streams, rivers, and estuaries. There is as yet no comprehensive Federal policy in place to protect the environment and human health from CAFO generated pollutants.

KEY WORDS: swine; poultry; nutrients; pathogens; eutrophication.

INTRODUCTION

Humans first domesticated a number of animal species in several regions of the world ca. 4–6,000 years ago (Diamond, 1997). Early domes-

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tication of animals allowed humans to exploit their abilities to convert otherwise inaccessible resources into useful products and services. Animal production was necessarily resource-limited and since production was tightly coupled to the productivity of the landscape, animal waste production would seldom have exceeded the assimilation capacity of the landscape.

In recent decades livestock production, particularly that of swine, cattle and poultry, has undergone a major change toward industrialization. The industrialization of the cattle and poultry industries began in the late 1950s while industrialization of swine production began in the 1970s (Thu & Durrenberger, 1998). Industrialization of livestock production basically consists of moving animals from pastures and lots into large buildings, where they are confined and fed throughout their lives until they are ready for market. Adoption of confined feeding techniques, together with the availability of large quantities of feedstuffs and efficient transportation systems, now allow animal producers to circumvent the ecological constraints otherwise imposed by the landscape. As a consequence, animal waste production often exceeds the assimilatory capacity of the landscape both locally and regionally.

Individual concentrated animal feeding operations (CAFOs) now house hundreds to thousands of animals in each confinement structure, and vast amounts of animal waste are generated by these facilities. Swine waste is deposited on the floor of the structures by the animals, where it is periodically washed between slats in the floor into a system of trenches and pipes beneath the buildings. From there it is conveyed outside and into a cesspit called a "waste lagoon." Some anaerobic treatment occurs in the lagoon and the liquid waste is periodically applied on surrounding fields by surface spraying, surface spreading, or in some cases subsurface injection. Crops planted on the fields, such as Bermuda grass, cotton, corn, and soy take up some of the plant nutrients in the waste material. Some poultry CAFOs utilize the lagoon system, but the majority of poultry CAFOs dispose of dry litter on the fields (Williams et al., 1999). In any case, concentrated waste material is spread onto fields, from where it can enter the environment through surface runoff or groundwater infiltration (Edwards & Daniel, 1992; Mallin, 2000). Thus, individual CAFOs represent an ecologically anomalous concentration of animals whose waste production can easily exceed the assimilatory capacity of the local landscape.

Regional concentrations of CAFOs create circumstances in which very large imbalances of waste production versus waste assimilation capacity can arise (Barker and Zublena, 1995; Jackson et al., 2000). The use of carefully formulated feeds, the need for large amounts of these feeds, and trans-

portation cost considerations have led to the regional concentration of CAFOs around feed mills and meat packing facilities (C. Wright, personal communication). Swine CAFOs are abundant on the North Carolina Coastal Plain, and in Midwestern states such as Iowa, Minnesota, Michigan, and Indiana, and are moving into western areas such as Utah and Colorado (Thu & Durrenberger, 1998). Poultry CAFOs are abundant in Iowa, Arkansas, Georgia, Maryland, Virginia, Delaware, North Carolina, California, and Mississippi (Edwards & Daniel, 1992). Cattle CAFOs are rare on the east coast but common in Texas and several midwestern states. The environmental challenge of regional concentration has been recognized explicitly for some time, e.g., in legislation introduced by Sen. Harkin (D-Iowa) in 1997 (the Animal Agriculture Reform Act, S.B. 1223). Sen. Harkin (1997) cited the Department of Agriculture as reporting: "The continued intensification of animal production systems without regard to the adequacy of the available land base for manure recycling presents a serious policy problem."

CAFOs have also had many acute pollution problems with their waste disposal systems, including lagoon ruptures and major leaks caused by mismanagement or weather (Mallin, 2000). For example, 25 million gallons of liquid swine waste entered North Carolina's New River and its estuary following a waste lagoon rupture in 1995, polluting 22 miles of the river and much of the upper estuary. The pollution load caused freshwater and estuarine fish kills and algal blooms, and polluted the river and its sediments with fecal bacteria for months (Burkholder et al., 1997). That same year a poultry lagoon breach and a large swine waste lagoon leak also caused algal blooms, fish kills, and microbial contamination in North Carolina's Cape Fear River basin (Mallin et al., 1997). In all of these cases large quantities of nutrients (nitrogen and phosphorus) entered downstream water bodies from the CAFO sites. Major CAFO accidents have also occurred in Iowa, Maryland, and Missouri (Thu & Durrenberger, 1998; Mallin, 2000). While the acute pollution caused by CAFOs is well documented, the sheer magnitude of their distribution and abundance merits an examination of the chronic effects that these facilities may have on our water resources.

North Carolina presents an excellent example of the effects of rapidly increasing industrialized livestock production, particularly that of swine. Industrialization of North Carolina's swine production began in the 1980s, and continued rapidly until the mid to late 1990s (Burkholder et al., 1997). The lagoon waste disposal system was deployed with little foresight for the environmental consequences, and CAFOs were constructed with little regulation until lagoon construction standards, siting regulations, and waste management plans were legally required in 1993 (Burkholder et al., 1997).

A moratorium on new CAFO production was begun in 1997; however, this did not take full effect until nearly 10,000,000 head of swine were present in eastern North Carolina, the vast majority in CAFOs (Burkholder et al., 1997; Mallin, 2000).

This large number of swine (currently exceeding the North Carolina human population of 7,900,000), as well as poultry and cattle, requires vast amounts of animal feed, which contains nitrogen (N) and phosphorus (P), nutrients that can lead to the eutrophication of water bodies (Carpenter et al., 1998; Correll, 1998; Cahoon et al., 1999; Glasgow & Burkholder, 2000; Mallin, 2000). Cahoon et al. (1999) noted that as of 1995 the animal production industry in North Carolina's Cape Fear River basin produced some 82,700 metric tons of N and 26,000 metric tons of P as waste in this watershed. Glasgow and Burkholder (2000) computed that in 1998 North Carolina's Neuse River watershed received 41,000 metric tons of N and 16,000 metric tons of P from CAFOs in that basin. Since the vast majority of feed for swine and poultry is shipped into these watersheds from midwestern states (Thu & Durrenberger, 1998; Cahoon et al., 1999), most of the nutrients added to the watershed through animal manures are considered "new" nutrients, imported into the system rather than recycled within it. The purpose of this paper is to describe the magnitude of industrialized animal production in a large region of the North Carolina Coastal Plain (see Figure 1), assess the potential contribution of nutrients and microbial pollution to this region, and describe the realized and potential effects of this pollutant load.

METHODS

An assessment of animal waste contributions to pollutant loads on the North Carolina Coastal Plain required computation of livestock numbers by animal category in the region, and estimates of the amount of N, P, and bacteria excreted by each species of livestock on an annual basis. The Coastal Plain contains over 90% of the State's swine population, the vast majority of its turkeys, and about 30% of the chicken population. For each of the 38 counties in the region, the most recent available data on annual production of several types of livestock (swine, broiler chickens, other chickens, turkeys, and cattle) were obtained from the website of the North Carolina Department of Agriculture (NCDA, http://www.agr.state.nc.us/stats/cntysumm). On an annual basis, there are approximately 2.9 turkey generations (cohorts) and 6.5 broiler chicken generations produced. Thus, the turkey and broiler production figures provided on the NCDA website for each

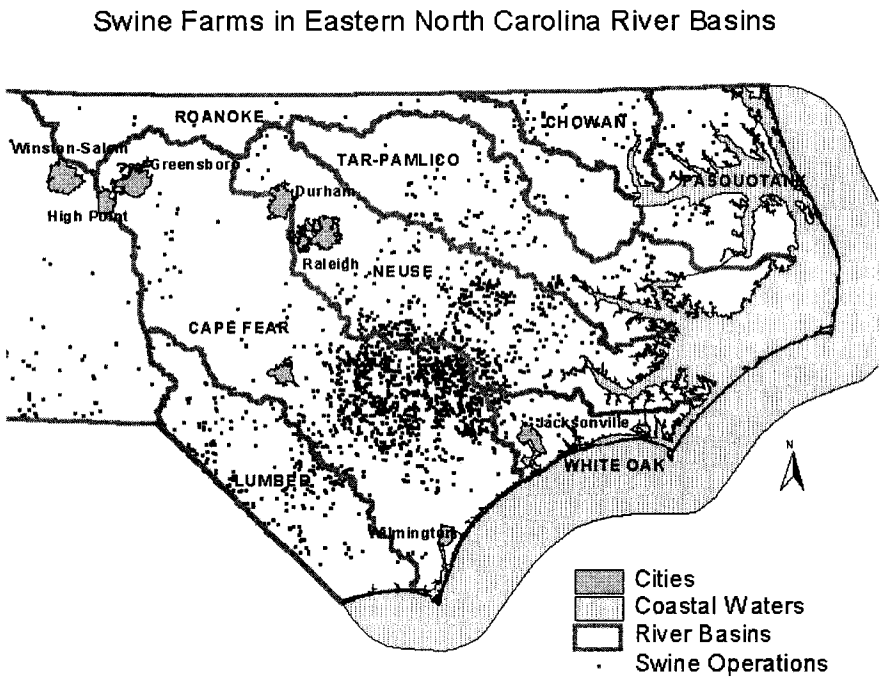

FIGURE 1. Location of swine CAFOs (operations with 250 or more head) on the North Carolina Coastal Plain by river basin.

county were divided by these numbers to yield average annual standing stock (total animals present at any one time), and subsequent annual manure production.

Animal waste N and P production rates were calculated using recent published information or data from industry sources. Swine waste N and P contents were calculated using data supplied by T. van Kempen (North Carolina State University): 15.9 kg N/yr and 5.3 kg P/yr for sows, 11.1 kg N/yr and 2.3 kg P/yr for grower-finisher pigs, and are similar to those reported elsewhere, e.g., Powers and Van Horn (1998). Total swine N and P excretion rates were then calculated using the proportion of sows and grower-finisher pigs (0.103 and 0.897, respectively in 1998 (NCDA, 1999). Turkey and broiler chicken N excretion were calculated using data from Powers and Van Horn (1998); they report N excretion as 0.395 kg N/turkey produced and 0.017 kg N/broiler produced. Using N:P ratios of 3.57:1 for turkey waste and 3.23:1 for broiler chicken waste (NRCS, 1996, Chapter

4), P excretion was calculated as 0.11 kg P/turkey produced and 0.0053 kg P/broiler produced. Annual N and P excretion rates for cattle were calculated as in Cahoon (1999), using estimates of 46.8 kg N/cow and 11.7 kg P/cow.

The Lower Cape Fear River Program at the University of North Carolina at Wilmington has collected nutrient data at 35 locations located throughout the Cape Fear River basin since 1995. Published data for a station in the Northeast Cape Fear River near the town of Sarecta (GPS coordinates N34 43.365, W77 51.752) are presented below. These data are of interest because of that station's proximity to numerous CAFOs (see Figure 1). Since ammonium volatilization is most active during warm months (NCDAQ, 1997), summertime (May–September) ammonium data are presented for a six-year period from 1996 through 2001.

Estimates of fecal coliform bacteria excreted on a daily basis for several of the livestock species were obtained from Sobsey (1996). Based on this reference the following fecal coliform bacterial daily production figures were used for pigs (1.2×10^{10} colony-forming units (CFU)), chickens (1.4×10^{8} CFU), and cows (6.0×10^{9} CFU).

RESULTS

The North Carolina Coastal Plain produces large numbers of swine, broiler chickens, and turkeys, and smaller but significant numbers of other chickens and cattle (Table 1). Swine production in North Carolina is second

TABLE 1

Population of Livestock by Category on the North Carolina Coastal Plain, 2000–2001 (About 6.5 generations of broilers and 2.9 turkey generations are produced per year. Dividing broiler chicken and turkey production by these factors provides standing stock, or numbers present at any one time on the Coastal Plain.)

Animal Category	Numbers Used in Nutrient Calculations
Swine	8,700,000 (standing stock)
Broiler chickens	210,000,000 (produced)
Other Chickens	3,480,000 (produced)
Turkeys	31,800,000 (produced)
Cattle	149,000 (standing tock)

in the United States only to Iowa (Burkholder et al., 1997; USNASS, 1997). North Carolina ranks fourth in the United States in broiler chickens sold, and first in the United States in turkeys sold (USNASS, 1997). The vast majority of the swine and poultry are in CAFOs, whereas many of the cattle are grazed on open lands.

Our computations show that swine and turkey production contribute the greatest amount of N and P in the annual waste stream (Table 2). Swine alone generate 101,000 metric tons of N and turkeys 12,600 metric tons. Swine also generate 22,700 tons of P and turkeys 3,500 metric tons. Thus, swine are by far the largest producers of nutrients in comparison with other livestock on the Coastal Plain, and the manner of their waste disposition deserves attention. Swine waste from CAFOs is invariably pumped into lagoons, some of which are located on river floodplains. In North Carolina liquid waste from the lagoons is typically then sprayed out on adjoining fields, from which surface drainage to waterways or subsurface drainage to groundwaters can occur. The nutrients produced by poultry CAFOs as manure are largely spread as dry litter on fields, with some pumped into waste lagoons, from which they are sprayed as liquid waste onto fields. Secondary treatment of livestock waste for nutrient removal is seldom practiced.

This analysis does not take into account nutrients produced by the decomposition of dead animals. Following Hurricane Floyd in October 1999, the news media published numerous photographs of drowned swine and poultry from CAFOs in areas inundated by floodwaters. The numbers of drowned livestock may have been very large, as Wing et al. (2002) determined that 241 CAFOs were within the geographical coordinates of the areas inundated by post-Floyd floodwaters according to satellite imagery.

TABLE 2

Estimated Amounts of Nitrogen and Phosphorus (metric tons) Excreted Annually by Various Livestock Categories on the North Carolina Coastal Plain, 2000–2001

Animal Category	Nitrogen	Phosphorus
Swine	101,000	22,700
Broiler chickens	3,570	1,110
Other Chickens	60	20
Turkeys	12,600	3,500
Cattle	7,000	1,750
Grand Total	124,230	29,080

N.C. Department of Agriculture statistics report over 1 million swine mortalities per year as of 1998, not counting piglets lost (N.C. D.A., 1999); thus, animal carcasses are likely another significant source of nutrients to the environment.

Data published by the Lower Cape Fear River Program (available at the website http://www.uncwil.edu/cmsr/aquaticecology/laboratory/lcfrp) demonstrate that there was a statistically significant increase in ammonium levels at a Northeast Cape Fear River station (Sarecta) during the period 1996–2001 (see Figure 2). Ammonium comprises the largest portion of total N in swine and poultry liquid waste (Burkholder et al., 1997; Mallin et al., 1997; Williams et al., 1999). Along with transport of ammonium in runoff or subsoil movement, it can be volatilized and transported in the gaseous ammonia form (Edwards & Daniel, 1992; Williams et al., 1999; Mallin, 2000). The station at Sarecta has 344 swine CAFOs within a 20 km radius, and 587 swine CAFOs within a 30 km radius (we have no data on poultry CAFOs). This station likely receives ammonium inputs from overland runoff and lateral groundwater flow, and airborne deposition. The implications of nutrient increases to downstream waters are discussed below.

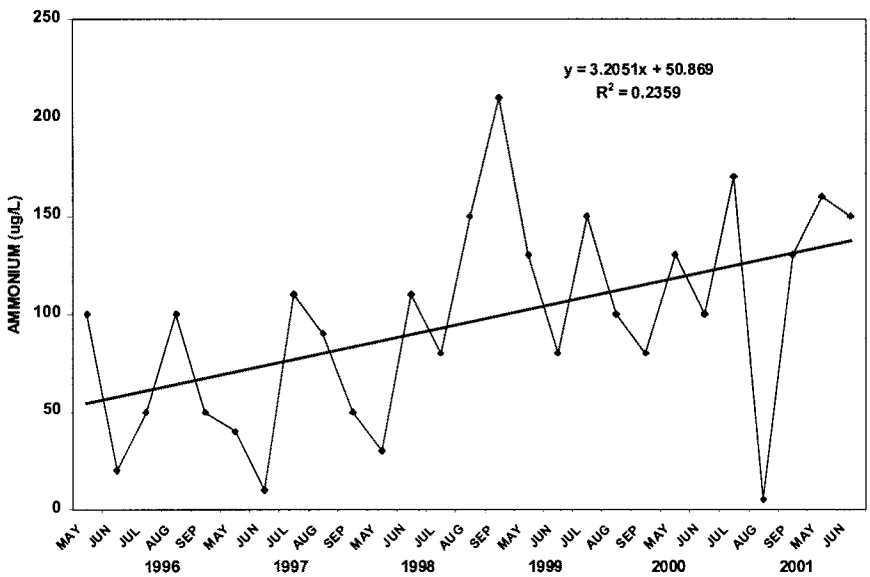

FIGURE 2. Summer ammonium concentrations at Sarecta, a water quality station on the Northeast Cape Fear River in a location near numerous CAFOs, data from 1996 to 2001.

Applying Sobsey's (1996) conversion factors figures to livestock populations on North Carolina's Coastal Plain yields estimated annual excretion of fecal coliform bacteria of 3.8×10^{18} from swine, 1.7×10^{18} CFU from broilers, 1.8×10^{17} from other chickens, and 3.3×10^{17} from cattle.

DISCUSSION

Fate of Excreted Nutrients

As mentioned earlier, major storms and accidents are documented mechanisms by which large amounts of nutrients have been abruptly transported from CAFOs to receiving waters (Burkholder et al., 1997; Mallin et al., 1997; 1999; Mallin, 2000). However, CAFOs also chronically export nutrients to water resources through several means. Normal rain events carry nutrients from swine sprayfields to nearby streams through surface and subsurface runoff (Evans et al., 1984; Westerman et al., 1987) where these inputs have caused stream nitrate-N to rise above 5 mg N/L and P above 1 mg P/L (Stone et al., 1995; Gilliam et al., 1996). Nutrients, mainly nitrate and ammonium, also leach downwards into groundwater from animal waste lagoons, sprayfields, and litter fields. In a set of 11 North Carolina swine lagoons, Huffman and Westerman (1995) found average inorganic (ammonium and nitrate) N concentrations of 143 mg/L in nearby groundwater, and found that through leakage the lagoons exported on average 4.7 kg N/day to groundwater. Also in North Carolina Westerman et al. (1995) found average concentrations of ammonium in downslope well fields that exceeded 50 mg N/L, compared with upslope wells that were less than 1 mg N/L. The nitrate form of N is especially mobile in soils and can pass readily through soils to contaminate groundwater. Liebhardt et al. (1979) found high levels of nitrate in soil groundwater beneath Delaware cornfields where poultry waste was applied as the sole fertilizer, with evidence that the nitrate moved laterally toward a nearby stream. Using nitrogen isotopic techniques Karr et al., (2001) have traced nitrate generated from swine waste spray fields through shallow groundwater into receiving stream waters, and at least 1.5 km downstream. Phosphorus is much less mobile, and binds readily to soil particles. However, when the P content of soils is built up dramatically through excessive manure application, both surface export and subsurface loss of P occurs (Sharpley et al., 1999).

Anaerobic treatment of swine wastes with high concentrations of organic N promotes deamination, resulting in high concentrations of ammonium-N in lagoon liquid. Liming is used to maintain a pH above about 7,

favoring ammonia formation. Ammonia volatilizes from sprayfields and waste lagoons, and is transported downwind (McCulloch et al., 1998; Aneja et al., 2000; Walker et al., 2000). The North Carolina Department of Air Quality estimates that 70–80% of all swine waste N and a somewhat lesser percentage of poultry waste N is thus volatilized (N.C. D.A.Q., 1997). It is notable that the Neuse River watershed, which contains approximately 25% of North Carolina's swine population and numerous poultry production facilities and is downwind of a large concentration of CAFOs in the Cape Fear watershed, registered a 14% increase in total N and a 34% increase in nitrate over the seven year period 1990–1997 (Glasgow & Burkholder, 2000). While other anthropogenic sources of N undoubtedly contributed to this loading, the large recent rise in CAFOs in those watersheds would suggest that animal production is a significant cause of these nutrient inputs. Walker et al. (2000) and Mallin (2000) have documented a trend of increasing ammonium deposition in the coastal region of North Carolina, which they attribute to animal production sources. At Sarecta on the Northeast Cape Fear River a steady rise in river ammonium concentrations from 1996–2001 is evident (see Figure 2). There are no new or large wastewater treatment facilities in that area that can account for this increase. The single major land use change in that area has been the rapid proliferation of CAFOs during the 1980s and 1990s (see Figure 1).

Potential Impacts on Water Resources

Kellogg (2000) prioritized U.S. watersheds in terms of vulnerability to manure nutrient contamination based on a number of factors, including soil percolation, soil runoff potential, soil erosion potential, and amount of animal nutrients applied to soils. Much of the North Carolina Coastal Plain, especially the Albemarle-Pamlico and Cape Fear watersheds, ranked highest in the nation in vulnerability. Many of the surface water supplies downstream of CAFO-dense areas on the North Carolina Coastal Plain (Figure 1) are sensitive to N and/or P loading, and will respond by formation of algal blooms (Rudek et al., 1991; Paerl et al., 1990; Glasgow & Burkholder, 2000). This is especially true in the Neuse, Pamlico, and New Rivers and their estuaries (Dame et al., 2000; Mallin et al., 2000). Algal blooms can build up high concentrations of biomass, and eventually die and become a source of labile organic material. Bacteria feed on this biomass and multiply, creating high biochemical oxygen demand (BOD) that will at times lower dissolved oxygen concentrations to levels that can kill sessile bottom organisms and create areas in which finfish cannot survive—a loss of usable habitat. Another impact of increased nutrient loading on estuaries is

to stimulate growth of the toxic dinoflagellates *Pfiesteria piscicida* and *P. shumwayae*, which have bloomed downstream of CAFO areas in the Neuse, Pamlico, and New River Estuaries of North Carolina and the Chesapeake Bay in Maryland (Burkholder et al., 1995; Burkholder & Glasgow, 1997; Glasgow et al., 2001). Growth of *P. piscicida* is more stimulated by P loading whereas *P. shumwayae* appears to be more stimulated by N inputs (Glasgow et al., 2001). Both species of *Pfiesteria* have caused many fish kills in North Carolina and some in Maryland, as well as human health problems to researchers and watermen exposed to its toxins (Burkholder et al., 1995; Burkholder & Glasgow, 1997; Burkholder & Glasgow, 2001). Blooms of these organisms and consequent fish kills have led to closures of areas in the Chesapeake Bay region and the Albemarle-Pamlico estuarine region in North Carolina to commercial fishing, due to health concerns over the consumption of affected fish and exposure to airborne *Pfiesteria* toxins when on the water (Burkholder & Glasgow, 2001).

In the Cape Fear River basin, which produces 50% of North Carolina's swine and vast numbers of poultry, most of the CAFOs are in watersheds drained by blackwater streams. These are streams that drain lowland forests and riverine swamps, and in pristine condition are naturally nutrient poor. Recent experiments have been conducted on the response of blackwater streams to increased nutrient loading (Mallin et al., 2001). These experiments showed that N inputs of 1 mg/L led to spring and summer algal blooms in test waters, while P levels of 1 mg/L caused significant production of heterotrophic microbes and increased biochemical oxygen demand (Mallin, 2000; Mallin et al., 2000; Mallin et al., 2001). Since recent assessments (Figure 2) show a steady increase in ammonium in certain downstream locations in the Cape Fear basin, this loading has the potential for degrading water quality in areas receiving nutrient inputs.

Seagrass beds are an important coastal habitat for many species of finfish and shellfish. Historically, important seagrass habitat has been located downstream of CAFO-rich areas in the Albemarle-Pamlico estuarine system in North Carolina as well as the Chesapeake Bay. Much of that habitat disappeared in the mid-to-late 1900s. A number of factors can cause losses of seagrass, including reduced photosynthesis from increased turbidity (Dennison et al, 1993). However, the most important seagrass species on the mid-Atlantic seaboard (eelgrass—*Zostera marina*) has been shown to be sensitive to nitrate loading, and can die under prolonged exposure to nitrate concentrations of 50 to 100 µg N/L or higher (Burkholder et al., 1992; Burkholder et al., 1994). Some coastal North Carolina waters can periodically receive extended inputs of nitrate from upstream freshwater sources that exceed these critical levels (Mallin et al., 1993; Paerl

et al., 1995; Mallin et al., 1999; Glasgow & Burkholder, 2000) thus providing a habitat stressful to eelgrass survival or re-establishment.

Animal Pathogens and Humans

Livestock are known to excrete many of the same pathogenic bacteria, viruses, and protozoans that can afflict humans. These organisms include pathogenic bacteria such as *Escherichia coli*, *Salmonella* spp., and *Streptococcus* spp., pathogenic protozoans such as *Giardia lamblia* and *Cryptosporidium parvum*, and a number of viruses (Mawdsley et al., 1995). The way animal waste is treated will affect pathogen survival and potential transmission to humans. Composting of manure raises temperatures high enough to kill most microbes, but animal waste slurries do not reach lethal temperatures (Mawdsley et al., 1995). Microbes in animal waste slurries such as lagoon liquid can survive for extended periods; *E. coli* has been known to survive up to 11 weeks in such an environment (Mawdsley et al., 1995). If waste is applied to the land surface survival time is cut to a matter of days, particularly under conditions of bright sunlight (Crane et al., 1983; Mawdsley et al., 1995). However, rain events occurring shortly after animal waste is surface-applied to fields cause vertical and horizontal movement of microbes to nearby water bodies (Crane et al., 1983; Mawdsley et al., 1995; Mallin, 2000). Large-scale microbial disease outbreaks have been traced to livestock vectors. In 1999 and 2000 the news media reported incidents in Albany, New York (MMWR 1999) and Walkerton, Ontario of mass illnesses and some deaths to humans that were exposed to pathogenic *E. coli* in water sources contaminated by runoff from cattle husbandry areas.

As indicated above, livestock on the Coastal Plain excrete large amounts of fecal bacteria in manure. Unlike human waste, microbes generated by CAFOs are not exposed to secondary treatment or chlorination to disinfect the material. When applied to fields in manure the vast majority of these microbes are likely deactivated by ultraviolet radiation, microbial competition and predation, or other means (Crane et al., 1983). However, because of the sheer volume of microbes deposited, there still remains a significant pollution potential from this material entering surface or groundwaters that humans will contact. If CAFO-generated microbes enter the sediments of water bodies, organisms such as *E. coli* can find a favorable environment where they can remain viable for over two months (Davies et al., 1995). For example, following a large swine waste lagoon spill in the New River, North Carolina, Burkholder et al. (1997) found fecal coliform bacterial counts ranging from 1,000,000 to 3,000,000 per 100 ml of river water

several km downstream from the spill site. These very high concentrations declined to the range of 1,000 to 5,000 per 100 ml after 14 days, and to less than 1,000 per 100 ml in 61 days. However, further sampling indicated that the river sediments maintained concentrations of fecal bacteria up to 5,000 per 100 ml for 61 days. The risk of large quantities of fecal microbes entering the environment is thus high following acute CAFO mishaps; although the risk of human exposure to these microbes chronically through normal operations is yet undetermined.

Regulation

Point source discharges from municipal or industrial wastewater treatment plants are regulated under the National Pollution Discharge Elimination System (NPDES) enacted by the National Environmental Policy Act of 1971 (NEPA). This process authorizes the US Environmental Protection Agency or individual states to license and inspect dischargers, and set maximum pollutant discharge concentrations. However, CAFOs have been considered to be non-point source dischargers, and were thus exempt from this process. As such, regulation of pollutant discharges from them has been piecemeal and varies from state to state. Current legislated and regulatory controls on the environmental effects of CAFOs have generally followed demonstration of negative environmental impacts, rather than preventing them, e.g., Maryland's Water Quality Improvement Act of 1998. Laws and regulations in many states define CAFOs as farms and tacitly assume that CAFOs manage nutrients and other wastes as do conventional farms, when in fact CAFO operations depart significantly from the ecological relationships that control farm productivity (Jackson et al., 2000). Moreover, most laws and regulations address CAFOs as individual operations, thus neglecting the considerable effects of concentration of many CAFOs in relatively small regions.

Although some Federal legislators have shown concern for the environmental impacts of CAFOs (Harkin, 1997), comprehensive legislation designed to regulate CAFO-generated pollution has not yet occurred on the Federal level. Federal regulations have only recently recognized the need to limit P over-application in animal wastes; the U. S. Department of Agriculture's Natural Resource Conservation Service mandates soil P management in its most recent version of the Nutrient Management Standard 590 (Sharpley & Tunney, 2000). Implementation by the states is not uniform, however, as they utilize different soil test procedures, different risk assessment methods, and different remediation responses. North Carolina has just developed a Phosphorus Loss Assessment Tool (PLAT), which has not yet

been fully implemented. However, these new regulations address only one aspect of the larger set of environmental challenges posed by CAFOs, and fail to address the consequences of regional concentration of CAFOs at all. Consequently, CAFOs present a major challenge to the current system of environmental law and regulations in the United States.

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REFERENCES

Aneja, V.P., Chauhan, J.P., & Walker, J.P. (2000). Characterization of atmospheric ammonia emissions from swine waste storage and treatment lagoons. *Journal of Geophysical Research 105,* 11, 535–11545.

Barker, J.C., & Zublena, J. P. (1995). Livestock manure nutrient assessment in North Carolina. In *Proceedings of the Seventh International Symposium on Agricultural and Food Processing Wastes* (*ISAFPW95*) (pp. 98–106). Chicago: American Society of Agricultural Engineering.

Burkholder, J. M., & Glasgow, H. B. Jr. (1997). *Pfiesteria piscicida* and other *Pfiesteria*-like dinoflagellates: Behavior, impacts, and environmental controls. *Limnology and Oceanography 42*, 1052–1075.

Burkholder, J. M., & Glasgow, H. B. Jr. (2001). History of toxic *Pfiesteria* in North Carolina estuaries from 1991 to the present. *BioScience 51*: 827–841.

Burkholder, J. M., Glasgow, H. B. Jr., & Cooke, J. E. (1994). Comparative effects of water-column nitrate enrichment on eelgrass *Zostera marina*, shoalgrass *Halodule wrightii*, and widgeongrass *Ruppia marina. Marine Ecology Progress Series 105,* 121–138.

Burkholder, J. M., Glasgow, H. B. Jr., & Hobbs, C. W. (1995). Distribution and environmental conditions for fish kills linked to a toxic ambush predator dinoflagellate. *Marine Ecology Progress Series 124,* 43–61.

Burkholder, J. M., Mallin, M. A., Glasgow, H. B. Jr., Larsen, L. M., McIver, M. R., Shank, G. C., Deamer-Melia, N., Briley, D. S., Springer, J., Touchette, B. W., & Hannon, E. K. (1997). Impacts to a coastal river and estuary from rupture of a swine waste holding lagoon. *Journal of Environmental Quality 26,* 1451–1466.

Burkholder, J. M., Mason, K. M., & Glasgow, H. B. Jr. (1992). Water-column nitrate enrichment promotes decline of eelgrass *Zostera marina* L.: Evidence from seasonal mesocosm experiments. *Marine Ecology Progress Series 81,* 163–178.

Cahoon, L. B., Mickucki, J. A., & Mallin, M. A. (1999). Nutrient imports to the Cape Fear and Neuse River basins to support animal production. *Environmental Science and Technology 33,* 410–415.

Carpenter, S. R., Caraco, N. F., Correll, D. L., Howarth, R. W., Sharpley, A. N., & Smith, V. H. (1998). Nonpoint pollution of surface waters with phosphorus and nitrogen. *Ecological Applications 8,* 559–568.

Correll, D. L. (1998). The role of phosphorus in the eutrophication of receiving waters: A review. *Journal of Environmental Quality 27,* 261–266.

Crane, S. R., Moore, J. A., Grismer, M. E., & Miner, J. R. (1983). Bacterial pollution from agricultural sources: A review. *Transactions of the American Society of Agricultural Engineers 26,* 858–872.

Dame, R., Alber, M., Allen, D., Chalmers, A., Gardner, R., Gilman, C., Kjerfve, B., Lewitus, A., Mallin, M., Montague, C., Pinckney, J., & Smith, N. (2000). Estuaries of the south Atlantic coast of North America: Their geographical signatures. *Estuaries 23,* 793–819.

Davies, C. M., Long, J. A. H., Donald, M. & Ashbolt, N. J. (1995). Survival of fecal microorganisms in marine and freshwater sediments. *Applied and Environmental Microbiology 61*, 1888–1896.

Dennison, W. C., Orth, R. J., Moore, K. A., Stevenson, J. C., Carter, V., Kollar, S., Bergstrom, P. W., & Batiuk, R. A. (1993). Assessing water quality with submersed aquatic vegetation. *BioScience 43,* 86–94.

Diamond, J. (1997). *Guns, Germs, and Steel*. W. W. New York, Norton and Company.

Edwards, D. R., & Daniel, T. C. (1992). Environmental impacts of on-farm poultry waste disposal—a review. *Bioresource Technology 41,* 9–33.

Evans, R.O., Westerman, P. W., & Overcash, M. R. (1984). Subsurface drainage water quality from land application of swine lagoon effluent. *Transactions of the American Society of Agricultural Engineers 27,* 473–480.

Gilliam, J. W., Huffman, R. L., Daniels, R. B., Buffington, D. E., Morey, A. E., & Leclerc, S. A. (1996). *Contamination of surficial aquifers with nitrogen applied to agricultural land*. Report No. 306. Water Resources Research Institute of the University of North Carolina, Raleigh, N.C.

Glasgow H. B., & Burkholder, J. M. (2000). Water quality trends and management implications from a five-year study of a eutrophic estuary. *Ecological Applications 10,* 1024–1046.

Glasgow, H. B., Burkholder, J. M., Mallin, M. A., Deamer-Melia, N. J., & Reed, R. R. (2001). Field ecology of toxic *Pfiesteria* complex species and a conservative analysis of their role in estuarine fish kills. *Environmental Health Perspectives 109,* 715–730.

Harkin, T. (1997). *Animal waste pollution in America: an emerging national problem. Environmental risks of livestock and poultry production*. Report compiled by the minority staff of the United States Senate Committee on Agriculture, Nutrition and Forestry for Senator Tom Harkin (D-IA).

Huffman, R. L., & Westerman, P. W. (1995). Estimated seepage losses from established swine waste lagoons in the lower coastal plain of North Carolina. *Transactions of the American Society of Agricultural Engineers 38,* 449–453.

Kellogg, R. L. (2000). *Potential priority watersheds for protection of water quality from contamination by manure nutrients*. Paper presented at the Animal Residuals Management Conference 2000, November 12–14, Kansas City, MO.

Jackson, L. L., Keeney, D. R. & Gilbert, E. M. 2000. Swine manure management plans in north-central Iowa: nutrient loading and policy implications. *Journal of Soil and Water Conservation 55,* 205–212.

Karr, J. D., Showers, W. J., Gilliam, J. W., & Andres, A. S. (2001). Tracing nitrate transport and environmental impact from intensive swine farming using Delta nitrogen-15. *Journal of Environmental Quality 30,* 1163–1175.

Liebhardt, W. C., Golt, C., & Tupin, J. (1979). Nitrate and ammonium concentrations of ground water resulting from poultry manure applications. *Journal of Environmental Quality 8,* 211–215.

Mallin, M. A. (2000). Impacts of industrial-scale swine and poultry production on rivers and estuaries. *American Scientist 88,* 26–37.

Mallin, M. A., Burkholder, J. M., Cahoon, L. B., & Posey, M. H. (2000). The North and South Carolina coasts. *Marine Pollution Bulletin 41,* 56–75.

Mallin, M. A., Burkholder, J. M., McIver, M. R., Shank, G. C., Glasgow, H. B. Jr., Touchette, B. W., & Springer, J. (1997). Comparative effects of poultry and swine waste lagoon spills on the quality of receiving stream waters. *Journal of Environmental Quality 26,* 1622–1631.

Mallin, M. A., Cahoon, L. B., Parsons, D. C. & Ensign, S. H. (2001). Effect of nitrogen and phosphorus loading on plankton in Coastal Plain blackwater streams. *Journal of Freshwater Ecology 16,* 455–466.

Mallin, M. A., Paerl, H. W., Rudek, J., & Bates, P. W. (1993). Regulation of estuarine primary production by rainfall and river flow. *Marine Ecology-Progress Series 93,* 199–203.

Mallin, M. A., Posey, M. H., Shank, G. C., McIver, M. R., Ensign, S. H., & Alphin, T. D. (1999). Hurricane effects on water quality and benthos in the Cape Fear Watershed: Natural and anthropogenic impacts. *Ecological Applications 9,* 350–362.

Mawdsley, J. L., Bardgett, R. D., Merry, R. J., Pain, B. F., & Theodorou, M. K. (1995). Pathogens in livestock waste, their potential for movement through soil and environmental pollution. *Applied Soil Ecology 2,* 1–15.

McCulloch, R. B., Few, G. S., Murray, G. C., Jr., & Aneja, V. P. (1998). Analysis of ammonia, ammonium aerosols and acid gases in the atmosphere at a commercial hog farm in eastern North Carolina, USA. *Environmental Pollution 102,* 263–268.

MMWR. (1999). Public health dispatch: Outbreak of *Escherichia coli* 0157:H7 and *Campylobacter* among attendees of the Washington County fair, New York, 1999. Morbidity and Mortality Weekly Report, Centers for Disease Control and Prevention.

N.C.D.A. (1999). *North Carolina Agricultural Statistics.* North Carolina Department of Agriculture, North Carolina Agricultural Statistics, Raleigh, N.C.

N.C. D.A.Q. (1997). *Assessment plan for atmospheric nitrogen compounds: Emissions, transport, transformation, and deposition.* N.C. Department of Environment, Health and Natural Resources, Division of Air Quality, Raleigh, N.C.

NRCS. (1996). *Agricultural waste characteristics, Agricultural Waste Management Field Handbook.* (pp. 4.1–4.24). Natural Resources Conservation Service.

Paerl, H. W., Mallin, M. A., Donahue, C. A., Go, M & Peierls, B. J. (1995). *Nitrogen loading sources and eutrophication of the Neuse River Estuary, North Carolina: Direct and indirect roles of atmospheric deposition.* UNC WRRI-95-291. Water Resources Research Institute of the University of North Carolina, Raleigh, N.C.

Paerl, H. W., Rudek, J., & Mallin, M. A. (1990). Stimulation of phytoplankton productivity in coastal waters by natural rainfall inputs; nutritional and trophic implications. *Marine Biology 107.* 247–254.

Powers, W., & Van Horn, H. H. (1998). Whole-farm nutrient budgeting: A nutritional approach to manure management. In *Soil and Water Conservation Society, Manure Management in Harmony with the Environment and Society* (pp. 276–280). Ames, Iowa: Soil and Water Conservation Society West North Central Region.

Rudek, J., Paerl, H. W., Mallin, M. A., & Bates, P. W. (1991). Seasonal and hydrological control of phytoplankton nutrient limitation in the Neuse River Estuary, North Carolina. *Marine Ecology-Progress Series 75,* 133–142.

Sharpley, A. N., Daniel, T., Sims, T., Lemunyon, J., Stevens, R., & Parry, R. (1999). *Agricultural phosphorus and eutrophication.* U.S. Department of Agriculture, Agricultural Research Service, ARS-149.

Sharpley, A. N., Tunney, D. 2000. Phosphorus research strategies to meet agricultural and environmental challenges of the 21st century. *Journal of Environmental Quality* 29:176–181.

Sobsey, M. D. (1996). Pathogens and their indicators in North Carolina surface waters. In *Solutions: Proceedings of a Technical Conference on Water Quality* (pp 6–10). North Carolina State University, Raleigh, N.C.

Stone, K. C., Hunt, P. G., Coffey, S. W. & Matheny, T. A. (1995). Water quality status of a USDA water quality demonstration project in the Eastern Coastal Plain. *Journal of Soil and Water Conservation 50,* 567–571.

Thu, K. M., & Durrenberger, E. P. (1998). *Pigs, Profits, and Rural Communities.* Albany, State University of New York Press.

USNASS (1997) US National Agricultural Statistics Service census data for 1997. website: www.nass.usda.gov/census97/rankings.

Walker, J. T., V. P. Aneja, & Dickey, D. A. (2000). Atmospheric transport and wet deposition of ammonium in North Carolina. *Atmospheric Environment 34,* 3407–3418.

Westerman, P. W., Huffman, R. L., & Feng, J. S. (1995). Swine-lagoon seepage in sandy soil. *Transactions of the American Society of Agricultural Engineers 38,* 1749–1760.

Westerman, P. W., King, L. D., Burns, J. C., Cummings, G. A. & Overcash, M. R. (1987). Swine manure and lagoon effluent applied to a temperate forage mixture: II. Rainfall runoff and soil chemical properties. *Journal of Environmental Quality 16,* 106–112.

Williams, C. M., Barker, J. C., & Sims, T. (1999). Management and utilization of poultry wastes. *Reviews in Environmental Contamination and Toxicology 162,* 105–157.

Wing, S., Freedman, S., & Band, L. (2002). The potential impact of flooding on confined animal feeding operations in eastern North Carolina. *Environmental Health Perspectives 110*, 387–391.

Exhibit 42

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Asthma Symptoms Among Adolescents Who Attend Public Schools That Are Located Near Confined Swine Feeding Operations

Maria C. Mirabelli, Steve Wing, Stephen W. Marshall and Timothy C. Wilcosky

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ARTICLE

Asthma Symptoms Among Adolescents Who Attend Public Schools That Are Located Near Confined Swine Feeding Operations

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ABSTRACT

OBJECTIVES. Little is known about the health effects of living in close proximity to industrial swine operations. We assessed the relationship between estimated exposure to airborne effluent from confined swine feeding operations and asthma symptoms among adolescents who were aged 12 to 14 years.

METHODS. During the 1999–2000 school year, 58 169 adolescents in North Carolina answered questions about their respiratory symptoms, allergies, medications, socioeconomic status, and household environments. To estimate the extent to which these students may have been exposed during the school day to air pollution from confined swine feeding operations, we used publicly available data about schools (n ff 265) and swine operations (n ff 2343) to generate estimates of exposure for each public school. Prevalence ratios and 95% confidence intervals for wheezing within the past year were estimated using random-intercepts binary regression models, adjusting for potential confounders, including age, race, socioeconomic status, smoking, school exposures, and household exposures.

RESULTS. The prevalence of wheezing during the past year was slightly higher at schools that were estimated to be exposed to airborne effluent from confined swine feeding operations. For students who reported allergies, the prevalence of wheezing within the past year was 5% higher at schools that were located within 3 miles of an operation relative to those beyond 3 miles and 24% higher at schools in which livestock odor was noticeable indoors twice per month or more relative to those with no odor.

CONCLUSIONS. Estimated exposure to airborne pollution from confined swine feeding operations is associated with adolescents' wheezing symptoms.

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Key Words
asthma, environmental health, epidemiology, school age children, school health

Abbreviations
CAFO—confined animal feeding operation
PR—prevalence ratio
NCSAS—North Carolina School Asthma Survey
SSLW—steady-state live weight
CI—confidence interval

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During the past 2 decades, the process of raising swine and other livestock has grown into a major industry in the United States. Production has shifted from smaller, family-owned farms to larger, industrialized confined animal feeding operations (CAFOs). Animals in North Carolina's industrialized operations are raised in confinement buildings, housing hundreds to thousands of hogs per operation. Residues of food additives, bedding, dried waste, and animal dander are vented from confinement buildings, and animal waste from the confinement houses is flushed into on-site cesspools, where it begins to decompose and aerosolize anaerobically before being sprayed onto nearby land. There are concerns about the health impacts of exposure to particulate matter, antibiotic residues, volatile organic compounds, and bioaerosols that are present in air that is downwind from confinement buildings, waste lagoons, and spray fields.[1–4]

In occupational settings, adverse respiratory symptoms and changes in bronchial responsiveness and lung function have been observed among confinement building workers.[5–12] Studies that have compared swine CAFO neighbors with other rural residents showed that neighbors reported more frequent respiratory symptoms and mucosal membrane irritation.[13] This literature about health impacts of residential exposures that arise from CAFOs focuses on adults[2,13–15] and may describe inadequately the potential respiratory health effects among children, who may experience notably different physical, educational, and social impacts from such exposures. We designed this research to assess the relationship between self-reported wheezing symptoms among adolescents who were aged 12 to 14 years and estimated exposure to airborne effluent from swine CAFOs.

METHODS

This study combined data about adolescents' respiratory health symptoms, data from a survey of school environments, and location data about swine CAFOs and public schools in North Carolina. Random-intercepts binary regression models were used to estimate prevalence ratios (PRs) that assessed the association between airborne swine pollutants and the prevalence of wheezing symptoms.

North Carolina School Asthma Survey Data

During the 1999–2000 school year, the North Carolina Department of Health and Human Services conducted a statewide respiratory health surveillance project to assess the prevalence of respiratory symptoms among middle school–aged children.[16] Approximately 67% (128 568 of 192 248) of all eligible students participated in the survey, which included core wheezing questions from the International Study of Asthma and Allergies in Childhood questionnaire, a standardized and validated instrument that combines a traditional written questionnaire with a series of video scenes that show children with asthma symptoms.[17–20] To complete the video-based survey questions, students viewed a sequence of video vignettes that showed adolescents experiencing asthma-related symptoms; each scene was followed by time to complete a written survey question, allowing each student to indicate whether he or she had experienced symptoms like those illustrated in the scene.[19,20] We analyzed the prevalence of any wheezing symptoms within the past year ("current wheezing"), as determined by responses to questions about wheezing at rest, waking at night as a result of wheezing, exercise-induced wheezing, and severe wheezing attacks. The definition of current wheezing used here is consistent with that applied in previous analyses of the North Carolina School Asthma Survey (NCSAS) data.[16,21–23]

To evaluate whether the estimated exposure had an impact other asthma-related outcomes, we assessed "severe wheezing" using responses to survey questions about waking at night as a result of wheezing and having a severe wheezing attack during the past year; considered the severe wheezing symptoms to be frequent when they occurred at least once per month ("frequent severe wheezing"); and evaluated physician-diagnosed asthma, medical care, and behavioral consequences of asthma-related symptoms.

Each adolescent also answered questions about age, race, Hispanic ethnicity, allergies, socioeconomic status, cigarette smoking history, and home environment. We included age as a continuous variable (centered at 13) and categorized all other variables: race (black/white); Hispanic ethnicity (yes/no); allergies to cat, dog, dust, grass, or pollen (yes/no); ever smoked cigarettes (yes/no); number of other smokers in household (0, 1, 2, or ff3); and use of a gas stove at home (ffi1 time per month vs ff1 times per month). Socioeconomic status was assessed using responses to a question about payment for lunch at school, with lower economic status designated by receiving free or reduced-price lunch at school compared with paying full price for lunch or bringing lunch to school.

School Environment Data

During the 2003–2004 school year, we mailed 4 copies of a survey to principals of 337 public schools and asked each to distribute the surveys to current school employees. More than 800 anonymous survey respondents, employed in 265 (79%) of the targeted schools, answered questions about their observations of the environmental conditions in and around the school buildings. The survey responses indicated whether there was visible evidence of the presence of cockroaches, rodents, or mold and noticeable odors from indoor (eg, mold) and outdoor (eg, nearby industries) sources of airborne pollutants. Responses were used to create school-level indicator variables for the presence of indoor respiratory

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irritants and sources of outdoor air pollution from agriculture and industries that are located near the school. Because of concerns about response bias resulting from social and political conflict surrounding industrial swine production in North Carolina, we asked survey respondents to answer a question about livestock odor generically rather than about odor specifically arising from swine operations. When we received ffl1 survey from a single school, schools were categorized as positive for a given survey question when any respondent reported the given condition.

Swine CAFO Exposure Estimates

Estimates of exposure to airborne pollution from 2343 swine CAFOs were generated using data from permits that were issued by the North Carolina Division of Water Quality to all CAFOs that house at least 250 animals and use a liquid waste management system. Records contained mandatory information about each CAFO facility, including geographic coordinates and the number, type, and weight of animals (called steady-state live weight [SSLW]) at each operation.[3,24] CAFO operators who filed applications for liquid waste management permits with the state agency provided latitude and longitude coordinates of their operations; the coordinates were verified and corrected, when necessary, when state inspectors visited the operations, although the extent to which the information was corrected by agency inspectors was not recorded in the data (S. Lewis, personal communication, 2002).

Separate exposure estimates were developed on the basis of distances between schools and swine CAFOs and of survey responses about noticeable odors from livestock farms. Distances and geographic directions between schools and CAFOs were calculated using the formulas given by Goldberg et al[25] and Sinnott,[26] respectively. We used calculations of proximity to create 3 metrics of potential exposure for each school: (1) distance to the nearest operation; (2) SSLW within 3 miles; and (3) a weighted SSLW based on the distance between the school and nearby swine CAFOs, the SSLW of each operation, and the proportion of wind measurements in the direction from the operation to the school. We obtained measurements of wind speed and direction recorded at 16 automated weather stations located throughout the state from the State Climate Office of North Carolina (Raleigh, NC). Hourly averages from January 1999 through December 1999 and from the weather station located nearest each school–CAFO pair were used to compute the proportion of time when the wind was blowing from the operation to the school. Weighted SSLW values for each CAFO within 3 miles of a school were the product of the squared inverse of the distance between the school–CAFO pair, the operation's SSLW value, and the proportion of time that regional wind measurements indicated that wind was blowing from the operation toward the school. For each school, weighted SSLW values were summed and the schools were assigned categories of low, medium, and high exposure on the basis of tertiles of the distribution of values among schools with 1 or more swine CAFOs located within 3 miles. A 3-mile radius was selected on the basis of previous research about the impacts of swine CAFOs on health and quality of life among neighbors who live within a 2-mile radius[2,13]; for this research, we expanded the potential zone of exposure to 3 miles because odors from swine CAFOs sometimes are reported at distances of ffl2 miles.

Study Population

Students in 499 public schools participated in NCSAS, and each student provided data about his or her respiratory health. Schools in 14 counties that did not contain a swine CAFO or border a county with at least 1 swine CAFO (*n* ff 45), schools within the city limits of the 6 cities with populations ffl100 000 (*n* ff 61), schools within 5 miles of the state border (*n* ff 18), schools with ffi25 students surveyed (*n*ff 34), schools that had closed or relocated since 2000 (*n* ff 11), and schools that did not respond to the survey about in-school environmental conditions (*n* ff 72) were excluded from our study. The remaining 265 public schools were included in our study. From these 265 schools, a total of 73 305 boys and girls who were aged 12 to 14 years responded to NCSAS. Of those, 58 169 (79%) who reported black or white race and provided complete data for all asthma survey variables of interest constituted our final study population.

Statistical Analyses

Multivariate analyses were conducted separately for individuals with and without self-reported allergies to cat, dog, dust, grass, and/or pollen. To assess the relationship between the prevalence of wheezing symptoms and the estimates of in-school exposure, we used random-intercepts binary regression. This method accounted for the hierarchical clustering of student-level data within schools. Specifically, we used a variation of the generalized linear mixed model $E(Y x)$ ff exp(ffi⌋ | ffix) similar to those described by Singer[27] and McLeod,[28] in which the student's outcome is modeled by a combination of student-level (level 1) and school-level (level 2) models. The student-level model was defined as

$$\log_e{}^{-}P_{ij}\bullet^{\rfloor} \text{ ffl}_{0j} \mid \text{ ffl}_1 x_{1j} \mid \text{ ffl}_2 x_{2j} \mid \ldots \mid \text{ ffl}_n x_{nj} \text{ (level 1)},$$

where P_{ij} is the probability of outcome y ff 1 for individual i in school j, p_{ij} ◻ binomial; ffl_{0j} is school-specific intercept (intercept for school j); and ffl is the effect of individual-level predictor x_{ij}. Level 1 models included student-level variables for age, gender, race, Hispanic ethnicity, economic status, allergy status, ciga-

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rette smoking experience, number of other smokers in the household, and use of a gas kitchen stove at home. The school-level (level 2) model was defined as

$$\text{ffl}_{0j} \lrcorner \ \text{ffl}_0 \mid -_1 z_1 \mid -_2 z_2 \mid \ \ldots \mid -_n z_m \mid -_{0j} \text{ (level 2)},$$

where ffl_0 is the mean of school-level means for outcome y (ie, fixed intercept); $-$ is the effect of school-level predictor z_j; z_j is the school-level predictor for school j; $-_{0j}$ ◻ $N(0,\bullet_{00})$; and $\bullet_{00}$ is between-school variance. The level 2 models included main exposure variable(s) and indicator variables for rural school locale, survey-reported presence of indoor respiratory irritants (cockroaches, rodents, mold visible, mold odor, or flooding of school buildings within the past 5 years), and survey-reported industry other than a swine CAFO located near the school. The level 2 model, substituted into the level 1 model, results in a final 2-level random-intercepts model,

$$\log_e \text{-}P_{ij}\bullet \lrcorner \ \text{ffl}_{0j} \mid \text{ffl}_1 x_{1j} \mid \text{ffl}_2 x_{2j} \mid \ \ldots \mid \text{ffl}_n x_{nj} \mid -_1 z_1 \mid -_2 z_2 \mid \ \ldots \mid -_n z_m \mid -_{0j},$$

where $-_{0j}$ is the random intercept term. Associations were estimated as PRs (exp[$-$]) using SAS statistical software version 8.2 (SAS Institute Inc, Cary, NC).

RESULTS

More than 26% (15 250 of 58 169) of students who participated in NCSAS during the 1999–2000 school year reported wheezing during the past year (ie, current wheezing). Table 1 shows adjusted PRs for individual- and school-level characteristics. Of the individual-level characteristics, the highest PR was observed for self-reported allergy status (PR: 2.20; 95% confidence interval [CI]: 2.14–2.27). Variations in the prevalence of current wheezing by school-level characteristics and indicators of school-specific environmental health conditions were less pronounced.

Of the 265 schools, 66 (25%), including 10 518 (18%) surveyed students, were located within 3 miles of at least 1 (range: 1–27) swine CAFO. More than 50% of the schools were within 7 miles of the nearest operation (median: 6.7 miles; range: 0.22–42.0 miles). The average SSLW capacity of operations that were located within 3 miles of a school was slightly lower than that of operations that were located beyond 3 miles (556 283 lb vs 605 139 lb), and, overall, the SSLW capacity of swine CAFOs increased with increasing distance from the nearest surveyed school (ffl [SE] per mile ff 15 948 [4791]). On the basis of the environmental health surveys and according to survey respondents, livestock odor was noticeable outside buildings in 86 (33%) schools and inside the buildings in 39 (15%) schools.

Table 2 presents adjusted PRs for wheezing using each exposure measure separately for students with and without allergies. PRs were 1.05 (95% CI: 1.00–1.10) and 1.02 (95% CI: 0.94–1.11) for adolescents who did and did not have allergies, respectively, and attended schools that were located within 3 miles of the nearest swine CAFO. PRs were approximately unity for schools that were closer than 2 miles, compared with schools with no nearby swine CAFOs, and were 1.12 (95% CI: 1.04–1.19) and 1.08 (95% CI: 0.95–1.21), respectively, for students who did and did not have self-reported allergies and attended schools that were located between 2 and 3 miles from the nearest operation. Associations with SSLW and the weighted SSLW exposure categories also tended to be highest for the low exposure groups and closer to unity for higher exposure groups compared with schools with no nearby swine CAFOs. Basing potential exposure estimates on survey-reported livestock odor resulted in 20 fewer schools' and 3315 fewer adolescents' being considered unexposed. The prevalence of current wheezing was 24% and 21% higher among allergic and nonallergic students, respectively, at schools in which livestock odor was noted inside the school building 2 or more times per month relative to the prevalence at schools without any survey reports of livestock odor.

Table 3 presents adjusted associations between school proximity within 3 miles of a swine CAFO and alternative asthma outcomes as well as functional consequences of asthma-related symptoms. Results indicate that larger proportions of adolescents who attended school near at least 1 swine CAFO experienced respiratory symptoms, physician diagnosis, asthma-related medical treatment, activity limitations, and missing school because of their symptoms. In the population of all students, the largest PRs were observed for physician-diagnosed asthma (PR: 1.07; 95% CI: 1.01–1.14), medication use (PR: 1.07; 95% CI: 1.00–1.15), and visit to a physician or an emergency department or hospitalization (PR: 1.06; 95% CI: 1.00–1.12). Most associations were slightly higher in adolescents with self-reported allergies; however, the PR for physician-diagnosed asthma was higher among students without (PR: 1.14; 95% CI: 1.01–1.26) compared with those with (PR: 1.06; 95% CI: 0.99–1.12) self-reported allergies. Adjusted associations between these outcomes and the presence of livestock odor in and around the schools indicate only slightly elevated proportions of wheezing symptoms, physician diagnosis, use of asthma-related medical care, activity limitations, and missed school among students in schools where employees reported noticeable livestock odor (Table 4). When school-level exposures were assigned on the basis of reported livestock odor (Table 4), the PRs for severe wheezing (PR: 1.05; 95% CI: 1.00–1.10) and frequent severe wheezing (PR: 1.06; 95% CI: 0.98–1.14) were higher than when exposure was assigned on the basis of distance to the nearest swine CAFO (severe wheeze, ◻ 3 miles: 1.02 [95% CI: 0.97–

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TABLE 1 **Characteristics of North Carolina School Asthma Survey Participants and Public Schools in North Carolina**

	N	Students Who Reported Current Wheezing, *n* (%)	PR (95% CI)[a]
Total	58 169	15 250 (26.2)	—
Age, y[b]			
12	17 905	4873 (27.2)	1.06 (1.04–1.08)
13	28 130	7268 (25.8)	1.00[c]
14	12 134	3109 (25.6)	0.95 (0.93–0.96)
Race			
White	43 590	10 919 (25.1)	1.00
Black	14 579	4331 (29.7)	1.04 (1.01–1.08)
Gender			
Male	28 342	6798 (24.0)	1.00
Female	29 827	8452 (28.3)	1.07 (1.04–1.10)
SES indicator			
Lunch not subsidized	41 719	10 088 (24.2)	1.00
Lunch subsidized	16 450	5162 (31.4)	1.16 (1.12–1.20)
Hispanic ethnicity			
No	54 827	14 236 (26.0)	1.00
Yes	3342	1014 (30.3)	1.11 (1.06–1.16)
Allergies			
No	31 480	5149 (16.4)	1.00
Yes	26 689	10 101 (37.9)	2.20 (2.14–2.27)
Ever smoked			
No	40 632	9154 (22.5)	1.00
Yes	17 537	6096 (34.8)	1.35 (1.31–1.39)
No. of other smokers in household[b]			
0	27 662	6138 (22.2)	1.00
1	16 079	4447 (27.7)	1.09 (1.07–1.10)
2	10 209	3178 (31.1)	1.18 (1.15–1.21)
ff3	4219	1487 (35.3)	1.29 (1.24–1.34)
Frequency of gas kitchen stove use			
Less than once per more	45 546	11 384 (25.0)	1.00
Once per month or more	12 623	3866 (30.6)	1.14 (1.11–1.17)
Rural school locale			
No	30 154	8074 (26.8)	1.00
Yes	28 015	7076 (25.6)	0.96 (0.92–1.00)
In-school asthma triggers[d]			
No	4619	1147 (24.8)	1.00
Yes	53 550	14 103 (26.3)	1.03 (0.95–1.11)
Location near non-livestock industry[e]			
No	52 184	13 603 (26.1)	1.00
Yes	5985	1647 (27.5)	1.06 (0.99–1.13)

PR indicates prevalence ratio; SES, socioeconomic status.

[a] Adjusted for all individual-level and school-level covariates in the table.

[b] Included in the model as a continuous variable.

[c] Referent category.

[d] Environmental Health Survey responses about cockroaches, rodents, mold, and/or flooding in school buildings (no: 24 schools; yes: 241 schools).

[e] Environmental Health Survey responses about non-livestock industries located near the school (No: 236 schools; Yes: 29 schools).

1.07]; frequent severe wheeze, ◻ 3 miles: 1.01 [95% CI: 0.92–1.09]; Table 3).

DISCUSSION

We observed elevated prevalences of current wheezing among 12- to 14-year-old students who attended public schools near swine CAFOs, especially among students with self-reported allergies. Such associations are plausible, given that swine CAFOs are sources of bioaerosols, endotoxins, and other airborne asthma triggers. The availability of standardized symptom data and the independence of symptom and exposure data strengthen confidence in the validity of our findings. Overall, estimates of excess current wheezing symptoms among students who attended schools nearby swine CAFOs are as high as 24% among students who attended schools where livestock odor was reported outside as well as inside 2 or more times per month. Excess prevalence of current wheezing tended to be greater among students who reported allergies. Although the majority of the

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TABLE 2 **Associations Between the Prevalence of Wheezing and Exposure to Confined Swine Feeding Operations by Adolescents' Self-Reported Allergic Status, North Carolina**

	Total No. of Schools	Self-Reported Allergies (*n* ff 26 689)			No Self-Reported Allergies (*n* ff 31 480)			All (*N* ff 58 169)		
		Total No. of Students	Wheeze, *n* (%)[a]	PR (95% CI)[b]	Total No. of Students	Wheeze, *n* (%)	PR (95% CI)[b]	Total No. of Students	Wheeze, (%)	PR (95% CI)[c]
Current wheeze			10 101 (37.9)			5149 (16.4)			15 250 (26.2)	
Miles to nearest swine CAFO										
ffl3	199	21 898	8145 (37.2)	1.00	25 753	4138 (16.1)	1.00	47 651	12 283 (25.8)	1.00
□ 3	66	4791	1956 (40.8)	1.05 (1.00–1.10)	5727	1011 (17.7)	1.02 (0.94–1.11)	10 518	2967 (28.2)	1.04 (0.99–1.09)
2 t o□ 3	22	1865	822 (44.1)	1.12 (1.04–1.19)	2107	396 (18.8)	1.08 (0.95–1.21)	3972	1218 (30.7)	1.10 (1.02–1.18)
□ 2	44	2926	1134 (38.8)	1.01 (0.95–1.07)	3620	615 (17.0)	0.99 (0.89–1.09)	6546	1749 (26.7)	1.01 (0.95–1.07)
Hog pounds (in millions) within 3 miles of school										
None	199	21 898	8145 (37.2)	1.00	25 753	4138 (16.1)	1.00	47 651	12 283 (25.8)	1.00
0.1 to ffi2.0	42	3342	1388 (41.5)	1.07 (1.01–1.12)	4017	713 (17.8)	1.03 (0.93–1.12)	7359	2101 (28.6)	1.05 (1.00–1.11)
2.0 to ffi5.0	12	733	294 (40.1)	1.04 (0.93–1.14)	858	150 (17.5)	0.99 (0.81–1.16)	1591	444 (27.9)	1.01 (0.91–1.12)
ff5.0	12	716	274 (38.3)	1.00 (0.89–1.11)	852	148 (17.4)	1.04 (0.85–1.23)	1568	422 (26.9)	1.02 (0.91–1.13)
Exposure category										
None	199	21 898	8145 (37.2)	1.00	25 753	4138 (16.1)	1.00	47 651	12 283 (25.8)	1.00
Low	21	1655	711 (43.0)	1.10 (1.03–1.18)	1922	359 (18.7)	1.09 (0.95–1.23)	3577	1070 (29.9)	1.09 (1.01–1.18)
Medium	22	1741	771 (40.8)	1.04 (0.97–1.12)	2139	378 (17.7)	1.01 (0.89–1.13)	3880	1089 (28.1)	1.03 (0.96–1.11)
High	23	1395	534 (38.3)	1.01 (0.93–1.08)	1666	274 (16.5)	0.97 (0.84–1.10)	3061	808 (26.4)	1.00 (0.92–1.08)
Livestock odor										
None	179	19 055	7188 (37.7)	1.00	22 438	3694 (16.5)	1.00	41 493	10 882 (26.2)	1.00
Outside school only	47	4625	1766 (38.2)	1.04 (0.98–1.09)	5593	843 (15.1)	0.94 (0.85–1.02)	10 218	2609 (25.5)	1.00 (0.95–1.06)
Outside ┘ inside ffi2 times/mo	36	2745	1022 (37.2)	0.99 (0.93–1.06)	3137	550 (17.5)	1.04 (0.93–1.15)	5882	1572 (26.7)	1.01 (0.94–1.07)
Outside ┘ inside ff2 times/mo	3	264	125 (47.4)	1.24 (1.03–1.44)	312	62 (19.9)	1.21 (0.85–1.57)	576	187 (32.5)	1.23 (1.01–1.44)

[a] Any wheeze in the past 12 months (current wheeze).

[b] Adjusted for individual-level characteristics (gender, age, race, Hispanic ethnicity, economic status, smoking status, exposure to second-hand smoke at home, and use of a gas stove more than once per month) and school-level characteristics (rural locale, indoor air quality, and reports of other non-livestock industries nearby).

[c] Adjusted for variables listed above plus self-reported allergy to cats, dogs, dust, grass, and/or pollen.

TABLE 3 **Associations Between the Prevalence of Asthma-Related Symptoms and School Location Within 3 Miles of a Confined Swine Feeding Operation by Adolescents' Self-Reported Allergic Status, North Carolina**

	PR (95% CI) for □ 3 v sffl3 Miles From Nearest Swine CAFO		
	Self-Reported Allergies (*n* ff 26 689)	No Self-Reported Allergies (*n* ff 31 480)	All (*N* ff 58 169)
Wheezing symptoms			
Current wheeze	1.05 (1.00–1.10)	1.02 (0.94–1.11)	1.04 (0.99–1.09)
Current wheeze without physician diagnosis	1.08 (1.01–1.15)	0.99 (0.90–1.08)	1.04 (0.98–1.11)
Severe wheeze[b]	1.01 (0.96–1.07)	1.05 (0.96–1.14)	1.02 (0.97–1.07)
Frequent severe wheeze[a]	1.02 (0.92–1.11)	0.97 (0.80–1.14)	1.01 (0.92–1.09)
Physician-diagnosed asthma	1.06 (0.99–1.12)	1.14 (1.01–1.26)	1.07 (1.01–1.14)
Medical care			
Asthma-related physician visit, emergency visit, and/or hospitalization in past year	1.06 (1.00–1.13)	1.03 (0.92–1.13)	1.06 (1.00–1.12)
Asthma medication use in past year	1.09 (1.00–1.18)	1.03 (0.88–1.18)	1.07 (1.00–1.15)
Functional consequences of symptoms			
Activity limitations in past year as a result of asthma symptoms	1.09 (1.01–1.16)	—[b]	—
Missed school in past year as a result of asthma symptoms	1.06 (0.98–1.14)	—	—

[a] Among individuals with current wheeze.

[b] Nonconvergent model.

estimates are small in relative terms, the increases are important in absolute terms because of the high prevalence of asthma-related symptoms in this age group; the impact that symptoms have on adolescents' ability to attend school and participate in social, recreational, and physical activities; and the costs and burdens of symp-

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TABLE 4 **Associations Between the Prevalence of Asthma-Related Symptoms and the Presence of Livestock Odor at the School by Adolescents' Self-Reported Allergic Status, North Carolina**

	PR (95% CI) for Livestock Odor Reported Outside or Inside School Building Versus No Reported Odor		
	Self-Reported Allergies (*n* ff 26 689)	No Self-Reported Allergies (*n* ff 31 480)	All (*N* ff 58 169)
Wheezing symptoms			
Current wheeze	1.03 (0.98–1.07)	0.99 (0.91–1.06)	1.01 (0.97–1.06)
Current wheeze without physician diagnosis	1.04 (0.97–1.10)	0.99 (0.90–1.07)	1.01 (0.96–1.07)
Severe wheeze[a]	1.06 (1.01–1.12)	1.00 (0.91–1.08)	1.05 (1.00–1.10)
Frequent severe wheeze[a]	1.04 (0.95–1.14)	1.10 (0.92–1.28)	1.06 (0.98–1.14)
Physician-diagnosed asthma	1.00 (0.94–1.06)	1.04 (0.93–1.15)	1.01 (0.95–1.06)
Medical care			
Asthma-related physician visit, emergency visit, and/or hospitalization in past year	0.99 (0.94–1.05)	1.01 (0.91–1.10)	1.00 (0.95–1.05)
Asthma medication use in past year	1.03 (0.96–1.11)	1.02 (0.89–1.15)	1.03 (0.96–1.10)
Functional consequences of symptoms			
Activity limitations in past year as a result of asthma symptoms	1.02 (0.96–1.08)	—[b]	—
Missed school in past year as a result of asthma symptoms	1.02 (0.94–1.09)	—	—

[a] Among individuals with current wheeze.
[b] Nonconvergent model.

tom-related medical care. In these data, the effect estimates for swine CAFO exposures are of similar magnitude to the effects that have been estimated for established risk factors for wheeze, such as age, race, gender, economic status, Hispanic ethnicity, exposure to secondhand cigarette smoke, and use of a gas stove at home.

We estimated potential exposure on the basis of distance and a mailed survey. Although distance is a crude measure of exposure, our findings suggest a consistent trend toward higher symptom prevalence, especially among adolescents with allergies, at schools that were between 2 and 3 miles of a swine CAFO. The finding that schools that were located within 2 miles had a lower prevalence of current wheezing may reflect the lack of a direct relationship between exposure to etiologically active agents and distance. Use of distance and SSLW as exposure measures does not take account of waste management and sanitation practices of swine CAFOs, ages and conditions of the facilities' equipment, localized weather patterns, topography surrounding the school, school building structure, and ventilation practices, all of which may affect the quantity and the duration of the exposures. In addition, swine CAFO practices such as waste and sanitation procedures may be influenced by population density, land availability, and other features of the communities in which the operations are located, although we do not know the extent to which this occurs. Indeed, results of analyses that used exposure metrics of increasing complexity failed to show a monotonic dose-response relationship between the exposure and current wheezing, further suggesting that if the exposure is associated with an increase in respiratory symptoms, then relevant exposure may not correlate directly with the factors that we used for our distance-based exposure categories.

The higher prevalence of current wheezing among students who attended schools that were located 2 to 3 miles from the nearest swine CAFO compared with the prevalence among students who attended schools within 2 miles also may be attributable to exposures that were experienced at home, in the communities where students lived, and in other locations that could not be assessed in our study. In many of the rural areas in North Carolina, students may live many miles from the public schools that they attend. As the distance between the school and the CAFO becomes small, few homes can be equally close or closer to a CAFO; as the distance increases, more of the students' homes can be located closer to a CAFO than the distance between the CAFO and the school, and school-based exposure estimates will underestimate students' total swine CAFO exposures. In addition, reports of odor from swine CAFOs tend to be more common in early morning and evening hours rather than in the daytime, when students are in school. Although this phenomenon may not affect exposures in geographic areas where both schools and homes are far from CAFOs, identifying exposure as the distance between a school and a CAFO may be more problematic in regions where schools are located very near or within several miles of CAFOs if exposure varies throughout the day. Previous research that was conducted in a rural population of school-aged children who may have experienced swine farm exposures at home indicated a higher prevalence of asthma-related symptoms among children who lived on farms where swine were raised

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than among children who lived on farms where swine were not raised and among children who did not live on farms,[29] although the extent to which exposures that resulted from residence on a swine farm were attributable to performing chores or occupation-like tasks, rather than simply living close to swine, are unknown. Although information about adolescents' household farming exposures are unavailable in our study population, the majority of swine in North Carolina are raised in nonresidential, factory farm settings; therefore, the proportion of children who perform chores or live on swine farms is expected to be low.

Results of analyses of the distance-based measures of each exposure suggest lower prevalence of wheezing among students who attended schools that were located nearest to CAFOs and located in areas with the highest density of swine compared with those in the highest exposure categories. To assess potential misclassification of exposure, we excluded from all analyses schools with reported livestock odor from the unexposed distance-based categories, schools that were located beyond 3 miles of swine CAFO from the exposed survey-based categories, and schools for which survey respondents specifically identified livestock odor as arising from poultry and found no notable differences in the direction, magnitude, or precision of the PRs generated. An alternative explanation for the lower prevalence of wheezing among students in schools that were located nearby swine CAFOs may be the hygiene hypothesis, which postulates that early-life exposures and childhood infections may confer protection against hay fever, atopy, and asthma.[30,31] Specifically, rural living and early-life exposures to allergens, irritants, and other bioaerosols on farms may be associated with lower rates of atopy and asthma.[29,32–38] In our study, the prevalence of wheezing was slightly lower (1.2%) in rural compared with nonrural schools. Although we could not assess early-life exposures, higher exposures to animal dander and bacterial endotoxin during early developmental stages among individuals who attend schools closest to swine CAFOs and therefore often live in rural areas could provide some resistance to exposures later in childhood and lead to lower prevalence of wheezing during adolescence compared with students who attend schools farther away.

Twenty-one percent (*n* ff 72) of schools were excluded from our final analysis because of nonparticipation in our mailed survey about in-school environmental conditions. When we compared the populations of schools that participated and those that did not, we found differences in mean distance to the nearest swine CAFO (participating schools: 8.7 miles; nonparticipating schools: 8.0 miles), percentage of nonwhite enrollment (participating schools: 36%; nonparticipating schools: 42%), and percentage of enrolled students who received subsidized school lunches (participating schools: 48%; nonparticipating schools: 51%). Systematic differences between participating and nonparticipating schools in levels of exposure and prevalences of asthma-related symptoms could have influenced our findings.

We received up to 7 completed surveys per school, and for each survey question, we assigned an exposure to a school when any respondent indicated the presence of the exposure. This method of classifying schools' environmental conditions and, in particular, the presence of livestock odor at the school was sensitive to the number of surveys completed and returned from each school and did not take into account the variation in survey responses from a single school. Our intention was to survey employees in several occupations who would be familiar with different aspects of the school building and students' behaviors: teacher, administrator, maintenance or custodial staff, and school nurse or health care personnel. Previous literature about the economic, political, and social impacts of a strong swine industry presence in communities in Iowa and North Carolina suggested that residents who live near swine CAFOs may be reluctant to voice their concerns for fear of social ostracism or conflict in their communities.[39–42] Although our school survey was anonymous and designed to minimize risks for deductive disclosure of respondents' identities, we recognize the possibility that respondents may have underreported livestock odor out of concern for expressing their opinions, and we cannot know fully the extent to which our survey reports were influenced by the social and political context in the communities in which the schools were located.

Lack of data on medical risk factors, environmental asthma triggers, and classification of allergic status on the basis of survey reports rather than of a clinical assessment of atopy are limitations of this study. Because students self-identified asthma-related symptoms, our current wheezing variable may include other respiratory symptoms that the respondents experience and mistake for the symptoms that were illustrated in the video scenes. Cross-sectional asthma-related symptom data and survey-based exposure data prohibit specific assessment of temporal relationships between the symptoms and exposures evaluated here. Our findings are vulnerable to systematic error if students with asthma-related symptoms changed their environments or behaviors because of symptoms that were caused by exposure to airborne pollution that arose from swine CAFOs; such a systematic error would lead to underestimation of associations between swine CAFOs and asthma symptoms.

CONCLUSIONS

This research was designed to estimate exposures to a source of air pollution that is of great concern to swine CAFO neighbors and to investigate relationships between school exposures and respiratory health of middle school–aged children. Our findings identify a plausible

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association between exposure to airborne pollution from swine CAFOs and wheezing symptoms among adolescents. Environmental pollution measurement and standardized clinical information about asthma symptoms and atopic status could help to determine better the magnitude and the temporality of the relationships between swine CAFO emissions and respiratory symptoms. Our findings should be used by public health personnel who are interested in understanding possible adverse respiratory health consequences of an important rural environmental exposure.

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REFERENCES

1. Thu KM. Piggeries and politics: rural development and Iowa's multibillion dollar swine industry. *Cult Agric.* 1995;53:19–23
2. Wing S, Wolf S. Intensive livestock operations, health, and quality of live among Eastern North Carolina residents. *Environ Health Perspect.* 2000;108:233–238
3. Wing S, Cole D, Grant G. Environmental injustice in North Carolina's hog industry. *Environ Health Perspect.* 2000;108: 225–231
4. Donham KJ, Thu KM. Relationships of agricultural and economic policy to the health of farm families, livestock, and the environment. *J Am Vet Med Assoc.* 1993;202:1084–1091
5. Vogelzang PF, van der Gulden JW, Folgering H, Heederik D, Tielen MJ, van Schayck CP. Longitudinal changes in bronchial responsiveness associated with swine confinement dust exposure. *Chest.* 2000;117:1488–1495
6. Vogelzang PF, van der Gulden JW, Folgering H, et al. Endotoxin exposure as a major determinant of lung function decline in pig farmers. *Am J Respir Crit Care Med.* 1998;157:15–18
7. Vogelzang PFJ, van der Gulden JWJ, Preller L, Heederik D, Tielen MJM, van Schayck CP. Respiratory morbidity in relationship to farm characteristics in swine confinement work: possible preventive measures. *Am J Ind Med.* 1995;30:212–218
8. Radon K, Weber C, Iversen M, Danuser B, Pedersen S, Nowak D. Exposure assessment and lung function in pig and poultry farmers. *Occup Environ Med.* 2001;58:405–410
9. Heederik D, Brouwer R, Biersteker K, Boleij JS. Relationship of airborne endotoxin and bacteria levels in pig farms with the lung function and respiratory symptoms of farmers. *Int Arch Occup Environ Health.* 1991;62:595–601
10. Haglind P, Rylander R. Occupational exposure and lung function measurements among workers in swine confinement buildings. *J Occup Med.* 1987;29:904–907
11. Dosman JA, Senthilselvan A, Kirychuk SP, et al. Positive human health effects of wearing a respirator in a swine barn. *Chest.* 2000;118:852–860
12. Donham K, Rubino M, Thedell T, Kammermeyer J. Potential health hazards to agricultural workers in swine confinement buildings. *J Occup Med.* 1977;19:383–387
13. Thu K, Donham K, Ziegenhorn R, et al. A control study of physical and mental health of residents living near a large-scale swine operation. *J Agric Saf Health.* 1997;3:13–26
14. Thu KM. Public health concerns for neighbors of large-scale swine production operations. *J Agric Saf Health.* 2002;8: 175–184
15. Schiffman SS, Miller EA, Suggs MS, Graham BG. The effect of environmental odors emanating from commercial swine operations on the mood of nearby residents. *Brain Res Bull.* 1995; 37:369–375
16. Sotir M, Yeatts K, Shy C. Presence of asthma risk factors and environmental exposures related to upper respiratory infection-triggered wheezing in middle school-age children. *Environ Health Perspect.* 2003;111:657–662
17. International Study of Asthma and Allergies in Childhood (ISAAC) Steering Committee. ISAAC Manual. 2nd ed. December 1993. Available at: isaac.auckland.ac.nz/PhaseOne/Manual. Accessed December 21, 2005
18. Shaw RA, Crane J, Pearce N, et al. Comparison of a video questionnaire with the IUATLD written questionnaire for measuring asthma prevalence. *Clin Exp Allergy.* 1992;22:561–568
19. Yeatts K, Davis KJ, Sotir M, Herget C, Shy C. Who gets diagnosed with asthma? Frequent wheeze among adolescents with and without a diagnosis of asthma. *Pediatrics.* 2003;111: 1046–1054
20. Yeatts K, Shy C, Wiley J, Music S. Statewide adolescent asthma surveillance. *J Asthma.* 2000;37:425–443
21. Sturm JJ, Yeatts K, Loomis D. Effects of tobacco smoke exposure on asthma prevalence and medical care use in North Carolina middle school children. *Am J Public Health.* 2004;94:308–313
22. Yeatts K, Johnston Davis K, Peden D, Shy C. Health consequences associated with frequent wheezing in adolescents without asthma diagnosis. *Eur Respir J.* 2003;22:781–786
23. Yeatts K, Shy C, Sotir M, Music S, Herget C. Health consequences for children with undiagnosed asthma-like symptoms. *Arch Pediatr Adolesc Med.* 2003;157:540–544
24. Wing S, Freedman S, Band L. The potential impact of flooding on confined animal feeding operations in eastern North Carolina. *Environ Health Perspect.* 2002;110:387–391
25. Goldberg MS, Siemiatyck J, DeWar R, Desy M, Riberdy H. Risks of developing cancer relative to living near a municipal solid waste landfill site in Montreal, Quebec, Canada. *Arch Environ Health.* 1999;54:291–296
26. Sinnott RW. Virtues of the Haversine. *Sky Telescope.* 1984;68:159
27. Singer J. Using SAS PROC MIXED to fit multilevel models, hierarchical models, and individual growth models. *J Educ Behav Stat.* 1998;24:323–355
28. McLeod A. Multivariate multilevel models. In: Leyland AH, Goldstein H, eds. *Multilevel Modelling of Health Statistics.* New York, NY: Wiley; 2001:59–73
29. Merchant JA, Naleway AL, Svendsen ER, et al. Asthma and farm exposures in a cohort of rural Iowa children. *Environ Health Perspect.* 2005;113:350–356
30. von Mutius E. Influences in allergy: epidemiology and the environment. *J Allergy Clin Immunol.* 2004;113:373–379
31. Strachan DP. Family size, infection and atopy: the first decade of the "hygiene hypothesis." *Thorax.* 2000;55(suppl 1):S2–S10
32. Ernst P, Cormier Y. Relative scarcity of asthma and atopy among rural adolescents raised on a farm. *Am J Respir Crit Care Med.* 2000;161:1563–1566
33. von Ehrenstein OS, von Mutius E, Illi S, Baumann L, Bohm O, von Kries R. Reduced risk of hay fever and asthma among children of farmers. *Clin Exp Allergy.* 2000;30:187–193
34. Riedler J, Braun-Fahrlander C, Eder W, et al. Exposure to farming in early life and development of asthma and allergy: a cross-sectional survey. *Lancet.* 2001;358:1129–1133
35. Ownby DR, Johnson CC, Peterson EL. Exposure to dogs and cats in the first year of life and risk of allergic sensitization at 6 to 7 years of age. *JAMA.* 2002;288:963–972
36. Braun-Fahrlander C, Riedler J, Herz U, et al. Environmental

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exposure to endotoxin and its relation to asthma in school-age children. *N Engl J Med.* 2002;347:869–877
37. Chrischilles E, Ahrens R, Kuehl A, et al. Asthma prevalence and morbidity among rural Iowa schoolchildren. *J Allergy Clin Immunol.* 2004;113:66–71
38. Elliott L, Yeatts K, Loomis D. Ecological associations between asthma prevalence and potential exposure to farming. *Eur Respir J.* 2004;24:938–941
39. Greenberg DS. Conference deplores corporate influence on academic science. Speakers argue that corporate funds should be separated from science to prevent undue influence. *Lancet.* 2003;362:302–303
40. Thu KM, Durrenberger EP, Schiffman SS, Morgan R. *Pigs, Profits, and Rural Communities.* Albany, NY: State University of New York Press; 1998
41. Thu KM. Agriculture, the environment, and sources of state ideology and power. *Cult Agric.* 2001;23:1–7
42. Wing S, Grant G, Green M, Stewart C. Community based collaboration for environmental justice: south-east Halifax environmental reawakening. *Environ Urban.* 1996;8:129–140

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Asthma Symptoms Among Adolescents Who Attend Public Schools That Are Located Near Confined Swine Feeding Operations

Maria C. Mirabelli, Steve Wing, Stephen W. Marshall and Timothy C. Wilcosky

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Exhibit 43

Race, Poverty, and Potential Exposure of Middle-School Students to Air Emissions from Confined Swine Feeding Operations

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Previous studies suggest that airborne effluent from swine confined animal feeding operations (CAFOs) may affect the health and quality of life of adults and the prevalence of asthma symptoms among children. To investigate the extent to which public school students may be exposed to airborne effluent from swine CAFOs and to evaluate the association between schools' demographic characteristics and swine CAFO exposures, we assessed the proximity of 226 schools to the nearest swine CAFO and conducted a survey of school employees to identify schools with noticeable livestock odor. We used publicly available information describing the enrollment of each school to assess the association between race and socioeconomic status (SES) and swine CAFO exposure. Odor from livestock was noticeable outside (*n* = 47, 21%) and inside (*n* = 19, 8%) school buildings. Schools with < 63% enrollment of white students and ≥ 47% of students receiving subsidized lunches at school were located closer to swine CAFOs (mean = 4.9 miles) than were the remaining schools (mean = 10.8 miles) and were more likely to be located within 3 miles of an operation than were schools with high-white/high-SES enrollment (prevalence ratio = 2.63; 95% confidence interval, 1.59–4.33). The prevalence of reported livestock odor varied with SES (low SES, 25%; high SES, 17%). These analyses indicate that the potential for in-school exposure to pollution arising from swine CAFOs in North Carolina and the environmental health risks associated with such exposures vary according to the racial and economic characteristics of enrolled students. ***Key words:*** **adolescent health, children's health, confined swine feeding, environmental epidemiology, environmental justice, industrial hog operations, school health.** ***Environ Health Perspect*** **114:591–596 (2006). doi:10.1289/ehp.8586 available via *http://dx.doi.org/* [Online 10 November 2005]**

Confined animal feeding operations (CAFOs) house large numbers of animals, flush animal wastes into open-air waste pits, and apply partially decomposed wastes to land, releasing pollutants into soil, air, and water (National Research Council 2003). Odor and local air pollution—including ammonia (Reynolds et al. 1997; Subramanian et al. 1996; U.S. Environmental Protection Agency 2002), hydrogen sulfide (Reynolds et al. 1997), methane (Sharpe and Harper 1999), residues of veterinary antibiotics (Hamscher et al. 2003), total bacteria (Radon et al. 2001), fungi (Radon et al. 2001), and endotoxin (Reynolds et al. 1997)—arise from CAFO buildings and waste pits and are of particular concern to CAFO neighbors because of their documented impacts on the health and quality of life of livestock farm workers and neighbors (Cole et al. 2000; Merchant et al. 2005; Schiffman 1998; Schiffman et al. 1995; Thu et al. 1997; Vogelzang et al. 1999, 2000; Wing and Wolf 2000). A study of the mental and physical health of swine CAFO neighbors in Iowa found elevated rates of respiratory symptoms among CAFO neighbors compared with residents not living near livestock production (Thu et al. 1997). One study of swine CAFO neighbors in North Carolina reported negative impacts of odor on tension, depression, and anger among individuals living near operations (Schiffman et al. 1995), and another in North Carolina reported "increased occurrences of headaches, runny nose, sore throat, excessive coughing, diarrhea and burning eyes" and decreased quality of life among residents living near swine CAFOs (Wing and Wolf 2000). In an investigation of possible stress-mediated impacts on immune function, swine CAFO neighbors had lower average concentration and secretion of salivary immunoglobulin A during periods of moderate to high odor (Avery et al. 2004). Among children, increased prevalence of asthma symptoms has been associated with proximity to swine CAFOs (Chrischilles et al. 2004; Merchant et al. 2005).

In the United States, race and socioeconomic status (SES) are closely intertwined and have been widely associated with health, including chronic disease morbidity and mortality (Borrell et al. 2004; Roux et al. 2001; Winkleby et al. 1998), infectious diseases (Centers for Disease Control and Prevention 2005), immunization (Egede and Zheng 2003), health care services (Gaskin and Hoffman 2000; Monheit and Vistnes 2000; Weinick et al. 2000), and environmental exposures (Evans and Kantrowitz 2002; Guidry and Margolis 2005; Northridge et al. 2003). Swine CAFOs are disproportionately located in communities of color and regions of poverty (Edwards and Ladd 2000; Wilson et al. 2002; Wing et al. 1996, 2000) and are thus located among populations that may be more susceptible to the airborne exposures and more likely to experience detrimental health consequences of such exposures (Bradley and Corwyn 2002; Williams and Jackson 2005). The literature published to date about health impacts of CAFO-related exposures focuses on health impacts of exposures among adults; however, knowledge about the growth and development of the human respiratory tract suggests that the children in these exposed communities may be at increased risk of respiratory health effects because of their size, behavior, and developmental stage (Dietert et al. 2000; Kim et al. 2004; Peden 2000).

In light of recent research about health effects of CAFO-related exposures, children's susceptibility to environmental pollutants, and concern about the conditions of school buildings, we sought to assess the extent to which adolescents attending public schools may be exposed to swine CAFO emissions. Based on a large sample of public schools in North Carolina, we estimated potential exposure using both record-based and survey-based exposure indices and examined racial and economic differences in potential exposure.

Materials and Methods

During the 1999–2000 school year, seventh- and eighth-grade students from 499 public schools in North Carolina participated in a statewide school-based survey designed to assess the prevalence of asthma-related symptoms among adolescents (North Carolina Department of Health and Human Services 2001; Sotir et al. 2003). During the 2003–2004 school year, we conducted a follow-up survey of employees in the participating schools to collect

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information about environmental health conditions inside the schools and for an evaluation of the relationship between sources of environmental pollution located near schools and students' self-reported respiratory health symptoms. From the 499 participating schools and based on the aims of our study, we excluded 160 schools from further data collection because of school locale and level of participation in the asthma survey. Specifically, we excluded schools located in counties with no swine CAFOs and none in neighboring counties (n = 45), schools with < 25 students surveyed (n = 34), schools located within 5 miles of a state border (n = 17), schools physically located within a city with population > 100,000 (n = 61), and schools that had closed or relocated to a new building since the 1999–2000 school year (n = 10). The remaining 339 schools composed our final target population of public schools.

We used publicly available records about the geographic positions of schools (North Carolina Center for Geographic Center and Analysis 2002) and swine CAFOs (Wing et al. 2000, 2002) to generate location-based estimates of in-school exposure for each school. We calculated distance to the nearest operation using the formula given by Goldberg et al. (1999) and categorized proximity as within or beyond 3 miles of the nearest operation. A 3-mile radius was selected as a suitable zone of potential exposure because elevated prevalence of asthma has been reported among children attending schools within 3 miles of a swine CAFO (Mirabelli et al., in press). Furthermore, although previous studies about the impacts of swine CAFOs on health and quality of life use a 2-mile radius (Thu et al. 1997; Wing and Wolf 2000), odors are sometimes reported at distances > 2 miles, and a radius of 3 miles yields a more balanced distribution of schools in our data. Swine CAFOs typically store animal waste in open waste pits, whereas other types of livestock operations in North Carolina tend not to employ such practices. Details about the locations of operations not using this liquid waste management system are not publicly available and could not be included in these analyses.

For a second metric of in-school exposure, we conducted a four-page, 21-item pencil-and-paper–style survey about environmental health conditions inside and surrounding the school buildings. In October 2003, we mailed the surveys to school principals and asked each to distribute four surveys to potential respondents in the following jobs: administrator, teacher, maintenance or custodial staff, and school nurse or health care provider. During a 9-month survey collection period, respondents from 267 (79%) of the surveyed schools returned 801 of the 1,632 surveys, whereas the remaining schools either actively (n = 1) or passively (n = 71) declined to participate. After receiving completed surveys, we excluded two additional schools based on updated information about the location of one school and because respondents from another school indicated that the school had closed and reopened in a new building since the 1999–2000 school year.

Respondents were asked whether odors from livestock farms were noticeable outside or inside the school buildings never, once per month or less, two to three times per month, about once per week, or more than once per week, and were asked to rate the odor, at its worst, on a five-point scale: 1, very faint; 2, faint; 3, moderate; 4, strong; 5, very strong. We assigned an odor rating of zero for respondents who indicated that they never noticed livestock farm odor at the school, and we created final school-level exposure indicator variables based on whether any survey respondent reported ever noticing livestock farm odor outside or inside the school building. For schools with livestock odors reported by any respondent, the odor ratings assigned to that school and used in the analyses are averages of the ratings provided by all survey respondents for the school. Because of publicity about the effects of industrialized swine production in North Carolina, we were concerned that survey questions specifically about swine CAFOs would cause response bias; therefore, respondents were asked about livestock odor in general. Public concern about odor from swine CAFOs has generated more reports to the health department than have other types of livestock operations in the state (Cline JS, personal communication). However, survey respondents did report odor from other livestock, primarily poultry; this was sometimes noted as a comment on the survey form. To avoid misclassifying these schools as being exposed to swine CAFO odor, we excluded from analysis 39 schools located > 5 miles from a swine CAFO for which respondents indicated the presence of livestock odor. Our final population for analysis was 226 public schools. Approximately 11% (145,704 of 1,315,363) of all students in North Carolina were enrolled in our population of schools during the 2003 school year.

To assess survey response within demographic and economic categories, we used data from the State of North Carolina (National Center for Education Statistics 2004; North Carolina Department of Public Instruction 2003) describing each school's racial and ethnic composition and enrollment in the National School Lunch Program, used here as a proxy for SES. Students participating in the National School Lunch Program receive lunches for free or at reduced price, with the level of subsidy determined by the income of each child's family. Children from families with incomes ≤ 130% or between 130 and 185% of the poverty level are eligible for fully or partially subsidized lunches, respectively (Child Nutrition and WIC Reauthorization Act 2004; U.S. Department of Agriculture 2004). We classified schools into race and SES categories using the median values of white enrollment (median, 63%) and subsidized lunch (median, 47%). The resulting matrix of race and economics was used to identify schools as high white/high SES (96 schools), low white/high SES (16 schools), high white/low SES (18 schools), and low white/low SES (96 schools).

We assessed the association between the race, economics, and both metrics of school-based swine CAFO exposure using binary regression in a log-linear model to estimate the prevalence of the exposures. Regression models were adjusted for rural school locale using data from the National Center for Education Statistics (2004), which uses information about proximity to metropolitan areas and population size and density to assign a locale code to each school. We categorized schools as rural if they were identified as "not within a consolidated metropolitan statistical area (CMSA) or metropolitan statistical area (MSA) and designated as rural" or "within a CMSA or MSA and designated as rural." All remaining categories, including location within large or mid-size central cities, urban locations, or small towns with populations of at least 2,500, were categorized as nonrural. All independent variables in the models are school-level variables, and the resulting measures of association are prevalence ratios (PRs). We used SAS statistical software (version 8.2; SAS Institute Inc., Cary, NC) for all analyses.

Results

Across the 226 schools, mean enrollments of black and white students, respectively, were 26% and 63%. The mean enrollments of Asian students (< 1%), Hispanic students (3%), and Native-American students (< 1%) were low, and none of the schools had majority enrollment of Asian or Hispanic students. The percentage of enrolled students receiving fully or partially subsidized lunches was highly correlated with white, non-Hispanic enrollment (Figure 1).

For the 226 schools, distances between schools and the nearest swine CAFO ranged from 0.2 to 42 miles (mean ± SE, 8.3 ± 0.5), and mean distances increased across tertiles of white enrollment (low, 4.9; medium, 7.0; high, 12.7 miles) and SES (low, 4.6; medium, 8.4; high, 12.1 miles). Sixty-six (66) schools were located within 3 miles of one or more operations (Figure 2). Livestock odor was reported outdoors at 47 (21%) of the surveyed schools. In 19 schools (8%), the livestock odor was noticeable indoors, including in classrooms and hallways of the school buildings

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and in temporary, portable classroom buildings. Overall, the average livestock odor rating was 2.2 (SE = 0.2), which corresponds to an odor rating between "faint" and "moderate" on the scale used for the survey. The average rating of odor at schools with odor noticeable inside the school building was 2.8 (SE = 0.3). The percentage of schools reporting livestock odor and ratings of the strength of the odor each decreased with increasing distance to the nearest swine CAFO (Figure 3). The percentage of schools located within 3 miles of a swine CAFO was lowest (16%) in high-SES schools. A similar percentage (17%) was observed when exposure was considered using reported livestock odor.

Table 1 shows estimates of the relationship of race and SES with distance to the nearest swine CAFO. Having a swine CAFO within 3 miles was most prevalent in schools with low-white/low-SES enrollment [PR = 2.93; 95% confidence interval (CI), 1.79–4.80] compared with schools in the highest category of white enrollment and SES. Restricting the outcome to school location within 2 miles (n = 44) showed a similar trend of higher prevalence among low SES schools. A swine CAFO within 2 miles was more prevalent in schools with low-white/low-SES enrollment (n = 26; PR = 2.62; 95% CI, 1.38–4.97), high-white/low-SES enrollment (n = 5; PR = 2.43; 95% CI, 0.97–6.06), and low-white/high-SES enrollment (n = 2; PR = 1.39; 95% CI, 0.34–5.71) compared with schools with high-white/high-SES enrollment (n = 11). When exposure was considered using survey-based reports of livestock odor, the highest prevalences of noticeable odors outside or inside the school buildings were in schools with low SES enrollment (high white/low SES: n = 5, 28%; low white/low SES: n = 23, 24%), and the lowest prevalence of such odor was observed in schools with high-white/high-SES enrollment (n = 16, 17%) (Table 2). The mean (± SE) odor rating declined across tertiles of percent white, non-Hispanic enrollment (low, 2.1 ± 0.3; medium, 2.5 ± 0.4; high, 1.9 ± 0.4) and SES (low 2.4 ± 0.3; medium, 2.1 ± 0.3; high, 2.0 ± 0.5).

By excluding 39 schools for which survey respondents reported livestock odor, but located beyond 5 miles of a swine CAFO, we intended to reduce misclassification of schools located near nonswine CAFOs. Among the excluded schools, 33 had high enrollments of white students (high white/high SES, 25 schools; high white/low SES, 8 schools). Inclusion of these 39 schools approximately doubled the prevalence of reported odor (outside or inside, 34%; outside only, 18%; outside and inside, 19%) and resulted in marked attenuation of the effect of low white enrollment (outside or inside: PR = 0.89; 95% CI, 0.59–1.32; outside only: PR = 0.88; 95% CI, 0.48–1.61; outside and inside: PR = 0.86; 95% CI, 0.45–1.64).

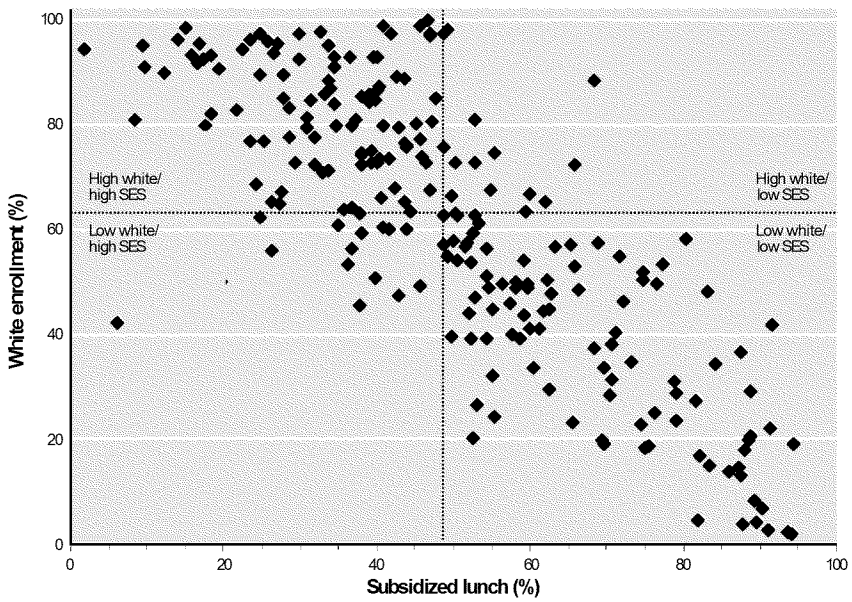

Figure 1. Distribution of white race and economic disadvantage in 226 public schools in North Carolina. Percentages are based on the population students enrolled during the 2003–2004 school year identified as white, non-Hispanic, and receiving subsidized lunches through the National School Lunch Program.

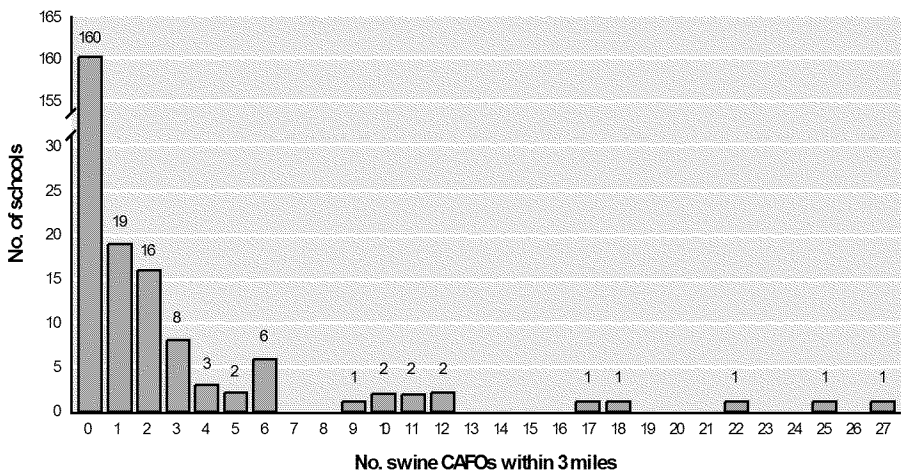

Figure 2. Number of schools by number of swine CAFOs within 3 miles.

Discussion

In 2002, there were approximately 56,000 crop and livestock farms in North Carolina, and nearly 30% of the state's land was used for agricultural production, including the cattle, hog, and poultry industries that significantly contribute to the state's agricultural economy (North Carolina Department of Agriculture and Consumer Services 2003). Previous research about the presence of swine CAFOs shows a disproportionately high concentration of the industry in communities of color despite the declining number of black farmers in the southeastern United States (Wilson et al. 2002; Wing et al. 1996, 2000). In this study we examined the relationship of the racial and economic characteristics of students enrolled in public schools in North Carolina with estimated exposure to airborne effluent from nearby swine CAFOs and found that economic disadvantage was associated

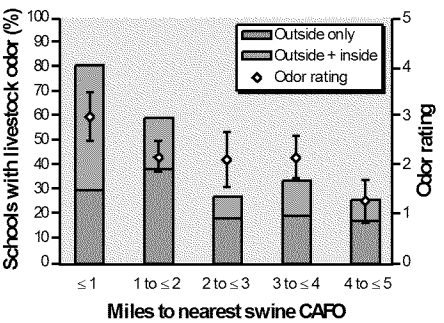

Figure 3. Percentage of schools with noticeable livestock odor and mean ± SE odor ratings for schools with reported odor, by distance between the school and the nearest swine CAFO.

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with proximity to the nearest swine CAFO and with strength of the odor. These findings suggest that swine CAFO emissions and any inhalable exposures, including odorant and nonodorant chemicals and respirable organic dusts, that correlate with odor disproportionately affect a population of children and adults who, regardless of their livestock-related exposures, may be predisposed to asthma-related health outcomes and other illnesses for reasons largely attributable to their economic disadvantage (Gee and Grimpayne-Sturgesalt 2004).

Odorous plumes arising from livestock farms contain a variety of gaseous and particulate elements, including inhalable dusts, bacteria, mold, hydrogen sulfide, ammonia, methane, pharmaceutical residues, and animal dander (Reynolds et al. 1997; Subramanian et al. 1996). In this study, the composition of the air present when livestock-related odors were reported and the specific agents responsible for the odor are both unknown. Without information about the extent to which odorous plumes from CAFOs contain respiratory irritants or odorants capable of inducing health effects (Shusterman 1992), we cannot draw conclusions about exposures relevant for respiratory health of the enrolled students, school employees, or neighbors. However, livestock-related odor at public school buildings indicates the presence of airborne livestock effluent beyond the agricultural land from which it arose and in the surrounding community. Reports of livestock odor outside and inside school buildings raise concern not only about health risks resulting from swine CAFO effluent but also about educational and behavioral consequences such as classroom disruptions that might occur when livestock odor reaches the classroom, anxiety associated with the students' and staff members' inability to avoid the odor or change their environments, and concerns or precautions for students who have a history of acute respiratory reactions. Our results clearly suggest that livestock odor is a more common problem for schools with lower SES enrollment. Livestock odors at public schools, particularly those in economically disadvantaged areas, may have broad implications for schools and communities if such schools are unappealing to new teachers and staff or if odors affect the retention of current employees, influence parent and volunteer involvement, or affect the use of school facilities for recreational and community purposes.

Because nonodorous pollutants arising from swine CAFOs may also be present in these communities, our analysis included distance as a measure of potential exposure to airborne swine CAFO effluent. Overall, we observed increased frequency of swine CAFOs near schools with above-median enrollment in the National School Lunch Program. Distances between schools and swine CAFOs were estimated using publicly available data about the locations of public school buildings and hog operations that raise more than 250 animals using a liquid waste management system. Smaller confinement-based operations, smaller "family farms," and confined livestock operations that produce chickens, turkeys, or other animals are not included in our distance comparisons but may be included in reports of odor from livestock farms. We excluded 39 schools for which respondents reported livestock odor but that were located > 5 miles beyond a swine CAFO. Inclusion of the excluded schools approximately doubled the prevalence of reported odor, and the effect of low white/low SES, compared with high white/high SES, changed from elevated risk to reduced risk in each of the three livestock odor models, suggesting that schools with high white enrollment are disproportionately exposed to odors from other types of livestock operations. Among the excluded schools, 13% ($n = 5$) returned surveys with specific mention of livestock odor from poultry, compared with 3% ($n = 7$) of the schools included in our main analysis. In both populations of schools, reports of poultry odor were more common among schools with ≥ 63% enrollment of white students (excluded schools, 15%; schools in main analysis, 4%) than among schools with < 63% enrollment of white students (excluded schools, 0%; schools in main analysis, 2%); a less pronounced division was observed across categories of SES. Information about odor from poultry operations was not directly solicited on our surveys, so our supposition that poultry operations are located near schools with higher white enrollment, based on the demographics of schools with survey-reported poultry odor, is uncertain. We were unable to evaluate the proximity of schools to poultry operations because few poultry operations in North Carolina require government-issued liquid waste management permits from which location data can be abstracted. The State of North Carolina does not currently release information about the locations of poultry CAFOs because of state regulations about confidentiality of agricultural data (State of North Carolina 2002).

Study limitations. Our survey-based reports of livestock odor are vulnerable to several sources of potential bias. If respondents at schools with higher enrollment of white students are more likely to report livestock odor on our survey than are respondents at schools with higher nonwhite enrollment, then this finding may be the result of biased survey response. If ventilation or window use correlate with enrollment, then differences in the odor reports may be due to differences in indoor odor levels. School SES may be correlated with the size, age, technology, or other features of livestock operations that affect odor. And, although in the distance-based analyses we categorized proximity to a swine CAFO as within 3 miles of at least one swine

Table 1. Associations between distance to the nearest swine CAFO and public school enrollment in North Carolina.

		Distance to nearest swine CAFO		
	All schools	> 3 miles	≤ 3 miles	
Enrollment[a]	(no.)	No. (%)	No. (%)	PR (95% CI)[b]
All schools	226	160 (70.8)	66 (29.2)	
High white/high SES	96	80 (83.3)	16 (16.7)	1.00
High white/low SES	18	12 (66.7)	6 (33.3)	1.95 (0.90–4.25)
Low white/high SES	16	14 (87.5)	2 (12.5)	0.95 (0.24–3.72)
Low white/low SES	96	54 (56.3)	42 (43.8)	2.93 (1.79–4.80)

[a]Enrollment categories: high white, ≥ 63% enrollment of white, non-Hispanic students; low white, < 63% enrollment of white, non-Hispanic students; high SES, < 47% of students receiving free or reduced price lunch at school; low SES, ≥ 47% of students receiving free or reduced price lunch at school. [b]Adjusted for rural school locale.

Table 2. Associations between noticeable livestock odor and public school enrollment in North Carolina.

			Outside or inside		Outside only		Outside + inside	
Enrollment[a]	All schools (no.)	No odor No. (%)	No. (%)	PR (95% CI)[b]	No. (%)	PR (95% CI)[b]	No. (%)	PR (95% CI)[b]
All schools	226	179 (79.2)	47 (20.8)		28 (12.4)		19 (8.4)	
High white/high SES	96	80 (83.3)	16 (16.7)	1.00	9 (9.4)	1.00	7 (7.3)	1.00
High white/low SES	18	13 (72.2)	5 (27.8)	1.63 (0.70–3.80)	4 (22.2)	2.42 (0.86–6.84)	1 (5.6)	0.89 (0.12–6.62)
Low white/high SES	16	13 (81.3)	3 (18.8)	1.44 (0.48–4.30)	2 (12.5)	1.87 (0.45–7.79)	1 (6.3)	1.12 (0.15–8.49)
Low white/low SES	96	73 (76.0)	23 (24.0)	1.58 (0.90–2.78)	13 (13.5)	1.63 (0.74–3.61)	10 (10.4)	1.66 (0.66–4.15)

[a]Enrollment categories: high white, ≥ 63% enrollment of white, non-Hispanic students; low white, < 63% enrollment of white, non-Hispanic students; high SES, < 47% of students receiving free or reduced price lunch at school; low SES, ≥ 47% of students receiving free or reduced price lunch at school. [b]Adjusted for rural school locale.

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CAFO, the number of swine CAFOs located near a school and the distances and geographic directions between the school and each of the nearby swine CAFOs are each reflected in the survey-based estimates of swine CAFO exposure. The surveys provided an estimate of total exposure, whereas the analysis based solely on distance may have underestimated the burden of exposure on schools located near more than one swine CAFO. These components of exposure would be important to consider in an assessment of health impacts of swine CAFO–related exposures.

Our sample size was determined largely by whether employees in each of the surveyed schools participated in our environmental health survey. If the presence of livestock odor at the school or the presence of the livestock industry in the community systematically influenced employees' decisions to complete and return surveys, then our sample of schools may not be representative of the surveyed population. If embarrassment, denial, or exaggeration of the odor problem affected respondents' odor ratings, or if respondents' adaptation to the odor affected their ratings, then the distribution of odor reported on our surveys may not reflect the presence of odorant chemicals in this population of schools. For example, if respondents in farming communities and who routinely smell livestock odor rate the odor as less severe than do survey respondents who are not routinely exposed outside of the school, then the exposures of more exposed schools may be underestimated in these data.

To assess potential bias in survey response, we evaluated school-level survey participation and found that response rates increased across tertiles of increasing percent enrollment of white, non-Hispanic students (< 51% white, 75% participation; 51% to < 78%, 77%; ≥ 78%, 85%). Lower participation among schools with larger nonwhite populations may reflect a broad pattern of nonparticipation in research activities initiated by predominantly white institutions (Corbie-Smith et al. 1999, 2004; Gamble 1993; Shavers-Hornaday et al. 1997). Among participating schools, our classification of the presence of livestock odor based on employees' responses to the survey question may have introduced additional bias in our results. We mailed more than one survey to each school and received up to seven completed surveys per school; for each survey question, we assigned the exposure to a school if any respondent indicated the presence of livestock odor at the school. Consequently, our exposure assignments were sensitive to the number of surveys completed and returned from each school. With each additional survey returned from a single school, and with each additional respondent providing a new opportunity for the school to be classified as exposed, the likelihood of a school's classification as having noticeable livestock odor increased. To assess the impacts of our use of all survey responses and our method of classifying exposure, we estimated the effect of race and economic characteristics on livestock odor using data from one randomly selected survey from each of the participating schools. We repeated this sampling 50 times to generate a range of estimates. On repeated sampling and estimation of the effect of race and economics on any noticeable livestock odor, variation in PRs was low, with 76% (38 of 41) of low-white/high-SES estimates, 80% (40 of 50) high-white/low-SES estimates, and 42% (21 of 50) of low-white/low-SES estimates being closer to the null than the results we report.

Conclusions

Our results provide evidence that North Carolina's swine CAFOs are located closer to schools enrolling higher percentages of nonwhite and economically disadvantaged students and that livestock odor is a more common problem for schools with lower SES enrollment. By considering the environmental exposures that adolescents attending school near the facilities may experience, our findings support and extend previous research about the density of swine CAFOs in nonwhite and poor communities (Wilson et al. 2002; Wing et al. 2000), and the association between environmental exposure and race and poverty in communities located near industrial sources of air pollution (Perlin et al. 1999). Understanding the vulnerability of populations bearing the burden of swine CAFO exposures is of public health importance because of the health risks associated with swine CAFOs and swine odor in other studies (Avery et al. 2004; Merchant et al. 2005; Thu et al. 1997; Wing and Wolf 2000) and the likelihood that hazardous air pollutants arising from swine CAFOs affect the health of children in similar ways. Our findings may have implications for school personnel, particularly those in economically disadvantaged communities, who are concerned about this common exposure and its potential impact on adolescents' respiratory health and should be used to address existing racial and economic disparities in exposure to environmental health hazards.

References

Avery R, Wing S, Marshall S, Schiffman S. 2004. Odor from industrial hog operations and mucosal immune function in neighbors. Arch Environ Health 59(2):101–108.

Borrell LN, Diez Roux AV, Rose K, Catellier D, Clark BL. 2004. Neighbourhood characteristics and mortality in the Atherosclerosis Risk in Communities Study. Int J Epidemiol 33(2):398–407.

Bradley RH, Corwyn RF. 2002. Socioeconomic status and child development. Annu Rev Psychol 53:371–399.

Centers for Disease Control and Prevention. 2005. Racial disparities in nationally notifiable diseases—United States, 2002. MMWR Morbid Mortal Wkly Rep 54(1):9–11.

Child Nutrition and WIC Reauthorization Act of 2004 [S. 2507]. 2004. Public Law 108-265.

Chrischilles E, Ahrens R, Kuehl A, Kelly K, Thorne P, Burmeister L, et al. 2004. Asthma prevalence and morbidity among rural Iowa schoolchildren. J Allergy Clin Immunol 113(1):66–71.

Cole D, Todd L, Wing S. 2000. Concentrated swine feeding operations and public health: a review of occupational and community health effects. Environ Health Perspect 108:685–699.

Corbie-Smith G, Moody-Ayers S, Thrasher AD. 2004. Closing the circle between minority inclusion in research and health disparities. Arch Intern Med 164(13):1362–1364.

Corbie-Smith G, Thomas SB, Williams MV, Moody-Ayers S. 1999. Attitudes and beliefs of African Americans toward participation in medical research. J Gen Intern Med 14(9):537–546.

Dietert RR, Etzel RA, Chen D, Halonen M, Holladay SD, Jarabek AM, et al. 2000. Workshop to identify critical windows of exposure for children's health: immune and respiratory systems work group summary. Environ Health Perspect 108(suppl 3):483–490.

Edwards B, Ladd A. 2000. Environmental justice, swine production and farm loss in North Carolina. Sociol Spectr 20(3):263–290.

Egede LE, Zheng D. 2003. Racial/ethnic differences in influenza vaccination coverage in high-risk adults. Am J Public Health 93(12):2074–2078.

Evans GW, Kantrowitz E. 2002. Socioeconomic status and health: the potential role of environmental risk exposure. Annu Rev Public Health 23:303–331.

Gamble VN. 1993. A legacy of distrust: African Americans and medical research. Am J Prev Med 9(suppl 6):35–38.

Gaskin DJ, Hoffman C. 2000. Racial and ethnic differences in preventable hospitalizations across 10 states. Med Care Res Rev 57(suppl 1):85–107.

Gee GC, Grimpayne-Sturgesalt DC. 2004. Environmental health disparities: a framework integrating psychosocial and environmental concepts. Environ Health Perspect 112:1645–1653.

Goldberg MS, Siemiatyck J, DeWar R, Desy M, Riberdy H. 1999. Risks of developing cancer relative to living near a municipal solid waste landfill site in Montreal, Quebec, Canada. Arch Environ Health 54(4):291–296.

Guidry VT, Margolis LH. 2005. Unequal respiratory health risk: using GIS to explore hurricane-related flooding of schools in Eastern North Carolina. Environ Res 98(3):383–389.

Hamscher G, Pawelzick HT, Sczesny S, Nau H, Hartung J. 2003. Antibiotics in dust originating from a pig-fattening farm: a new source of health hazard for farmers? Environ Health Perspect 111:1590–1594.

Kim JJ, American Academy of Pediatrics Committee on Environmental Health. 2004. Ambient air pollution: health hazards to children. Pediatrics 114(6):1699–1707.

Merchant JA, Naleway AL, Svendsen ER, Kelly KM, Burmeister LF, Stromquist AM, et al. 2005. Asthma and farm exposures in a cohort of rural Iowa children. Environ Health Perspect 113(3):350–356.

Mirabelli MC, Wing S, Marshall SW, Wilcosky TC. In press. Asthma symptoms among adolescents attending public schools located near confined swine feeding operations. Pediatrics.

Monheit AC, Vistnes JP. 2000. Race/ethnicity and health insurance status: 1987 and 1996. Med Care Res Rev 57(suppl 1):11–35.

National Center for Education Statistics. 2004. Common Core of Data: Public Elementary/Secondary School Universe Survey, 2001–2002. Available: http://nces.ed.gov/ccd/pubschuniv.asp [accessed 16 April 2004].

National Research Council, Ad Hoc Committee on Air Emissions from Animal Feeding Operations. 2003. Air Emissions from Animal Feeding Operations: Current Knowledge, Future Needs. Washington, DC: National Academies Press.

North Carolina Center for Geographic Information and Analysis. 2002. BasinPro. Raleigh, NC: North Carolina Center for Geographic Information and Analysis.

North Carolina Department of Agriculture and Consumer Services. 2003. North Carolina Agricultural Overview. Available: http://www.ncagr.com/stats/general/general1.htm [accessed 15 December 2004].

North Carolina Department of Health and Human Services. 2001. Unraveling the Mystery of Asthma: The North Carolina School Asthma Survey. Summary of Results, January 9, 2001. Raleigh, NC: North Carolina Department of Health and Human Services, Division of Public Health.

North Carolina Department of Public Instruction. 2003. Education Directory of North Carolina. Available: http://www.ncpublicschools.org/nceddirectory[accessed 1 September 2003].

Northridge ME, Stover GN, Rosenthal JE, Sherard D. 2003.

ED_001369_00043779-00084

Environmental equity and health: understanding complexity and moving forward. Am J Public Health 93(2):209–214.
Peden DB. 2000. Development of atopy and asthma: candidate environmental influences and important periods of exposure. Environ Health Perspect 108(suppl 3):475–482.
Perlin SA, Sexton K, Wong DW. 1999. An examination of race and poverty for populations living near industrial sources of air pollution. J Expo Anal Environ Epidemiol 9(1):29–48.
Radon K, Weber C, Iversen M, Danuser B, Pedersen S, Nowak D. 2001. Exposure assessment and lung function in pig and poultry farmers. Occup Environ Med 58(6):405–410.
Reynolds S, Donham K, Stookesberry J, Thorne P, Subramanian P, Thu K, et al. 1997. Air quality assessments in the vicinity of swine production facilities. In: Agricultural Health and Safety: Recent Advances (Donham KJ, ed). Binghamton, NY:Haworth Press, 37–45.
Roux AVD, Merkin SS, Arnett D, Chambless L, Massing M, Nieto FJ, et al. 2001. Neighborhood of residence and incidence of coronary heart disease. N Engl J Med 345(2):99–106.
Schiffman SS. 1998. Livestock odors: implications for human health and well-being. J Anim Sci 76(5):1343–1355.
Schiffman SS, Miller EA, Suggs MS, Graham BG. 1995. The effect of environmental odors emanating from commercial swine operations on the mood of nearby residents. Brain Res Bull 37(4):369–375.
Sharpe RR, Harper LA. 1999. Methane emissions from an anaerobic swine lagoon. Atmos Environ 33:3627–3633.
Shavers-Hornaday VL, Lynch CF, Burmeister LF, Torner JC. 1997. Why are African Americans under-represented in medical research studies? Impediments to participation. Ethn Health 2(1–2):31–45.
Shusterman D. 1992. Critical review: the health significance of environmental odor pollution. Arch Environ Health 47(1):76–87.
Sotir M, Yeatts K, Shy C. 2003. Presence of asthma risk factors and environmental exposures related to upper respiratory infection-triggered wheezing in middle school-age children. Environ Health Perspect 111:657–662.
State of North Carolina. 2002. Confidentiality of Information Collected and Published. NC General Statute §106–24.1.
Subramanian P, Reynolds S, Thorne PS, Donham K, Stookesberry J, Thu K. 1996. Assessment of airborne ammonia in a swine farming environment by fluorimetric enzyme method. Int J Environ Annal Chem 64:301–312.
Thu K, Donham K, Ziegenhorn R, Reynolds S, Thorne PS, Subramanian P, et al. 1997. A control study of physical and mental health of residents living near a large-scale swine operation. J Agric Saf Health 3:13–26.
U.S. Department of Agriculture. 2004. Nutrition Program Facts. Available: http://www.fns.usda.gov/cnd/Lunch/AboutLunch/NSLPFactSheet.pdf [accessed 10 December 2004].
U.S. Environmental Protection Agency. 2002. Review of Emission Factors and Methodologies to Estimate Ammonia Emissions from Animal Waste Handling. EPA-600/R-02-017. Research Triangle Park, NC:National Risk Management Research Laboratory.
Vogelzang PF, van der Gulden JW, Folgering H, Heederik D, Tielen MJ, van Schayck CP. 2000. Longitudinal changes in bronchial responsiveness associated with swine confinement dust exposure. Chest 117(5):1488–1495.
Vogelzang PF, van der Gulden JW, Folgering H, van Schayck CP. 1999. Organic dust toxic syndrome in swine confinement farming. Am J Ind Med 35(4):332–334.
Weinick RM, Zuvekas SH, Cohen JW. 2000. Racial and ethnic differences in access to and use of health care services, 1977 to 1996. Med Care Res Rev 57(suppl 1):36–54.
Williams DR, Jackson PB. 2005. Social sources of racial disparities in health. Health Aff (Millwood) 24(2):325–334.
Wilson SM, Howell F, Wing S, Sobsey M. 2002. Environmental injustice and the Mississippi hog industry. Environ Health Perspect 110(suppl 2):195–201.
Wing S, Cole D, Grant G. 2000. Environmental injustice in North Carolina's hog industry. Environ Health Perspect 108:225–231.
Wing S, Freedman S, Band L. 2002. The potential impact of flooding on confined animal feeding operations in eastern North Carolina. Environ Health Perspect 110:387–391.
Wing S, Grant G, Green M, Stewart C. 1996. Community based collaboration for environmental justice: south-east Halifax environmental reawakening. Environ Urban 8(2):129–140.
Wing S, Wolf S. 2000. Intensive livestock operations, health, and quality of live among eastern North Carolina residents. Environ Health Perspect 108:233–238.
Winkleby MA, Kraemer HC, Ahn DK, Varady AN. 1998. Ethnic and socioeconomic differences in cardiovascular disease risk factors: findings for women from the Third National Health and Nutrition Examination Survey, 1988–1994. JAMA 280(4):356–362.

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Exhibit 44

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CAFOs *and* Environmental Justice

The Case *of* North Carolina

The home of a minority family in Kenansville, North Carolina, situated next to a concentrated animal feeding operation, or CAFO. Dust, odors, and manure from CAFOs can reach nearby residents' homes, including their laundry.
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On the coastal plain of eastern North Carolina, families in certain rural communities daily must deal with the piercing, acrid odor of hog manure—reminiscent of rotten eggs and ammonia—wafting from nearby industrial hog farms. On bad days, the odor invades homes, and people are often forced to cover their mouths and noses when stepping outside. Sometimes, residents say, a fine mist of manure sprinkles nearby homes, cars, and even laundry left on the line to dry.[1]

Today's industrial-scale farms—called concentrated animal feeding operations (CAFOs)—house thousands of animals whose waste is periodically applied to "spray fields" of Bermuda grass or feed crops.[2,3] The waste can contain pathogens, heavy metals, and antibiotic-resistant bacteria,[4,5] and the spray can reach nearby homes and drinking water sources. The odor plume, which often pervades nearby communities, contains respiratory and eye irritants including hydrogen sulfide and ammonia.[6,7,8] A growing body of research suggests these emissions may contribute not only to mucosal irritation[9] and respiratory ailments[10] in nearby residents but also decreased quality of life,[11] mental stress,[12,13] and elevated blood pressure.[14]

Although the Midwest is the traditional home for hogs, with Iowa still the top-producing state, North Carolina went from fifteenth to second in hog production between the mid-1980s and mid-1990s.[15] This explosive growth resulted in thousands of CAFOs located in the eastern half of the state—squarely in the so-called Black Belt, a crescent-shaped band throughout the South where slaves worked on plantations.[16,17] After emancipation many freed slaves continued to work as sharecroppers and tenant farmers. A century later, black residents of this region still experience high rates of poverty, poor health care, low educational attainment, unemployment, and substandard housing.[18,19]

The clustering of North Carolina's hog CAFOs in low-income, minority communities—and the health impacts that accompany them—has raised concerns of environmental injustice and environmental racism.[20] As one pair of investigators explained, "[P]eople of color and the poor living in rural communities lacking the political capacity to resist are said to shoulder the adverse socio-economic, environmental, or health related effects of swine waste externalities without sharing in the economic benefits brought by industrialized pork production."[21] Although North Carolina is not the only area with environmental justice concerns vis-à-vis CAFOs, it has become one of the best studied.

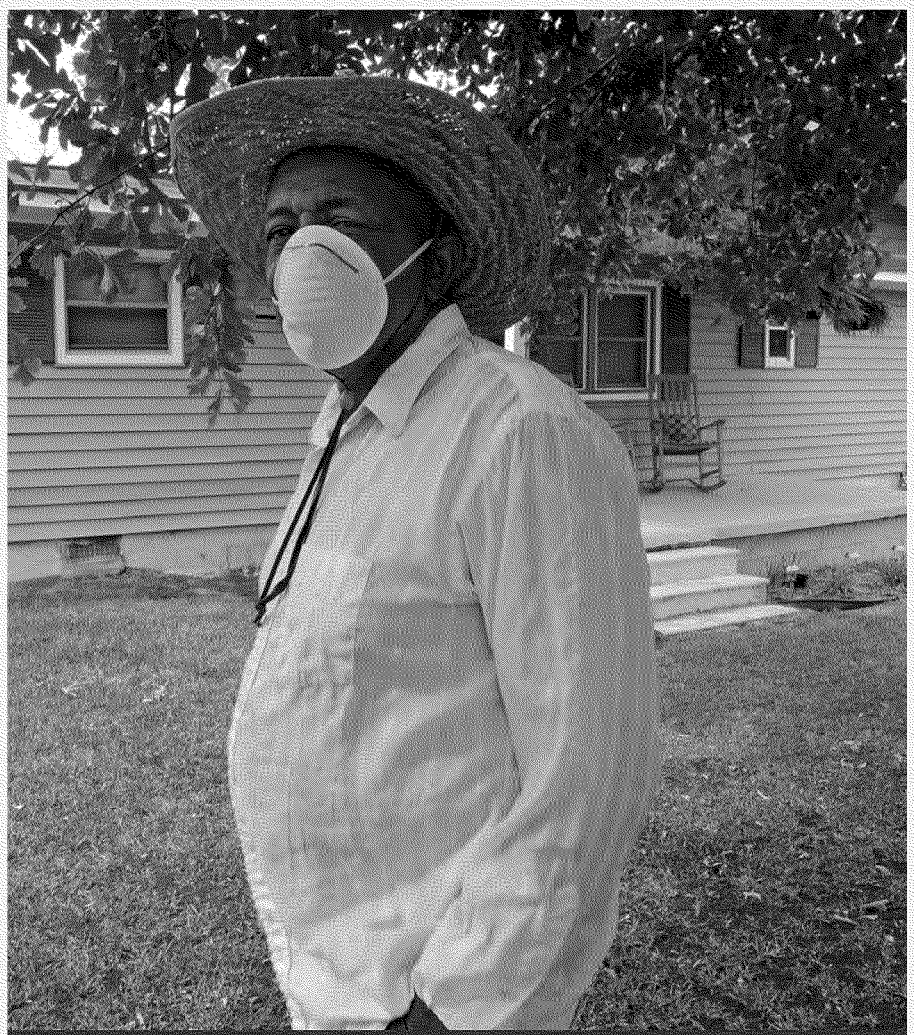
Environmental Injustice?

One of the misunderstandings about environmental racism, in particular, is that the term suggests malicious or at least discriminatory intent in terms of locating hazards. Although that may exist in some cases, several studies have argued that industry or government simply followed the "path of least resistance" in choosing sites where people were less likely to object or land was cheap.[22,23] The situation nevertheless results in environmental injustice if minority populations are disproportionately affected, no matter the reason.[24]

From a scientific perspective, hundreds of studies have documented disparities in the location of environmental hazards relative to race and class, and, further, in the extent and timeliness of remediative actions.[25,26,27,28] "Environmental justice science [seeks to] understand how burden disparities lead to exposure, risk, and health disparities," says Sacoby Wilson, a University of Maryland environmental health professor.

Debates still exist over the relative importance of race versus socioeconomic status[29] and whether hazards are disproportionately sited in regions where minorities and impoverished people live, or whether communities change after polluting facilities move in. Most studies suggest the former.[22,30] However, research also suggests that people who can afford to move away from environmental hazards often do, increasing disparities.[30]

East Carolina University sociology professor Bob Edwards says he had heard environmental justice groups claiming disparities in the siting of hog farms and industry



This resident of Kenansville usually wears a facemask when he's in his yard because of the dust from the neighboring CAFO. Most studies suggest that communities already have high levels of poverty and large percentages of minority residents when CAFOs are built there. People who can afford to move away often do.
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Another Kenansville resident stands in his front yard, feet from the CAFO across the street. Donn Young, the North Carolina–based photographer who took these images, says of his time in Kenansville, "I encountered problems with my eyes—itchy, watering, something akin to allergies." To the people who live there, CAFOs are simply a fact of everyday life.
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proponents denying them when he realized it was an empirical question. "There was no real research at the time," he says. So in 2000 he began a study with collaborator Anthony E. Ladd of the Loyola University Department of Sociology. They found that even when controlling for regional differences, urbanization level, property value, and attributes of the labor force, eastern North Carolina counties with larger minority populations were home to greater concentrations of hog waste, a function of hog population density, compared with more urbanized counties with a higher percentage of white residents.[21] Another North Carolina study later reported

What Is Environmental Justice?

Environmental justice refers to both a social movement and a field of scientific research. As a movement, it is a marriage of civil rights and environmentalism, emerging in 1982 when black citizens lay down on the road to stop the government from dumping 120 million pounds of soil contaminated with polychlorinated biphenyls in Warren County, North Carolina.[74] Although the Warren County waste site ultimately was established,[75,76] the protests captured the nation's attention.

The study of environmental justice began in earnest in 1983, when the Government Accountability Office (then known as the General Accounting Office) investigated the racial composition of communities near four hazardous waste sites in the Southeast, three of which were located in predominantly black communities where at least 26% of the population lived below the poverty level.[77] In 1987 the first national study to analyze the issue with multivariate statistics found that even after controlling for household income, housing values, amount of hazardous waste generated in an area, and other factors, the percentage of minority residents in a zip code proved the greatest predictor of hazardous waste facility siting. Zip codes with hazardous waste sites had double the percentage of minority residents compared with those with none, and zip codes with more than one facility had triple the percentage of minority residents.[74]

By the early 1990s, the federal government first acknowledged environmental justice with a working group that published the report Environmental Equity: Reducing Risks for All Communities.[78] Soon after, the Environmental Protection Agency created the Office of Environmental Equity, since renamed the Office of Environmental Justice. The agency defines environmental justice as "the fair treatment and meaningful involvement of all people regardless of race, color, national origin, or income with respect to the development, implementation, and enforcement of environmental laws, regulations, and policies."[79]

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nine times more hog CAFOs in areas where there was more poverty and higher percentages of nonwhite people even after adjusting for population density as a measure of rural location and cheaper land.[20]

Edwards has also reported that large hog operations forced small farmers out of business.[31] As the industry consolidated, the primary slaughterhouse in North Carolina refused to accept hogs in lots of fewer than 1,000.[32] With the exception of the slaughterhouse, the industry does not create many working-class jobs and sometimes creates major rifts in the social fabric of communities between proponents and opponents of local CAFOs.[31,33,34,35]

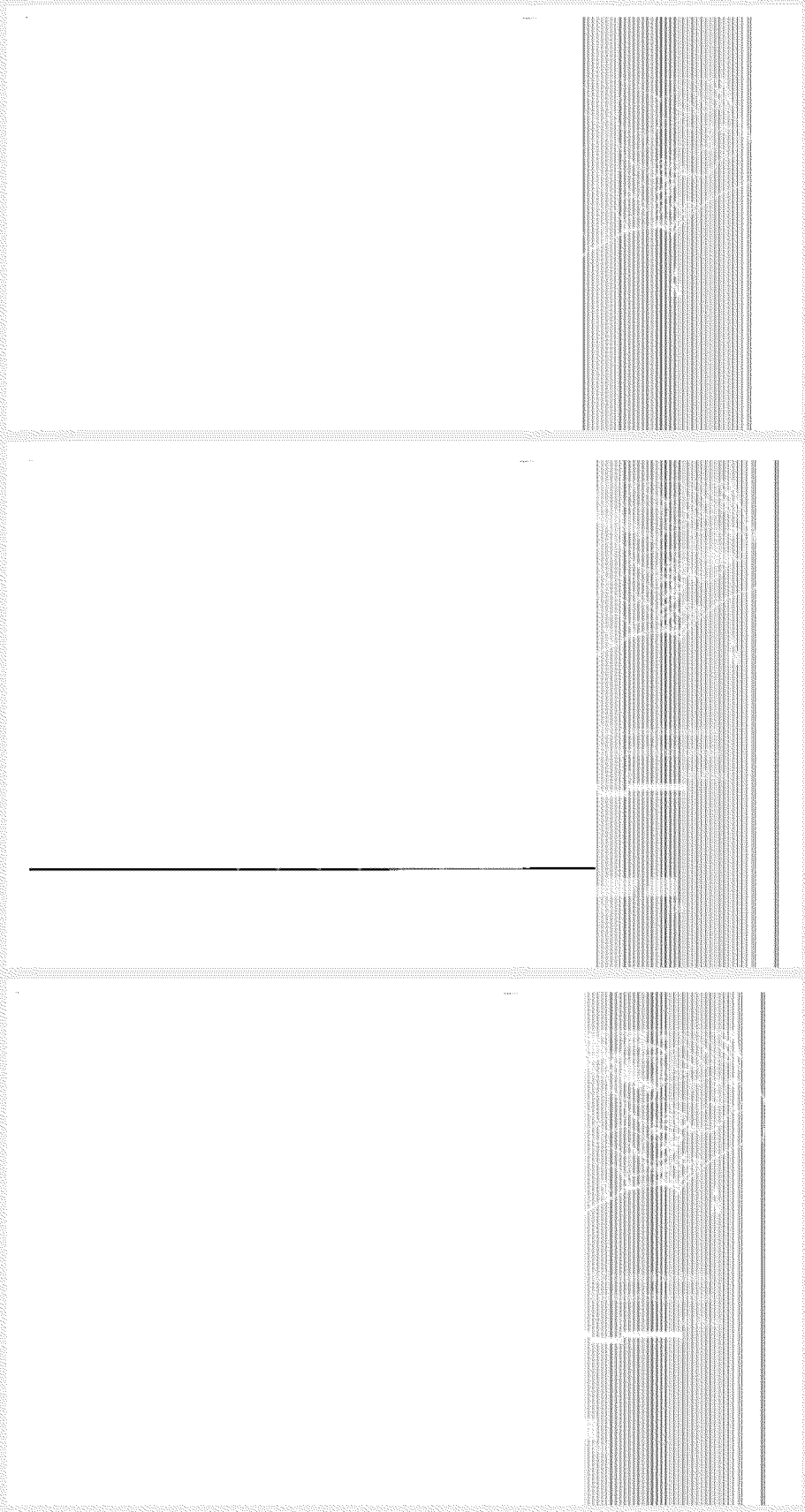
A Brief History of Swine

For centuries, animal husbandry operated much like a farm in a cartoon: pigs wallowing in mud, chickens wandering about pecking the ground, and cows grazing on grass, with a barn to store hay and feed. Farms were largely sustainable; they generally did not deplete the soil, water, or land resources needed to maintain the farm for the next generation. The waste from the animals helped grow the next year's crops.

Today, the vast majority of America's 1 billion–plus food animals slaughtered annually[36] are raised in CAFOs.[37] John Ikerd, professor emeritus of agricultural economics at the University of Missouri, says farms have changed over his long career in three main ways. First, today's farms specialize in growing one crop or in one phase of production; in the hog industry there are facilities for breeding sows, raising piglets to about 40 pounds, and finishing operations, where animals are raised to the point of slaughter. Second, large corporations ("integrators") contract with individual farmers to raise animals and set precise standards for what the animals eat, their housing conditions, and the antibiotics and hormones they receive. Finally, there's been a consolidation of control and ownership that, as mentioned, has forced small farmers out of business and altered local economies and communities.[31,32]

The hog industry in North Carolina changed rapidly starting in the 1970s, when Wendell Murphy applied the CAFO model, already used for poultry, to swine.[38] As a successful hog farmer, Murphy was elected to the North Carolina House of Representatives in 1983 and to the state Senate in 1988, where he sponsored and helped to pass legislation—dubbed "Murphy's laws"—that eliminated sales tax on hog farm equipment and prevented local authorities from using zoning authority to deal with odor issues.[39,40]

The industry's rapid growth in the state followed the passage of these bills, causing a major shift in the state's hog farming. In 1982



Maps from an older study show distributions of poverty, minority residents, and hog CAFOs in North Carolina as of 1998–2000. Little has changed appreciably since then.
Source: Wing et al. (2000)[20]

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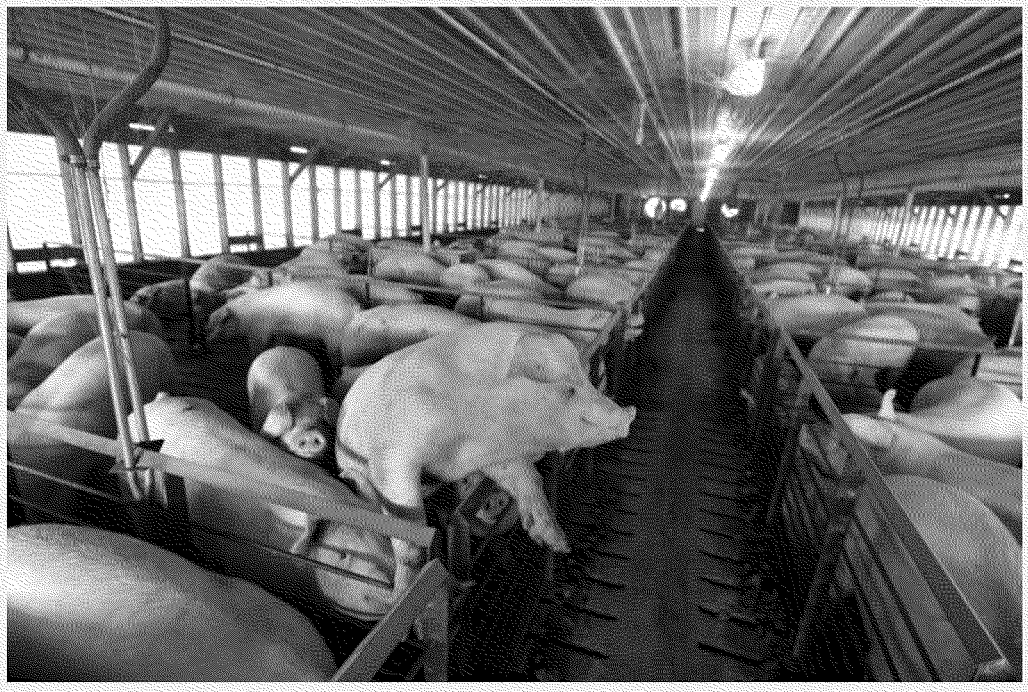
every county in North Carolina but one had a commercial hog farm; by 1997, 95% of hog farms were located in the eastern counties of the coastal plain.[32]

Today the North Carolina hog herd, all told, numbers around 9–10 million animals annually, according to the state Department of Agriculture and Consumer Services.[41] This results in an enormous amount of manure, with each hog producing an estimated four to eight times as much feces as a human.[32,42] In 2008 the Government Accountability Office reported that some 7.5 million hogs in five eastern North Carolina counties produced an estimated 15.5 million tons of waste per year, and that in one year a single 80,000-head facility could create 1.5 times the waste of the city of Philadelphia.[43]

The lagoons in which this waste is stored contain pathogens such as *Salmonella*, insecticides, antimicrobial agents and other pharmaceuticals, and nutrients that cause widespread pollution and impairment of watersheds across the coastal plain.[44,45,46] Much concern has been raised over antibiotic-resistant bacteria that result from CAFO animals' near-continual exposure to subtherapeutic doses of antibiotics as an inexpensive means to prevent disease and promote growth.[47,48]



Upper: CAFOs apply accumulated animal waste to spray fields of Bermuda grass or field crops located around the barns and lagoons. Lower: Hogs are packed tightly inside CAFOs like this one in Princeton, North Carolina.

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Whereas human sewage is treated with chemical and mechanical filtration before being released into the environment, CAFOs channel waste from hog houses into pits or lagoons, where it is stored untreated until it is applied to land. All lagoons leach to some degree,[49,50,51] and during hurricanes and storms they can overflow or burst, spilling raw sewage onto the landscape and into waterways. In 1995 an eight-acre lagoon ruptured, spilling 22 million gallons of manure into North Carolina's New River, killing millions of fish and other organisms; other spills followed that summer.[52,53] Even without spills, ammonia and nitrates may seep into groundwater, especially in the coastal plain where the water table is near the surface.[32,54]

Odors, Plumes, and Toxics

Although more research is needed on the impact of CAFO emissions on susceptible groups of people,[10] studies have linked hog odors and air pollution from the associated odor plume with adverse effects on health and quality of life.[55] Wilson, who has documented environmental justice issues surrounding hog farms in North Carolina and Mississippi, explains that CAFO emissions go beyond bad smells. "It's much more complex than that," he says. "You have exposures through air, water, and soil. You have … inhalation, ingestion, and dermal exposures. People have been exposed to multiple chemicals: hydrogen sulfide, particulate matter, endotoxins, nitrogenous compounds. Then you have a plume that moves; what gets into the air gets into the water. You have runoff from spray fields. These are complex exposure profiles."

University of North Carolina epidemiology professor Steve

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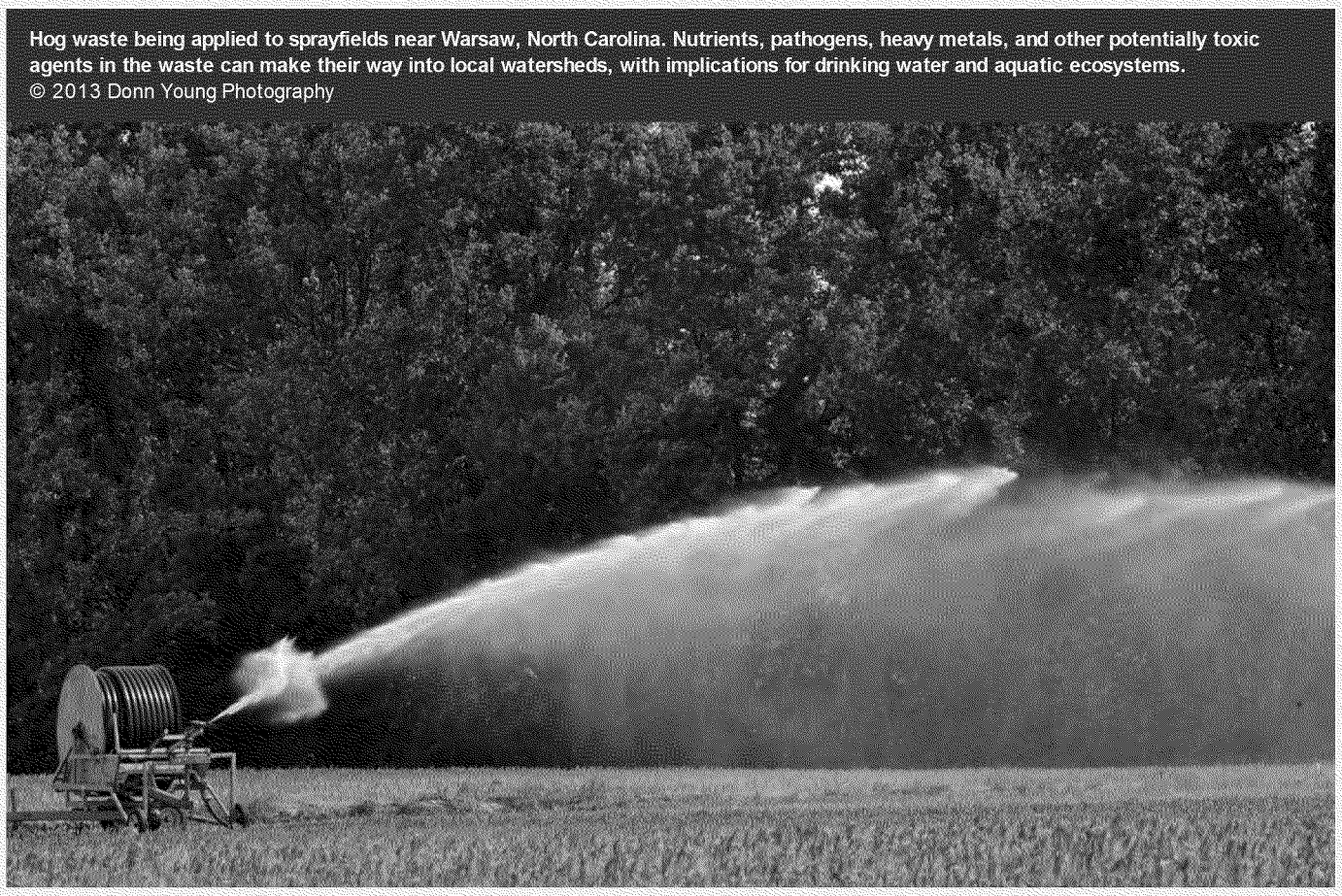

Hog waste being applied to sprayfields near Warsaw, North Carolina. Nutrients, pathogens, heavy metals, and other potentially toxic agents in the waste can make their way into local watersheds, with implications for drinking water and aquatic ecosystems.
© 2013 Donn Young Photography

Wing and colleagues have reported that waste odor frequently prevents local residents from spending time outdoors, opening windows, putting laundry out to dry, or inviting visitors over.[9,56] In the Community Health Effects of Industrial Hog Operations study, a repeated-measures, community-driven project, Wing and colleagues enrolled 102 individuals in 16 communities to sit outside twice a day, recording odor strength and symptoms such as eye irritation and difficulty breathing. Participants self-monitored aspects of their physical health, including blood pressure and lung function, and also used mobile air pollution monitors to collect data on levels of hydrogen sulfide, endotoxin, coarse particulate matter (PM_{10}), and semivolatile compounds in particle phase within each neighborhood.

The researchers found that hydrogen sulfide levels were strongly related to odor.[57] Furthermore, measures of odor, endotoxin, hydrogen sulfide, and PM_{10} were associated, variously, with increased respiratory difficulty, sore throat, chest tightness, nausea, and eye irritation,[58] whereas hydrogen sulfide and semivolatile particles were linked to reports of feeling stressed, annoyed, nervous, and anxious.[13]

Most recently, Wing reported associations between blood pressure increases and increased odor and hydrogen sulfide.[14] "In this primarily African-American population, in a region that is known historically as the Stroke Belt because of very high rates of death from cerebrovascular disease, we don't need environmental exposures that are leading to additional blood pressure increases," Wing says.

Because these communities are typically impoverished and lack political clout, they often have little means to fight back.[59] "It creates a major burden on communities when they have few legal protections," says Wilson. However, getting communities involved in data collection has empowered citizens.[59] "When we train residents to do sampling, they understand the science of the process," says Wilson. "They can go to the town council, they can go to the media, they can explain it. That's powerful. It helps build up a community's ability to be more involved in decision making."

Who Looks After Residents' Health?

The shift to CAFOs happened so fast that regulations and laws protecting human health and the environment have not caught up with the changing face of animal husbandry. A 2013 report revealed that despite the highly localized health impacts associated with CAFOs, local and state health departments generally do not have jurisdiction over them; instead, that responsibility is typically held by state environmental or natural resource agencies.[60] Jillian Fry, a researcher at the Johns Hopkins Center for a Livable Future who was lead author on that report, says, "The agencies responsible for regulating CAFOs—their mission is not to protect human health."

Fry says the study was inspired by a CAFO expansion meeting she attended with a colleague. A proponent of the expansion stood up at the meeting and stated that if hog farms caused health concerns, the health department would make the community aware; therefore, there was nothing to worry about. "I knew … that the health department was not involved, so we wanted to see what the situation was in other parts of the country," Fry says.

She and her colleagues interviewed health department staff in eight states and found that most health departments did not deal with CAFO issues. Either they lacked the jurisdiction, had no budget or expertise, or were dealing with political pressure. Fry says, "Even if a health department thinks this is a really important issue, we're hearing from a lot of them, 'We're aware of the science, we

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Piles of what is believed to be poultry litter in a field near New Bern, North Carolina. A state moratorium on new hog CAFOs has resulted in the construction of more poultry CAFOs, according to researcher Steve Wing.
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know of the problem, but it's the political barriers.'"

The survey also found that community members did not get very far with inquiries. "We asked community members, 'Was there ever a time you contacted a health department and they addressed your complaint?' They all said no," says Fry. "They were almost always referred to another agency, or maybe they would look into it and hit a barrier."

An Eye to the Future

With accumulating scientific evidence over the environmental and community health impacts of hog CAFOs and extensive media coverage of ruptured lagoons, opposition crescendoed in the mid-1990s. In 1997 North Carolina passed a law prohibiting the expansion of existing hog operations and placing a temporary moratorium on new hog CAFOs,[61] although permits in the hopper were approved. The moratorium became permanent in 2007 with the Swine Farm Environmental Performance Standards Act, which banned new lagoons and mandated that any new or expanded CAFOs must use environmentally superior technologies (ESTs) to substantially reduce emissions and prevent waste discharges into surface and ground waters.[62] The 2007 law provided for a substantial cost-share for operators to upgrade their lagoons and implement ESTs, yet only 11 of 2,200 have applied, and only 8 have participated.[63,64]

Although the act limited growth of new hog facilities, it didn't clean up existing ones, says Wing. Local residents still deal daily with odor and pollutants in the vicinity of hog farms. The moratorium also catalyzed other changes whose impact is yet to be fully realized. "More poultry facilities have been built," Wing says. "That brings up other issues such as the spread of microbes between species."

Another milestone occurred when Smithfield Foods, Inc., entered into an agreement with the state Attorney General in 2000 after dozens of lagoons ruptured during Hurricane Floyd, resulting in Clean Water Act violations.[65] Smithfield Foods agreed to pay $15 million toward research on ESTs and $50 million toward environmental enhancement.[66,67] Premium Standard Farms, a subsidiary of Smithfield Foods, later voluntarily added $2.1 million toward the agreement for EST research and development.[68] If an EST were found to be both economically feasible and environmentally superior in five categories, the companies agreed to implement it at each of the farms they owned, although not at farms they subcontracted. (Mike Williams, director of the Animal and Poultry Waste Management Center at North Carolina State University and supervisor of the agreement, says an estimated 5–10% of North Carolina hog farms are company-owned.)

After phase 1 of development, only one of the new technologies examined—the Super Soil System (since renamed Terra Blue)—met all five environmental standards, but it was deemed uneconomical. Improvements made during phase 2 reduced the cost but not enough to meet the economic criteria. The project is now in the final weeks of phase 3. "If the process shows that it does meet bona fide EST status and economic criteria, then the agreement states [farms have a certain] amount of time to implement," Williams says.

In 2011 the state passed a bill that allows hog CAFOs to upgrade their buildings without needing to upgrade their waste management systems or use ESTs, counter to the previous decade's mandates.[69] Some critics have called this a loophole, given that the 2007 law stipulated hog farmers were supposed to implement ESTs if they wanted to increase herd size or install new buildings.[70]

At the same time, the handful of pioneers who are implementing ESTs are creating what could be the future of hog farming.[71] In one of those projects, Google has partnered with Duke University and Duke Energy to turn Yadkin County's Loyd Ray Farms into a sustainable operation that generates renewable energy and carbon offsets.[72] The 8,600-head finishing farm captures methane from its hog waste using an anaerobic digester. The methane provides fuel to run a microturbine that powers part of the farm and supports components that reduce odors, nutrients, pathogens, and heavy metals. Google and Duke University

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share the carbon credits, while Duke Energy receives renewable energy certificates (credits for generating renewable energy that are sold separately from the actual electricity produced[73]). Although projects like these so far make up only a tiny fraction of the market, their experimental approach could lead the way toward hog farms becoming better neighbors.

Wendee Nicole, based in Houston, TX, has written for *Nature*, *Scientific American*, *National Wildlife*, and other magazines.

REFERENCES AND NOTES

1. Wing S. Social responsibility and research ethics in community-driven studies of industrialized hog production. Environ Health Perspect 110(5):437–444 (2002); http://www.ncbi.nlm.nih.gov/pmc/articles/PMC1240831/.
2. Zublena JP, et al. Soil Facts: Swine Manure as a Fertilizer Source. Publication AG-439-4. Raleigh, NC: North Carolina Cooperative Extension Service (updated Dec 1997). Available: http://goo.gl/BmEvj [accessed 22 May 2013].
3. EPA. Managing Manure Nutrients at Concentrated Animal Feeding Operations. Washington, DC: U.S. Environmental Protection Agency (Aug 2004). Available: http://tammi.tamu.edu/final-manure-guidance.pdf [accessed 22 May 2013].
4. Lowman A, et al. Land application of treated sewage sludge: community health and environmental justice. Environ Health Perspect 121(5):537–542 (2013); http://dx.doi.org/10.1289/ehp.1205470.
5. Marks R. Cesspools of Shame: How Factory Farm Lagoons and Sprayfields Threaten Environmental and Public Health. Washington, DC: Natural Resources Defense Council and Clean Water Network (2001). Available: http://goo.gl/o0lhr [accessed 22 May 2013].
6. Wilson SM, Serre ML. Examination of atmospheric ammonia levels near hog CAFOs, homes, and schools in eastern North Carolina. Atmos Environ 41(23):4977–4987 (2007); http://dx.doi.org/10.1016/j.atmosenv.2006.12.055.
7. NRC. The Scientific Basis for Estimating Air Emissions from Animal Feeding Operations: Interim Report. Washington, DC: Committee on Animal Nutrition, National Research Council (2002). Available: http://goo.gl/oX1hD [accessed 22 May 2013].
8. Ciganek M, Neca J. Chemical characterization of volatile organic compounds on animal farms. Veterinarni Medicina 53(12):641–651 (2008); http://www.vri.cz/en/publications/+dt-73.
9. Wing S, Wolf S. Intensive livestock operations, health, and quality of life among eastern North Carolina residents. Environ Health Perspect 108(3):233–238 (2000); http://www.ncbi.nlm.nih.gov/pmc/articles/PMC1637983/.
10. Thome PS. Environmental health impacts of concentrated animal feeding operations: anticipating hazards—searching for solutions. Environ Health Perspect 115(2):296–297 (2007); http://dx.doi.org/10.1289/ehp.8831.
11. Schiffman SS, et al. The effect of environmental odors emanating from commercial swine operations on the mood of nearby residents. Brain Res Bull 37(4):369–375 (1995); http://www.ncbi.nlm.nih.gov/pubmed/7620910.
12. Bullers S. Environmental stressors, perceived control, and health: the case of residents near large-scale hog farms in eastern North Carolina. Hum Ecol 33(1):1–16 (2005); http://dx.doi.org/10.1007/s10745-005-1653-3.
13. Horton RA, et al. Malodor as a trigger of stress and negative mood in neighbors of industrial hog operations. Am J Public Health 99(suppl 3):S610–S615 (2009); http://dx.doi.org/10.2105/AJPH.2008.148924.
14. Wing S, et al. Air pollution from industrial swine operations and blood pressure of neighboring residents. Environ Health Perspect 121(1):92–96 (2013); http://dx.doi.org/10.1289/ehp.1205109.
15. Furuseth OJ. Restructuring of hog farming in North Carolina: explosion and implosion. Prof Geogr 49(4):391–403 (1997); http://dx.doi.org/10.1111/0033-0124.00086.
16. Baharanyi N, et al., eds. Focus on Black Belt Counties: Life Conditions and Opportunities. Proceedings of a Preconference of the 50th Annual Professional Agricultural Workers Conference, Tuskegee, AL, 5–6 Dec 1992. Tuskegee, AL and Mississippi State, MS: Tuskegee University and the Southern Rural Development Center (1993). Available: http://goo.gl/4iCrN [accessed 22 May 2013].
17. Wimberley DW. Quality of life trends in the southern Black Belt, 1980–2005: a research note. J Rural Soc Sci 25(1):103–118 (2010); http://goo.gl/crUCJ.
18. Calhoun SD, et al. Federal funds in the Black Belt. Rural Am 15(1):20–27 (2000); http://goo.gl/IMVmY.
19. Wimberley RC, Morris LV. The regionalization of poverty: assistance for the Black Belt South? South Rural Soc 18(1):294–306 (2002); http://goo.gl/9fxMz.
20. Wing S, et al. Environmental injustice in North Carolina's hog industry. Environ Health Perspect 108(3):225–231 (2000); http://www.ncbi.nlm.nih.gov/pmc/articles/79837958/.
21. Edwards B, Ladd AE. Race, poverty, political capacity and the spatial distribution of swine waste in North Carolina, 1982–1997. North Carolina Geogr (9):55–77 (2001); http://goo.gl/v6YyJ.
22. Mohai P, et al. Environmental justice. Annu Rev Environ Resour 34:405–430 (2009); http://dx.doi.org/10.1146/annurev-environ-082508-094348.
23. Pulido L. Rethinking environmental racism: white privilege and urban development in Southern California. Ann Assoc Am Geogr 90(1):12–40 (2000); http://dx.doi.org/10.1111/0004-5608.00182.
24. Attempts to get comment from the National Pork Producers Council and the North Carolina Pork Council on this question were not answered.
25. Brown P. Race, class, and environmental health: a review and systematization of the literature. Environ Res 69(1):15–30 (1995); http://dx.doi.org/10.1006/enrs.1995.1021.
26. Bryant B, Mohai P, eds. Race and the Incidence of Environmental Hazards: A Time for Discourse. Boulder, CO: Westview Press (1992).
27. Ringquist EJ. Assessing evidence of environmental inequities: a meta-analysis. J Policy Anal Manage 24(2):223–247 (2005); http://dx.doi.org/10.1002/pam.20088.
28. Anderton DL, et al. Environmental equity: the demographics of dumping. Demography 31(2):229–248 (1994); http://dx.doi.org/10.2307/2061884.
29. Evans GW, Kantrowitz E. Socioeconomic status and health: the potential role of environmental risk exposure. Annu Rev Public Health 23:303–331 (2002); http://dx.doi.org/10.1146/annurev.publhealth.23.112001.112349.
30. Brulle RJ, Pellow DN. Environmental justice: human health and environmental inequalities. Annu Rev Public Health 27:103–124 (2006); http://dx.doi.org/10.1146/annurev.publhealth.27.021405.102124.
31. Edwards B, Ladd AE. Environmental justice, swine production and farm loss in North Carolina. Sociol Spectr 20(3):263–290 (2000); http://dx.doi.org/10.1080/027321700405054.
32. Edwards B, Driscoll A. From farms to factories: the environmental consequences of swine industrialization in North Carolina, 1982–2007. In: Twenty Lessons in Environmental Sociology (Gould K, Lewis T, eds.). New York, NY: Oxford University Press (2008).
33. Pew Commission on Industrial Farm Animal Production. Putting Meat on the Table: Industrial Farm Animal Production in America. Philadelphia, PA and Washington, DC: The Pew Charitable Trusts (2008). Available: http://goo.gl/us9XR [accessed 22 May 2013].
34. DeLind LB. Social consequences of intensive swine production: some effects of community conflict. Culture Agric 26(1–2):80–89 (2004); http://dx.doi.org/10.1525/cag.2004.26.1-2.80.
35. LeDuff C. At a slaughterhouse, some things never die: who kills, who cuts, who bosses can depend on race. How Race Is Lived in America [special series]. The New York Times, online edition (16 Jun 2000). Available: http://goo.gl/ME4lH [accessed 22 May 2013].
36. USDA. Livestock Slaughter [website]. Washington, DC: National Agricultural Statistics Service, U.S. Department of Agriculture (updated 25 Apr 2013). Available: http://goo.gl/L3swQ [accessed 22 May 2013].
37. Farm Forward. Factory Farming [website]. Portland, OR: Farm Forward (2013). Available: http://goo.gl/CgQxM [accessed 22 May 2013].
38. Starmer E, Wise TA. Living High on the Hog: Factory Farms, Federal Policy, and the Structural Transformation of Swine Production. Medford, MA: Global Development and Environment Institute, Tufts University (Dec 2007). Available: http://goo.gl/MBNh [accessed 22 May 2013].
39. Stith P, Warrick J. Murphy's laws: for Murphy, good government means good business. Raleigh News & Observer (22 Feb 1995). Available: http://www.pulitzer.org/archives/5897 [accessed 22 May 2013].
40. McKown AM. Hog Farms and Nuisance Law in *Parker v. Barefoot*: Has North Carolina Become a Hog Heaven and Waste Lagoon? Agriculture Law Research Article. Fayetteville, AR: The National Agricultural Law Center. Available: http://goo.gl/IQ5V5 [accessed 22 May 2103].
41. NCDACS. 2012 North Carolina Agricultural Statistics. Raleigh, NC: North Carolina Department of Agriculture and Consumer Services/National Agricultural Statistics Service, U.S. Department of Agriculture (2012). Available: http://goo.gl/s3TXX [accessed 22 May 2013].
42. Thu KM, Durrenberger EP. Pigs, Profits and Rural Communities. Albany, NY: State University of New York Press (1998). Available: http://goo.gl/u0khB [accessed 22 May 2013].
43. GAO. Concentrated Animal Feeding Operations. EPA Needs More Information and a Clearly Defined Strategy to Protect Air and Water Quality from Pollutants of Concern. GAO-08-944. Washington, DC: U.S. Government Accountability Office (Sep 2008). Available: http://www.gao.gov/new.items/d08944.pdf [accessed 22 May 2013].
44. Burkholder JM, et al. Impacts of waste from concentrated animal feeding operations on water quality. Environ Health Perspect 115(2):308–312 (2007); http://dx.doi.org/10.1289/ehp.8839.
45. Burkholder JM, et al. Impacts to a coastal river and estuary from rupture of a large swine waste holding lagoon. J Environ Qual 26(6):1451–1466 (1997); http://dx.doi.org/10.2134/jeq1997.00472425002600060003x.
46. Gerba CP, Smith JE Jr. Sources of pathogenic microorganisms and their fate during land application of wastes. J Environ Qual 34(1):42–48 (2005); http://goo.gl/zWjhW.
47. Silbergeld EK, et al. Industrial food animal production, antimicrobial resistance, and human health. Annu Rev Public Health 29:151–169 (2008); http://dx.doi.org/10.1146/annurev.publhealth.29.020907.090904.
48. Gibbs SG, et al. Isolation of antibiotic-resistant bacteria from the air plume downwind of a swine confined or concentrated animal feeding operation. Environ Health Perspect 114(7):1032–1037 (2006); http://dx.doi.org/10.1289/ehp.8910.
49. Huffman RL, Westerman PW. Estimated seepage losses from established swine waste lagoons in the lower coastal plain of North Carolina. Trans ASAE 38(2):449–453 (1995).
50. Westerman PW, et al. Swine-lagoon seepage in sandy soils. Trans ASAE 38(6):1749–1760 (1995).
51. Huffman RL. Seepage evaluation of older swine lagoons in North Carolina. Trans ASAE 47(5):1507–1512 (2004); http://goo.gl/hhZgH.
52. Burns JD. The Eight Million Little Pigs—A Cautionary Tale: Statutory and Regulatory Responses to Concentrated Hog Farming. Fayetteville, AR: The National Agricultural Law Center, University of Arkansas (1996). Available: http://goo.gl/bA6LJ [accessed 22 May 2013].
53. EPA. Animal Waste Disposal Issues. Washington, DC: Office of Inspector General, U.S. Environmental Protection Agency (1997). Available: http://www.epa.gov/oig/reports/1997/hogexsm.pdf [accessed 22 May 2013].
54. Warrick J, Stith P. New studies show that lagoons are leaking: groundwater, rivers affected by waste. Raleigh News & Observer (19 Feb 1995). Available: http://www.pulitzer.org/archives/5893 [accessed 22 May 2013].
55. Cole D, et al. Concentrated swine feeding operations and public health: a review of occupational and community health effects. Environ Health Perspect 108(8):685–699 (2000); http://www.ncbi.nlm.nih.gov/pmc/articles/PMC1638284/.
56. Tajik M, et al. Impact of odor from industrial hog operations on daily living activities. New Solut 18(2):193–205 (2008); http://dx.doi.org/10.2190/NS.18.2.i.
57. Wing S, et al. Air pollution and odor in communities near industrial swine operations. Environ Health Perspect 116(10):1362–1368 (2008); http://dx.doi.org/10.1289/ehp.11250.
58. Schinasi L, et al. Air pollution, lung function, and physical symptoms in communities near concentrated swine feeding operations. Epidemiology 22(2):208–215 (2011); http://dx.doi.org/10.1097/EDE.0b013e3182093c8b.
59. Wing S, et al. Community based collaboration for environmental justice: south-east Halifax environmental reawakening. Environ Urban 8(2):129–140 (1996); http://dx.doi.org/10.1177/095624789600800214.
60. Fry JP, et al. Investigating the role of state and local health departments in addressing public health concerns related to industrial food animal production sites. PLoS ONE 8(1):e54720 (2013); http://dx.doi.org/10.1371/journal.pone.0054720.
61. General Assembly of North Carolina. S.L. 1997-458. HB 515: Clean Water Responsibility Act. Effective 27 Aug 1997. Available: http://goo.gl/rkl9C [accessed 22 May 2013].
62. General Assembly of North Carolina. House DRH30306-SB-6: Swine Farm Env. Performance Standards/Funds. Effective 1 Jul 2007 and 1 Sept 2007. Available: http://goo.gl/6Eyc8 [accessed 22 May 2013].
63. NCDACS. 2012 Annual Report on the Implementation of the Lagoon Conversion Program. 2012 Semi-annual Report on the Pilot Program for the Inspection of Animal Waste Management Systems. Raleigh, NC: Division of Soil and Water Conservation, North Carolina Department of Agriculture and Consumer Services (9 Oct 2012). Available: http://goo.gl/kuK94 [accessed 22 May 2013].
64. Karan A. Pigs, Profit, Planet: North Carolina Farmers' Perspectives on Waste Lagoon Conversion [undergraduate honors thesis]. Durham, NC: Sanford School of Public Policy, Duke University (Dec 2011). Available: http://goo.gl/fzf4Y [accessed 22 May 2013].
65. Wing S, et al. The potential impact of flooding on confined animal feeding operations in eastern North Carolina. Environ Health Perspect 110(4):387–391 (2002); http://www.ncbi.nlm.nih.gov/pmc/articles/PMC1240801/.
66. Development of Environmentally Superior Technologies for Swine Waste Management per Agreements Between the Attorney General of North Carolina, Smithfield Foods, Premium Standard Farms and Frontline Farmers [website]. Raleigh, NC: Animal and Poultry Waste Management Center, College of Agriculture and Life Sciences, North Carolina State University. Available: http://goo.gl/ObcEn [accessed 22 May 2013].
67. Attorney General of the State of North Carolina. Agreement between the Attorney General of North Carolina; Smithfield Foods, Inc.; Brown's of Carolina, Inc.; Carroll's Foods, Inc.; Murphy Farms, Inc.; Carroll's Foods of Virginia, Inc.; and Quarter M Farms, Inc. Raleigh, NC: Office of the Attorney General, State of North Carolina (25 Jul 2000). Available: http://goo.gl/5s68N [accessed 22 May 2013].
68. Premium Standard Farms, Inc. Annual Report, Filed 5/16/2005 for Period Ending 3/26/2005. Kansas City, MO: Premium Standard Farms, Inc. (2005). Available: http://www.psfarms.com/PSF_FY_2005_10K.pdf [accessed 22 May 2013].
69. General Assembly of North Carolina. S.L. 2011-118. SB 501: An Act to Facilitate Improved Operations and Conditions at Certain Preexisting Swine Farms by Providing for the Construction or Renovation of Swine Houses at Those Farms. Effective 13 Jun 2011. Available: http://goo.gl/J5RMN [accessed 22 May 2013].
70. Bindell R. Hog Waste Is Dragging North Carolina Through the Manure [weblog entry]. http://www.foodandwaterwatch.org (11 May 2011). Available: http://goo.gl/TlK83 [accessed 22 May 2013].
71. Prasodjo D, et al. A Spatial-Economic Optimization Study of Swine-Waste Derived Biogas Infrastructure Design in North Carolina. Durham, NC: Duke University, Duke Carbon Offsets Initiative (April 2013). Available: http://goo.gl/cxFT7 [accessed 22 May 2013].
72. The Loyd Ray Farms Swine Waste-to-Energy Offsets Project [website]. Durham, NC: Duke University (2013). Available: http://goo.gl/Swyxw [accessed 22 May 2013].
73. EPA. Renewable Energy Certificates (RECs) [website]. Washington, DC: U.S. Environmental Protection Agency (updated 16 Oct 2012). Available: http://www.epa.gov/greenpower/gpmarket/rec.htm [accessed 22 May 2013].
74. United Church of Christ Commission for Racial Justice. Toxic Wastes and Race at Twenty: 1987–2007: A Report Prepared for the United Church of Christ Justice and Witness Ministries. Cleveland, OH: Justice and Witness Ministries, United Church of Christ (2007). Available: http://goo.gl/4AqvD [accessed 22 May 2013].
75. Bullard RD, ed. Unequal Protection: Environmental Justice and Communities of Color. San Francisco, CA: Sierra Club Books (1994).
76. The PCB dump was remediated in 2004. See: Bullard RD. Environmental Racism PCB Landfill Finally Remedied But No Reparations for Residents. Atlanta, GA: Environmental Justice Resource Center, Clark Atlanta University (12 Jan 2004). Available: http://goo.gl/Djih5 [accessed 22 May 2013].
77. GAO. Siting of Hazardous Waste Landfills and Their Correlation with Racial and Economic Status of Surrounding Communities. RCED-83-168. Washington, DC: U.S. General Accounting Office (1983). Available: http://www.gao.gov/assets/150/140159.pdf [accessed 22 May 2013].
78. EPA. Environmental Equity: Reducing Risks for All Communities. Washington, DC: U.S. Environmental Protection Agency (Jun 1992). Available: http://goo.gl/gey0u [accessed 22 May 2013].
79. EPA. Environmental Justice [website]. Washington, DC: U.S. Environmental Protection Agency (updated 20 May 2013). Available: http://goo.gl/lWgdL [accessed 22 May 2013].

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Erratum: "CAFOs and Environmental Justice: The Case of North Carolina"

The June 2013 News article "CAFOs and Environmental Justice: The Case of North Carolina" [Environ Health Perspect 121:A182–A189 (2013)] referred to farms that companies "co-own with farmers." These farms should have been referred to as "company-owned." *EHP* regrets the error.

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Exhibit 45

Environmental Impact of Industrial Farm Animal Production

A Report of the Pew Commission on Industrial Farm Animal Production

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To Plc:

Industrial Farm Animal Production , Environmental Impact of Industrial Farm Animal Production

Rolf U. Halden, MS, PhD
Kellogg J. Schwab, PhD

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PcIFAP Staff Summary Environmental Impact of Industrial Farm Animal Production

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The Pew Commission on Industrial Farm Animal Production was established by a grant from The Pew Charitable Trusts to the Johns Hopkins Bloomberg School of Public Health. The two-year charge to the Commission was to study the public health, environmental, animal welfare, and rural community problems created by concentrated animal feeding operations and to recommend solutions.

Like many industries, Industrial Farm Animal Production (IFAP) results in a number of environmental impacts that affect populations both near and far. While every industry may contribute to society via production of some necessary or desired good, as our population increases, we have become more and more aware of the finite nature of our world's resources and of the impacts of our various industries upon those resources and our own human health. Industrial farm operations impact all major environmental media, including water, soil, and air. Of most concern are the pollution of ground and surface water resources with nutrients, industrial and agricultural chemicals, and microorganisms; the use of freshwater resources; the contamination and degradation of soil; and the release of toxic gases and odorous substances, as well as particulates and bioaerosols containing microorganisms and pathogens. The Commission queried the authors of this report on the magnitude and key determinants of these impacts, and the resulting impacts on both human health and ecosystems.

The major causes of the above noted environmental impacts of IFAP are the enormous amounts of waste that are produced in a very small area in this agricultural model, the inadequate systems we now have to deal with

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that waste, and the large energy and resource inputs required for this type of production, including feed production and transport.

The USDA Agricultural Research Services (ars) estimated the manure output from farm animals in the United States to be nearly 1 million US short tons of dry matter per day in 2001. Eighty-six percent of this was estimated to be produced by animals held in confinement. Different groups have posited both lower and higher estimates, but the fact remains that food animals produce an enormous amount of waste every day, exceeding human sanitary waste production by at least one order of magnitude. However, disposal of this waste is far less closely regulated than disposal of human waste. Animal manure and other agricultural waste result in water and air degradation, which in turn impact both the aquatic and the terrestrial ecosystems surrounding these operations.

In addition to the enormous waste produced by industrial agriculture, this system requires major inputs of both energy and resources. Water use is more significant in these systems because it is often used for cleaning the buildings and in the waste management systems. In addition, the industrial model utilizes feed, which is grown in monocultures, often far away from the facility. Enormous quantities of both water and petroleum-based pesticides may be used in the production of this feed, leading not only to the depletion of water resources, but also to soil erosion and pollution with pesticides. Pesticide residues may remain in the animal feed, leading to the possibility of toxic residues in the food animals themselves. Feed crop monocultures also contribute to loss of biodiversity, as they are planted in place of other plants

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and/or animal habitats.

Finally, but growing more urgent every day, industrial agriculture may be a significant contributor to climate change, as the production of greenhouse gases from these facilities (both from the animals themselves and from the decomposition of their waste) is significant.

Taken together, these data suggest that the present industrial model of farm animal production is not sustainable for the long term. The overuse and degradation of natural resources may be too great to allow the current form of this production model to continue to be viable. The commission requested that the authors of this report investigate the scope of these environmental factors, to help grasp the breadth of the possible impacts of the feedlot system.

By releasing this technical report, the Commission acknowledges that the author/authors fulfilled the request of the Commission on the topics reviewed. This report does not reflect the position of the Commission on these, or any other, issues. The final report, and the recommendations included in it, represents the consensus position of the Commission.

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Introduction

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Industrial farm operations adversely impact all major environmental media, including water, soil, and air. Key issues of concern for ecological and human health include the contamination of ground and surface water resources with nutrients, industrial and agricultural chemicals, and microorganisms such as viruses, bacteria, and parasites. Unsustainable use of freshwater for feed production, animal care, and slaughterhouses contributes to water scarcity and is depleting precious resources needed by future generations (Burkholder et al., 2007; Walker et al., 2005). Contamination of soil is another pervasive problem caused by the unsustainable, year-round deposition of excess nutrients, chemicals, and pathogens on land in the vicinity of industrial feeding operations. Poor air quality results from the localized release of significant quantities of toxic gases and odorous substances, as well as particulates and bioaerosols containing a variety of microorganisms and human pathogens. Adverse ecological outcomes include excessive nutrient loading and euthrophication of surface waters resulting in oxygen-depleted dead zones in both inland and marine surface waters, recurring algal blooms, fish kills, and a decline in species populations and biodiversity.

An array of adverse human health effects have begun to be documented in conjunction with the rise of industrial farm animal production (ifap) (Sapkota et al., 2007b; Donham et al., 2007). Health outcomes observed in farm workers and exposed rural populations include an increased prevalence in serious respiratory diseases (up to 25% for workers in the swine industry) (Heederick et al., 2007), bacterial infections that may be resistant to antimicrobials, and a general decline in physical, mental, and social wellbeing, as perceived by affected rural populations (Donham et al. 2007; Gilchrist et al., 2007; Heederick et al. 2007).

This paper explores the magnitude and key determinants of ifap impacts on air, water, and soil, and the resulting impacts on human health and ecosystems. To gain a proper understanding of the origin of environmental and human health issues surrounding modern animal farming, it is important to define current agricultural farming practices and contrast them with traditional methods that evolved over the course of centuries in the interplay between farmers, their land, and the animals raised.

The Industrial Farming Model.

In the past few decades, American farming has undergone significant changes. Today 54% of US food animals are concentrated on only 5% of the remaining farms. ifap is designed to increase production yield and decrease production costs by using high-efficiency practices that rely heavily on economies of scale as well as on a standardization of processes and end products (Sapkota et al., 2007b). This model differs from traditional farming in both approach and scale. The traditionally numerous but small and independently owned and operated farms have largely been replaced with a much more limited number of large facilities for growing food animals. These large farming operations now supply most of the meat and poultry products for domestic consumption and for markets around the world. ifap employs high-throughput farming of thousands of animals of a single breed for a single purpose, such as the large-scale production of hogs, broiler chickens, turkeys, or dairy cattle, often in confined locations under highly controlled conditions using formulated foods in lieu of access to forage. These facilities are known as animal feeding operations (afos). According to the US Environmental Protection

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Agency (EPA), an animal feeding operation (afo) is a lot or facility (other than an aquatic animal production facility) where the following conditions are met: (a) animals have been, are, or will be stabled or confined and fed or maintained for a total of 45 days or more in any 12-month period; and (b) crops, vegetation, forage growth, or post-harvest residues are not sustained in the normal growing season over any portion of the lot or facility (USepa Compliance Assistance website).

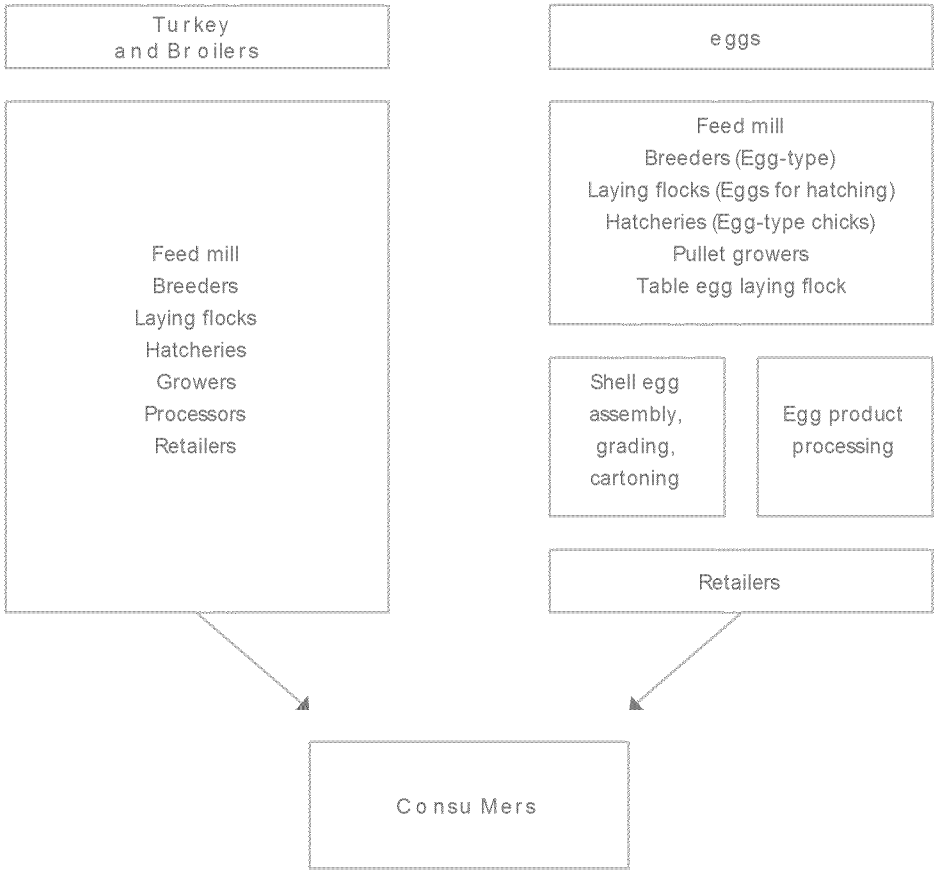
Concentrated animal feeding operations (CAFOs) are a sub-category, which previously was defined based on animal units, but now instead is determined by the actual number of animals at the operation. cafos can be divided into small, medium, and large operations based on the number of animals housed, as specified on the USepa Compliance Assistance website. Presently, cows, hogs, and poultry, i.e., turkeys and chickens, are the most common food animals raised in cafos in the United States.

Industrialized farm animal production evolved from a change to a management structure, in which a corporation controls all aspects of production from the selective breeding of young animals to the processing of animal meat into consumer products. This organizational structure is referred to as vertical integration (Economic Research Service/USDA, undated). A distinctive feature is that most or all management and economic responsibilities of animal production lie with companies known as integrators.

The shift from traditional animal husbandry to ifap has occurred rapidly in the United States, mostly within the last five decades. It has transformed the structure of rural communities and impacted environmental quality and public health in its wake. Today, fewer people are raising more food animals, and the traditional model of the self-employed farmer has shifted to that of a grower of animals, responsible only for raising young animals to market weight using methods prescribed by entities external to the geographic location of the animal production site (usda/NASS, 2005). While growers may still own the land and structures used for farming, they no longer own the animals and do not grow animal feed crops. This loss of independence is offset by the perceived benefits to farmers of obtaining price stability and a multi-year contract (usda/ERS, undated). In ifap, growers typically perform contract work for the integrators, who provide young animals and the formulated feed. They also control the terms and conditions of animal production and set the compensation paid to the grower. Whereas it is the grower's responsibility to carry out day-to-day operations, the integrators are instrumental in determining and administering veterinary care and inspection, as well as in managing animal removal from the grower's site, mostly by using contract labor. Animals having reached market weight are then taken to integrator-owned and -managed plants that, increasingly, furnish ready-to-sell consumer products for the retail market (Figure 1).

The shift in animal production toward this industrialized business model has important environmental and public health implications. Today, more animal waste than ever before is produced by a very limited number of large farms. The disposal of these unprecedented amounts of animal waste generated in a few discrete locations poses new and significant challenges. Animal waste or manure, which traditionally has been regarded as a welcome source of nutrients for soil improvement (often referred to as amendment), in many cases, has turned into a liability and a problematic byproduct causing ecosystem degradation and public health concerns in communities surrounding ifap facilities (Osterberg and Wallinga, 2004). High-density confinement of animals has created indoor air pollution hazards for workers and significant point sources for outdoor air pollution (Mitloehner and Schenker, 2007). Industrial animal farming practices also have promoted the use of non-traditional chemicals in agriculture, including antimicrobials for disease control, prophylaxis, and growth promotion, as well as heavy metal–containing arsenicals for control of parasitic diseases (Graham et al., 2007). The presence of these non-traditional chemicals in animal waste poses new challenges for appropriate management. Furthermore, the centralization of animal production facilities has made American agriculture more vulnerable to large-scale outbreaks of food- and waterborne diseases, thereby adversely impacting food safety and food security (Gilchrist et al., 2007). Finally, centralized meat production and animal slaughtering houses have increased energy consumption, long-distance transport of agricultural products, and the output of noxious gases suspected of contributing to air quality degradation, adverse human health effects, and climate change phenomena (Heederik et al., 2007).

Figure 1. conceptual diagram illustrating the integrated business model extant in the poultry and egg industry. Typically, integrators own and control all aspects of production to the point of retail sale (Source: USDA ERS AER-807)



origin and Magnitude of Environmental Impacts

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In the United States, an estimated 173,000 miles of national waterways are impacted by runoff from agricultural sources (Cook, 1998). Animal farming is estimated to account for 55% of soil and sediment erosion, 37% of nationwide pesticide usage, 80% of antibiotic usage, and more than 30% of the total nitrogen and phosphorus loading to national drinking water resources (Steinfeld et al., 2006).

There are three root causes of environmental degradation from IFAP:

1. The large volumes of animal waste produced;
2. Lack of appropriate management and disposal of these materials; and
3. Unsustainable water usage and soil degradation associated with feed production.

Before these environmental issues are explored in greater detail, it is important to gain an appreciation for the scale of IFAP operations in the United States and how extensively they have penetrated the national agricultural sector.

The structural shift toward IFAP.

Contract production of meat in IFAP facilities is a national phenomenon now dominating the agricultural sector. In 1999, the IFAP business model already accounted for almost the entire broiler production, more than 60% of the hog production and about 35% of the cattle output (Donham et al., 2007; US Government Accountability Office, 2005). Today, eight years later, its role certainly is even more pronounced. (Release of updated information by the USDA is pending.)

The trend toward intensive, industrialized production of confined cattle, hogs, and poultry can be illustrated by the broiler industry. Figure 2 shows the relative increase of very large IFAP facilities producing tens of thousands of broilers per year.

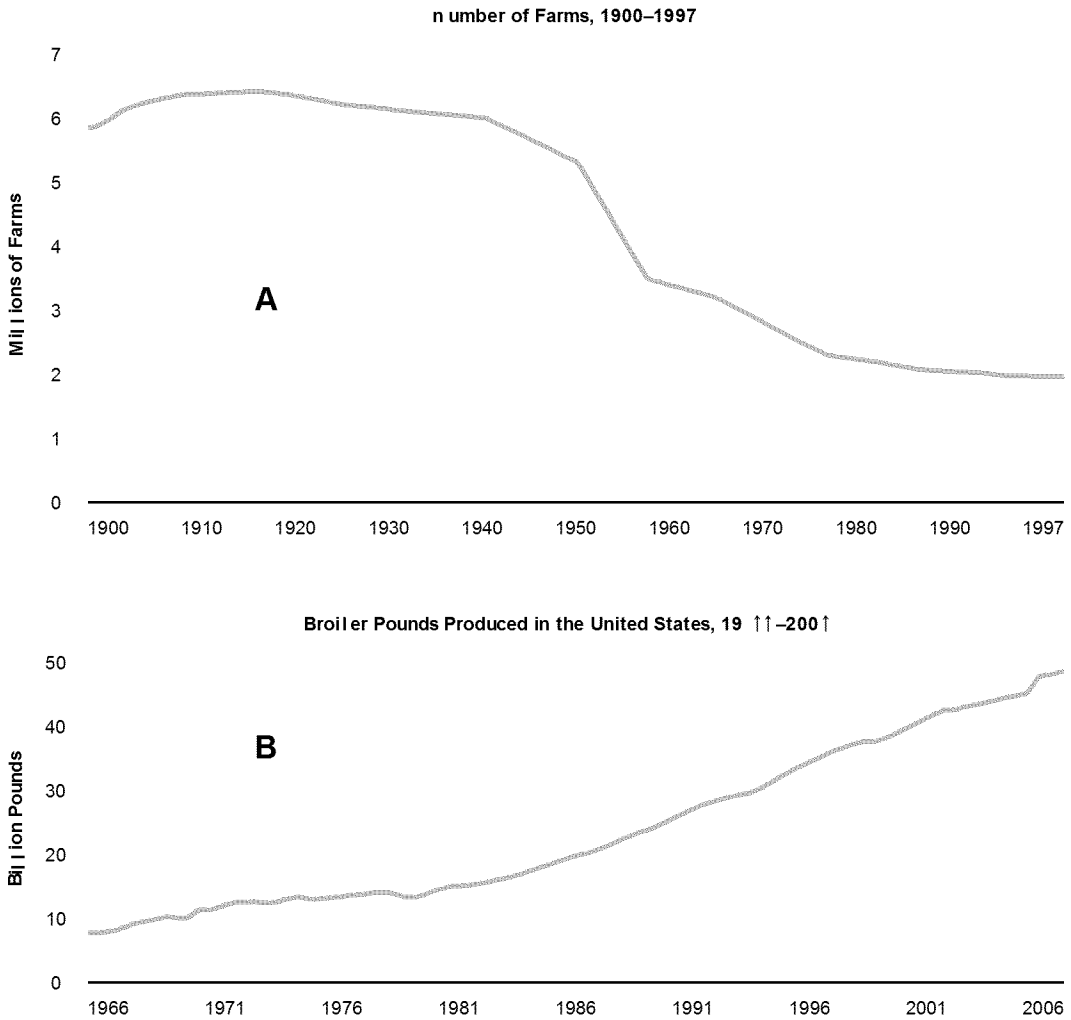
Over the course of several decades, millions of US backyard operations featuring small flocks of chickens often raised for the dual purpose of egg and meat production have been replaced with less than 50 agricultural firms that operate as highly specialized, vertically integrated businesses with most of the production coming from the top four integrators (USDA-NASS undated [http://www.usda.gov/nass/pubs/trends/broiler.htm]; USDA-ERS undated).

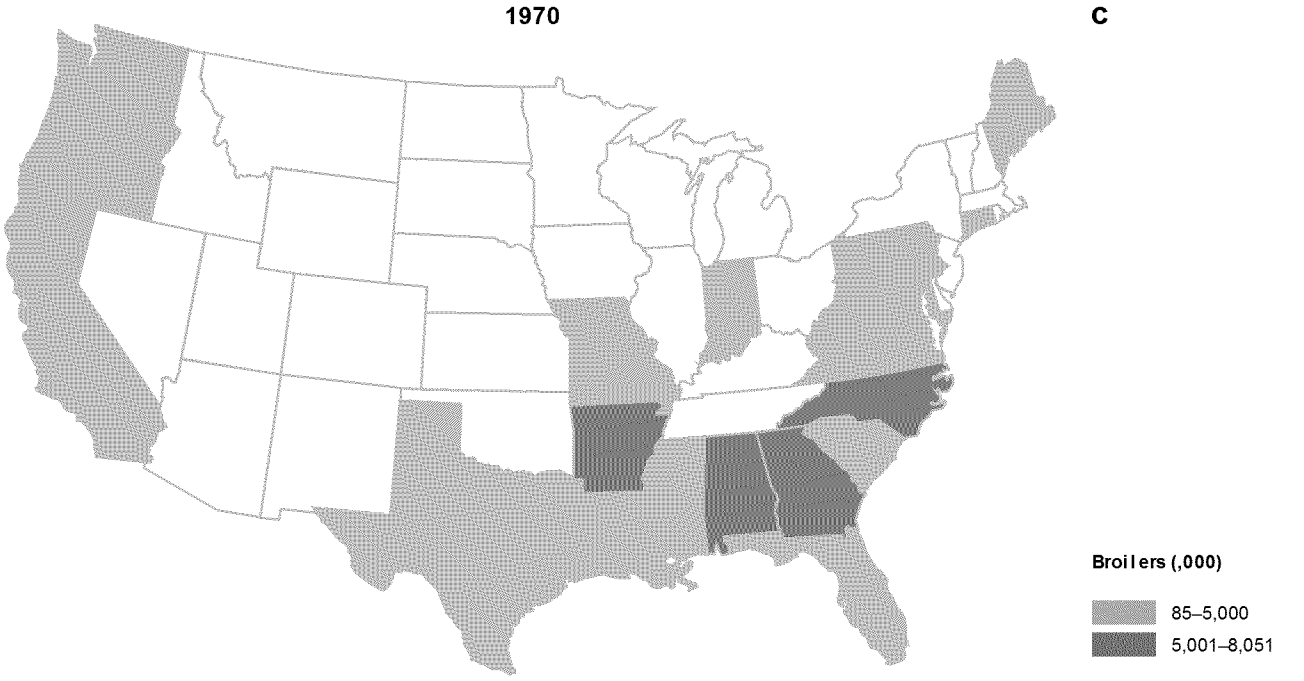
Hallmarks of new production techniques are high-density facilities in which 25,000 to 50,000 confined chickens are raised to market weight within a few weeks by automated feeding apparatuses dispensing a growth-optimized diet usually supplemented with antimicrobials that also are used as life-saving remedies in human medicine. Use of these techniques has allowed for a doubling of broiler production from 1980 to 1999 (USDA-NASS undated [http://www.usda.gov/nass/pubs/trends/livestockproduction.csv]) and has triggered a remarkable reduction in prices of broilers, now available for less than what was charged (in inflation-adjusted dollars) in the 1950s (USDA-ERS undated). However, this seemingly favorable cost comparison of meat from IFAP versus traditional farms does not account for environmental and public health costs.

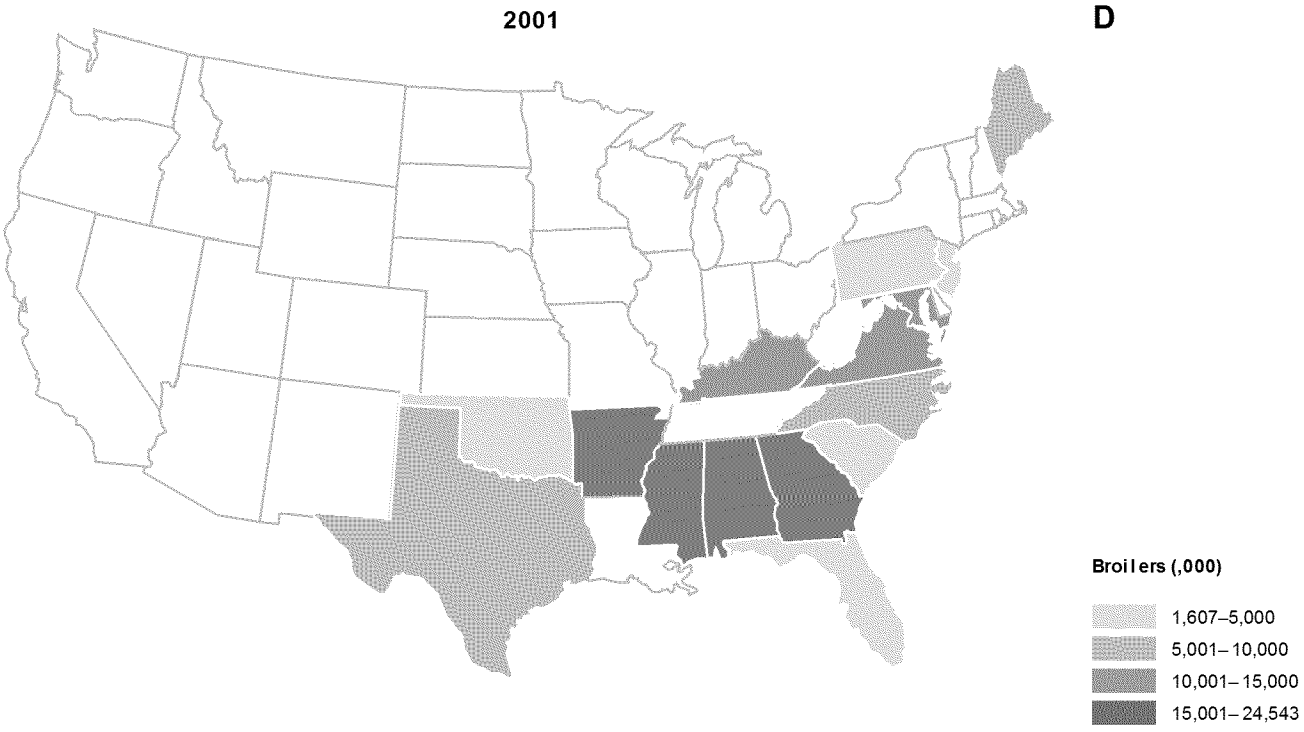
Statistics for the hog industry show similar trends of a sharp decrease in the number of farms and a notable increase in their sizes. In 2005, the United States produced more than 103 million pigs at 67,000 production facilities (USDA 2006a; 2006b). Facilities housing tens of thousands of pigs accounted for more than half of the total US swine inventory, reflecting the increasing consolidation and concentration of US swine production (USDA 2006a).

Statistics for the US broiler and pork industry show today's animal production to be dominated by IFAP practices (Figure 3). This trend has resulted in the generation of large volumes of wastes in relatively confined geographical areas. For example, swine manure is typically stored in deep pits or outdoor lagoons and then applied to agricultural fields as a natural fertilizer. However, runoff events and percolation (i.e., water soaking into the ground) of manure components, including bacteria pathogenic to humans as well as chemical contaminants, have impacted surface water and groundwater proximal to swine CAFOs, thereby posing health risks to the environment and human populations (Anderson and Sobsey, 2006; Campagnolo et al., 2002; Jongbloed and Lenis, 1998; Krapac et al., 2002; Sayah et al., 2005; Thurston-Enriquez et al., 2005; Sapkota et al., 2007a).

Figure 2. Between the 1940s and 1980s (A), the United States has experienced a notable shift toward a small number of larger farms. This trend is exemplified by the broiler industry, which has markedly increased its meat output (B) while reducing the number of farms, formerly spread across multiple states (C), to a small number of larger facilities concentrated in a few southeastern and south-central states. (Sources: USDA-NASS: http://www.usda.gov/nass/pubs/trends/farmnumbers.htm, and Paudel and McIntosh, 2001) (Source: Census of Agriculture)







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Magnitude of animal waste produced.

By any estimate, the total amount of farm animal waste produced annually in the United States is substantial. In its report for the year 2001, the USDA estimated the output of manure from farm animals at 920,000 US short tons of dry matter per day (USDA ARS 2002). This translates to greater than 300 million metric tons of dry mass or more than 660 billion pounds per year. Of this mass, 86% (788,000 tons per day) was projected to stem from animals held in confinement. In contrast, the American Society of Agricultural Engineers provides a higher estimate of 540 million metric tons of dry weight excreta per annum (American Society of Agricultural Engineers, 2005). Lower estimates of 133 million tons of manure per year on a dry weight basis also have been reported recently in the peer-reviewed literature using information contained in USDA online databases (Burkholder et al., 2007). Reporting the volume of excreta based on the lifespan of the food animal results again in a different set of data. Regardless of the exact amount generated, farm animal waste exceeds human sanitary waste production by at least one order of magnitude (Burkholder et al., 2007). Yet in comparison to the lesser amount of human waste, the management and disposal of animal wastes are poorly regulated. This lack of protection may have been without consequence in traditional agriculture, because animal wastes produced by traditional animal husbandry methods in rural locations did not usually present risks to local communities that relied on ecosystem services for attenuating pathogens and absorbing or diluting nutrients. However, similar to large human settlements, improper management of feces from IFAP facilities can and does overwhelm natural cleansing processes.

Resource requirements of IFAP.

IFAP, as practiced today, is more resource intensive than the traditional practices of raising food animals (e.g., cows grazing on pastures), exhausting and eroding soils, and requiring disproportionately large inputs of fossil fuel, industrial fertilizers, and other synthetic chemicals, as well as substantial amounts of water, often withdrawn at unsustainable rates from scarce freshwater resources. Whereas the ratio of fossil fuel energy inputs per food unit produced averages 3:1 calories for all US agricultural products combined, it is substantially higher for industrially produced meat products. With a ratio as high as 35:1, beef produced in feedlots has a particularly unfavorable energy balance (Horrigan et al., 2002; these estimates exclude additional energy inputs for food processing and distribution).

Increased industrial animal production (Figures 2 and 3) implies an increase in the amount of nutrients and chemicals released to the environment. Approximately 21.3 million tons of nutrients have been applied in agriculture each year over the past three decades, with nitrogen and phosphorus contributing 11.4 and 4.6 million tons each, respectively (USDA Economic Research Service, 2007; potash accounts for the balance of the total). Pesticide inputs to the US environment from industrial meat production also are considerable (Steinfeld et al., 2006). Numbers available for the time period of 2000–2001 show the annual total pesticide usage in the United States at about 700 million pounds of active ingredient, 77% of which is applied in agriculture, with about half of this mass going to farmland used for the production of grain fed to industrial farm animals (Kiely et al., 2004; Steinfeld et al., 2006). Corn and soybeans, which now are replacing traditionally used grass as cattle feed, largely are produced in crop monocultures maintained on agricultural land that in many instances is irrigated using groundwater from aquifers whose natural recharge rates are outpaced by this intense, unsustainable usage (Horrigan et al., 2002).

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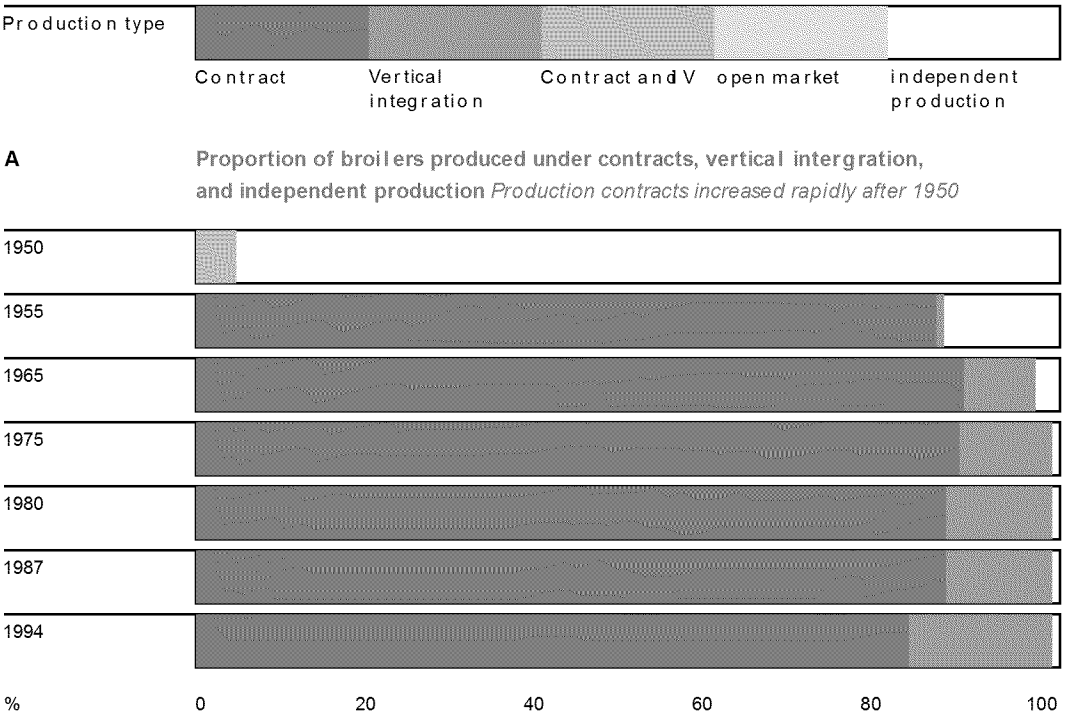
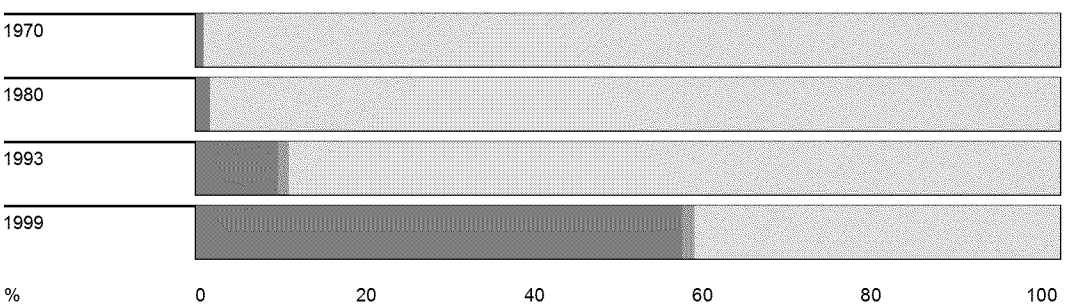
Figure 3. The number of US farm animals raised in independent production has declined at the expense of contract meat production, as illustrated by statistics for broilers (A) and hogs (B) (Source: Economic Research Service /USDA, undated)



Source: Compiled by ERS, USDA from Roy; Knutson, Penn, and Boehm; and Manchester. Note: Roy does not distinguish contracting and vertical integration in 1950.



Sources: Compiled by ERS, USDA from Hayenga, Lawrence, Rhodes, and Grimes; Marion; and University of Missouri and National Pork Producers Council.

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Affected populations.

The model of contract meat production now dominating the US market has physically separated key decision makers and many employees from the locality of animal farming operations, a development that has resulted in a loss of accountability and land stewardship as well as a degradation of the quality of life in rural communities harboring CAFO facilities (Horrigan et al., 2002; Donham et al., 2007). Adverse impacts have been documented in the areas of economic health, physical health, mental health, and social health, thereby creating an environmental justice issue for rural communities (Donham et al., 2007). Reports have documented associations between CAFO facilities in rural communities and increases in self-reported respiratory diseases including asthma and bronchitis; impaired mental health including depression; anxiety and post-traumatic stress disorder; harassment of outspoken community members; and a general perception by local residents of societal neglect (Dosman et al., 2004; Thu et al., 1997; Bullers, 2005; Schiffman et al., 1995). Documented impacts of CAFO include a relative decline in retail purchases made locally, more hired farmhands versus self-employed small-acreage farmers, decreased tax revenue, degradation of the community fabric, and a decline in land and property values (Goldschmidt, 1978; Thu, 1996; Wright et al., 2001).

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Key Determinants of Environmental Impacts of IFAP

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Swine, beef, and poultry IFAP facilities are the source of an array of chemical and biological pollutants (see Figure 4) discharged to air, water, and soil, where they have been observed to cause ecological effects and diseases in exposed individuals (Thorne, 2007; Heederik et al., 2007; Gilchrist et al., 2007). In the following, contaminant loading to all three major environmental media is discussed to emphasize that the chemical and biological agents emitted from IFAP facilities occur in multiple environmental media and migrate between them. Thereafter, key determinants of this pollution are explored in greater detail to identify opportunities for intervention and amelioration. Finally, the important role of dietary choices and their impact on environmental quality is discussed.

Water.

IFAP operations can impact the water environment by depleting limited freshwater sources and by contaminating surrounding surface and groundwater, two phenomena most frequently observed in arid regions and in floodplains, respectively (Burkholder et al. 1997; Mallin et al., 1997, 2000). Contamination of water resources occurs either directly, via intentional discharge of insufficiently treated liquid waste, or indirectly, via infiltration of contaminants into groundwater from unlined waste lagoons, as runoff from locations where solid waste is stored or has been disposed of, and from the deposition of airborne contaminants onto surface waters (Burkholder et al., 2007).

Air.

Airborne contaminant emissions arise from both ventilation and passive release. These emissions can include toxic gases and particulates (Bunton et al., 2007; Heederick et al., 2007). Decomposing animal excreta produce and release a complex mixture of dust particles, bacteria, endotoxins, and volatile organic compounds, as well as hydrogen sulfide, ammonia, and other odorous substances (Bunton et al. 2007). An association between health problems and air emissions has been reported in the literature. Some IFAP emissions such as ammonia can travel beyond the immediate CAFO location, thereby causing unwanted effects at the regional level (Aneja et al., 2003).

Soil.

The soil environment is stressed as a result of both the monoculture methods employed for producing soy and corn for animal feeds, and the disposal of animal wastes (Horrigan et al., 2002; Walker et al., 2005). Feed production in agricultural monocultures requires extensive application of pesticides and other agrichemicals, as well as irrigation, which, if not properly managed, can promote erosion and degrade terrestrial and aquatic ecosystems (Park and Egbert, 2005). Already, a significant area of US land is affected by heavy erosion, driven primarily by agricultural use, including the production of feed crops for food animals (Figure 5).

Equally important, animal wastes from IFAP are disposed of on agricultural land oftentimes year-round and without a suitable nutrient management plan. The latter practice results in over-fertilization of the soils, toxic runoff, and leaching of contaminants, which then pose additional risks to adjacent water environments and also may impact drinking water sources (Burkholder et al., 2007). While federal regulations recently have been revised (http://www.epa.gov/guide/cafo/), a lack of federal oversight and enforcement by state governments is a longstanding and continuing problem, as concluded by the US Government Accountability Office (US GAO, 2005).

None of the above issues are truly unique to industrialized farming, so why is it that IFAP plays such a critical role in the magnitude and severity of these processes and outcomes? Taking a historical view can be instructive. Many traditional animal farming methods, which evolved over more than 10,000 years, have proved to be sustainable because they strike a balance between agricultural inputs and outputs as well as the need to preserve ecosystems (one notable exception being slash-

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and-burn agriculture, which is still practiced around the world despite its severe impacts on environmental and human health). In contrast, industrial agriculture and particularly ifap are relatively recent phenomena, dating back less than half a century. The rapid ascent of ifap is driving the magnitude and importance of the key determinants of environmental and human health impacts discussed hereafter.

Meat production.

US meat production is at an all-time high and projected to increase to the year 2016 and beyond (usda 2007). The broiler industry, which has been converted almost entirely to industrial farm practices, exemplifies this trend (Figure 6). The increase in US meat consumption and in other areas of the world is due to multiple factors, including higher production capacities resulting from ifap, a growing world population, growing exports, and a trend toward a Western diet high in animal protein (Horrigan et al. 2002). A contributing major, but frequently overlooked, factor of increased meat consumption is artificially low retail prices resulting from government agricultural subsidies as well as the exclusion of external costs, i.e., costs resulting from current business practices that are excluded from the price of food (Walker et al. 2005); specifically, these external costs include the adverse environmental and human health impacts triggered by the release of insufficiently treated agricultural waste. The increased production of food animals has triggered an increase in feed crop production. Today, 66% of the grain produced in the US is fed to livestock (World Resource Institute, 2000). This simultaneous increase in feed and meat production has caused additional ecological impacts, including the need for disposal of increasing amounts of animal wastes. These wastes are produced in highly concentrated areas that have insufficient crop fertilizer needs to absorb the massive burden of nutrients and contaminants that are continuously generated.

Figure 4. Source-to-effect diagram illustrating the role of IFAP facilities as a source of hazardous agents whose emission adversely impacts the environmental quality of air, water, and soil, and creates conditions for biological exposure and unwanted health outcomes in affected animal and human populations (Voc s, volatile organic compounds; figure adapted from Walker et al., 2005)

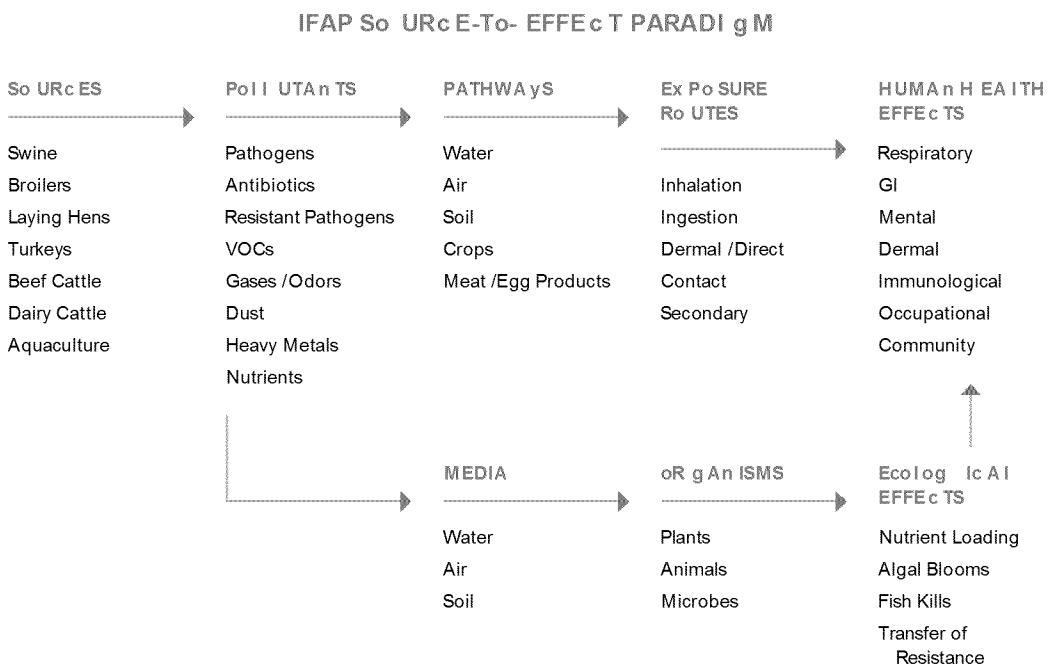


Figure 1. Map of the United States showing the rate of soil loss due to sheet and rill erosion resulting, in part, from the agricultural production of corn and other feed crops used in IFAP. Shown is the average value of soil erosion in units of pounds per acre calculated according to the Universal Soil dss Equation (USLE) for cultivated cropland and pastureland (Taken from Kellogg, 2000)

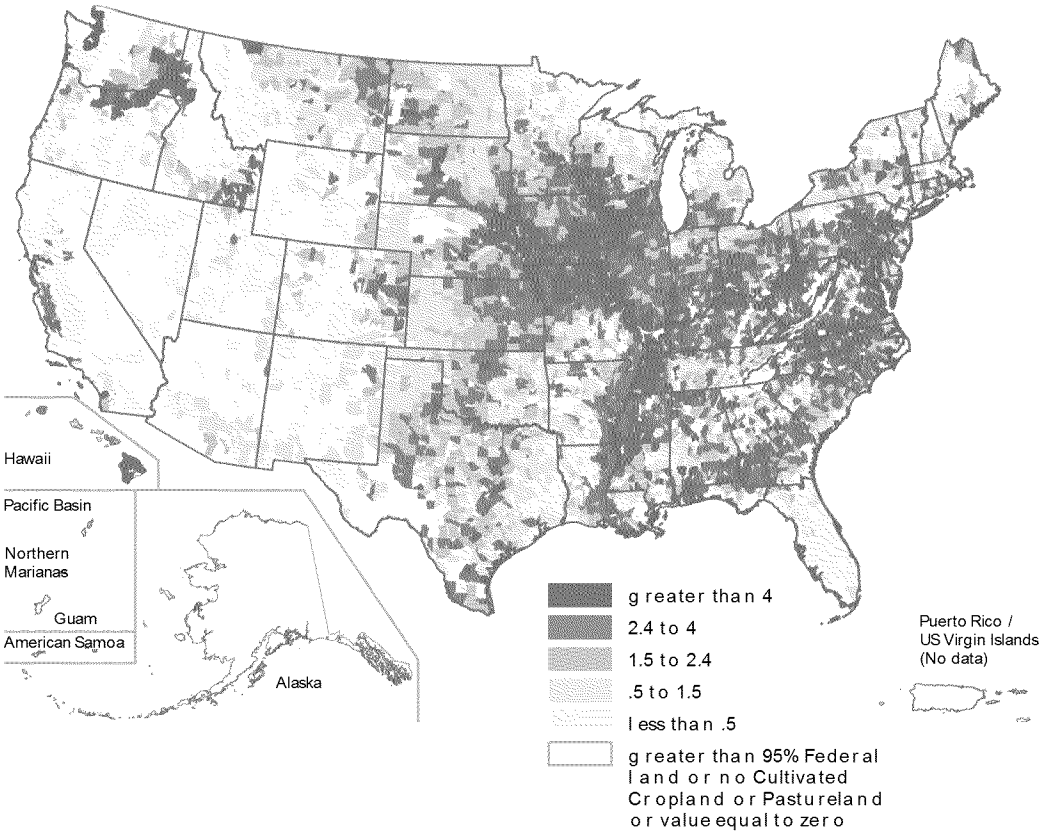
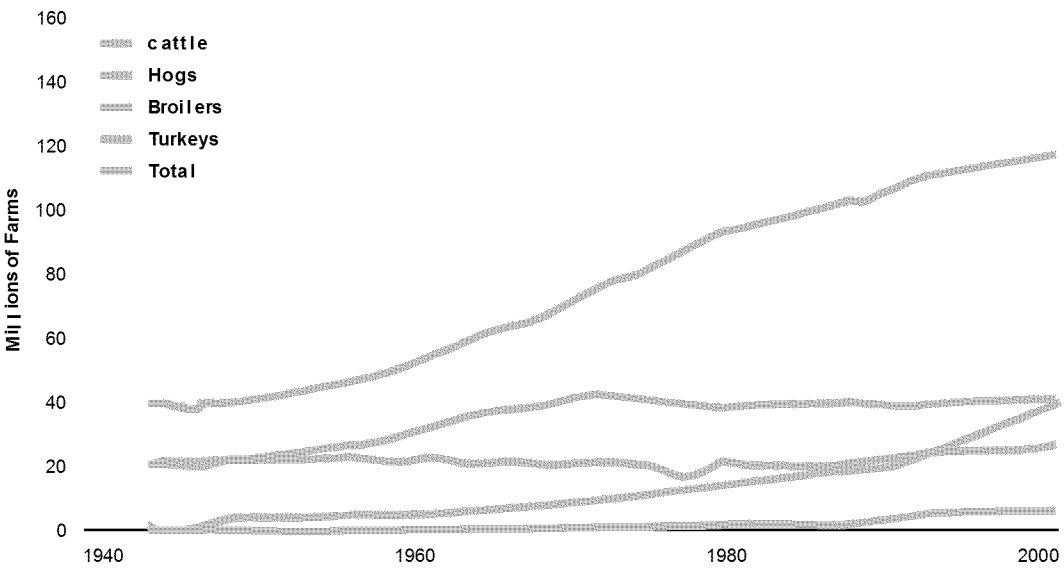


Figure 1. Trends in US meat production for the years 1941 through 1999 (Source: USDA)



n utrients.

Chief among the ecological concerns regarding current management practices of animal wastes are excess nutrients, including nitrogen and phosphorus. These elements control the fertility of soils and aquatic environments. Another important parameter is the so-called biochemical oxygen demand otbod , a lump measure of organic and inorganic substances that readily undergo aerobic microbial metabolism. As discussed later in greater detail, excessbod originating fromifap facilities can cause dangerous drops in dissolved oxygen levels in surface waters, a condition threatening the survival of most aquatic life.

Nitrogen-containing pollutants, principally ammonium, nitrate and nitrite, pose both ecological and human health threats. Constituents of animal waste applied on fields for feed crop production frequently find their way into surface waters as a result of leaching and surface runoff (Burkholder et al.,2007). Nitrogen in animal waste, present largely as ammonium, is quickly converted by microorganisms to nitrate in aerobic conditions. Nitrate is highly soluble and hence moves with water into rivers or groundwater. The problem is that nitrogen (as nitrate or ammonia) represents the limiting nutrient in marine and estuarine environments. As a result, an increased loading of nitrogen-containing compounds to surface waters can dramatically change these downstream coastal ecosystems. Discharge of excess nitrogen into streams and rivers, such as the Mississippi River and its tributaries (Figure7), also is known to contribute to both eutrophication in freshwater as well as annually recurring large dead zones in marine waters of the Gulf of Mexico (Figure 8). It is important to note that this phenomenon is driven not only by the land application ofafo waste but also by an increased reliance on fertilizer used for the production of grain fed to animals held in distant cafo s.

The resultant increased incidence of hypoxia, or lack of oxygen (Figure9), is responsible for massive fish kills. This phenomenon is a direct result of excessive use of fertilizers and improper disposal of animal wastes in agriculture.

Nitrate also is a key drinking water contaminant, regulated underepa's Safe Drinking Water Act at a level of10 mg per liter as nitrogen (10 mg/L NO_3^--N). Exposure to nitrate of infants under six months of age can result in blue baby syndrome or methemoglobinemia, a potentially deadly condition triggered via the conversion of ingested nitrate (NO_3^-) to toxic nitrite (NO_2^-) by commensal microorganisms within the human digestive tract (Ward et al.,2005). Adults also can be affected by nitrate-contaminated drinking water. Documented outcomes of human exposure to nitrates in drinking water are cancer and non-cancer diseases, including hyperthyroidism, insulin-dependent diabetes, and increased risk of adverse reproductive outcomes and neurodevelopmental defects. A recent review of public health issues related tofap summarizes the controversial issue of health outcomes from nitrate exposure (Burkholder et al.,2007).

Phosphorus is another major water contaminant that can originate fromcafo s. Similar to nitrogen in marine and coastal environments, phosphorus is the limiting nutrient for the productivity of freshwater environments.

Figure 7. Fertilizers, whose use has increased six-fold since the 19↑0s, represent a major source of nitrogen (purple trend line) annually released in the Mississippi Basin (Taken from goolsby and Battaglin, 2000)

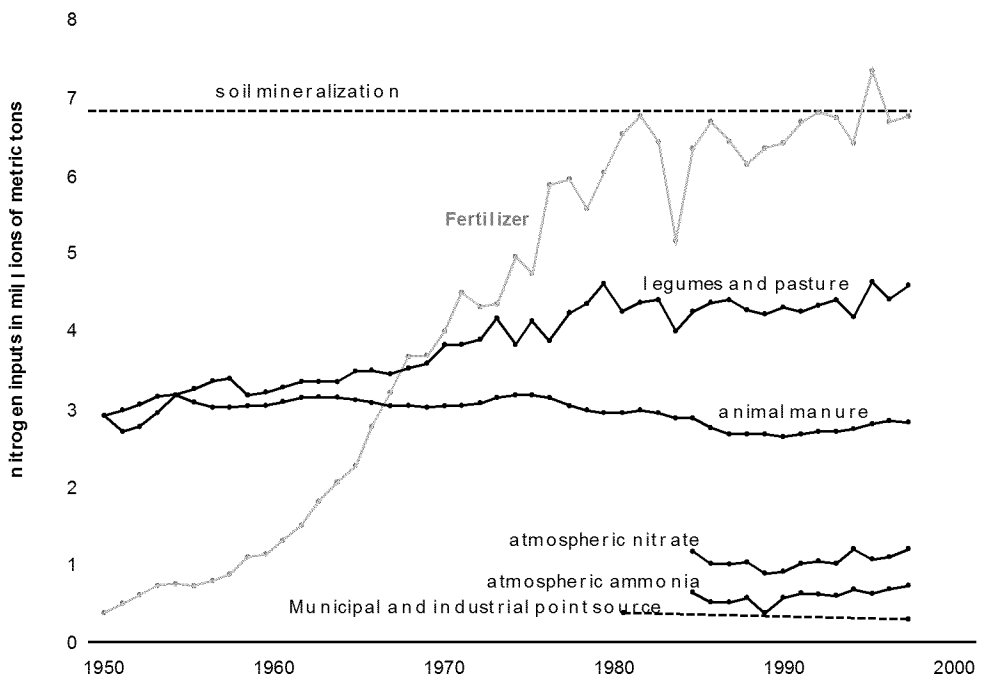


Figure 8. Excess nutrients flushed from agricultural soils into the Mississippi Delta create annually recurring dead zones in the gulf of Mexico (Source: no AA: www.noaanews.noaa.gov/stories/s2004.htm)

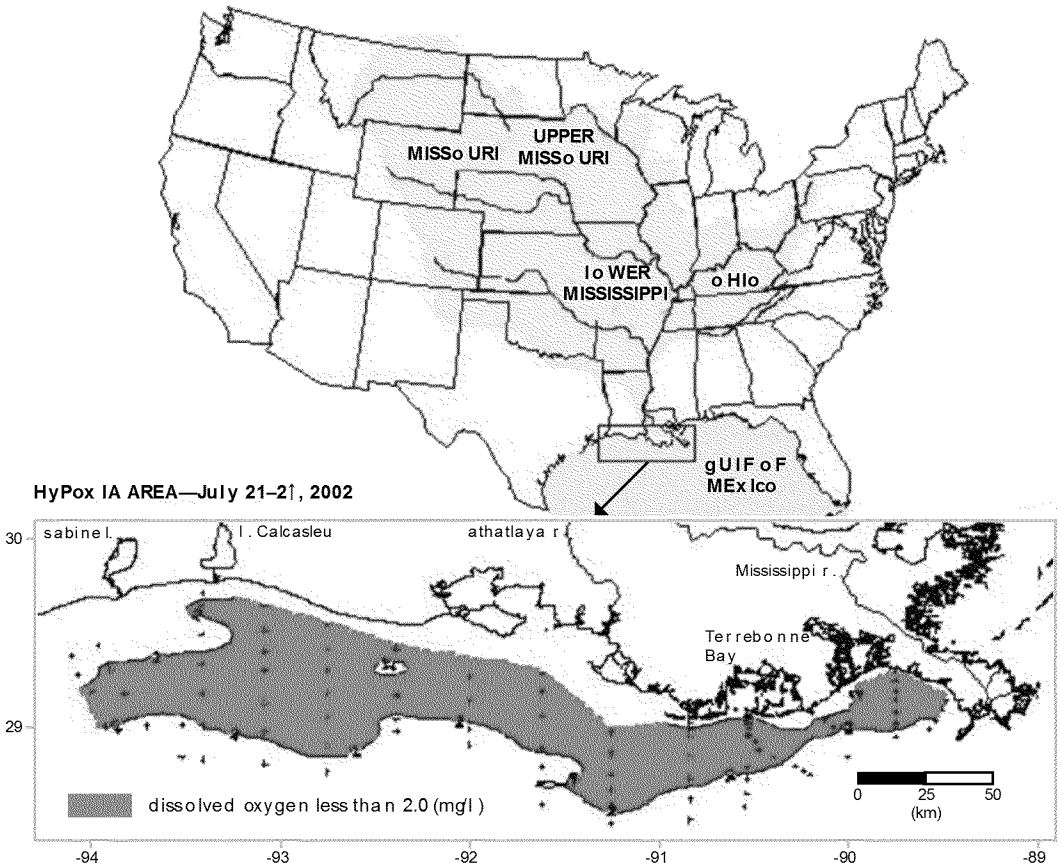
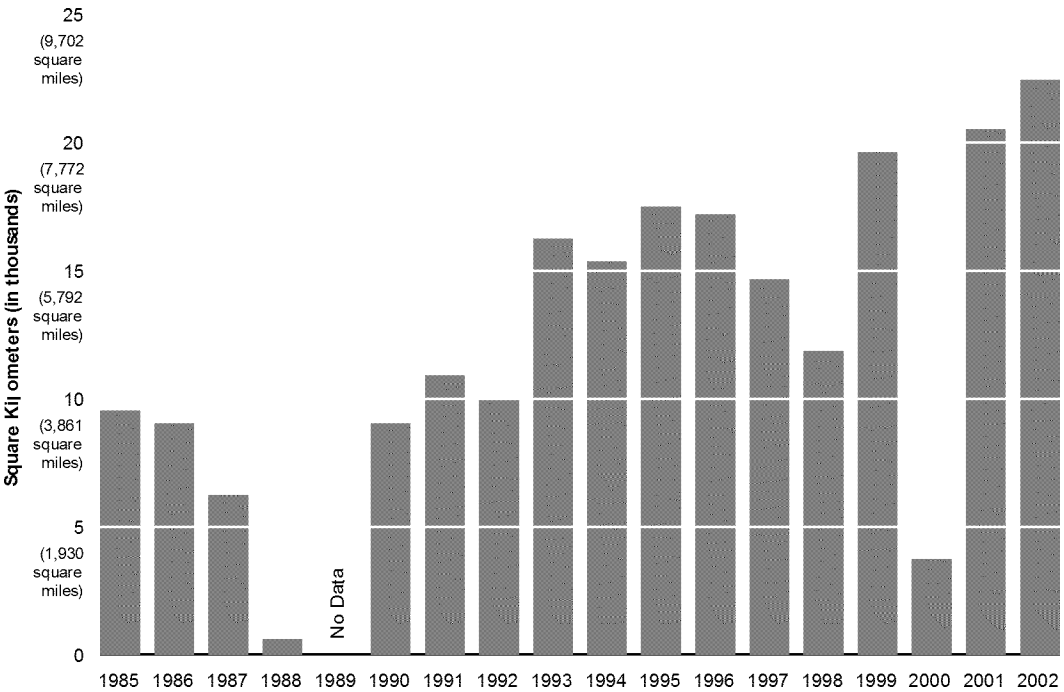


Figure 9. Hypoxic conditions in the gulf of Mexico have increased from 198↑ to 2002 (Source: US EPA: www.epa.gov/indicate/roe/html/roeWaterW2.htm)



Note: Hypoxia in the Gulf is defined as less than 2.0 parts per million (ppm).

Annual midsummer cruises have been conducted systematically over the past 15 years (with the exception of 1989). Hypoxia in bottom waters covered an average of 8,000–9,000 km ^{2} in 1985–92 but increased to 16,000–20,000 km ^{2} in 1993–99.

Source: For 1985–1999 data years: Rabalais, Nancy N. et al. *Characterization of Hypoxia: Topic 1 Report for the Integrated Assessment on Hypoxia in the Gulf of Mexico.* May 1999, updated July 2000; for 2000–2002 data years: Rabalais, Nancy N., Lousiana Universities Marine Consortium. Unpublished data, personal communication. February 11, 2003.

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Agricultural fertilizers employed in feed crop production and animal wastes from livestock operations contain large quantities of phosphorus, mostly in the form of inorganic phosphate (PO_4^{3-}). Disposal, leaching, and runoff of agricultural phosphorus compounds into freshwater resources form the principal cause for eutrophication of US surface freshwaters. Eutrophication is known to spawn excessive aquatic productivity and the development of recurring toxic algal blooms (Schindler, 1990) (Figure 10).

The burden of nitrogen and phosphorus from animal waste is considerable. As shown in Table 4, the estimated inventory of 9.6 billion food animals in the United States excretes a combined total of 9.2 million metric tons of nitrogen and 857,000 tons of phosphorus. Deposition of these materials on agricultural soils vulnerable to runoff and leaching creates environmental and human health risks (Figure 2).

As stated in the nutrient overview, biochemical oxygen demand (bod) is another important parameter closely related to the issues of excess nutrient burden. It is a simple measure of the amount of oxygen required to aerobically digest compostable matter (mostly organics) in a given period of time, typically 5 days. Swine waste slurries exhibit a bod of 20,000 to 30,000 mg per liter (Webb and Archer, 1994), which is about 75 times and 500 times more concentrated, respectively, than raw sewage and treated effluent discharged by the average municipal wastewater treatment facility in the United States. The contribution of raw or marginally treated animal manure to surface waters has been implicated with depressed oxygen levels and fish kills, particularly during storm events. Many i fap facilities are susceptible to extreme weather events because they have been sited in flood plains, a practice that, albeit in accordance with existing regulations, is creating significant problems.

Figure 10. nutrient-rich freshwater (bottom of picture) is subject to eutrophication and algal blooms, a condition of excessive aquatic photosynthetic activity that frequently is followed by severe depletion of dissolved oxygen, thereby resulting in fish kills (Source: http://www.umanitoba.ca/institutes/fisheries/eutro.html)

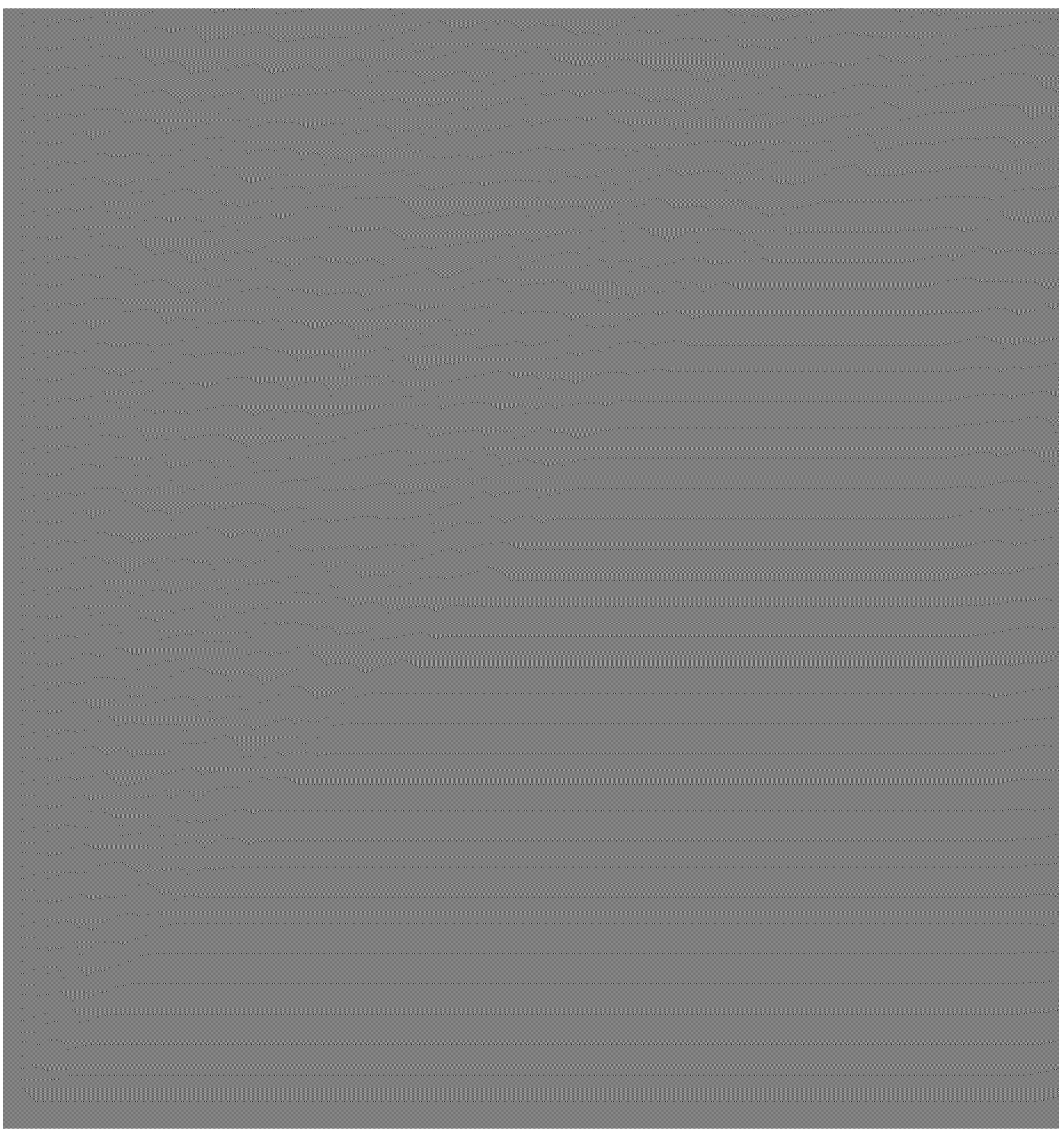

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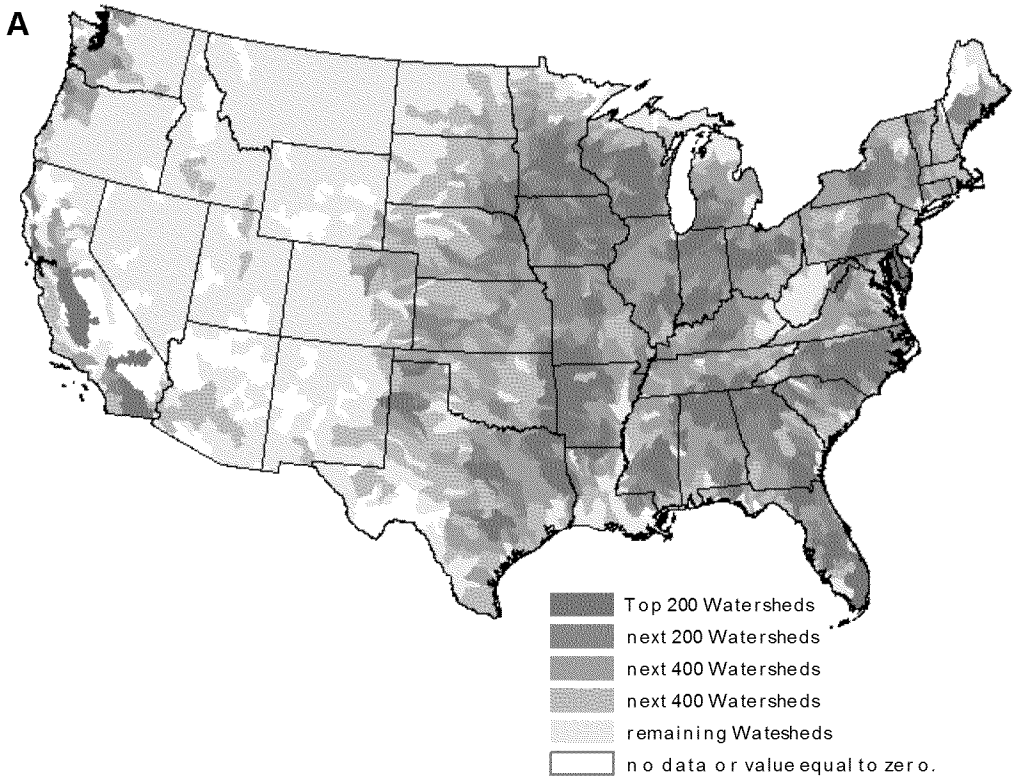
Figure 11. Map of the United States showing areas identified for the year 1997 as being vulnerable to runoff (A) and leaching (B) of manure nitrogen (Taken from Kellogg et al., 2000)



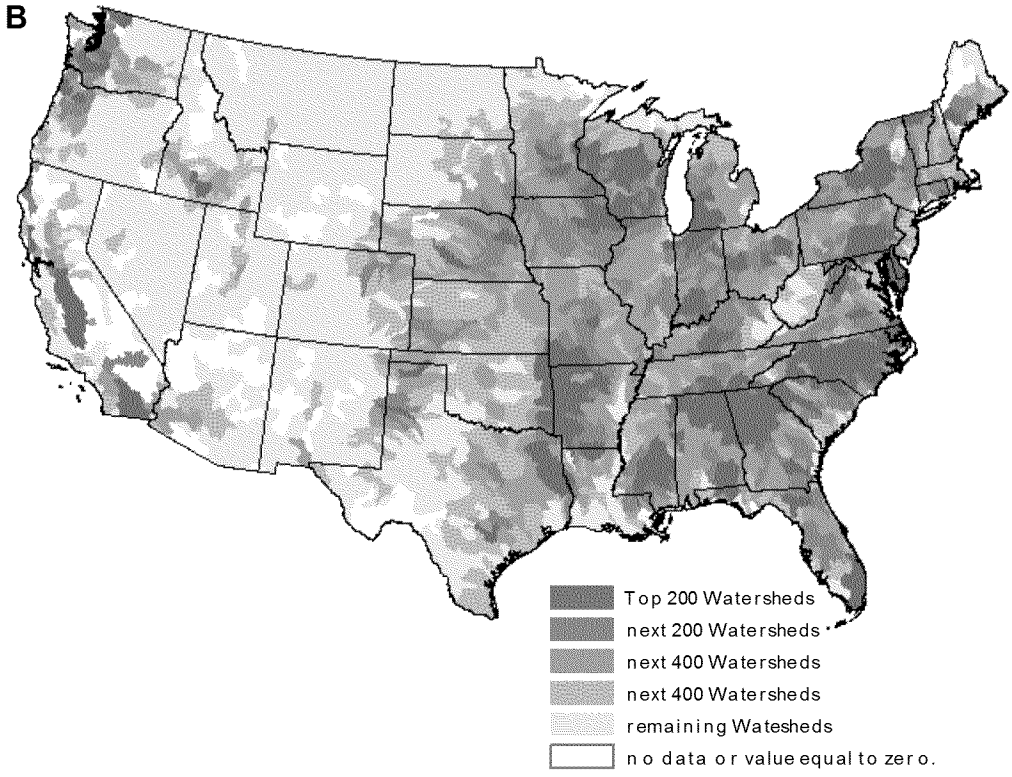


Table 1. Estimated manure and nutrient mass produced in the United States and excreted by food animals. Average amounts of manure and nutrients are reported as either kg per finished animal (kg/f.a.) or kg per day per animal (kg/d-a).

Major US Animal Welfare Standards (Source: Mench et al., 2008)

Animal type	number of animals in 2001	Avg. amount of nitrogen per finished animal (kg/f.a.)	Average amount of phosphorus per finished animal (kg/f.a.)	Total dry wt. of manure per finished animal (kg/f.a.)	Total nitrogen per animal type (Mg‡)	Total phosphorus per animal type (Mg‡)	Total dry wt. of manure per animal type (Mg‡)
Poultry							
Broilers	8,870,000,000	0.53	0.016	1.274	4,701,100	141,920	11,300,380
Turkeys	264,874,000						
Females	132,437,000	0.26	0.074	4.42	34,434	9,800	585,372
Males	132,437,000	0.55	0.16	9.36	72,840	21,190	1,239,610
layers	343,501,000	0.0016	0.00048	0.022	200,605	60,181	2,758,313
Beef–finishing cattle†	101,400,500	25	3.3	360	2,535,013	334,622	36,504,180
Swine							
Nursery pig (<40lbs)	19,988,000	0.41	0.06	4.8	8,195	1,359	95,942
Grow–finish	40,188,000	4.7	0.76	56	188,884	30,543	2,250,528
Dairy cows (lactating)	9,041,000	.45	0.078	8.84	1,484,984	257,397	29,171,691
Total	9,648,992,500				9,226,054	857,013	83,906,016

†Average US cattle herd between January 1, 2006 and July 1, 2006 ‡Mg or one metric ton equals 1,000 Kg

Endocrine disruptors.

An important but somewhat loosely defined group of chemicals found in animal waste are endocrine disrupting compounds or edcs. They can occur as natural constituents of animal excreta or represent drugs added to the feed of certain food animals, such as beef cattle. They are of both organic and inorganic nature and share the ability to interfere with hormonal signaling in animals and humans, thereby possessing the potential for causing adverse health effects in the exposed organism or its progeny (European Union, 2007). edcs can mimic the function of estrogenic or androgenic hormones, or they can interfere with hormone receptors to alter the outcome of internal signaling events. A major concern of edcs is that some may display activity at very low concentrations in the parts-per-trillion or nanogram-per-liter range (Porter et al., 1999). Examples of edcs in animal wastes include steroids and possibly arsenic in the form of arsenate (Liu et al., 2006). Endocrine-disrupting steroids include the natural estrogens 17alpha-estradiol, 17beta-estradiol, estrone, and estriol; all are common constituents of farm animal waste (Sarmah et al., 2006b). Figure 12 illustrates the transport of estrone from hog waste into groundwater.

Another indirect but important source of EDCs from ifap facilities is the use of pesticides for production of crops grown as animal feed. Pesticides that have been implicated with endocrine disruption are numerous and include alachlor and atrazine, the latter being applied extensively in the production of corn and other feed crops. Atrazine, which is regulated under the Safe Drinking Water Act (sdwa), has endocrine-disrupting activity in fish and amphibia (Freeman et al., 2005; Hayes et al., 2002, 2006; Thomas and Daughty, 2004). Environmental transformation products of atrazine and alachlor are also toxic and have been included on epa's current chemical Contaminant Candidate List (ccl) (usepa, 2005). Chemicals on the ccl are under consideration for regulation by the sdwa.

Water stress.

IFAP operations can create water stress in a number of ways. The production of animal protein requires 100 times more water than for vegetable protein (Pimentel and Pimentel, 1996). For example, it takes 3,500 liters of water to produce 1 kg of grain-fed broiler chicken (Pimentel et al., 1997). Therefore, siting of cafos in arid or semi-arid regions or in any area with water supply limitations is problematic due to the limited amount of water available and the substantial quantities needed for ifap. Eighty-seven percent of freshwater withdrawn in the United States from surface and groundwater resources is used in agriculture (Pimentel et al. 1997). Agriculture withdraws water from rivers and freshwater aquifers for irrigation of farmland used in feed crop production. This practice reduces the availability of water for riparian water users downstream and, in some locations, has resulted in unsustainable water use and

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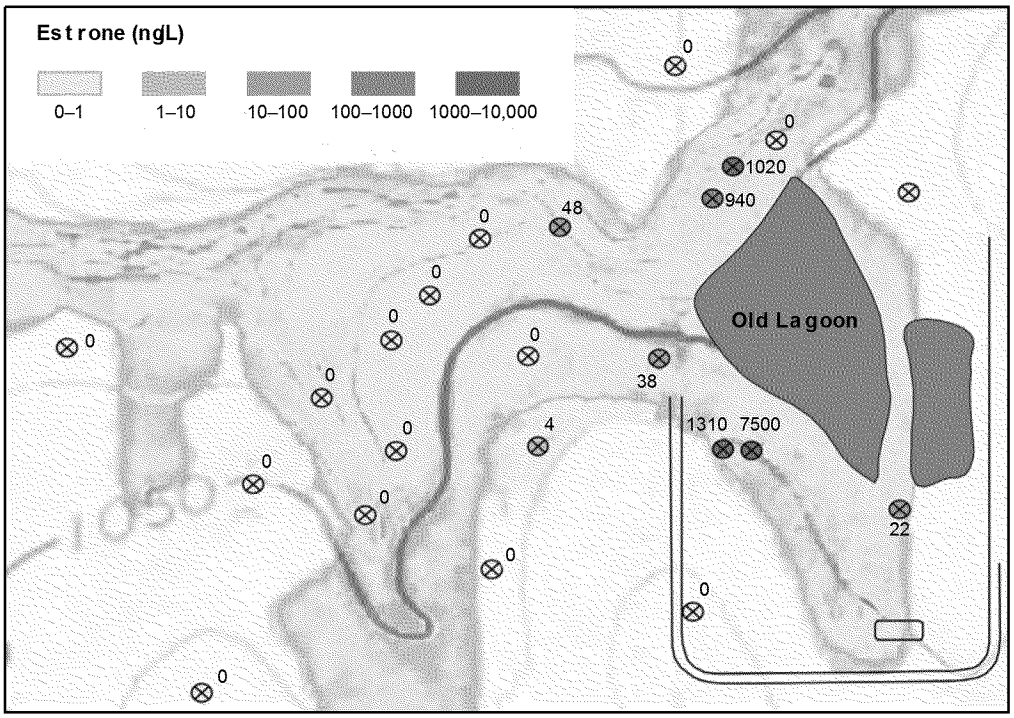
Figure 12. Map of a farm site, illustrating the movement of estrone, a natural hormone and potential endocrine-disrupting contaminant, from a hog waste lagoon into underlying groundwater (Source: Data by Hutchins et al., contained in a presentation by Mills, 2007)



a dramatic decline in the groundwater table in some locations. For example, the large Ogallala Aquifer, which underlies parts of Nebraska, Kansas, Colorado, Oklahoma, New Mexico, and Texas, is severely stressed by overwithdrawal and has been depleted by half, with water levels dropping at a rate of meter per year (Soule and Piper, 1992; McMichael, 1993) (Figure 13).

Pesticides and fertilizers applied to farmland also degrade the quality of surface and groundwater not used directly by farming operations. Animal husbandry requires additional water and is more demanding for ifap, where water consumption per animal can exceed that of traditional animal raising practices by up to a factor of five (Chapagain and Hoekstra, 2003).

Finally, pollution from animal waste disposal further reduces the availability of safe drinking water and impairs environmental and ecological health (Burkholder et al., 2007); epa's 2000 national water quality inventory identifies agriculture as the leading cause for water quality impairment in rivers, streams, lakes, and reservoirs (epa, 2002).

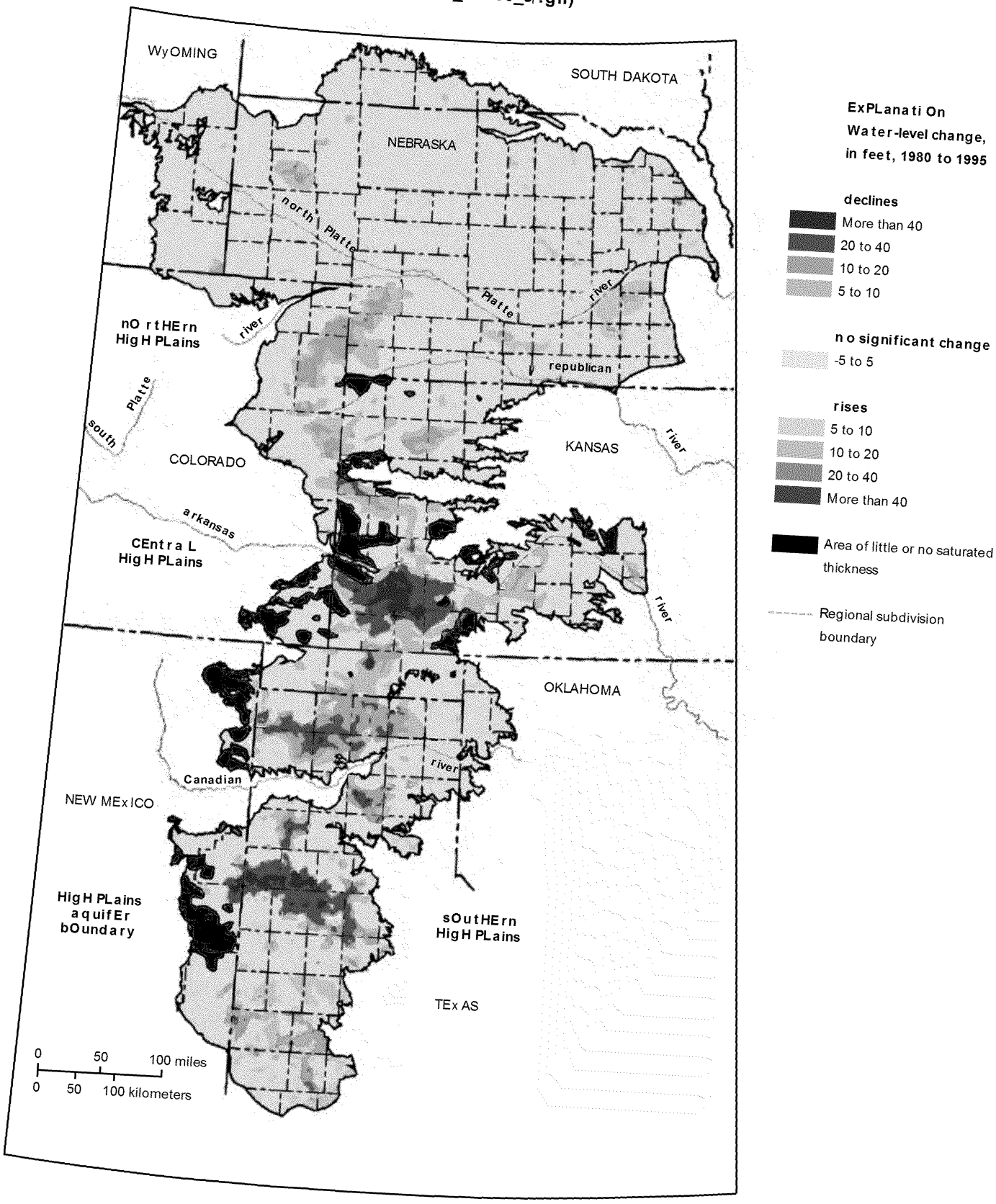
climate.

Greenhouse gas emissions from livestock operations are significant. At 18% on a global scale, they even exceed the emissions caused by the transportation sector (Steinfeld et al., 2006). Greenhouse gases, primarily methane, carbon dioxide, and nitrous oxide, are given off by the animals during the digestion process in the gut. Additional emissions result from degradation processes occurring in uncovered waste lagoons and anaerobic digesters. Deforestation for feed grain crops represents a major source of greenhouse gas emission. More detailed information on this issue is provided later in the paragraph on air emissions. Emission control solutions are now being examined by the epa along with potential opportunities for carbon credits and credit trading (Jensen, 2006). North Carolina has also recently passed legislation that sets strong performance standards for permits for new hog fos with substantial reductions required in emissions of ammonia, odors, and pathogens (General Assembly of North Carolina, 2007).

Antimicrobials.

Antibiotics and related antimicrobial compounds are widely administered for animal health and management and are used to treat diseases, promote growth, and improve feed efficiency (Sarmah et al., 2006a). Many antimicrobials used in the animal food-producing industry are provided in the feed throughout the lifetime. Much of this intake, between 80 and 90% of the initial dose, is being excreted. Therefore, antimicrobials applied in farming operations can and do find their way into the receiving environment, where they can be present either as the parent compound or as a metabolite (Sarmah et al., 2006a). Once in the environment, their efficacy and persistence depends on their physio-chemical properties, prevailing climatic conditions, and soil types and variety, as well as other environmental factors. In many instances, these

Figure 13. The ogallala aquifer, at 174,000 square miles representing one of the largest aquifers in the world, has experienced substantial drops in water levels in many regions as a result of unsustainable agricultural water use (Source: USGS image downloadable at: http://water.usgs.gov/gIS/browse/ofr99-197_wlc80_9f.gif)

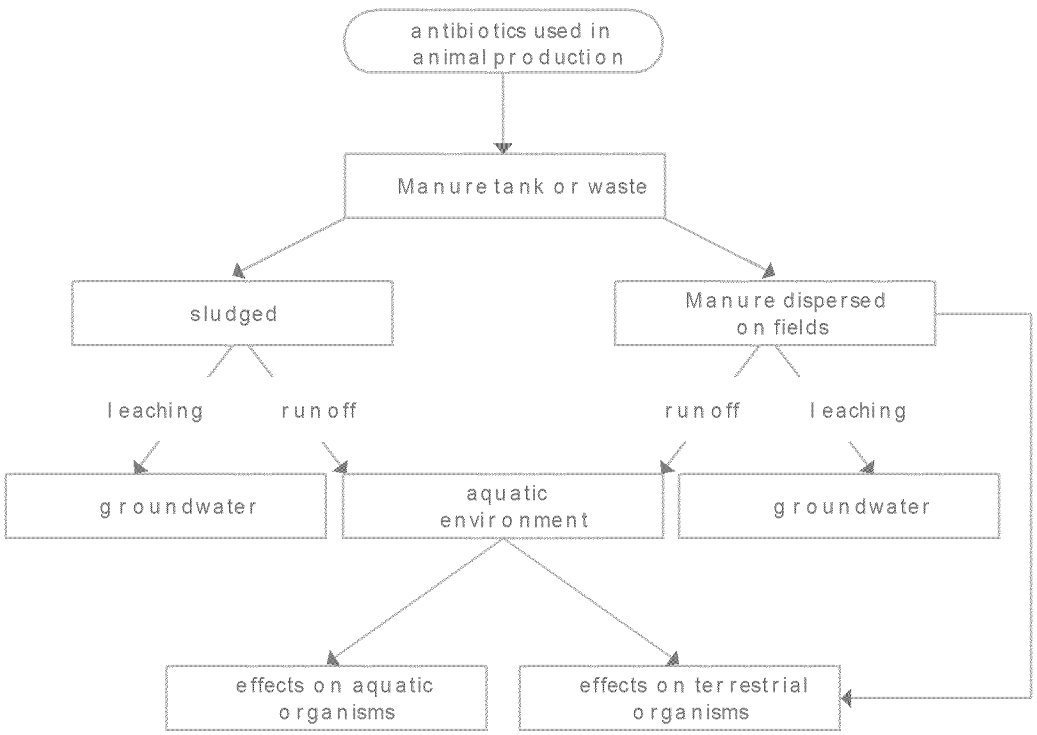


excreted antibiotics are not efficiently degraded, and the resulting residues can promote both maintenance and development of antibiotic-resistant microbial populations. Thus, cyclic application of manure on the same location may result in the continuous exposure of soil microbes to antibiotic residues, thereby fostering the potential development of drug-resistant microbial populations. Release of antimicrobials contained in manure also can have additional deleterious effects on aquatic life and human health, especially if the residues are transported by surface runoff or leaching through soil and reach nearby rivers or lakes (Sarmah et al., 2006a).

The Union of Concerned Scientists estimates that 10.3, 10.5, and 3.7 million pounds of antibiotics are used annually in the United States, respectively, in swine, poultry, and cattle production for non-therapeutic purposes such as promoting growth and improving feed efficiency (Mellon et al., 2001). These antibiotics are the same, or in the same family of, drugs that are used in human clinical medicine and include tetracycline, erythromycin, lincomycin, virginiamycin, and ampicillin, to name a few (fda, 2004). The Animal Health Institute (ahi) issued a press release in 2000 on antimicrobial production based on a 1998 survey of ahi members. Although the absence of detail in terms of methodology hampers interpretation, ahi reported 17.8 million pounds of antimicrobial production, apparently for all animal uses, therapeutic and non-therapeutic. Of the 17.8 million pounds, 14.7 million were attributed to therapeutic use and disease prevention, and 3.1 million pounds were attributed to growth promotion (Mellon et al., 2001).

Veterinary antibiotics can enter terrestrial and aquatic environments through spilled or excreted feed additives, overland flow runoff, unsaturated zone transport from fields to which agricultural waste has been applied, and leaky waste-storage structures (Figure 14) (Sarmah et al., 2006a).

Figure 14. Anticipated exposure pathways for veterinary antibiotics in the environment (Source: Sarmah et al., 2006a)



Bacteria in waste.

The practice of administering non-therapeutic levels of antimicrobials in swine feed selects for antibiotic resistance among commensal and pathogenic bacteria in swine (Aarestrup et al.,2000; Bager et al.,1997; Wegener,2003), resulting in high prevalence of resistant bacteria and resistance genes in swine waste (Chee-Sanford et al.,2001; Haack and Andrews,2000; Parveen et al.,2006; Koike et al.,2007). Monitoring results showed 1.6×10^7 (16,000,000) colony forming units (cfu)/ml of total tetracycline-resistant bacteria and 2.1×10^5 (210,000) cfu/ml of tetracycline-resistant *enterococci* in swine waste (Haack and Andrews,2000). Another study determined resistance to at least one antibiotic in 85% of *Escherichia coli* isolates recovered from a swine lagoon (Parveen et al.,2006). Other researchers detected up to eight known tetracycline resistance genes in total dna extracted from swine lagoon samples (Chee-Sanford et al.,2001). In the same study, a broad range of tetracycline resistance determinants were found in groundwater samples collected downstream of swine lagoons. One study also detected higher percentages of antibiotic-resistant *E. coli* in groundwater collected in the vicinity of large-scale swine facilities versus groundwater collected at reference sites (Anderson and Sobsey,2006). In another study, 80.6% of *E. coli* isolates collected from surface waters located near swine and other livestock facilities were found to be resistant to at least one antibiotic (Sayah et al.,2005).

The presence of swine-associated resistant bacteria in rural surface water and groundwater sources is important to human health because exposure to these sources could enable the transfer of resistant bacteria from swine to humans, thereby contributing to the spread and persistence of antibiotic resistance. However, there are few studies in the peer-reviewed literature regarding the presence of antibiotic-resistant bacteria in surface waters and groundwater from the vicinity of swine cafos (Chee-Sanford et al.,2001; Anderson and Sobsey,2006; Sayah et al.,2005; Sapkota et al.,2007a). Moreover, there are few data available comparing concentrations of fecal indicators in groundwater and surface waters impacted by swine cafos versus unaffected waters.

The widespread practice of using sub-therapeutic doses of antimicrobials to promote growth and improve feed efficiency has become one of the most controversial practices in cafo management. Recent studies have shown that antibiotic compounds administered to food-producing animals subsequently can be detected in liquid and solid manure of cafos. Upon application of these materials to fields, residues can persist in the soil and may be transported to surface and groundwater, as described in a white paper on antibiotic-resistant bacteria (Silbergeld et al.,2007).

Arsenic.

More than 8 billion broiler chickens are produced annually in the United States (usda-nass, 2004). For the purposes of promoting growth and improving feed efficiency, broilers are fed non-therapeutic levels of antimicrobials, including arsenic, which is usually in the form of the organoarsenical compound roxarsone (Chapman and Johnson,2002; National Research Council,1999). Roxarsone is added to poultry feed at concentrations ranging from 22.7 to 45.4 g/ton (Mellon et al.,2001). Approximately 70% of the US broiler industry utilizes roxarsone (Chapman and Johnson,2002) and researchers have calculated that 9×10^5 kg of roxarsone is excreted in poultry litter each year (Garbarino et al.,2003). Once roxarsone is excreted, it degrades into metabolites such as arsenite (As^{III}) and arsenate (As^{V}) (Bednar et al.,2003). Since these inorganic metabolites are classified as human carcinogens, researchers have begun to investigate the fate of arsenic in poultry meat, poultry litter, soil, and water (Chapman and Johnson,2002; Garbarino et al., 2003; Han et al.,2004; Lasky et al.,2004; Rutherford et al.,2003). Meanwhile, some large producers of animal products have announced a cessation of the use of arsenicals, a commendable but voluntary and therefore easily reversible action.

Microbial contaminants.

The production of food has always involved microbiological risks, which have been well recognized by farmers, government, industry, and other stakeholders. Microbiological issues in food safety are not unique to ifap. However, the scale and methods of ifap can both contribute to and prevent pathogen contamination of consumer food products. In particular, zoonotic (animal to human) transmission can be exacerbated by current ifap practices. All segments of livestock production potentially contribute to zoonotic disease, including manure handling practices, meat processing, transportation of livestock, and animal rendering (Gilchrist et al.,2007). The leading causes of bacterial illness listed above all have predominant zoonotic transmission routes. Viruses, including hepatitis E virus and nipah virus, have also been directly transmitted from animals to humans (Gilchrist et al.,2007; Leblanc et al.,2007; Feagins et al.,2007; Bellini et al.,2005). Because of the mass of animals produced in each herd or flock, a microbiological issue can affect thousands of animals. Large-scale production and high-throughput processing can increase the magnitude of pathogen contamination when control systems fail because of the large volume of production and processing; on the other hand, the concentration of production and processing in fewer large facilities can result in more consistent practice, more extensive regulatory coverage, and the use of more advanced control technologies. Newer technologies for pathogen

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control include food irradiation, extensively used in Europe and approved by the fda for certain meat and poultry products.

While food-borne pathogens are of general concern in food production, the risks of human exposure to *antibiotic resistant bacterial pathogens* is of particular relevance to ifap because of the use of antibiotics in feed for growth promotion, which is distinct from disease treatment and prevention. This use results in low doses of growth-promoting antibiotics (gpas) to each animal, thereby contributing to the selection and proliferation of antibiotic-resistant strains of bacteria, as does the administration of higher doses for disease prevention. Antibiotic resistance can be transferred among bacteria from non-pathogenic to pathogenic organisms, which increases the complexity and challenge of understanding and preventing this problem (Silbergeld et al.,2007). The potential for resistance reservoirs and interspecies transfer of resistance determinants is a high priority issue in the federal government's program to reduce the threat of antibiotic-resistant infections (Silbergeld et al.,2007).

Recent studies have found that the air inside large-scale swine feeding operations and downwind can also be contaminated with high levels of multidrug-resistant bacteria (Gibbs et al.,2004, 2006; Chapin et al.,2005). Airborne bacteria (*Staphylococcus aureus*, *Salmonella spp.*, fecal coliforms, and total coliforms) collected inside and downwind of two large-scale swine operations were found to be resistant to two or more antibiotics, including ampicillin, penicillin, erythromycin, tylosin, tetracycline, and/or oxytetracycline (Gibbs et al., 2004). Airborne bacteria collected upwind of the swine operations were significantly more susceptible to all of the antibiotics evaluated, suggesting that releases from the swine facilities were the likely sources of airborne multidrug-resistant bacteria recovered downwind (Gibbs et al.,2004). One study involved the collection of air samples via liquid impingers in a swine cafo and analysis for viable isolates of antibiotic-resistant bacteria (Chapin et al.,2005). *Enterococci*, *staphylococci*, and *streptococci* were analyzed for resistance to erythromycin, clindamycin, virginiamycin, tetracycline, and vancomycin. None of the isolates were resistant to vancomycin, which has never been approved for use in livestock in the United States. In contrast, 98% of these Gram-positive bacterial isolates were resistant to two or more, and 29% were resistant to all of the other four antibiotics that are commonly used as growth promoters in swine (Chapin et al.,2005). The high prevalence of antibiotic-resistant bacteria in swine facility air is relevant to swine growers and workers, as well as to other individuals who live or work close to these facilities. In addition, airborne antibiotic-resistant bacteria found within and around large-scale swine feeding operations could contribute to environmental reservoirs of antibiotic-resistance genes, participating in the genetic exchange of these genes among bacterial populations in animals, humans, and the environment. For this reason, understanding the prevalence of antibiotic-resistance genes in airborne bacteria emitted from large-scale swine operations is important in terms of both public health and bacterial ecology.

Air emissions.

Air emissions from livestock facilities are complex and of growing concern. Emissions from cafos and the spraying of animal waste on surrounding fields can result in environmental exposure to gases, organic dusts, bacteria, fungi, endotoxins, and residues of veterinary antibiotics (Radon et al.,2007; Mirabelli et al.,2006). In particular, large ifap facilities emit significant levels of several compounds, including endotoxins, particulate matter, ammonia, hydrogen sulfide, nitrous oxide, methane, and volatile organic compounds (rc, 2003). Exposures to these compounds are associated with a wide range of airway diseases, including mucous membrane irritation, bronchitis, asthma, asthma-like syndrome, and chronic obstructive pulmonary disease, as demonstrated in studies of farm workers (Heederik et al.,2007). Organic aerosols, combined with inflammatory agents and endotoxins, have been associated with the development of respiratory illness among swine workers (Donham,2000, Von Essen and Donham, 1999) and the community surrounding the cafo (Donham et al.,2007, Donham, 1995; Cole et al., 2000, Sapkota et al.,2007a). Table 2 lists potential respiratory diseases associated with swine production (Osterberg and Wallinga,2004).

A variety of analytical methods are available for measuring toxic gases, particulates, and odor (Bunton et al.,2007). Air pollution problems caused by emissions from cafos, such as hydrogen sulfide, particulate matter, and odor, are more generally local in scale because neighbors living near the cafo are affected. In contrast, pollutants such as oxides of nitrogen (NO_x) and ammonia are causing concerns on a regional scale. Nitrogen-containing pollutants can affect the quality of life in a multi-state area (Bunton et al., 2007). The quantitation of odor is more challenging because it represents a complex and variable mixture of free and particle-bound compounds. Ideally, odor characterization would involve analysis of each of the chemical constituents associated with a particular offensive odor. However, the correlation between human response and specific compounds identified by instrumental methods such as gas chromatography remains quite poor (Bunton et al.,2007).

Anaerobic lagoons are commonly used to store and treat manure from large-scale swine production facilities. Ultimate by-products of anaerobic digestion are methane (CH_4) and carbon dioxide (CO_2), with CH_4 making up between 60 and 70% of the biogas (DeSutter and Ham, 2005). Although some facilities have engineered systems to utilize the CH_4 for energy (Lusk,1998), most farms using anaerobic lagoons permit the CH_4 to escape into the atmosphere. Lagoons are commonly 2 to 6 m deep with surface areas between 0.5 and 5.0 ha or 1.2 to 12 acres (Ham and DeSutter,2000). The primary objective

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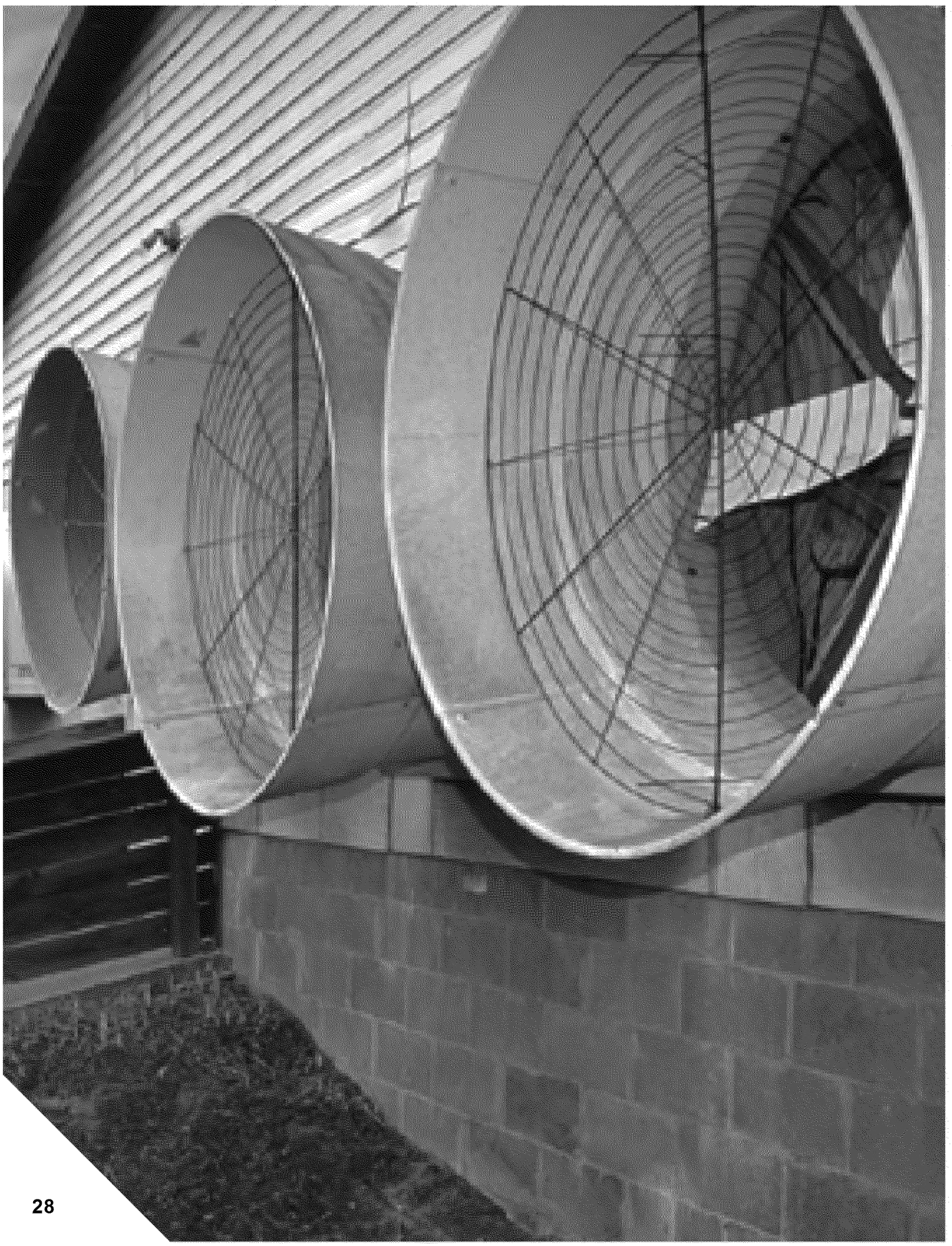

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Table 2. Respiratory Diseases Associated with Swine Production (Source: Adopted from Donham, 2000)

Upper airway disease	Sinusitis		
	Irritant rhinitis		
	Allergic rhinitis		
	Pharyngitis		
Interstitial disease	Alveolitis		
	Chronic interstitial infiltrate		
	Pulmonary edema		
Lower airway disease	Organic dust toxic syndrome		
	Occupational asthma	Non-allergic asthma,	hyperresponsive airway disease, or reactive airways disease syndrome
		Allergic asthma (IgE mediated)	
	Acute / subacute bronchitis		
	Chronic bronchitis		
	Chronic obstructive pulmonary disease		

of anaerobic digestion is to stabilize organic matter and, thus, reduce odors, pathogens, and the overall mass of organic solids; however, this process is often not adequately controlled in cafo lagoons (Parkin and Owen, 1986). The waste is converted to CH_4 and CO_2 by two groups of bacteria, methanogens and acetogens, and by a three-stage process called methanogenesis (Figure 15) (Lusk, 1998).

Greenhouse gases (GHG) produced from agriculture account for 6.8% of all US emissions (USepa, 2004), and global efforts are being directed to reduce the emissions of these gases from agricultural sources (DeSutter and Ham, 2005; Lusk, 1998). When the entire commodity chain is taken into consideration (including the production of feed grain), greenhouse gas emissions from livestock operations are significant.

Recently, a carbon budget was conducted by using a mass-balance approach as a way to quantify and trace various forms of carbon through agricultural systems (DeSutter and Ham, 2005). A total carbon balance analysis of animal production facilities is a mechanism that can provide valuable information about the quantity of ghg produced from the facility per mass of animal produced (i.e., emission factors). This information then can be extrapolated to regional sites with similar animal production practices and climates, and provide research-based information needed to model ghg emissions in the United States. Past analyses involved the measurement of biogas and CH_4 fluxes from an anaerobic-swine lagoon, and a mass balance of carbon from the entire swine production facility (DeSutter and Ham, 2005). The contribution of CH_4 from both lagoon and animal respiration to ghg inventories was about 2,132 mg of CO_2 equivalents, of which 85% was from lagoon emissions. Thus, even though swine are not considered large contributors of CH_4 through respiration or flatulence, there is a potential for substantial ghg contributions when animal waste is stored and treated in anaerobic lagoons (DeSutter and Ham, 2005).

Because of the complex environment created within cafos and the potential airborne releases into the surrounding environment and any proximal communities, research and development in hazard abatement is being actively pursued in order to explore opportunities for emission reduction. A number of different strategies have been examined, including air filtration to control emissions, replacing dry feed with liquid, and spraying vegetable oil inside the barn (Martens et al., 2001; Takai and Pedersen, 2000).

Figure 16 summarizes the major elements in agricultural air quality that need to be addressed by environmental managers and researchers. Accurate estimates of air emissions from cafos are needed to gauge their possible primary and secondary adverse impacts and the subsequent implementation of control measures (Aneja et al., 2006; Cole et al., 1997; Oenema et al., 2001).

Biodiversity.

Loss of biodiversity is known to be intimately linked to agricultural development. Policy reform can be an important driver of changes in agricultural land-use, but there is considerable spatial variation in response to policy and its potential impact on biodiversity (Mattison

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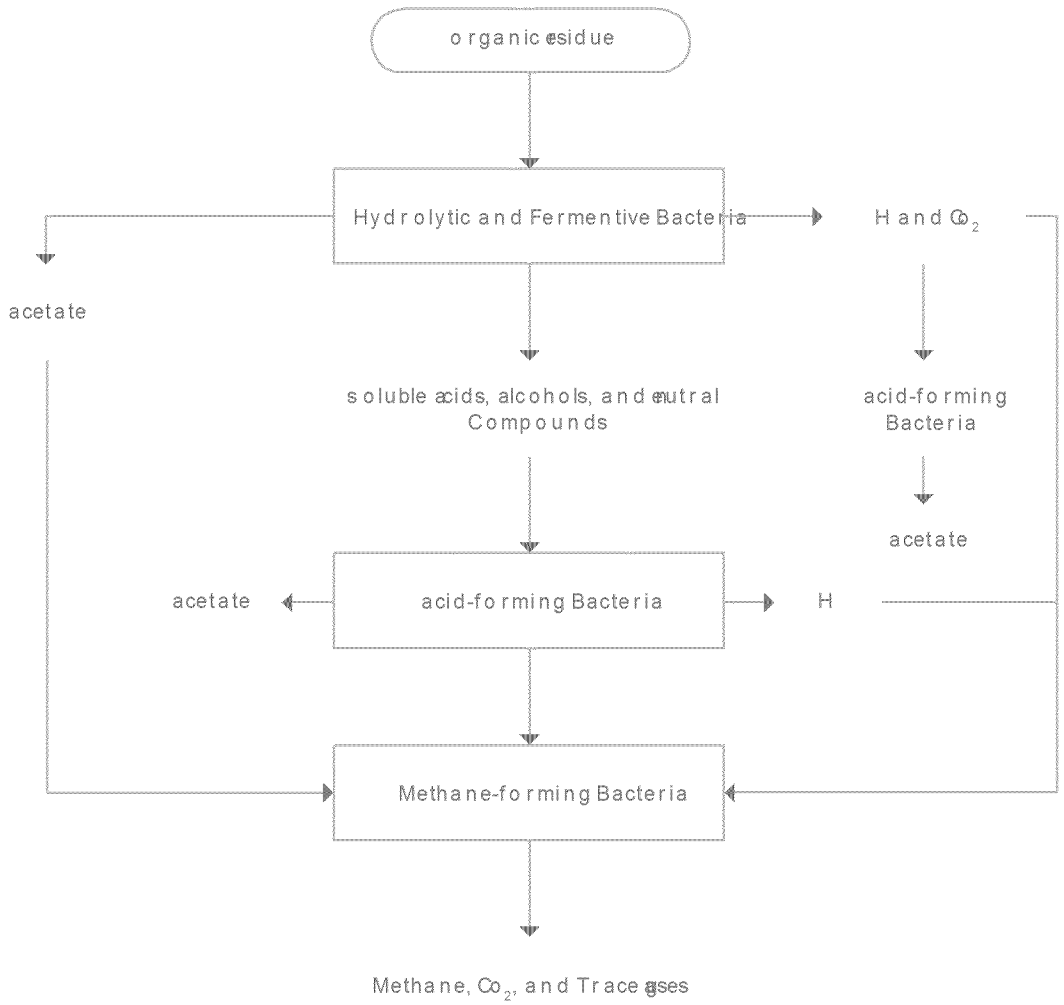
and Norris, 2005; Butler et al., 2007). Industrial agriculture limits biodiversity by favoring monoculture crop production, i.e., planting the same crop over a large land area, which diminishes diverse habitats and increases vulnerability to large-scale damage from pests. These monocultures can stretch over thousands of acres, leading to more chemical use, pesticide resistance in insects, and pollution of surface and groundwater by herbicides and insecticides (Horrigan et al. 2002). ifap facilities play an important role in the reduction of biodiversity as they contribute directly or indirectly to a loss of biodiversity via habitat change, climate change, invasive alien species, and pollution. Typically, biodiversity loss is caused by a combination of various processes of environmental degradation. This makes it hard to single out the specific contribution of ifap, particularly since the animal food product chain features many steps from which environmental impact may occur (Steinfeld et al., 2006).

Figure 1↑. The anaerobic digestion process (Source: Lusk 1998)



The role of the Western diet.

Environmental stress from chemical and biological agents is amplified by dietary choices of the American population. The standard Western diet, which is heavy on meat and light on vegetable intake, is taking a significant toll on the environment, public health, and the nation's economy. In the United States, meat is produced and consumed at unprecedented rates, with future increases projected (usda, 2005). Excess meat consumption has been linked to adverse human health outcomes, including obesity and an increased risk of mortality from cardiovascular disease (Kelemen et al., 2005). Thus, health impairments from a high-meat diet create a significant strain on the US economy, this representing only one of many unaccounted for externalities.

It has been suggested that the dietary model of the United States is environmentally unsustainable both nationally and globally (reviewed in Horrigan et al., 2002). Americans are among the top meat consumers in the world. Whereas animal protein constitutes only about one-third of dietary protein intake worldwide, Americans average more than two-thirds (un faostat, 2005). Excessive meat consumption takes a toll on human health and the environment. Contrary to farm animals raised by grazing on pastures, industrial farm animals are fed grains in confinement. Environmental consequences of this shift in agriculture already have been described. National natural resources, including water and farmland, are too limited to sustain the perpetual production of millions of tons of feed grain for the 10+ billion farm animals slaughtered each year in the United States (un faostat, 2005). In an average American household of four people, more than 120 chickens, four pigs and one cow are consumed annually (un faostat, 2005). US consumption rates for lean meat are above 100 kg per person per year and thus exceed the American Heart Association's recommended upper limit by more than 60% (calculated from data presented in Walker et al., 2005). Continuation of this unhealthy and environmentally unsustainable consumption is undesirable nationally and sets a poor example internationally.

But even if national meat production and consumption in future years were adjusted downward to match the recommendation of the American Heart Association (2005), current practices in fap would still continue to inflict significant harm to public health and the environment. This is due to the spatial concentration of animal wastes and public health threats of fap facilities. A single cafo routinely discharges to the environment untreated or minimally processed animal waste at a rate equivalent to the sewage flow of a small American city. Since waste excretion by pigs exceeds that of humans by a factor of four, a single cafo housing 5,000 pigs produces an environmental footprint similar to 20,000 residents of a city having no sewage treatment plant (Walker et al., 2005).

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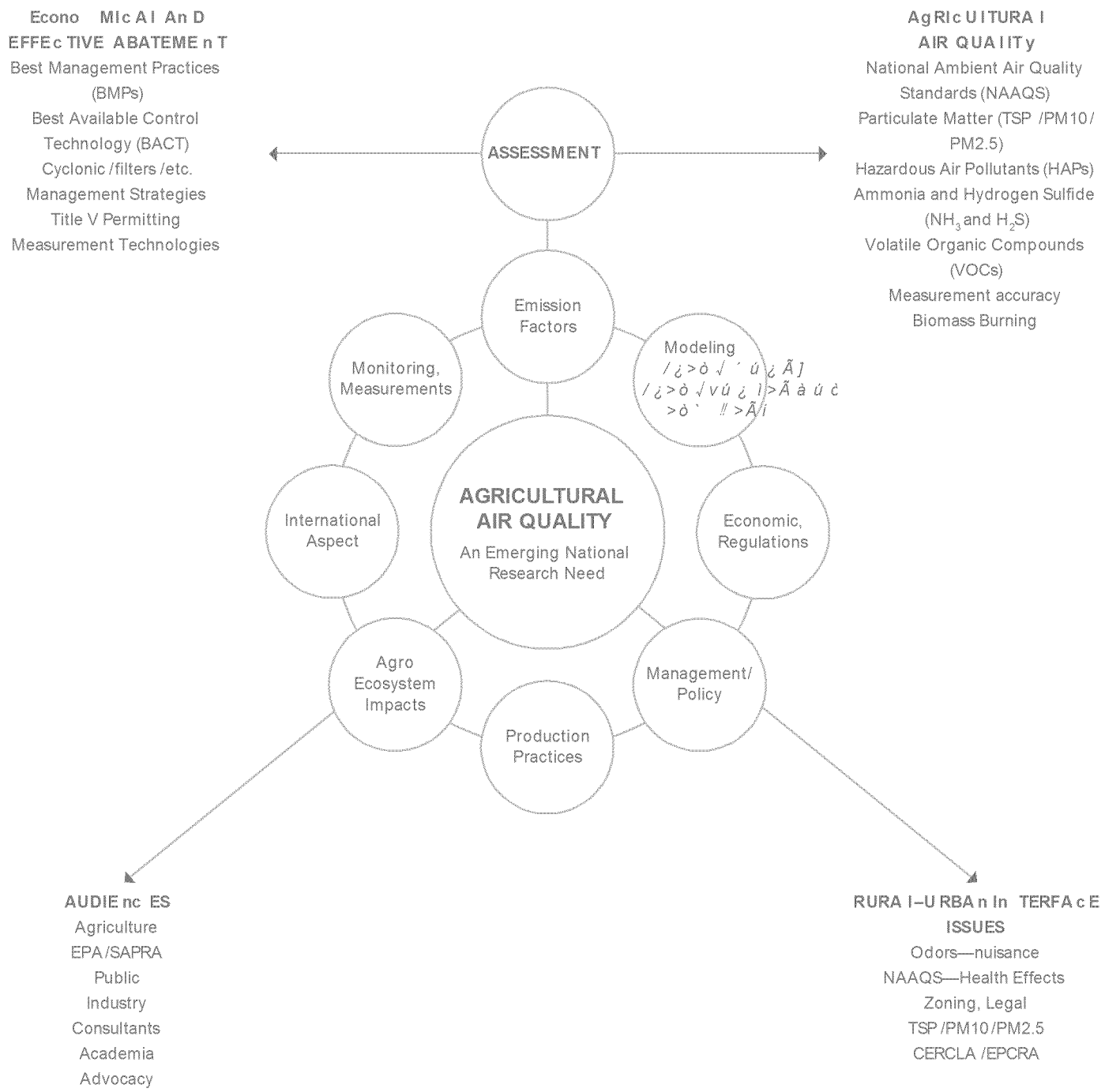
Figure 1↑. Interactions and assessment of agricultural air quality (Source: Aneja et al., 200↑)



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conclusions

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Current IFAP practices in the United States are unsustainable. Although some data gaps exist regarding the impact of IFAP on human health, a body of peer-reviewed literature clearly outlines an expanding array of deleterious environmental effects on local and regional water, air, and soil resources. Already, more than a million people are estimated to consume groundwater showing moderate or severe contamination with nitrogen-containing pollutants (Nolan and Hitt, 2006), caused primarily by heavy use of agricultural fertilizers and unsustainably high application rates of animal waste. In addition, existing federal environmental laws and most local zoning regulations allow for CAFOs to be operated and new ones to be built across the nation, in regions vulnerable to natural disasters such as flooding or arid ones lacking appropriate water resources. These practices run counter to environmental conservation, public health protection, and the goals of the Clean Air Act and the Clean Water Act.

In the face of this challenge, there is a need for more protective zoning as well as for better management practices, regulations, enforcement, and monitoring of IFAP facilities (Burkholder et al., 2007; Horrigan et al., 2002; Aneja et al., 2006; Donham et al., 2007; Sarmah et al., 2006b). The US Government Accountability Office recently concluded that as many as 60% of animal feeding operations in the United States are unregulated and that the few existing federal regulations are not enforced by state governments due to a lack of federal oversight (USGAO 2005). Right-to-farm legislation, originally designed to shield family farms from getting forced out of business by encroaching development, in some states prevents zoning laws that could serve as a mechanism to preclude siting of IFAP facilities in locations where detrimental effects to the environment and human populations are likely (Chapin et al., 1998; Hamilton, 1998).

To prevent further environmental degradation, greater accountability and land stewardship are needed, and due diligence should be placed on evaluating the environmental, financial, societal, and health effects of food animal production. To reach this goal, restrictive actions will be required, and further research should be conducted to define state-of-the-art animal husbandry practices that can adequately address environmental, health, and animal welfare criteria (Burkholder et al., 2007; Thorne, 2007; Sapkota et al., 2007b; Donham et al., 2007; Bunton et al., 2007).

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3↑

Figure 17. Spraying of manure on frozen soil, as shown here in yakima, WA, can trigger runoff of nutrients, pollutants, and pathogens during snow melt and heavy rain events (Photo source: Anonymous)

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References

Aarestrup FM, Kruse H, Tast E, Hammerum AM, Jensen LB (2000). Associations between the use of antimicrobial agents for growth promotion and the occurrence of resistance among *Enterococcus faecium* from broilers and pigs in Denmark, Finland, and Norway. *Microb Drug Resist* 6: 63-70.

American Heart Association (2005). An Eating Plan for Healthy Americans. Available at http://www.americanheart.org/presenter.jhtml?identifier_1088.

Accessed at check .

American Society of Agricultural Engineers (2005). Manure production and characteristics, St. Joseph, Michigan.

Anderson ME, Sobsey MD (2006). Detection and occurrence of antimicrobially resistant *E. coli* in groundwater on or near swine farms in eastern North Carolina. *Water Sci Technol* 54 (3): 211-8.

Aneja VP, Nelson DR, Roelle PA, Walker JT (2003). Agricultural ammonia emissions and ammonium concentrations associated with aerosols and precipitation in the southeast United States. *J Geophys Res* 108 (D4): ach 12-1, 12-11.

Aneja VP, Schlesinger WH, Niyogi D., Jennings G., Gilliam W., Knighton RE, Duke CS, Blunden J, and Krishnan S (2006). Emerging national research needs for agricultural air quality. eos , Volume 87: 25-29.

Bager F, Madsen M, Christensen J, Aarestrup FM (1997). Avoparcin used as a growth promoter is associated with the occurrence of vancomycin-resistant *Enterococcus faecium* on Danish poultry and pig farms. *Prev Vet Med* 31: 95-112.

Bednar AJ, Garbarino JR, Ferrer I, Rutherford DW, Wershaw RL, Ranville JF, and Wildeman TR (2003). Photodegradation of roxarsone in poultry litter leachates. *Sci Total Environ* 302: 237-245.

Bellini WJ, Harcourt BH, Bowden N, Rota PA (2005) Nipah virus: an emergent paramyxovirus causing severe encephalitis in humans. *J Neurovirol* 11: 481-487.

Bender A (1992). Meat and Meat Products in Human Nutrition in the Developing World. Food and Nutrition Paper No.53. Food and Agriculture Organization of the United Nations, Rome, Italy.

Bullers S (2005). Environmental stressors, perceived control, and health: the case of residents near large-scale hog farms in eastern North Carolina. *Hum Ecol* 33: 1-16.

Bunton B, O'Shaughnessy P, Fitzsimmons S, et al. (2007). Monitoring and modeling of emissions from concentrated animal feeding operations: overview of methods. *Environ Health Perspect* 115: 303-307.

Burkholder JM, Mallin MA, Glasgow HB, Larsen LM, McIver MR, Shank GC, et al. (1997). Impacts to a coastal river and estuary from rupture of a large swine waste holding lagoon. *J Environ Qual* 26: 1451-1466.

Burkholder J, Libra B, Weyer P, Heathcote S, Kolpin D, Thorne PS, and Wichman M (2007). Impacts of waste from concentrated animal feeding operations on water quality. *Environ Health Perspect* 115(2): 308-12.

Butler SJ, Vickery JA, and Norris K (2007). Farmland Biodiversity and the Footprint of Agriculture *Science* 315: 381-384.

Campagnolo ER, Johnson KR, Karpati A, Rubin CS, Kolpin DW, Meyer MT, Esteban JE, Currier RW, Smith K, Thu KM, McGeehin M (2002). Antimicrobial residues in animal waste and water resources proximal to large-scale swine and poultry feeding operations. *Sci Total Environ* 299: 89-95.

Chapagain AK and Hoekstra AY (2003). Virtual water flows between nations in relation to trade in livestock and livestock products. Value of Water Research Report Series No.13. unesco-ihe .

Chapin AC Boulind, and Moore A (1998). Controlling Odor and Gaseous Emission Problems from Industrial Swine Facilities: A Handbook for All Interested Parties. Yale Environmental Protection Clinic. Online at: http://www.yale.edu/envirocenter/clinic/swine/swine.html [accessed May 18, 2007].

Chapin A, Rule A, Gibson K, Buckley T, and Schwab K (2005). Airborne multi-drug resistant bacteria isolated from a concentrated swine feeding operation *Environ Health Perspect* 113: 137-142.

Chapman HD and Johnson ZB (2002) Use of antibiotics and roxarsone in broiler chickens in the usa : Analysis of the years 1995 to 2000. *Poultry Sci* 81: 356-364.

Chee-Sanford JC, Aminov RI, Krapac IJ, Garrigues-Jeanjean N, Mackie RI (2001). Occurrence and diversity of tetracycline resistance genes in lagoons and groundwater underlying two swine production facilities. *Appl Environ Microbiol* 67: 1494-1502.

ED_001369_00043779-00142

Cole CV, Duxbury J, Freney J, Heinemeyer O, Minami K, Mosier A, Paustian K, Rosenberg N, Sampson N, Sauerbeck D, and Zhao Q (1997). Global estimates of potential mitigation of greenhouse gas emissions by agriculture. *Nutr Cycling Agroecosyst* 49: 221-228.

Cole D, Todd L, Wing S. Concentrated swine feeding operations and public health: A review of occupational and community health effects. *Environmental Health Perspectives* (2000) 108: 685-699.

Cook M (1998). Reducing Water Pollution from Animal Feeding Operations. Testimony before Subcommittee on Forestry, Resource Conservation, and Research of the Committee on Agriculture, US House of Representatives, 13 May 1998. Available: http://www.epa.gov/ocirpage/hearings/testimony/105_1997_1998/051398.htm; accessed on April 14, 2007.

DeSutter TM, Ham JM (2005). Lagoon-biogas emissions and carbon balance estimates of a swine production facility. *J Environ Qual* 34: 198-206.

Donham KJ, Wing S, Osterberg D, JL Flora, Hodne C, KM Thu, and PS Thorne (2007). Community health and socioeconomic issues surrounding concentrated animal feeding operations. *Environ Health Perspect* 115(2): 317-20.

Donham KJ, Reynolds SJ, Whitten P, Merchant JA, Burmeister L, Popendorf WJ. Respiratory Dysfunction in Swine Production Facility Workers—Dose-Response Relationships of Environmental Exposures and Pulmonary-Function. *American Journal of Industrial Medicine* (1995) 27: 405-418.

Donham KJ (2000). The concentration of swine production—Effects on swine health, productivity, human health, and the environment. *Veterinary Clinics of North America-Food Animal Practice* 16: 559-597.

Dosman JA, JA Lawson, SP Kirychuk, Cormier Y, Biem J, and Koehncke N (2004). Occupational asthma in newly employed workers in intensive swine confinement facilities. *Eur Respir J* 24 (4): 698-702.

European Union. 2007. Endocrine Disruptors Website: How the European Union Uses the Precautionary Principle to Tackle Endocrine Disruptors. Online at http://ec.europa.eu/environment/endocrine/definitions/endodis_en.htm (Accessed May 19, 2007).

Feagins AR, Opriessnig T, Guenette DK, et al. (2007). Detection and characterization of infectious Hepatitis E virus from commercial pig livers sold in local grocery stores in the usa. *J Gen Virol* 88: 912-917.

Federal Registrar (2003). 40 cfr Parts 9, 122, 123, and 412 National Pollutant Discharge Elimination System Permit Regulation and Effluent Limitation Guidelines and Standards for Concentrated Animal Feeding Operations (cafos); Final Rule Federal Register/ Vol. 68, No. 29 / Wednesday, February 12, 2003 / Rules and Regulations http://www.epa.gov/npdes/regulations/cafo_fedrgstr.pdf

Food and Drug Administration 2004. fda approved animal drug products. Blacksburg, Virginia: Drug Information Laboratory, Virginia/Maryland Regional College of Veterinary Medicine.

Freeman JL, Beccue N, and Rayburn AL (2005). Differential metamorphosis alters the endocrine response in anuran larvae exposed to T3 and atrazine. *Aquat Toxicol* 75(3): 263-76.

Garbarino JR, Bednar AJ, Rutherford DW, Beyer RS, and Wershaw RL (2003). Environmental fate of roxarsone in poultry litter.i. Degradation of roxarsone during composting. *Environ. Sci. Tech.* 37: 1509-1514.

General Assembly of North Carolina (2007) session law 2007-523, senate bill 1465. http://www.ncga.state.nc.us/Sessions/2007/Bills/Senate/HTML/S1465v7.html

Gibbs SG, Green CF, Tarwater PM and Scarpino PV (2004) Airborne antibiotic resistant and nonresistant bacteria and fungi recovered from two swine herd confined animal feeding operations. *J Occup Environ Hyg* 1: 699-706.

Gibbs SG, Green CF, Tarwater PM, Mota LC, Mena KD and Scarpino VD (2006). Isolation of antibiotic resistant bacteria from the air plume downwind of a swine confined or concentrated animal feeding operation. *Environ Health Perspect* 114 (7): 1032-1037.

Gilchrist MJ, Greko C, Wallinga DB et al. (2007) The potential role of concentrated animal feeding operations in infectious disease epidemics and antibiotic resistance. *Environ Health Perspect* 115: 313-316.

Goldschmidt, WR (1978). As You Sow: Three Studies in the Social Consequence of Agribusiness. Rowman & Littlefield Publishers, Inc. isbn -10: 0916672115.

Goolsby DA and WA Battaglin (2000). Nitrogen in the Mississippi Basin-Estimating Sources and Predicting Flux to the Gulf of Mexico. Online at: http://ks.water.usgs.gov/Kansas/pubs/fact-sheets/fs.135-00.html#HDR3

Graham JP, Boland JJ, Silbergeld E (2007) Growth promoting antibiotics in food animal production: an economic analysis. *Public Health Rep* 122 (1): 79-87.

ED_001369_00043779-00143

Haack BJ, Andrews RE Jr (2000). Isolation of Tn916-like conjugal elements from swine lot effluent. *Can J Microbiol* 46: 542-549.

Ham, JM, and TM DeSutter (2000). Toward site-specific design standards for animal-waste lagoons: Protecting ground water quality. *J Environ Qual* 29: 1721-1732.

Hamilton ND (1998). Right-to-farm laws reconsidered: ten reasons why legislative efforts to resolve agricultural nuisances may be ineffective. *Drake J Agric Law* 3(1): 104.

Han FX, Kingery WL, Selim HM, Gerard PD, Cox MS, and Oldham JL (2004). Arsenic solubility and distribution in poultry waste and long-term amended soil. *Sci Total Environ* 320: 51-61.

Hayes TB, Haston K, Tsui M, Hoang A, Haeffele C, Vonk A. Herbicides: feminization of male frogs in the wild. *Nature* (2002) Oct 31; 419 (6910): 895-6.

Hayes TB, Stuart AA, Mendoza M, Collins A, Noriega N, Vonk A, Johnston G, Liu R, Kpodzo D. Characterization of atrazine-induced gonadal malformations in African clawed frogs (Xenopus laevis) and comparisons with effects of an androgen antagonist (cyproterone acetate) and exogenous estrogen (17beta-estradiol): Support for the demasculinization/feminization hypothesis. *Environ Health Perspect* (2006) 114 *Suppl* 1: 134-41.

Heederik D, Sigsgaard T, Thorne P et al (2007). Health effects of airborne exposures from concentrated animal feeding operations. *Environ Health Perspect* 115: 298-302.

Hirsch RM, Hamilton PA, and Timothy L. Miller (2006). The Increasing Need for Science to Inform Policy—More than 30 Years after Passage of the Clean Water Act. *Water Environ Res* 78 (9): 899-900.

Horrigan L, Lawrence RS, and Walker P (2002). How Sustainable Agriculture Can Address the Environmental and Human Health Harms of Industrial Agriculture. *Environ Health Perspect* 110 (5): 45-456.

Hutchins SR, White MV, Hudson FM, Fine DD (2007. Analysis of lagoon samples from different concentrated animal feeding operations for estrogens and estrogen conjugates. *Environ Sci Technol* 41: 738-44.

Jensen J (2006). Carbon Credits: New Opportunities for US Livestock Industry. Online at: http://www.epa.gov/agstar/pdf/conf06/jensen.pdf. (Accessed May, 2007).

Jongbloed AW, Lenis NP (1998). Environmental concerns about animal manure. *J Anim Sci* 76: 2641-8.

Kelemen LE, LH Kushi DR. Jacobs Jr., and Cerhan JR. Associations of dietary protein with disease and mortality in a prospective study of postmenopausal women. *American Journal of Epidemiology* (2005); 161(3): 239-49.

Kellogg RL (2000). Potential Priority Watersheds for Protection of Water Quality from Contamination by Manure Nutrients. A paper presented at the Animal Residuals Management Conference 2000, November 12-14, Kansas City, Missouri. Online at: http://www.nrcs.usda.gov/TECHNICAL /land/pubs/wshedpap_w.pdf

Kellogg RL, Lander CH, Moffitt DC and Gollehon N (2000). Manure Nutrients Relative to the Capacity of Cropland and Pastureland to Assimilate Nutrients: Spatial and Temporal Trends for the United States. United States Department of Agriculture, Natural Resources Conservation Service. Online at: http://www.nrcs.usda.gov/technical/land/pubs/manntr.html

Kiely T, Donaldson D, and Grube A (2004). Pesticides Industry Sales and Usage, 2000 and 2001 Market Estimates. Biological and Economic Analysis Division

Krapac IG, Dey WS, Roy WR, Smyth CA, Storment E, Sargent SL, Steele JD (2002). Impacts of swine manure pits on groundwater quality. *Environ Pollut* 120: 475-92.

Lasky T, Sun W, Kadry A, and Hoffman MK (2004) Mean total arsenic concentrations in chicken 1989-2000 and estimated exposures for consumers of chicken. *Environ Health Perspect* 112: 18-21.

Koike S, Krapac IG, Oliver HD, Yannarell AC, Chee-Sanford JC, Aminov RI, Mackie RI (2007). Monitoring and source tracking of tetracycline resistance genes in lagoons and groundwater adjacent to swine production facilities over a 3-year period. *Appl Environ. Microbiol* 73 (15): 4813-23.

Leblanc D, Ward P, Gagne MJ, et al (2007). Presence of hepatitis E virus in a naturally infected swine herd from nursery to slaughter. *Int J Food Microbiol* 2007 Mar 30; [Epub ahead of print].

Liu FJ, Wang JS, and Theodorakis CW (2006). Thyrotoxicity of sodium arsenate, sodium perchlorate, and their mixture in zebrafish Danio rerio. *Environ Sci Technol* 40 (10): 3429-36.

Lusk P (1998). Methane Recovery from Animal Manures: A Current Opportunities Casebook 3rd Edition. nrel /SR-25145. Golden, Colorado: National Renewable Energy Laboratory. Work performed by Resource Development Associates, Washington, DC.

Mallin MA (2000). Impacts of industrial-scale swine and poultry production on rivers and estuaries. *Am Sci* 88: 26-37.

Mallin MA, Burkholder JM, Shank GC, McIver MR, Glasgow, HB Springer J, et al. (1997). Comparative impacts of effluent from poultry and swine waste holding lagoon spills on receiving rivers and tidal creeks. *J Environ Qual* 26: 1622-1631.

Martens W, Martinec M, Zapirain R, Stark M, Hartung E, Palmgren U. Reduction potential of microbial, odour and ammonia emissions from a pig facility by biofilters. *International Journal of Hygiene and Environmental Health* (2001) 203: 335-345.

Mattison EH, Norris K (2005) Bridging the gaps between agricultural policy, land-use and biodiversity. *Trends Ecol Evol* 20: 610-616.

McMichael AJ (1993). *Planetary Overload: Global Environmental Change and the Health of the Human Species*. Cambridge, England, Cambridge University Press.

Mead PS, Slutsker L, Dietz V, McCaig LF, Bresee JS, Shapiro C, Griffin PM, Tauxe RV (1999). Food-related illness and death in the United States. *Emerg Infect Dis* 5: 607-625.

Mellon M, Benbrook C, Benbrook KL (2001). Hogging It: Estimates of Antimicrobial Abuse in Livestock. Cambridge, Massachussetts: Union of Concerned Scientists Publications. Available: http://www.ucsusa.org/food_and_environment/antibiotics_and_food/margaret-mellon-on-hogging-it.html [accessed 15 September 2006].

Mills M (2007). Endocrine Disrupting Chemicals and other Fluorochemicals in Wastewater Treatment Technologies. New England Interstate Water Pollution Control Commission (neiwpcc) Northeast Water Science Forum Pharmaceuticals and Personal Care Products: State of the Science Conference, Portland, Maine, August 8–9, 2007. http://www.neiwpcc.org/ppcpconference/ppcp-docs/MarcMills.pdf. (Slide 27). Accessed 15 December 2007.

Mitloehner FM, Schenker MB (2007) Environmental exposure and health effects from concentrated animal feeding operations. *Epidemiology* 18: 309-311.

Mirabelli M, Wing S, Marshall SW et al. (2006). Race, poverty, and potential exposure of middle-school students to air emissions from confined swine feeding operations. *Environ Health Perspect* 114: 591-596.

MMWR (2006). Surveillance for Foodborne-Disease Outbreaks—United States, 1998/2002. November 10, 2006/Vol. 55/No. SS/10.

National Research Council (2003) Air Emissions from Animal Feeding Operations: Current Knowledge, Future Needs. Washington DC: Committee on Animal Nutrition, National Research Council. National Academy Press.

National Research Council (1999). The use of drugs in food animals: Benefits and risks. National Academy of Sciences, Washington, DC.

Nolan BT, Hitt KJ (2006). Vulnerability of shallow groundwater and drinking-water wells to nitrate in the United States. *Environ Sci Technol* 40: 7834-40.

Oenema O, Velthof G, and Kuikman P (2001). Technical and policy aspects of strategies to decrease greenhouse gas emissions from agriculture. *Nutr Cycling Agroecosyst* 60: 301-315.

Office of Pesticide Programs, Office of Prevention, Pesticides, and Toxic Substances, US Environmental Protection Agency, Washington, DC. Accessible online at: http://www.epa.gov/oppbead1/pestsales/01pestsales/market_estimates2001.pdf; accessed on April 14, 2007.

Osterberg D, and Wallinga D (2004). Addressing Externalities From Swine Production to Reduce Public Health and Environmental Impacts. *American Journal of Public Health* 94: 1703-1708.

Park S, Egbert SL (2005). Assessment of soil erodibility indices for conservation reserve program lands in southwestern Kansas using satellite imagery and gis techniques. *Environ Manage* 36 (6): 886-98.

Parkin GF, and Owen WF (1986). Fundamentals of anaerobic digestion of wastewater sludges. *J Environ Eng* 112: 867-920.

Parveen S, Lukasik J, Scott TM, Tamplin ML, Portier KM, Sheperd S, et al. (2006). Geographical variation in antibiotic resistance profiles of *Escherichia coli* isolated from swine, poultry, beef and dairy cattle farm water retention ponds in Florida. *J Appl Microbiol* 100 50-57.

Paudel KP and McIntosh CS (2005) Country report: Broiler industry and broiler litter-related problems in the southeastern United States. *Waste Management* 25: 1083-1088.

Pimentel D, Houser J, Preiss E, White O, Fang H, Mesnick L, Barsky T, Tariche S, Schreck J, and Alpert S (1997). Water Resources: Agriculture, the Environment, and Society. *BioScience* 47 (2): 97-106.

Pimentel D and Pimentel M (1996). Food, energy and society. Niwot, Colorado. University Press of Colorado.

ED_001369_00043779-00145

Porter WP, Jaeger J and Carlson I (Part 1) (Part 2) Endocrine, immune and behavioral effects of aldicarb (carbamate), atrazine (triazine) and nitrate (fertilizer) mixtures at ground water concentrations. *Toxicology and Industrial Health* (1999) 15(1-2): 133-150.

Radon K, Schulze A, Ehrenstein V et al. (2007) Environmental exposure to confined animal feeding operations and respiratory health of neighboring residents. *Epidemiology* 18: 300-308.

Rutherford DW, Bednar AJ, Garbarino JR, Needham R, Staver KW, and Wershaw RL (2003). Environmental fate of roxarsone in poultry litter. Part 2. Mobility of arsenic in soils amended with poultry litter. *Environ Sci Tech* 37: 1515-1520.

Sapkota AR, Curriero FC, Gibson KE, and Schwab KJ (2007a). Antibiotic-resistant *enterococci* and fecal indicators in surface water and groundwater impacted by a concentrated Swine feeding operation. *Environ Health Perspect* 115(7): 1040-5.

Sapkota AR, Lefferts LY, McKenzie S, and Walker P (2007b). What do we feed to food-production animals? A review of animal feed ingredients and their potential impacts on human health. *Environ Health Perspect* 115(5): 663-70.

Sarmah AK, Meyer MT, Boxall AB (2006a). A global perspective on the use, sales, exposure pathways, occurrence, fate and effects of veterinary antibiotics (vas) in the environment. *Chemosphere* 65(5): 725-59.

Sarmah AK, Northcott GL, Leusch FD, and Tremblay, LA (2006b). A survey of endocrine disrupting chemicals (edcs) in municipal sewage and animal waste effluents in the Waikato region of New Zealand. *Sci Total Environ* 355(1-3): 135-44.

Sayah RS, Kaneene JB, Johnson Y, and Miller R (2005). Patterns of antimicrobial resistance observed in *Escherichia coli* isolates obtained from domestic- and wild-animal fecal samples, human septage, and surface water. *Appl Environ Microbiol* 71: 1394-1404.

Schiffman SS, Miller EA, Suggs MS, Graham BG (1995). The effect of environmental odors emanating from commercial swine operations on the mood of nearby residents. *Brain Res Bull* 37: 369-375.

Schindler DW (1990). Experimental Perturbations of Whole Lakes as Tests of Hypotheses Concerning Ecosystem Structure and Function. *Oikos* 57 (1): 25-41.

Schulze RH (1993). The 20-Year History of the Evolution of Air-Pollution Control Legislation in the usa. *Atmospheric Environment Part B-Urban Atmosphere* 27(1): 15-22.

Silbergeld EK, Graham J, Price LB (2007). Industrial Food Animal Production, Antimcirobial Resistance, and Human Health. White Paper solicited by the National Commission on Industrial Farm Animal Production.

Soule JD, and Piper D (1992). Farming in Nature's Image: *An Ecological Approach to Agriculture* Washington, DC, Island Press.

Steinfeld H, Gerber P, Wassenaar T, Castel V, Rosales M, de Haan C (2006). Livestock's Long Shadow _ Environmental Issues and Options 390 pp. Food and Agriculture Organization of the United Nations, Rome, Italy.

Takai H, Pedersen S, Johnsen JO, Metz JHM, Koerkamp PWGG, Uenk GH, Phillips VR, Holden MR, Sneath RW, Short JL, White RP, Hartung J, Seedorf J, Schroder M, Linkert KH, Wathes CM. Concentrations and emissions of airborne dust in livestock buildings in Northern Europe. *J of Agric Eng Research* (1998) 70: 59-77.

Takai H, Pedersen S. A comparison study of different dust control methods in pig buildings. *Applied Engineering in Agriculture* (2000) 16: 269-277.

Thomas P, and Doughty K (2004) Disruption of rapid, nongenomic steroid actions by environmental chemicals: interference with progestin stimulation of sperm motility in Atlantic croaker. *Environ Sci Technol* 38(23): 6328-32.

Thorne PS (2007). Environmental health impacts of concentrated animal feeding operations: anticipating hazards searching for solutions. *Environ Health Perspect* 115: 296-7.

Thu K, (Editor) (1996). Understanding the Impacts of Large-Scale Swine Production: Proceedings from an Interdisciplinary Scientific Workshop. Iowa City, Iowa: The University of Iowa.

Thu K, Donham K, Ziegenhorn R, Reynolds S, PS Thorne, Subramanian P et al. (1997). A control study of the physical and mental health of residents living near a large-scale swine operation. *J Agric Saf Health* 3: 13-26.

Thurston-Enriquez JA, Gilley JE, Eghball B (2005). Microbial quality of runoff following land application of cattle manure and swine slurry. *J Water Health* 3: 157-71.

United Nations Food and Agriculture Organization. faostat

Database [online], (2005) Data. Query at http://faostat.fao.org/Core Consumption Data. Accessed April 4, 2007.

University of Manitoba (2007). Experimental Lakes Area homepage: Eutrophication. http://www.umanitoba.ca/institutes/fisheries/eutro.html

USDA (United States Department of Agriculture) (2005. usda Agricultural Baseline

Projections to 2014. Baseline Report oce-2005-1, 116 pp. Available at http://www.usda.gov/oce/waob.

USDA, (2006a). Farms, Land in Farms, and Livestock Operations: 2005 Summary. Washington, DC: US Department of Agriculture. http://usda.mannlib.cornell.edu/nass/FarmLandIn/2000s/2005/FarmLandIn-01-31-2005.pdf. Accessed 15 December, 2007.

USDA, (2006b). Meat Animals Production, Disposition, and Income: 2005 Summary. Washington, DC: US Department of Agriculture. http://usda.mannlib.cornell.edu/usda/nass/MeatAnimPr//2000s/2006/MeatAnimPr-04-27-2006.pdf. Accessed 15 December, 2007.

USDA (2007). Rise in meat production. http://usda.mannlib.cornell.edu/MannUsda/viewStaticPage.do?url=http://usda.mannlib.cornell.edu/usda/ers/94005/../2007/index.html

USDA Economic Research Service (ers), 2007. Numbers calculated from Table 1 posted online at: http://www.ers.usda.gov/Data/FertilizerUse/Tables/Table1.xls; accessed April 14, 2007.

USDA-ers, undated. The Role of Changing Vertical Coordination in the Broiler and Pork Industries. http://www.ers.usda.gov/publications/aer777/aer777b.pdf. Accessed 15 December 2007.

USDA National Agricultural Statistics Service (nass), 2004. Poultry--production and value 2003 Summary. Pou 3-1. [Online] http://usda.mannlib.cornell.edu/reports/nassr/poultry/pbh-bbp/plva0404.pdf Accessed 17 August, 2005.

USDA-nass, undated. Trends in US Agriculture. http://www.usda.gov/nass/pubs/trends/broiler.htm and http://www.usda.gov/nass/pubs/trends/livestockproduction.csv

USDA Agricultural Research Service (ars), 2002. National Programs Manure and Byproduct Utilization,

National Program Annual Report: FY2001. http://www.ars.usda.gov/research/programs/programs.htm?np_code=206&docid=1076

USDA-ars, 2005. Available: http://www.nass.usda.gov/index.asp [accessed 2007].

United States Environmental Protection Agency (usepa) (2002). 2000 National water quality inventory. Office of Water, Washington, DC, Chapter 2, p 14 and 3, p. 22. Accessible at: http://www.epa.gov/305b/2000report.

USEPA (2004). Inventory of the US greenhouse gas emissions and sinks: 1990-2002 usepa, Washington, DC.

USEPA Compliance Assistance webpage. http://www.epa.gov/oecaerth/assistance/bystatute/cwa/afo.html. Accessed 15 December, 2007.

USEPA (2005). Fact sheet: The drinking water contaminant candidate list the source of priority contaminants for the drinking water program. Office of Water. epa 815-F-05-001.

USEPA (2007). Draft Report on the Environment: Water and Watersheds. http://www.epa.gov/indicate/roe/html/roeWaterW2.htm

United States Geological Survey (usgs) (1997). Digital data set of water-level changes in the High Plains aquifer in parts of Colorado, Kansas, Nebraska, New Mexico, Oklahoma, South Dakota, Texas, and Wyoming, 1980 to 1995. http://water.usgs.gov/GIS/metadata/usgswrd/XML/ofr99-197_wlc80_95.xml

US Government Accountability Office (USgoa) (2005). Livestock Market Reporting: usda Has Taken Some Steps to Ensure Quality, but Additional Efforts Are Needed. gao-06-202, 9 December 2005. Available at: http://www.gao.gov/new.items/d06202.pdf. Accessed 17 August, 2007].

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

Walker P, Rhubart-Berg P, McKenzie S, Kelling K and Lawrence RS (2005). Public health implications of meat production and consumption. *Public Health Nutr* 8(4): 348-356.

Ward MH, deKok TM, Levallois P, Brender J, Gulis G, Nolan BT, et al. (2005). Workgroup report: drinking-water nitrate and health recent findings and research needs. *Environ Health Perspect* 113: 1607-1614.

Webb J, Archer JR (1994). Pollution of soils and watercourses by wastes from livestock production systems. In: *Pollution in Livestock Production Systems* (Dewi IA, Axford RFE, Marai IFM, Omed HM, eds). Oxfordshire, uk, cabi Publishing, 189-204.

Wegener HC (2003). Antibiotics in animal feed and their role in resistance development. *Curr Opin Microbiol* 6: 439-445.

ED_001369_00043779-00147

WHO (World Health Organization) (2003). Diet, Nutrition, and the Prevention of Chronic Disease. who Technical Report Series No.913, Geneva.

World Resources Institute (2000) World Resources 2000-2001: People and Ecosystems—The Fraying Web of Life. Washington, DC.

Wright W, Flora CB, Kremer KS, Goudy W, Hinrichs CP, Lasley et al. (2001). Social and Community Impacts. Technical work paper. Prepared for the Generic Environmental Impact Statement on Animal Agriculture and the Minnesota Environmental Quality Board., St. Paul, Minnesota. Available online at: http://www.eqb.state.mn.us/geis/TWP_Social.pdf [accessed April 14, 2007].

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CLIMATE:
Clean Power Plan needs robust environmental justice component -- advocates

Ellen M. Gilmer, E&E reporter

Published: Friday, December 12, 2014

Though widely praised in the environmental community, U.S. EPA's proposed Clean Power Plan is falling short of some environmental justice goals, advocates said yesterday.

In a panel discussion sponsored by the Environmental Law Institute and the D.C. Bar, environmental justice leaders noted that the proposed rule to rein in power plant emissions should give more direction to states on how to engage with communities disproportionately affected by carbon emissions and other environmental degradation.

Jalonne White-Newsome, a federal policy analyst for the Harlem, N.Y.-based nonprofit WE ACT for Environmental Justice, pointed to the Clinton administration's 1994 executive order requiring agencies to include an environmental justice analysis for proposed rules.

The draft Clean Power Plan does include a section on environmental justice, noting that EPA's 2009 endangerment finding considered the specific risks of climate change to minorities and low-income populations, and that environmental justice advocates weighed in significantly on the rule. But WE ACT and other groups argue that the agency should go further and direct states to address local environmental justice issues as part of their implementation of the rule.

"I talk to a lot of states that say, 'Well, we're not sure how to conduct EJ [environmental justice] analysis or we're not sure what EJ is or we're not sure how to define an EJ community,'" White-Newsome said. "Well, we need to take those reasons/excuses out of the box, and as a part of the CPP and other vehicles that are coming down, we need to make sure states have that guidance, the proper guidance, to actually use all these tools and data to better inform how they plan to mitigate certain climate impacts."

EPA environmental justice chief Matthew Tejada did not address the suggestion directly but stressed that the agency collaborated extensively with environmental justice groups throughout the rulemaking process.

"We have been and will continue to fulfill one of the key elements and the key functions of not just my office but the entire agency in engaging with communities," he said during the panel discussion, "particularly communities that are particularly vulnerable because we see that they have a central role."

Tejada added that his office's goal is not just for more voices to be heard but for the agency to help communities meaningfully engage with the government through commenting, grant proposals and other collaborative work.

"I think you're seeing the results of that commitment in the rules that we are working on internally," he said.

Most notably, EPA this week finalized a solid waste regulation that leaned on an environmental justice analysis to justify the agency's promulgation of the rule (***E&ENews PM***, Dec. 11).

Environmental justice advocates are unlikely to push too hard for Clean Power Plan changes, as the proposal is generally seen as a major step forward in the environmental community. Earthjustice attorney Lisa Garcia, who formerly led EPA's environmental justice office, said any environmental justice complaints would likely take a back seat to the more high-profile battles between EPA, states and industry over the rule's broader economic impact.

"The question would be, 'Can EPA or does EPA have the discretion to mandate [environmental justice analysis] to the states?'" Garcia said, adding that she believes the agency does have that authority. "Those would be the arguments, but certainly after some of the bigger ones are argued in court."

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09 03 14 DENR Complaint - Exhibit Vol 2 Part A_Exs. 27 - 38.pdf

Dear Administrator McCarthy and Ms. Golightly-Howell,

Attached please find Exhibits 27-38, which represent the first part of the second set of Exhibits to the Complaint submitted earlier today by Earthjustice on behalf of North Carolina Environmental Justice Network, Rural Empowerment Association for Community Help, and Waterkeeper Alliance, Inc. We apologize for forwarding these exhibits in batches and are forwarding hard copy versions by overnight mail for your convenience.

Please feel free to let us know if these materials raise any question or if you have trouble downloading them.

Sincerely,

Alok Disa, on behalf of Marianne Engelman Lado and Jocelyn D'Ambrosio

---

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Complaint of North Carolina Environmental Justice Network, Rural Empowerment Association for Community Help, and Waterkeeper Alliance, Inc. under Title VI of the Civil Rights Act of 1964, 42 U.S.C. § 2000d and 40 C.F.R. Part 7

against

North Carolina Department of Environment and Natural Resources

filed with

the United States Environmental Protection Agency

SUPPORTING EXHIBITS

VOLUME 2 OF 3
EXHIBITS 27-45

Filed: September 3, 2014

Complaint of North Carolina Environmental Justice Network, Rural Empowerment Association for Community Help, and Waterkeeper Alliance, Inc. under Title VI of the Civil Rights Act of 1964, 42 U.S.C. § 2000d and 40 C.F.R. Part 7

Exhibits

Volume 1 of 3 Exhibits 1-26	
Exhibit 1.A	EPA Award of Federal Funds to DENR in Fiscal Year 2014
Exhibit 1.B	EPA Awards of Federal Funds to DENR Extending into Fiscal Year 2014 and Thereafter
Exhibit 2	Comments of Steve Wing, Ginger T. Guidry, Sarah Hatcher, and Jessica Rinsky, on General Permit AWG100000, December 6, 2013
Exhibit 3	Comments of Catawba Riverkeeper Foundation, Cape Fear River Watch, Neuse Riverkeeper Foundation, North Carolina Environmental Justice Network, Pamlico-Tar River Foundation, Waterkeepers Carolina, Western North Carolina Alliance, Winyah Rivers Foundation, and Yadkin Riverkeeper, Inc. on Renewal of North Carolina State General Permits to Control Animal Waste, AWG100000 (Swine Waste Management System General Permit), AWG200000 (Cattle Waste Management System General Permit), AWG300000 (Poultry Waste Management System), submitted by Earthjustice, Waterkeeper Alliance, Inc. and Southern Environmental Law Center, December 6, 2013 (with Exs. 1-3)
Exhibit 4	Steve Wing & Jill Johnston, Dep't of Epidemiology, Univ. of N.C. at Chapel Hill, Industrial Hog Operations in North Carolina Disproportionately Impact People of Color (2014)
Exhibit 5	Anonymous Declaration I
Exhibit 6	Declaration of Larry Baldwin Exhibit 1 Biography Exhibit 2 Photograph of Runoff from Hog Facility, Duplin County (Jan. 2012) Exhibit 3 Photograph of Runoff from Hog Facility, Duplin County (March 2013) Exhibit 4 Photograph of Runoff from Hog Facility, Greene County (March 2013) Exhibit 5 Photograph of Gully, Beaufort County (Aug. 2013) Exhibit 6 Photograph of Gully, Beaufort County (Aug. 2013) Exhibit 7 Photograph of Gully, Duplin County (Feb. 2014) Exhibit 8 Photograph of Dead Box, Craven County (Feb. 2014)

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Exhibit 8	Declaration of Tony Bennett (with map)
Exhibit 9	Declaration of Violet Branch (with map)
Exhibit 10	Declaration of Cynthia Brinson (with map)
Exhibit 11	Declaration of Eddie Dean Brinson (with map)
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Exhibit 15	Declaration of Hannah Louise Fullwood (with map)
Exhibit 16	Declaration of Devon Hall

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Exhibit 20	Declaration of Robert Houston (with map)
Exhibit 21	Declaration of Brittany Johnson (with map)
Exhibit 22	Declaration of Cleveland Ladson (with map)
Exhibit 23	Declaration of Jessie Ladson (with map)
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Exhibit 25	Declaration of Joan Malloy Exhibit 1 Map Showing Home and Church Exhibit 2 Map Showing Home, Church and Nearest Hog Facility Exhibit 3 Map Showing Hog Facilities Along Little Kelly Rd. Exhibit 4 Map Showing Hog Facilities Within Three Miles of Home
Exhibit 26	Declaration of Daniel Mejia Exhibit 1 Map Showing Hog Facilities Near Delway Home Exhibit 2 Map Showing Hog Facilities Near Clinton Home Exhibit 3 Map Showing Hog Facilities Near High School

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Exhibit 28	Declaration of Alvin Miller (with map)
Exhibit 29	Declaration of Audrey Miller Exhibit 1 Map Showing Home and Nearby Hog Houses, Lagoon and Sprayfield
Exhibit 30	Declaration of Naeema Muhammad Exhibit 1 The Rest of the Story: Corporate Hog Farming in North Carolina (DVD) Exhibit 2 Map Showing Hog Facilities Operating under North Carolina's General Permit in Duplin, Sampson, Bladen, Northampton, Greene and Pender Counties
Exhibit 31	Declaration of Beaford Lee Outlaw (with map)
Exhibit 32	Declaration of Stella Smith (with map)
Exhibit 33	Declaration of Latongia Tyrance (with map)
Exhibit 34	Declaration of Bennie Wallace (with map)
Exhibit 35	Declaration of Sandra Wallace Exhibit 1 Map Showing Sprayfields Around Home Exhibit 2 Map Showing Permitted Hog Facilities Near Home Exhibit 3 Map Showing Hog Facilities Within Three Miles of Home
Exhibit 36	Declaration of Luby C. Waters (with map)
Exhibit 37	M.E. Anderson & M.D. Sobsey, *Detection and Occurrence of Antimicrobially Resistant E. coli in Groundwater on or near Swine Farms in Eastern North Carolina*, 54 Water Sci. & Tech. 211 (2006)
Exhibit 38	Blue Ribbon Study Commission on Agricultural Waste, Report to the 1995 General Assembly of North Carolina, 1996 Regular Session (1996)
Exhibit 39	Dana Cole et al., *Concentrated Swine Feeding Operations and Public Health: A Review of Occupational and Community Health Effects*, 108 Envtl. Health Perspectives 685 (2000)

Exhibit 40	Carrie Hribar, Nat'l Ass's of Local Bds. of Health, Understanding Concentrated Animal Feeding Operations and Their Impact on Communities (2010)
Exhibit 41	Michael A. Mallin & Lawrence B. Cahoon, *Industrialized Animal Production—A Major Source of Nutrient and Microbial Pollution to Aquatic Ecosystems*, 24 Population & Env't 369 (2003)
Exhibit 42	Maria C. Mirabelli et al., *Asthma Symptoms Among Adolescents Who Attend Public Schools That Are Located Near Confined Swine Feeding Operations*, 118 Pediatrics e66 (2006)
Exhibit 43	Maria C. Mirabelli et al., *Race, Poverty, and Potential Exposure of Middle-School Students to Air Emissions from Confined Swine Feeding Operations*, 114 Envtl. Health Perspectives 591 (2006)
Exhibit 44	Wendee Nicole, *CAFOs and Environmental Justice: The Case of North Carolina*, 121 Envtl. Health Perspectives A182 (2013)
Exhibit 45	Pew Commission on Industrial Farm Animal Production, Environmental Impact of Industrial Farm Animal Production (2008)

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Exhibit 46	Pew Commission on Industrial Farm Animal Production, Putting Meat on the Table: Industrial Farm Animal Production in America (2008)
Exhibit 47	RTI International, Benefits of Adopting Environmentally Superior Swine Waste Management Technologies in North Carolina: An Environmental and Economic Assessment (2003)
Exhibit 48	Leah Schinasi et al., *Air Pollution, Lung Function, and Physical Symptoms in Communities Near Concentrated Animal Feeding Operations*, 22 Epidemiology 208 (2011)
Exhibit 49	Sacoby M. Wilson & Marc L. Serre, *Examination of Atmospheric Ammonia Levels Near Hog CAFOs, Homes, and Schools in Eastern North Carolina*, 41 Atmospheric Env't 4977 (2007)
Exhibit 50	Steve Wing et al., *Air Pollution and Odor in Communities Near Industrial Swine Operations*, 116 Envtl. Health Perspectives 1362 (2008)
Exhibit 51	Steve Wing et al., *Air Pollution from Industrial Swine Operations and Blood Pressure of Neighboring Residents*, 121 Envtl. Health Perspectives 92 (2013)
Exhibit 52	Steve Wing et al., *Environmental Injustice in North Carolina's Hog Industry*, 108 Envtl. Health Perspectives 225 (2000)
Exhibit 53	Steve Wing & Susanne Wolf, *Intensive Livestock Operations, Health, and Quality of Life Among Eastern North Carolina Residents*, 108 Envtl. Health Perspectives 233 (2000)

Exhibit 27

DECLARATION OF NORMA MEJIA

1. My name is Norma Mejia. I am of legal age and competent to give this declaration. All of the information in this declaration is based on my own personal knowledge unless otherwise indicated.

Background

2. I am Latina. I live at 382 Leonard Rich Road in the town of Magnolia, in Duplin County, North Carolina. (See Attached Map). I live here with my husband, Bernardo, and my two sons, Nicholas and Samuel. Bernardo is forty-nine years old. I am also forty-five years old. Nicholas will be fourteen this year, and Samuel is seven years old. We own our house. We have lived here for 10 years.

3. I work at the Rural Empowerment Association for Community Help (REACH) as an organizer and work on the hog sludge concerns in our area. We encourage people to protect themselves at work.

4. There are at least eight hog houses within two miles from where my family lives. I have a map pinpointing where the hog farms and houses are in proximity to my home. There are also turkey farms near me.

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Experience Living Next to a Hog Facility

5. Nicholas, my fourteen year old, is always complaining about his nose and breathing. The doctors say he has sinus issues, but we don't know if it is related to the contamination around us.

6. A few years ago, maybe three years ago, trucks started coming very close to my property to dispose of sludge near my property line. Now, the trucks are coming in even more often than before and it is very upsetting. They make more trips and have more truck drivers. There is a lot of noise and dust. I don't have the freedom to spend time with my children outside. I know from talking with my neighbors that there are plans to expand the sludge operation because they've been asked if it's permissible to spread the waste on their property.

7. We've been in even closer proximity to the sludge operation because our dog ran away and we went looking for him near the application area. It smells terrible back there.

8. I am concerned about my health and my privacy at home. I can't go outside because of the truck traffic associated with the sludge operation. They come in around 6:30 a.m. in the morning and keep going in and out all day. They do ten or more trips a day and they leave around 5 or 6 p.m., sometimes 7 p.m. I cannot rest because I hear the trucks coming in and out.

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9. I think they could make another road to enter the area where they spread the sludge so that they do not have to come so close to my home or take the sludge somewhere else. I want them to stop.

10. We use well water. Because we live so close to hog farms and the sludge operation, I am concerned if the water is safe to drink or safe for cooking. I don't drink it – I buy water every week. We spend about $10 or more a week, maybe $15, on purchased water.

11. Hog farms are everywhere. I smell them all the time and it's terrible. Sometimes I feel like I am going to get sick from smelling all this. The smell of the hog farms is worse in the afternoon. I've noticed the smell the whole time I've been living in Magnolia and it's worse than it used to be when I first moved here.

12. I live within a quarter mile of a sprayfield. It seems like they do it every two or three weeks. I don't keep my windows open because of the smell.

13. I see Latinos working at the hog farms. I never see Caucasian people working at the hog farms. The supervisors are Caucasian. The African-Americans and Latinos take care of the hogs. The Caucasian people tell them what to do and then they leave. The offices of supervisors are far from the hog farms. I have a lot of Hispanic friends that tell me different stories about the hog farms. They tell me that the Caucasian people don't work there.

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I declare under penalty of perjury that the foregoing statements are true and correct to the best of my knowledge, information, and belief.

Executed in Warsaw, North Carolina on August 31, 2014

Norma Mejia

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Address: 382 Leonard Rich Road, Magnolia, NC 28453

Addressee: Norma Mejia

Map radius: Approximately 2 miles

Source: Google Maps

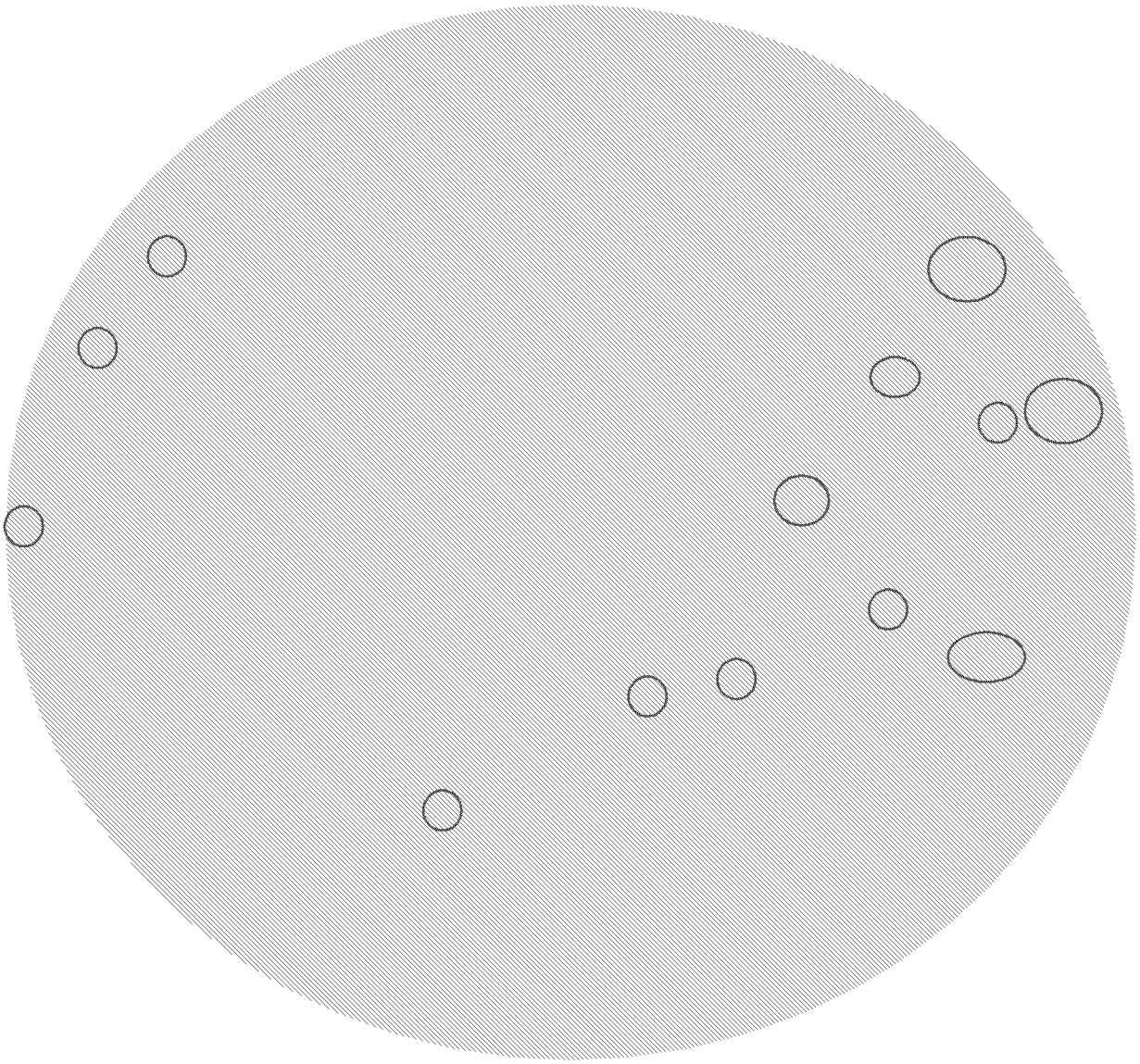

Exhibit 28

DECLARATION OF ALVIN MILLER

1. My name is Alvin Miller. I am of legal age and competent to give this declaration. All of the information herein is based on my own personal knowledge unless otherwise indicated.

Background

2. I am African-American.

3. I live at 426 Highway 11, 903 North, Kenansville, North Carolina. (See Attached Map). I rent my house.

4. The closest hog facility is five or six miles from where I live. I smell the hog waste at certain times of the day when the wind changes directions. I smell it when the facilitators are pumping spray on the fields. I smell it when the wind blows. I also smell it if I drive by the fields, even if they are not pumping. The mist of the spray has hit my windshield when I go to the store or to visit my family.

5. I used to fish more than I do now. Now, however, I fish less because the creeks and streams are polluted with hog waste. I didn't know that the streams and creeks were polluted until I started working with the Rural Empowerment Association for Community Help (REACH) taking water samples. I went to a creek and the water seemed clear, but I saw dead fish. All the creeks at which I used to fish are contaminated because of the hog farms. The hog farms affect the water in the streams.

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6. I have three grown hunting dogs and seven puppies. I enjoy hunting raccoon and rabbit. One night, while I was hunting raccoon with some friends, we had to go into the woods. We found out they were spraying into the wood line because we had on waders and we stepped knee-deep in hog sludge. That was not supposed to happen. I'm afraid that the hog sludge run off will contaminate the streams.

7. I started to notice that the facilities were spraying a lot of waste into the tree line in the mid-to-late 90's and early 2000's. I started to see more hog houses being built. In the early days, the hog farms used the gun sprayer. Now we see the pivot wheels and the stationary spray packs. The pivot wheel is automated; it rotates around the field. The spray gun is pulled out manually. The stationary spray pack has underground pipes that come up about every two and a half feet and they are fifty feet apart. The system is all underground and the spray comes up. Out of all these methods, the spray gun is the worst because it shoots out a big stream and it's spraying constantly – if you get in front of it, it will soak you. I know about the different types of sprayers because I used to work in a pig nursery and I had to turn the spray guns off.

8. My doctors tell me that I should walk to make sure that I stay in shape, but I don't walk as much as I should. There are hog trucks on the main 4-lane highway. There are hog trucks, turkey trucks, trucks from the Valley Proteins

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factory— I see it all, including dead hog trucks. I don't want to walk out there and smell the air from all those things. If you are in your car and hog trucks pass you, you will still smell the ammonia.

9. I have many concerns regarding the hog farms. I am concerned that the hog farms are polluting the air. I am also concerned that the hog farms are messing up the environment. If I go anywhere in the county, I smell where they are pumping off the lagoons. If I drive by a hog house, I smell it. When farmers started consolidating the hogs and started raising hogs in hog houses, things went bad. Back in the early 80's and early 90's, I didn't see many hog houses. I could walk anywhere to fish or hunt, but now I can't fish anywhere because the creeks are dead and all my neighbors have a "no-trespassing" sign posted on their land.

10. I try to stay far away from the hog farms because the smell is terrible and because I don't know what could potentially be in the air.

11. The hog facilities have boxes for the dead animals. During the summer, the dead boxes are particularly bad. It creates an awful smell. Six or seven years ago, I saw a truck carrying dead hogs and several came out of the back of the truck. The smell was awful then, too.

12. I have seen some hog farms wash out the houses. When they wash down the hogs waste in the hog house, the run off can go into ditches which then go into streams.

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13. I've been working with REACH since about 2008. I drive around to see if I can spot any hog farms that are violating the North Carolina law, like spraying in the rain. I also watch for when the facility sprays when no one is watching. The sprayers should have someone watching them, in case it starts to rain. Someone needs to be there to immediately turn them off. Someone needs to watch the spray because other detrimental things could happen too, like a pipe bursting. I've seen a hog farm spraying at 10 or 11 o'clock at night. I wonder if anyone is watching, or if they are at home watching television.

14. If I could change anything, I would try to figure out how the hog farms would not have to pump the waste onto the fields, or have them get rid of the lagoons so they wouldn't have to pump the spray. If that's not a possibility, then I would change the spraying system so that it would be drilled into the ground so it would not get into the wind. I wish that they wouldn't spray on windy or rainy days. If it's raining, then the ground is already saturated and there can be runoff which can result in polluted creeks.

15. I think hog facilities have more negative impacts on African-American populations than all others. Most hog farms I know only employ African-Americans or Hispanics. There are not many people of Caucasian ethnicity working on the hog farms. Most of the hog houses are in African-American neighborhoods. I don't know of any hog houses in Caucasian

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neighborhoods. In a Caucasian neighborhood, if they were to hear about a hog facility coming to their neighborhood, I think they would protest. From my experience, an African-American person is more afraid that what he has will be taken so he will just say that he has to learn to put up with it.

I declare under penalty of perjury that the foregoing statements are true and correct to the best of my knowledge, information, and belief.

Executed in Kenansville, North Carolina on August 30, 2014.

Alvin Miller

Alvin Miller

ED_001369_00043850-00019

Address: 426 Highway 11 903 N. Kenansville, NC 28349

Addressee: Alvin Miller

Map radius: Approximately 1.5 miles

Source: Google Maps

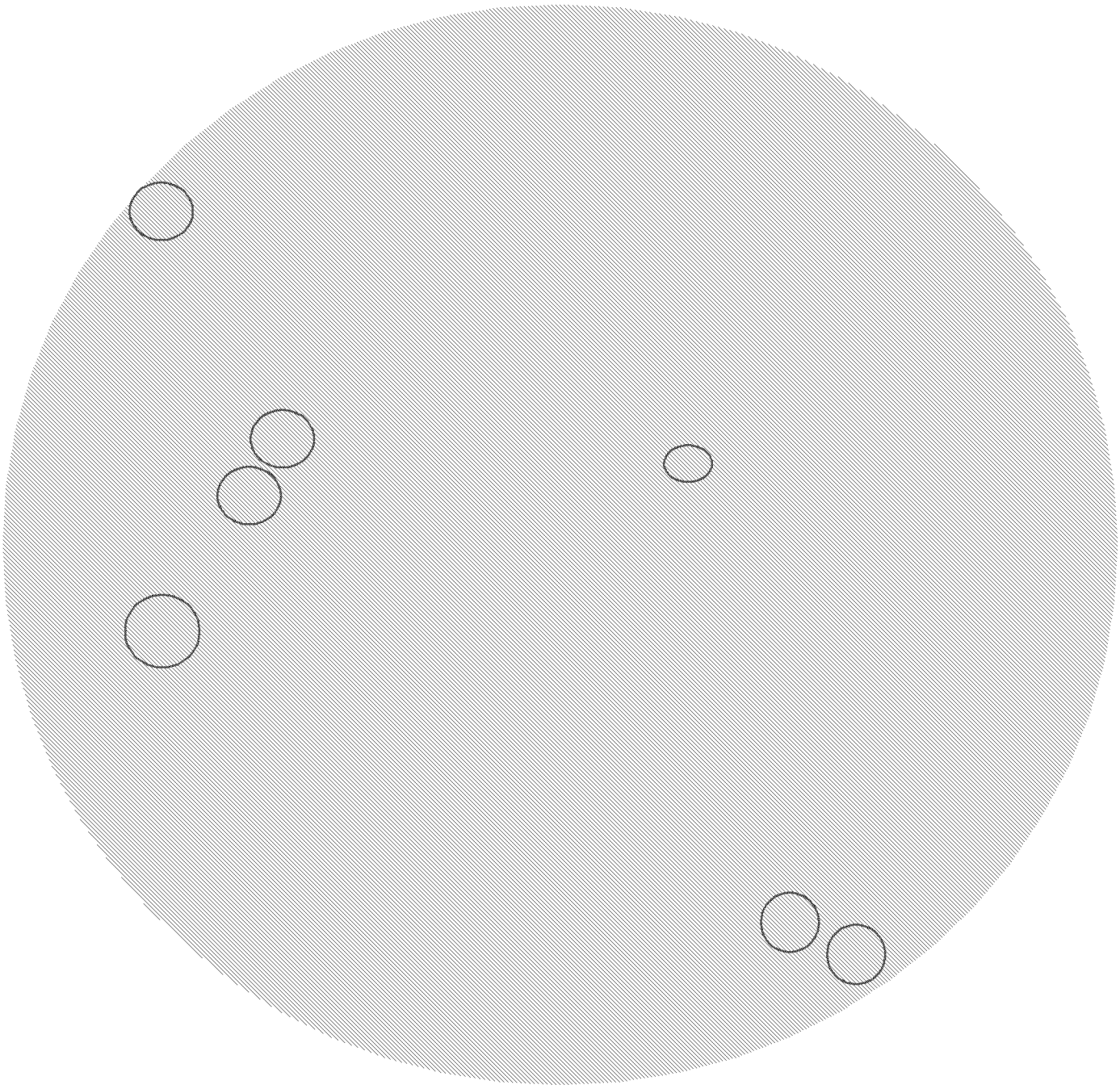

Exhibit 29

DECLARATION OF AUDREY MILLER

1. My name is Audrey Miller. I am of legal age and competent to give this declaration. All of the information herein is based on my own personal knowledge unless otherwise indicated.

Background

2. I am a 54 year old African American woman. I was born in Rose Hill in North Carolina, and I lived there until I was one year old. At that time, my family moved to a home in Wallace on Railroad Street. I have lived throughout the country, including New York, and throughout North Carolina. Three years ago, in 2011, I moved from Dudley, North Carolina, back to Wallace, North Carolina to be closer to my family.

3. I currently live in a house owned by my aunt, Elsie Herring. The house is located at 109 Beulah Herring Lane in Wallace, North Carolina, right next to a hog facility, as shown in Exhibit 1. My aunt and other family members live in houses and trailers nearby.

4. I understand from an attorney at Earthjustice that the hog facility next door is called Major Murray Hog Farm and that it has a permit from the state of North Carolina that allows it to house 1,180 hogs.

Experience Living Next Door to a Hog Facility

5. Living next door to a hog facility is difficult. When the facility is spraying, the smell is just awful. Sometimes, if the facility is spraying, I can even smell it from inside a car on River Road as I am heading toward my house. As the car drives around the last curve before my house, the smell just hits me. The closer I get to my house and the sprayfields, the worse it smells.

6. The facility next door sprays year round, even in the winter if the weather is warm enough.

7. I volunteer for a second hand store, tagging donated clothes to be sold. Some days I go with my mother to the store, but I usually work from home, sitting in my living room tagging. In the warmer months, it would be nice to open my doors and windows and enjoy the breeze as I work. My house gets a nice breeze off the trees. But if the facility is spraying, I have to keep the doors and windows tightly shut to keep the smell out. If I open the door just a crack, the smell gets in and lingers. When it is hot, I usually have to sit inside with the air conditioner on, running up my electric bill, to avoid the terrible smell. I wish I could spend more time outside.

8. I have limited mobility and spend a lot of time at home, even when I am not working. I am on crutches and cannot drive a car, so I have to rely on others if I want to leave the area just beyond my house. When the smell is bad or

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when I get stir-crazy and want to leave the house, I usually call my mother and ask her to come and pick me up, but she can't always come and get me. My mother is 70 years old and is not always up for a drive.

9. Because I am on crutches, it is especially difficult for me to be outside when the facility is spraying. I can't cover my nose with a handkerchief and get around on my crutches. If I have to pick up the mail or go outside to get to my deep freezer or my laundry room while the facility is spraying, I have to hold my breath to avoid the terrible odor.

10. Living next to the hog facility has changed the way me and my family use the outdoors. For example, because of the hog facility, I no longer hang my clothes out on the line to dry. I never know when the facility is going to spray. Before I got my clothes dryer, I often would hang my clothes out in the breeze to dry only to come back and find out the facility started spraying and my laundry was covered in a mist of manure. I used to get so upset and worried that the spray would ruin my clean clothes that I finally bought a dryer. I am happier knowing that the mist from the spraying won't ruin my laundry, but I would prefer to leave my clothes on the line to dry.

11. My family and I don't have cookouts in the summer because of our concern about the spraying. When the facility is spraying, the smell is unbearable.

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Because we don't know when the facility will spray, we can't plan around it, so we just stopped having cookouts.

12. Living next to the hog facility has taken a toll on my health. I have problems with my sinuses and bronchitis, and these problems have gotten worse since I moved next door to the hog facility. I often have a hard time breathing; my nose clogs up and my throat is raw and sore. People think I have a cold, but I think the hog facility is making it hard for me to breathe. My sleep apnea also has gotten a lot worse since I moved here. This January, I had to get a machine to help me breathe at night.

13. Living next to a hog facility is very different than what I am used to. Most recently, I lived in Dudley, North Carolina, near the railroad tracks. Living next to a hog facility is much worse than living next to the tracks. I prefer the noise of the trains to the smell of the hog waste.

14. It is hard living and working next to a hog facility. I want someone to help those of us that have to experience the terrible odor and breathe in the harmful pollutants.

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I declare under penalty of perjury that the foregoing statements are true and correct to the best of my knowledge, information, and belief.

Executed in Wallace, North Carolina on April 17, 2014

Audrey Miller

Audrey Miller

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EXHIBIT 1

NOTE: Hog Facility extent drawn from tax parcel information found on Duplin County Tax Administration's website and may not be 100% accurate

Exhibit 30

DECLARATION OF NAEEMA MUHAMMAD

1. My name is Naeema Muhammad. I am of legal age and competent to give this declaration. All of the information herein is based on my own personal knowledge unless otherwise indicated.

2. I am the Acting Director and a Community Organizer for the North Carolina Environmental Justice Network (the "EJ Network"). I have served as the Acting Director since October 2013. I have been with the EJ Network since 1999, when I joined as a community organizer.

3. I am the third director of the EJ Network. Nan Freeland served as the director from about 1998 until 2011. Gary Grant was the director from 2011 until 2013.

About the EJ Network

4. The EJ Network is a statewide, grassroots-led nonprofit organization made up of community members and other organizations that are working to fight environmental injustice. Member organizations include Bayden Concerned Citizens, Black Workers for Justice, North Hampton Concerned Citizens, Rural Empowerment Association for Community Help ("REACH"), and Roy Oaks Community.

5. The EJ Network exists to promote health and environmental equality for all people of North Carolina. We seek to accomplish these goals through

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organizing, advocacy, research, and education based on principles of economic equity and democracy for all people. We focus on the communities that are most impacted by environmental injustice, including people from low-income communities and communities of color. We use community-based participatory research, organize communities, engage media, educate elected and appointed government officials, and advocate statewide for practical solutions to achieve environmental justice.

6. The EJ Network grew out of the work of our founders, Nan Freeland and Gary Grant, to address environmental injustices in North Carolina.

7. Nan Freeland was involved in one of the first issues to launch the environmental justice movement in North Carolina, the fight against the plan to build a landfill in Warren County, North Carolina that would dispose of polychlorinated biphenyls, or PCBs. In 1982, industry needed a place to dispose of the PCBs, and they settled on Warren County, a county with a large elderly population and a large African American community. The people in Warren County were fighting the plan to dump PCBs in their community. The fight culminated with a demonstration; members of the community laid down in the roadways to stop the trucks from delivering the PCBs to the landfill. The National Guard was called in to disperse the protesters. Many people were arrested. Ultimately, the landfill was built, but the fight helped launch the environmental

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justice movement in North Carolina. Nan was instrumental in the Warren County fight and her experience there helped lead her to the environmental justice movement.

8. Gary Grant's experience with confined animal feeding operations in 1991 was the beginning of his path to found the EJ Network. Concentrated animal feeding operations were just coming to North Carolina in the early 1990s, around the same time the environmental justice movement was forming. Tillery, in Halifax County, North Carolina, where Gary Grant lived and worked with the Concerned Citizens of Tillery, was one of the proposed locations of some of this development. As Gary tells it, in 1991 a local paper ran a story claiming that economic development was coming to Tillery and that the development was centered on hog farms. Gary did not initially have any concerns about the hogs. He figured it was regular farming, as had been happening in the community for decades. Then one of Gary's neighbors, a white man, approached Gary to ask if he had heard about the hog farms that were coming. The man wanted to work with Gary and the Concerned Citizens of Tillery to stop the development. The man and Gary took a trip to one of the locations where they were planning to bring in the hogs. When Gary saw how the land had been excavated to make room for the huge hog houses, he understood that this was not typical hog farming. It was serious industrial development.

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9. Gary helped organize community protests against bringing industrial hog farms to Tillery. Eventually, the concerned black and white citizens of Tillery encouraged the Halifax County Commissioners to enact an ordinance that required hog operations to obtain permits to construct and operate within the county. The ordinance wound up being strong and, perhaps may have made the industry think twice before coming into Halifax County. There aren't many hog operations in Halifax County. The Halifax County fight was important because it protected communities from industrial agriculture, and because it was the first time that the black and white communities came together to address a common problem. It also helped the communities realize that the hog industry was an environmental justice issue in North Carolina.

10. Also in the 1990s, around the time of the Warren County fight, and Gary's experience with hog farms in Halifax County, there was a growing recognition of environmental justice issues. People were coming together to discuss the problem. As I understand it, in the late 1990s, the National Environmental Justice Advisory Committee ("NEJAC") met in North Carolina, and participated in a roundtable at North Carolina Central University where members heard reports about the growing hog industry. Gary was invited to talk about the hog operations and his experience in Tillery. I did not attend the meeting, but since learned about it.

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11. People raised concerns at the meeting about the growing hog industry and how it was affecting water quality and black communities. After the meeting, some of the community leaders, attorneys, and scientists recognized that they needed to do something about the growing hog problem and settled on having a conference. After the NEJAC meeting, Gary, Nan Freeland, and others worked to put on an Environmental Justice Summit at the Historic Franklinton Center at Whitakers, North Carolina, in Edgecombe County. About 75 or 80 people attended the Summit, including Professor Steve Wing of the University of North Carolina, Chapel Hill, and some of his students. At the Summit, people recognized that they needed an organization to continue to bring people together to address environmental injustices. The EJ Network grew out of the first annual Environmental Justice Summit, which was held in 1998.

EJ Issues: The Growing Problem with Factory Farms

12. Between 1992 and 1998, the hog industry in North Carolina experienced massive growth. During that time, many animals operations were built in the state, particularly the eastern portion of the state. Eastern North Carolina was very rural, with lots of farmland and a very poor community. Initially, the community did not know that the industry was expanding around it. They were not paying attention.

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13. The EJ Network realized that there was a strong need in the affected communities for additional information about the industrial hog operations. Around 2000, with Steve Wing, and the EJ Network worked on a project called the Community Health and Environmental Reawakening, or CHER, to meet the need for community education about industrial hog operations. I joined the EJ Network in 1999 and began work on the CHER Project in June of 2001. CHER was an extension of the Southeast Halifax Reawakening Project, which started before I joined the EJ Network.

14. The goal of CHER was to provide communities with information about the expanding hog industry and empower communities to fight back. We told people everything that they needed to know about the hog operations. We gave people three pieces of information.

15. First, we gave people a map of where the hog faculties were located so they could see how many hog operations were coming to their community. We had a student from the University of North Carolina, Chapel Hill create the map showing where the hog operations were located. The student reviewed the permits for the facilities, and mapped out the locations.

16. Second, we gave people information on how the hog operations affect the environment and human health.

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17. Finally, we gave people information on the principles of environmental justice and the definition of environmental justice to get them thinking bigger than they were thinking. Black communities in North Carolina had not been environmentalists. The environment was a new issue for these communities, so we introduced them to the issue and explained that the hog operations did not have the right to pollute the air and water and harm the community. And we discussed how it was environmental racism for the hog operations to target and move into African American communities.

18. CHER was not only about giving the community information to inspire advocacy. We also wanted to hear from the members of the communities about their own experience with the hog operations.

19. Most of the people that I spoke with were on well water and they were seeing changes with the quality of their water. The water in their wells was starting to smell like rotten eggs. People started relying on bottled water instead of their wells. People on a fixed income can barely afford to buy clean, bottled water, but they were forced to because their water smelled and often was unsafe to drink.

20. Often as I spoke to people about the hog operations, people began remembering things that they had pushed to the back of their minds. They talked about the odor, the boxes of dead animals at the facilities. They told me that there were more flies now than in the past and how the flies stuck to their window

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screens. They talked about seeing animal waste on their cars and how the mist from the irrigators traveled across the fields to their cars. They told me that they felt like prisoners in their own homes.

21. People complained that they would not hang their clothes on the line outside to dry. The odor would set into the clothes, and they would have to wash them out again. Children getting off the school busses would run home instead of walk. Some children even threw up because of the smell.

22. People told me that their eyes would tear up when they were outside. They complained of headaches. They said it was stressful to live near a hog facility.

23. One of the things that struck me as I spoke to people was that they had not realized that they could speak out against the hog operations. People told me that they did not think they could say anything because the hog facility had a right to use their property. I told them that no one has a right to prevent you from enjoying your own property in the way that you intended when you purchased it. I explained that it is an injustice for the hog operations to force you to change your own lifestyle because of how they chose to use their property.

24. The maps helped me open people's eyes to the injustice. People were easily able to identify where they lived and see how close they were to the hog operations. When they realized they were surrounded by hog operations, they

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started to understand why they smelled so much odor. Before the CHER project, often people had not paid addition to the lagoon and the pollutants that were coming from the lagoon. After I spoke with people, they began to see the connection between the smell and the hog operations.

25. I asked people to think about whether they were part of a community and if they were organized. I asked them if they knew what their neighbor was experiencing. People began to talk to each other. They began to see that the problem was larger than themselves.

26. Because the hog industry liked to say that it was fostering economic development and bringing in jobs, I asked people if they needed a job at any cost. People would tell me that they would not take a job if it destroyed their health. They realized that they should not trade the health and welfare of their community for the few jobs the hog operations provided.

27. The community wanted to be able to prove that the hog industry was affecting their health. The North Carolina Pork Council was and still is very intimidating to communities. Communities were told that they were making things up—people told me that the Pork Council and hog farmers said that it did not stink when they claimed it stank. Elected officials were no better. I once went to a county meeting where, in response to complaints about the hog industry, one of the elected officials had the gall to ask, "where are the body bags?" His statement

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made it clear to me that he thought that unless people were dying, there was not a problem.

EJ Network Initiative: Community Health Effects of Industrial Hog Operations

28. To fight the assertion that we could not prove that hog operations were affecting the environment and human health, the EJ Network contacted Steve Wing for help showing the impact that hog operations were having. Steve began looking at potential research projects that would allow the communities to understand what was happening to them. He looked for a project that would help demonstrate the health impacts of living in a community that is surrounded by hog operations.

29. Together, in 2005, the EJ Network and Steve's research team from the University of North Carolina began a project called the Community Health Effects of Industrial Hog Operations ("CHEIHO").

30. CHEIHO brought together community members and research scientists to study how industrial hog operations affected community members. I recruited members of the community to participate in the study. Each study participant attended a three-hour training session where we explained what would be expected. We explained that we were looking to understand how they reacted to hog operations. Community members were given a journal and blood pressure

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and breathing machines. We also tested people's ability to perceive odor, and recorded that information.

31. We asked the participants to sit outside their home for 10 minutes two times a day, at times of their own choosing. The participants were given a timer to make sure that they were only outside for ten minutes. While sitting outside, the participants would rate the odor on a scale from 1 to 8, with 8 being the strongest. We also asked that the participants to answer questions in a journal that we provided about the symptoms they were experiencing, like whether they had runny nose or runny eyes or were coughing, and to record how they were feeling emotionally, like whether they were stressed or angry or neutral. After the 10 minutes was up, we asked that the participants to take their blood pressure and print out the results to be placed in the journal. We also asked them to breathe into a peak flow meter that tested lung capacity. Finally, we asked the participants take a sample of their saliva, which they would place in a tube that we provided to be stored in the freezer.

32. We also placed processing equipment throughout the community. The equipment monitored particulate matter, capturing fine particles in the air. The student researchers from UNC would download the results from the monitoring equipment on a weekly basis. Every few weeks, the students would also collect the saliva samples to be analyzed.

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33. We studied at least 10 people at a time, for two weeks. At the end of the two weeks, we would move on to another group. The study lasted for four years.

34. The study has been very helpful in showing how industrial hog operations affect people. When people said it stunk, the equipment correlated with their responses. The machines would show high measurements of hydrogen sulfide.

The EJ Network's Advocacy Against Industrial Hog Operations

35. In addition to community education and research, the EJ Network has organized community action events, including rallies in Raleigh. We held our first rally in July 2007 in response to proposals to lift the moratorium prohibiting new hog operations in the state. The rally was a collaboration with other groups, including Riverkeepers, the Waterkeeper Alliance, and the Environmental Defense Fund.

36. We went to Raleigh seeking three things. First, we wanted to see the moratorium, which was set to expire in 2007, extended. Second, we asked for a deadline to get rid of the lagoon and sprayfield system and install clean technologies, like those that Mike Williams identified in the Smithfield study. Finally, we wanted the state to establish a fund that would help contract growers afford to install the clean technologies. We viewed this last request as a

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compromise. We thought that the Smithfields and others who brought industrial hog farming to North Carolina should be responsible for the pollution it created, but we were willing to compromise to bring about change.

37. We had busloads of people come to Raleigh to support the rally and meet with elected officials. Many of our members did not know that they had a right to go to Raleigh and address the legislature and tell them about their needs. They were captivated by the fact that they had the right to demand better for themselves.

38. The center of our trip was a 51-hour vigil. Three hours of our vigil were for the Governor. We also kept vigil for the entire time that the legislature was in session, another 48 hours. During our vigil, we showed a documentary that we had made specifically to show the legislators about how the hog industry affected people in communities. The documentary is called "The Rest of the Story: Corporate Hog Farming in North Carolina." We made 170 copies of a DVD containing the documentary, one for each of the legislators. As the name suggests, "The Rest of the Story" tells the other side of the hog farming story. It documents particular people's experience with pollution from hog operations. We wanted to provide the elected officials with information about how hog operations prevented people from enjoying their property and made them sick to encourage those elected officials to enact policies that would protect communities against the

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hog industry. A DVD containing a true and accurate copy of "The Rest of the Story" is attached as Exhibit 1.

39. We also set up a mock hog farm, complete with mini hog houses and two baby swimming pools that we filled with hog waste that we brought with us from Duplin County, right in the middle of Halifax Mall. During our vigil, a facilities manager came over and demanded to know who told us to bring the hog waste to Raleigh. We told him that no one told us to bring the hog waste, but no one told us not to. He seemed mad at this response, and told us that if we spilled one drop of the toxic waste, we would be fined thousands of dollars. He said that the state would have to bring in a haz-mat crew to help with clean up. But we were confused. We told him that when we loaded up in Duplin County, we were told that the hog waste was organic fertilizer. We asked how trucking the waste 40 miles to Raleigh transformed organic fertilizer into toxic waste.

40. The following year, in 2008, the EJ Network organized another 51 hour vigil in Raleigh, which we called the Clean Air Vigil. The Clean Air Vigil was a massive birthday party that we held for the children in our community who, because of the poor air quality from the hog operations near where they lived, were not able to celebrate their birthdays with fun and games outside. We brought around 100 children, between the ages of 6 and 15, to enjoy being outside. The party was complete with balloons, hot dogs, and chips. When people would ask us

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why we were in Raleigh having a picnic, we told them that we can't do this at home. We told them that where we come from the air is not clean and clear and our children aren't able to enjoy playing outside.

41. We had a permit for the Clean Air Vigil. At first, our application was processed without any problems. But, soon after the permit was issued, the office that had issued it called up the EJ Network offices and told us that they had to revoke our permit and reissue it. The reissued permit said "no hog waste."

42. We didn't bring a mini hog farm with us in 2008, but we did bring a gallon of hog waste. We took the hog waste to the Governor's mansion to give to him as a present. When we got to the mansion, we were told the Governor was not in and were asked to leave, so we went to the Governor's office. We were able to leave the hog waste and a letter that we crafted at night during our vigil with the Governor's secretary. The letter told the Governor that the waste was a gift from the community. We told him to put the waste on the lawn and to let us know how long it took for the odor to go away.

43. In addition to organizing vigils and rallies, the EJ Network joins other community action events in Raleigh, including Moral Mondays. Moral Mondays were brought to life in 2013 by the president of the National Association for the Advancement of Colored People ("NAACP"), William Barber. On Mondays when the legislature is in session, we gather to oppose decisions that we believe will

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harm disadvantaged people. The Moral Mondays started out small, but within the matter of a few Mondays, we had thousands of people in attendance.

44. One Moral Monday last year opposed environmental cutbacks. The former director of the EJ Network, Gary Grant, and I both spoke at the environmental Moral Monday on behalf of the EJ Network.

45. During the Moral Mondays, we gather in the rotunda of the administrative building to sing and make speeches. Last year, more than 900 people, including Gary and myself, were arrested during the Moral Mondays.

46. Every October since 1998, except for one year, the EJ Network also holds an environmental justice summit. We bring together members of the community, researchers, and attorneys to talk about environmental issues that impact the community. We wanted to have a forum where we could bring communities together to hear from each other and to understand that the issues facing them were not unique. We wanted people to see that there were problems that were larger than themselves, systemic problems that we could only address by working together. We wanted to bring people out of isolation, and to encourage them to work together as a network. Throughout the years, we have focused the problems associated with industrial agriculture, landfills, workers rights, energy, and Title VI as a tool for communities.

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47. We always begin the summit with research presentations designed to inform the community about issues they are facing. For research projects, like CHEIHO, that are collaborations with the community, the community and the researchers will present together.

48. Another important panel that we always have at the summit is the Government Listening and Community Speak Out panel. A representative from the North Carolina Department of Environment and Natural Resources ("DENR") has attended every summit and has had the opportunity to learn more about the community's concerns about inadequate environmental protections.

49. Every year, we have a keynote speaker. In 2012, Gwendolyn Keyes Fleming, then the Director of Region 4 of the United States Environmental Protection Agency came to speak.

50. The government, including DENR, has been well-informed about how industrial hog operations impact communities. DENR has participated in the Government Listening and Community Speak Out panel at every single Summit. We have taken representatives of DENR on tours of Duplin County. Representatives of DENR have sat in on meetings at the REACH office in Warsaw where scientists have presented their research about how children with asthma suffer because of the pollution from hog factory farms.

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My Work with the EJ Network

51. I joined the EJ Network as an organizer in 1999. I was working in eastern North Carolina helping communities as they recovered from Hurricane Floyd. When Hurricane Floyd hit the state, it brought massive floods, breaking 500 year floodplains. I went into communities that were impacted by the flooding and fought for their right to return to the homes. At the time, I represented Black Workers for Justice. Together with other environmental justice groups, including Concerned Citizens of Tillery and the EJ Network, we worked together to organize the flood survivors.

52. The flood recovery process was very discriminatory. Some of the communities that were the most affected were offered shelter space built on a landfill that had not been properly closed. To make matters worse, the landfills had accepted coal ash waste. The year of the flood, the EJ network held a meeting focused on helping flood survivors. The meeting shed light on the fact that the victims weren't just suffering because of the flood. There was a systemic problem where marginalized communities were hardest hit because they were forced to live in communities that were already suffering from dirty industry. People were feeling isolated so the best way to address the problem was to bring them together for a meeting.

53. At the meeting, I learned that the EJ Network was looking for an organizer. Steve Wing recommended me for the position, and I have been an organizer with the EJ Network ever since.

54. As a community organizer, I serve as a community educator. I go out into the community, listen to their problems, and report back to the EJ Network Board. Community concerns inform our planning; when I report back on community concerns, we think about what resources we have to help change conditions in the community.

55. Usually, when a community seeks our help, we will ask them to host us at a community meeting. At the meeting, we provide an environmental justice education session in which we discuss the history of environmental justice and the importance of being organized. Our Board also shares its expertise, for example offering advice on the importance of documenting the environmental harm and legal avenues to address the harm. We also share environmental justice success stories.

56. My work with the EJ Network takes me into communities that are burdened by industrial hog operations. In these communities, the odor is often really foul. Some days, the odor is worse than others. When the operations are spraying, the odor is just terrible.

57. I have focused on Duplin, Sampson, and Bladen Counties, and have also worked in Northampton, Greene, and Pender Counties. Duplin and Sampson Counties have the most hog operations of any county in the state, but the other counties have their share as well. A map of showing the hog operations operating under North Carolina's general permit in Duplin, Sampson, Bladen, Northampton, Greene, and Pender Counties is attached as Exhibit 2.

58. The people I have met are not just affected by the hog operations. Though not shown on the map attached as Exhibit 2, these counties, including Duplin County, also have a lot of industrial poultry facilities. People have complained that the poultry waste also stinks. Poultry facilities often have dry manure that they call litter. People are concerned that the dry litter will blow over to their property, just like the hog waste. People in these communities are overburdened by all types of industrial agriculture.

59. I have met many people who have been burdened by industrial hog operations. People in these counties tell me that they. I have heard many moving stories about how people have been affected.

60. One of the most moving stories I have heard was from Elsie Herring, who is featured in the documentary "The Rest of the Story." Elsie tells a powerful story about how the hog industry came onto her family's land, took over their property, and sprayed them with waste. The hog farmer intimidated Elsie and her

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family when they attempted to fight back, even coming onto her property with a loaded gun to threaten Elsie's elderly mother. Her account of the lack of respect the industry shows the community tells another side of the story of the impact of hog farms.

61. I also heard from a minister about how she was affected. The minister lived in Northampton County, an area where there were a lot of hog operations. She told me that one day she was at church, preaching from the pulpit, and she smelled this terrible smell. She couldn't figure out what it was and then, all of the sudden, she realized that the smell was her. Her clothes smelled of hog waste. When she realized that the smell was coming from her, she was so embarrassed. She told me that she ran from the pulpit and out of the church because she was completely embarrassed. This story highlights how the hog industry can take away people's dignity.

62. Another moving story that I have heard is about how working in a hog rendering facility destroyed a person's health. In my organizing, I met a man who lived around the hogs and already had been upset about the odor. He also worked in a hog rendering plant, which is a place where the grind up the dead animals. He had worked in the plant for 6 years in maintenance. One day, the plant had a problem in the upstairs area. The man had to walk upstairs to address the problem. He was wearing his hydrogen sulfide monitor, and it went off while he was up

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there. The monitor showed that the hydrogen sulfide levels had reached 90 parts per billion, a very dangerous level. The man passed out and was taken to the hospital. The hydrogen sulfide causes neurological problems. After the accident he could barely stand. He had to learn how to walk again. He has two children and a wife. His wife told me that her husband is not doing well. His illness and trouble recovering is ruining his life and their marriage, and affecting their children.

63. Between 1999 and 2011, I also was a community mentor in the Kellogg Foundation Program for postdoctoral students studying health disparities. As a mentor, I worked with students who were researching environmental health problems that affected communities. I worked with three students. The first was researching systemic problems with the recovery process following Hurricane Floyd. The second student was researching how life in communities in North Carolina had changed since the arrival of industrial agriculture. The final student I mentored was researching the impact that industrial agriculture had on water quality. I helped all of these students coordinate with the community, helping them interview community members to support their research. In the last project, I helped the student go into the community and figure out the best place to collect water samples.

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64. Since meeting Professor Wing, I have worked closely with his students, who are studying epidemiology, to educate them about environmental problems that are affecting community health and welfare. Steve and I work together on an 8-week class where we invite members of the community to come and speak about their experiences with environmental issues, like living near industrial hog operations. Steve and I decided to offer this class 14 years ago. Some of his students had attended the annual Environmental Justice Summit and came back energized. The students were captivated by the stories they heard about how people in North Carolina were affected by dirty industry and they demanded more access to the community to inform their work to promote public welfare. Steve decided that we should offer a class. I bring in people from the community to share their experience living near dirty industries. Many people from the community have never spoken to a classroom full of university students. It is another opportunity for them. It helps empower them to demand better.

65. Over time, as I have been organizing with the EJ Network, I have seen a change. People are more vocal than they were when I first went into communities. The industry and even elected officials were so intimidating, and people were often afraid to speak up. But as people became more informed about their rights and about principles of environmental justice they were more willing to talk. More people understand that one person should not be able to use his land in

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a way that harms others. As people are starting to understand their rights, I can see their fear begin to fade away.

66. We have more work to do to stop industrial hog operations to stop polluting communities, but we are making progress.

I declare under penalty of perjury that the foregoing statements are true and correct to the best of my knowledge, information, and belief.

Executed in Edgecomb County, North Carolina on August 29 2014

Naeema Muhammad

Naeema Muhammad

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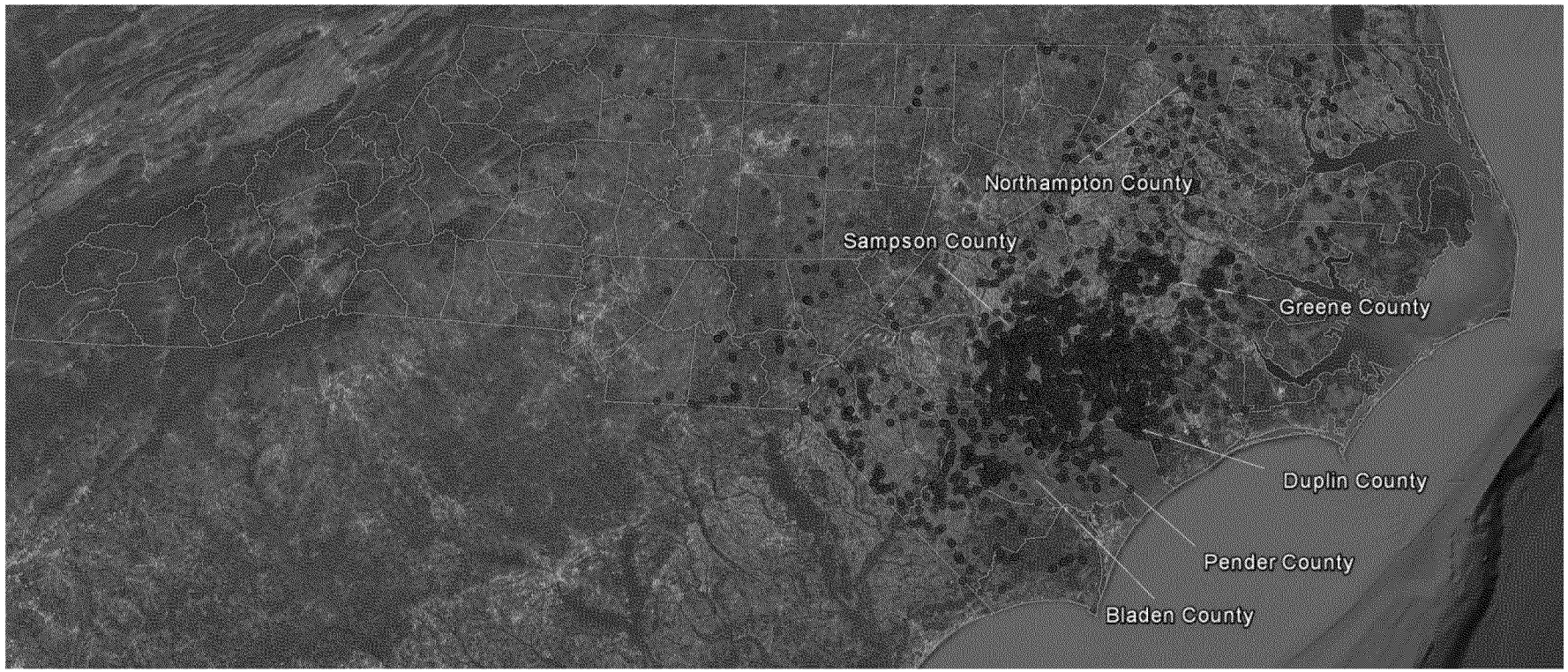
Exhibit 1

DVD copy of documentary entitled
"The Rest of the Story: Corporate Hog Farming in North Carolina"

EXHIBIT 2



NOTE: Map shows locations of swine facilities operating under the General Permit, as indicated in NCDENR's spreadsheet of permitted animal facilities, updated January 10, 2014.

Exhibit 31

DECLARATION OF BEAFORD LEE OUTLAW

1. My name is Beaford Lee Outlaw. I am of legal age and competent to give this declaration. All of the information herein is based on my own personal knowledge unless otherwise stated.

Background

2. I am African-American. I live at 1445 Sarecta Road in Pink Hill, Duplin County, North Carolina. I am eighty-three years old. This property is owned by my family.

3. I live near several hog houses. There is a hog house a mile from my house and another on the other side of my house.

4. I've been living near hog houses since they were built near my home nearly 20 years ago.

Experience Living Near the Hog Facilities

5. I am concerned about the hog facilities because it seems like I can smell the odor almost everywhere I go.

6. The hog facilities make it more difficult for me to breath. I believe that the hog facilities cause me to sneeze and my nose to stop up. I have a brother who lives next door to me who can hardly breathe. He has asthma. He's had this issue for about twenty years, so about the same time that the hog facilities have been nearby.

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7. The hog facilities have a very bad smell. They attract flies and the flies cover up my car port. I can't cook outside because of the smell and because of the flies. The odor is worse than anything anyone would ever want to inhale.

8. I have had these concerns about the odor, the flies and my families' well-being ever since the hog facilities were built—that's been about twenty years.

9. The hog facilities affect the whole community because of the odor. People in the community have the same problem as I have; they can't have cookouts or spend much time outdoors without flies and odor.

Activism around the Hog Facilities

10. If I could change the practices at these hog facilities, I would change the way the hog farmers spread the waste out in the fields. Everyone can smell it if they're close by. I think the hog farmers should do it a different way.

I declare under penalty of perjury that the foregoing statements are true and correct to the best of my knowledge, information, and belief.

Executed in Pink Hill NC, North Carolina on August 30, 2014.

Signed: Beaford Lee Outlaw
Beaford Lee Outlaw

ED_001369_00043850-00057

Address: 1445 Sarecta Road, Pink Hill, NC 28572

Addressee: Beaford Lee Outlaw

Map radius: Approximately 1 mile

Source: Google Maps

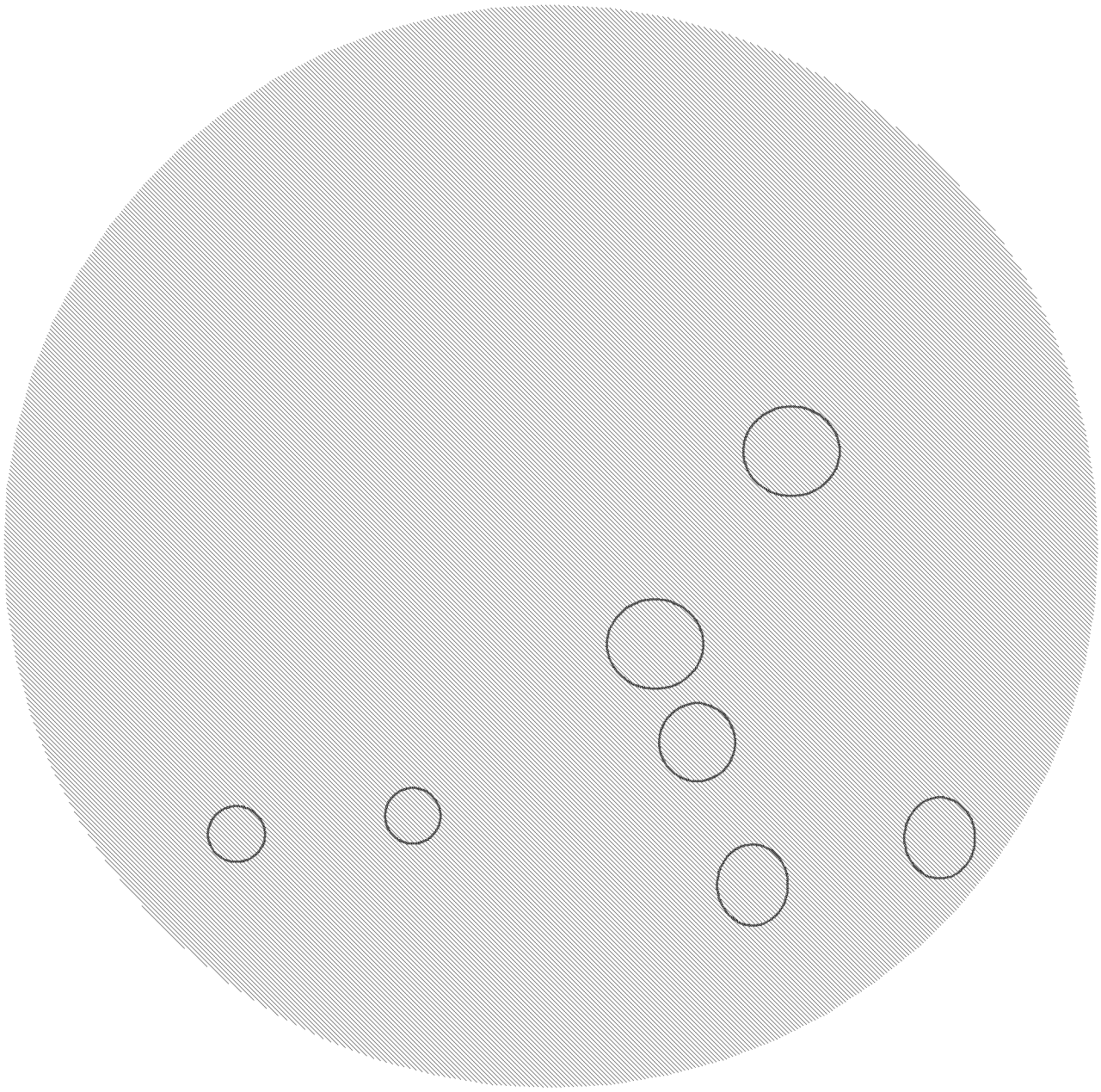

Exhibit 32

DECLARATION OF STELLA SMITH

1. My name is Stella Louise Smith. I am of legal age and competent to give this declaration. All of the information in this declaration is based on my own personal knowledge unless otherwise indicated.

Background

2. I am African-American. I live at 803 S. Jackson Street in Beulaville, Duplin County, North Carolina. (See Attached Map). I've lived here for ten years. I am sixty-one years of age.

3. The closest animal operations are about one and a half miles away. I also know that there are farms in Hallsville which is about five miles from here.

4. Before I moved to Beulaville, I lived on 1388 Sarecta Road in Pink Hill, with my son and two daughters. I owned the home. There were hog farms near my home there.

5. I have returned to work as a CNA (Certified Nursing Assistant). I work at the Warsaw Health and Rehabilitation center at 1609 Sunchase Drive in Warsaw. When I go to work, I travel from Beulaville to Hallsville, through Kenansville, and then to Warsaw. I see the hog farms all along the way. They're everywhere.

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Experience with Hog Facilities

6. I have three children: a son and two daughters.

7. I raised my family on Sarecta Road in Pink Hill, near hog farms. I think my son was affected by living next to the hog farms. He had a lot of health problems and it affected his schoolwork. I had to drive him back and forth to the doctor in Wilmington a lot of the time.

8. I noticed the hog and chicken farms when I lived at Sarecta Road in Pink Hill. They would spray in the afternoon. When they sprayed, the smell would last for about three or four days. They would spray the chicken waste in the fields right across the street. It was terrible.

9. When they sprayed the hog waste, I could smell the waste. I could smell the dead hogs on the trucks that passed by, and I could smell the fluid they left on the road. I could smell it from miles away.

10. My children played outside a lot when I lived on Sarecta Road. They didn't like that smell at all. When they smelled it, they came back inside.

11. I liked to dry my clothes outside, but when it smelled outside, I had to take my clothes to a laundromat.

12. My family and I drank from a well when we lived on Sarecta Road. It tasted bad, like rotten eggs. I think the hog farms made the water taste bad.

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13. I've had allergies my entire life. Sometimes my allergies are worse than other times. My allergies are much worse in the winter. Because of my allergies, I can't hear out of my ear. Sometimes my eyes are runny. I think the hog farms could be contributing to my allergies.

14. My main concern about the hog farms is the smell. It gets in my hair and it gets on my clothes. Other people can smell it on you. It's a terrible smell. It makes me sick. I smell it when I'm driving. Even when I roll up my windows, the smell still comes in my car.

15. My grandchildren live in Beulaville, near me. Where I live, we don't smell it very much so it doesn't affect them as much when they play outside. They're more affected by the smell when their parents take them to play at other places around here.

16. I go to church at Graham Chapel Church in Sarecta. We can smell it at the church when they spray. Most of our activities are inside the church. We don't have activities outside because we don't like to have to go back inside if they spray.

17. My brothers who like to go fishing can't go fishing anymore because there's green stuff that grows in the water. I think the green stuff could be growing there because of the waste from the hog farms.

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18. The hog farms affect our community because we can't have cookouts because of the smell and the flies. The smell and the flies are terrible so we can't spend time outside.

Desire to Change the Industrial Hog Farm System

19. I attend the Rural Empowerment Association for Community Help (REACH) meetings. I've been attending for about two years. It's very interesting and they're very serious about stopping how hog farms harm people. They have speakers from Raleigh and other different places. I try to attend all the REACH meetings.

20. I have a concern about the water we drink and the way the air smells. I am concerned about the health of the food we eat.

21. I don't think it's fair that we have to live in these conditions.

22. I feel like the hog farms are a civil rights issue. They don't put the hog farms where white people live — why are they only putting the hog farms where black people live? I don't think what they're doing is right. They're not being fair about it.

I declare under penalty of perjury that the foregoing statements are true and correct to the best of my knowledge, information, and belief.

Executed in Pink Hill, North Carolina on August 30, 2014

ED_001369_00043850-00063

Signed: Stella Smith

Stella Smith

ED_001369_00043850-00064

Address: 803 S. Jackson Street, Beulaville, NC 28518

Addressee: Stella Smith

Map radius: Approximately 1.5 miles

Source: Google Maps

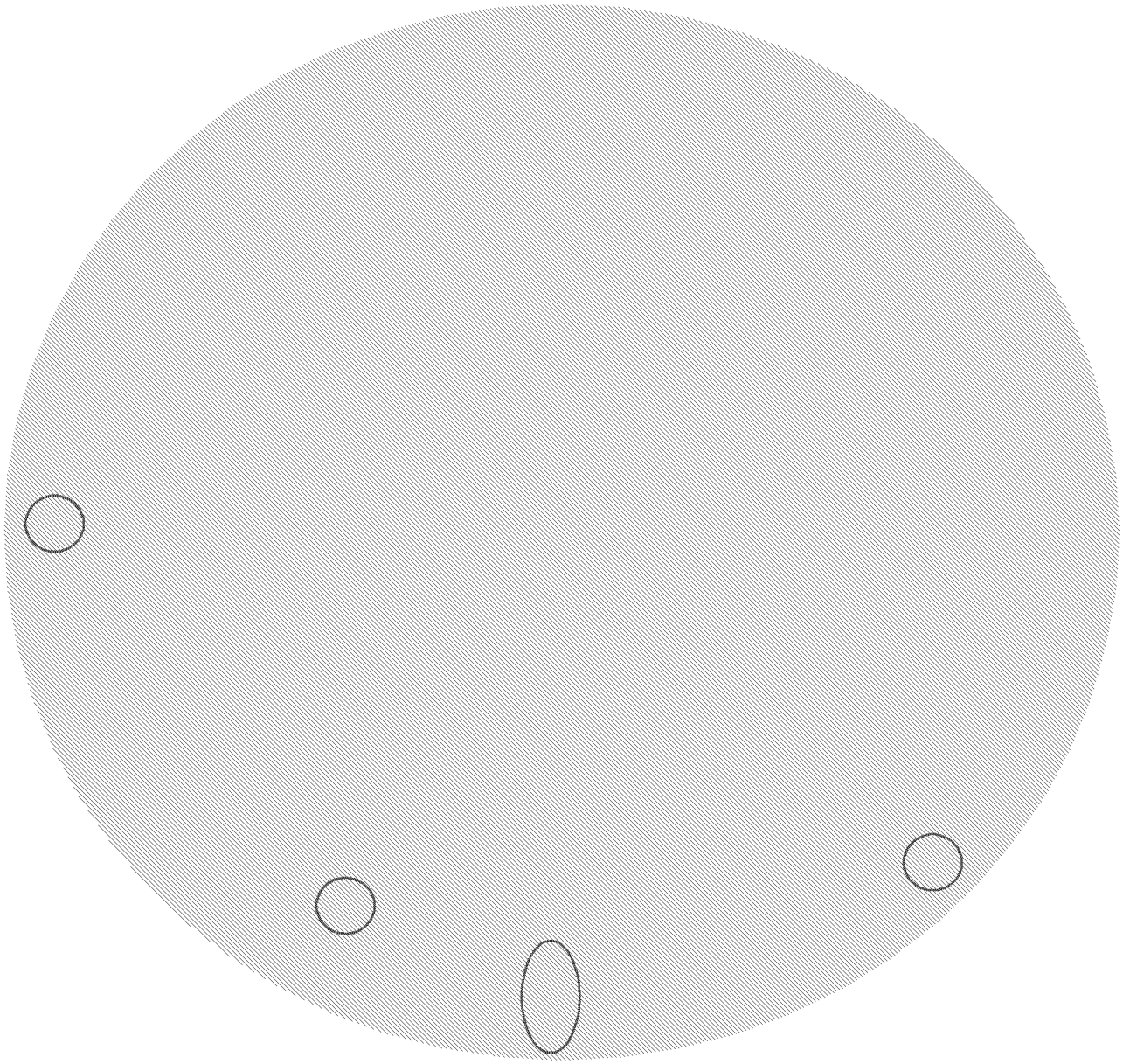

Exhibit 33

DECLARATION OF LATONGIA TYRANCE

1. My name is Latongia Tyrance. I am of legal age and competent to give this declaration. All of the information herein is based on my own personal knowledge unless otherwise indicated.

Background

2. I live at 1451 Sarecta Road in Pink Hill, Duplin County, North Carolina. (See Attached Map). I am fifty-one years old. I live here with my mother, Hannah Fullwood. She's eighty-five years old and will be eighty-six on September 5th, 2014. I have lived at this address, on and off, for forty-one years out of my fifty-one years.

3. The nearest hog farm from here is about half a mile away.

4. I also lived at 668 Sarecta Road in Kenansville; there were hog farms near there as well. I lived at that address for ten years. The closest hog farm to that location was a half-mile away.

5. I am a CNA (Certified Nursing Assistant). I work part-time, about 20 hours a week. I travel from one place to another for my work and I encounter hog farms when I travel.

Experience Living Next to the Hog Farm

6. I have health conditions related to hog farms. When the fields are being sprayed, my allergies and sinuses act up. I get sick to my stomach and throw

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up. When the smell starts, I have to turn on the air conditioning, keep the windows up, and I can't hang my clothes outside. It's an awful smell. The smell stays around for four to five days when it's raining. I try not to go out when it's like this, but I have to because I have to go to work.

7. I have talked to my family and friends about how I feel about the spraying. I tell my mother that I can't stand this smell. I have to shut myself into the house because every time I come outside, it makes me want to throw up.

8. I have concerns about air quality. I think that the air we breathe, which is polluted from the hog farms, could cause health problems and we would not know until later that it caused our health problems. I am concerned for the children in my family. I worry about my grandsons. One is eight years old and the other is eighteen. I feel like their health is at risk because they are exposed to hog farms. One lives in town, in Kenansville, and the other lives in Rockingham. They come to visit occasionally.

9. We have concerns about the property value. I think it would be difficult for my mother to sell the house because of the problems from the hog farms and the chicken farms.

10. The chicken houses are really bad. There is one that is very close to the house—we can see it from our window. The chicken houses smell bad because of the chicken litter piled up. They gather it up in the truck and they go out and

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spray it up and down in the fields. You know when they're spraying it over the fields because everything is going in your nose if you have your window down. They spray it when it's still dry so it ends up blowing in your house, in your car, on your clothes, and in your nose. I stopped drying my clothes outside and now I have to spend money to dry my clothes. I have to spend money to spray my house because of the odor. I have to spend more money keeping the air conditioner on so I don't have to smell that bad smell.

11. I only dry my clothes out on the line in the winter because the smell isn't as bad from the hogs and the chickens. It's still there in the winter time, but it's not as bad because they're not producing as much. In the spring, the summer, and the fall, it just stinks—the smell from the hog and chicken farms is sickening. In the summertime, there's more heat and the wind blows and it carries the smell.

12. In the summer, the smell from the hog farms affects how much time we spend outside. We'd like to have cookouts or play outside with my grandkids, but when they start spraying my grandson will say, "It stinks out there. I'm ready to go home." We have to find somewhere to take him so he can play or we have to go inside. We would have to go somewhere like Jacksonville or we'd have to spend money to do activities inside to keep him from breathing that bad air.

13. The smell is much worse than it used to be because it seems like they're spraying hog waste and spreading more chicken waste than they used to.

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14. I've lived here most of my life and it didn't use to be this bad. The Black farmers used to have their hog pins and their hog pastures far away in the woods. Now these new farmers have them right next to the road where everyone can see them—and smell them. I started to notice the hog farms being closer to where we lived about ten years ago. I started noticing the spraying when I started smelling it. This was when my husband and I moved back from Jacksonville, ten years ago.

15. The only time I can go outside is when I go within the city limits. Then I can go outside and go to a cookout with family or friends. We can't have cookouts around here because we have to wait three or four days after they spray. We don't know when they're going to spray, but we do know that we have to wait that long before we can do anything because the smell is unbearable. We can't have cookouts when the smell is bad because of the flies. The flies are really bad for those three days after they spray. They cover the windows and we have to make sure we shut the door and there aren't any holes in the screen door because the flies will come in. It's a nuisance to deal with the smell, the flies, and the throwing up, because the smell is so sickening. We can't sit out on our porch and laugh and talk with family.

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Advocacy Against Industrial Hog Farms

16. I have never tried to advocate with others to make this situation better. I'm going to start going to Rural Empowerment Association for Community Help (REACH) meetings in Warsaw. They advocate to make life better for people that live around hog farms.

17. I'm worried about my grandchildren because their immunity may not be as strong as ours is. They could get sicker than me from the hog farms.

18. I wish that they could control the smell. I would like to go back to my normal life and live comfortably.

19. I believe that industrial hog farming is a civil rights issue. The farms are located in Black neighborhoods and poor areas.

I declare under penalty of perjury that the foregoing statements are true and correct to the best of my knowledge, information, and belief.

Executed in Pink Hill, North Carolina on August 30, 2014

Signed: Latongia Tyrance
Latongia Tyrance

ED_001369_00043850-00071

Address: 1451 Sarecta Road, Pink Hill, NC 28572

Addressee: Latongia Tyrance

Map radius: Approximately 1 mile

Source: Google Maps

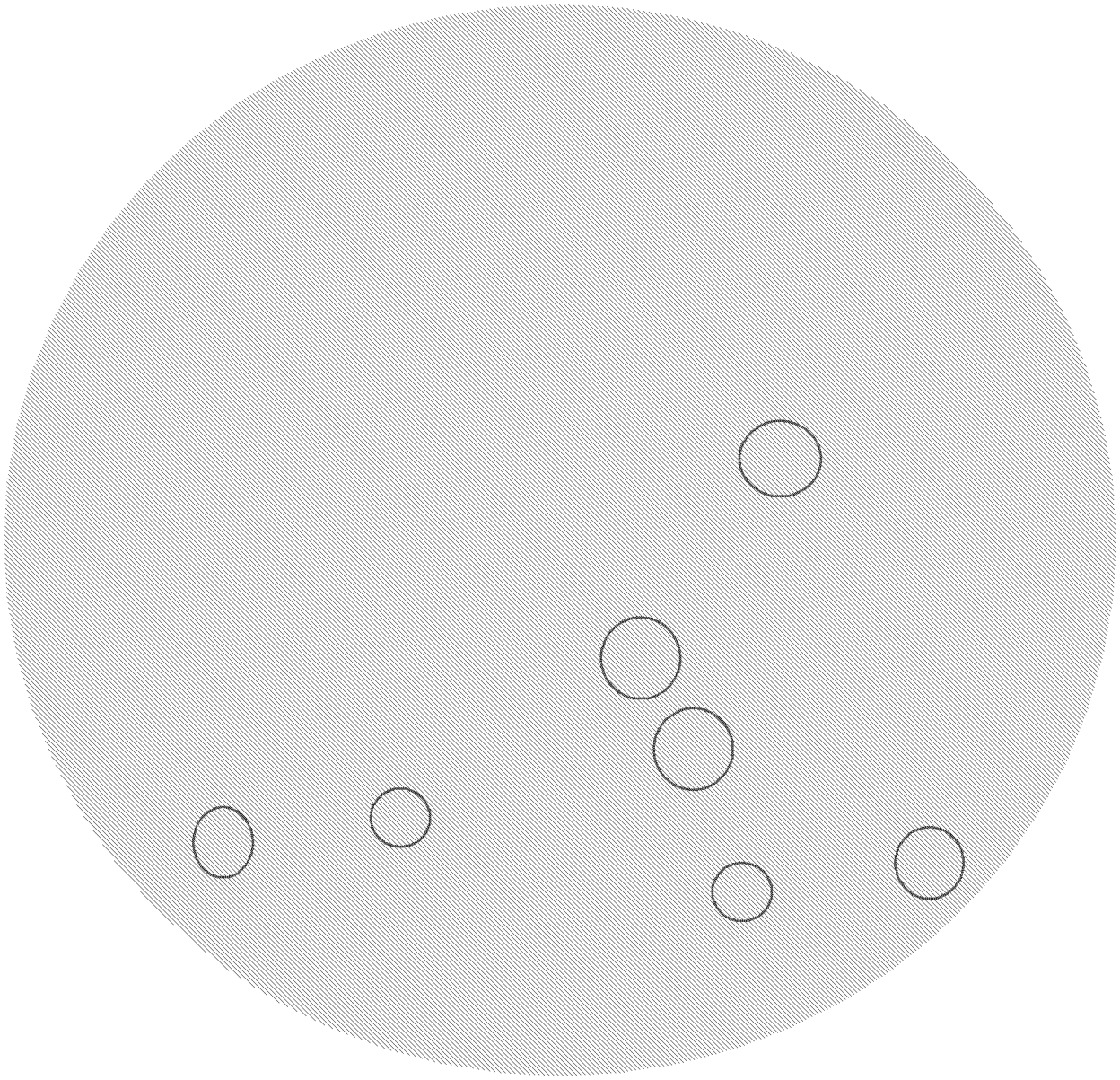

Exhibit 34

DECLARATION OF BENNIE WALLACE

1. My name is Bennie Wallace. I am of legal age and competent to give this declaration. All of the information in this declaration is based on my own personal knowledge unless otherwise indicated.

Background

2. I live at 233 Sarecta Road in Kenansville, Duplin County, North Carolina. (See Attached Map). I own my home and I have lived there for six years. Before I moved back to Kenansville, which is where I'm from originally, I lived in Brooklyn, New York.

3. I am African-American. I am seventy-four years old. I retired from driving trucks in 2005, and spend a lot of my time at home.

4. The nearest hog farm from my home is about half a mile away, right across the field.

5. I talk with neighbors about that hog farm and how it smells—and what we could do about it. I attend the Rural Empowerment Association for Community Help (REACH) meetings to learn about what's happening and to find out if there is anything that we can do about it.

6. I enjoy hunting. Every year I hunt from October to New Year's. I have a hunting dog. When I go hunting, I am about 50 feet from the hog farm that is closest to where I live. It smells even worse when I am so close to it.

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7. I have well water but I don't drink it–it's polluted. If it rains a lot, I can smell the hog waste in my well water, so I don't drink it. In 2009, I had my well water tested and I was told that it was not safe to drink. At that point, I decided to buy water. I spend about $10 a week on bottled water. I spend $5 dollars on a case and I buy two cases every week.

8. Because of the smell from the hog farms, I rarely go outside. The rain brings the smell around. I used to smell it every day depending on how the wind was blowing.

9. I can't keep the windows open in my home because of the smell from the hog farms. I can also smell the hog farms at the senior citizen building that I go to in Kenansville, on Routledge Road. There's a hog farm about a mile away from there. Between the chicken farms and the hog farms, it smells really bad.

10. I wish they would change how they spray the waste and how they maintain the open lagoons. I wish they'd close the hog farms.

11. African-Americans are more affected by the hog farms because the hog facilities are located in the Black people's communities.

12. I never expected to face the problems from the hog farms when I moved back from Brooklyn to North Carolina. When I moved away there weren't big hog farms like this. Now that I've come back home, the area is surrounded by them.

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I declare under penalty of perjury that the foregoing statements are true and correct to the best of my knowledge, information, and belief.

Executed in KENANSVILLE, NC North Carolina on August 30, 2014

Signed: Bennie Wallace
Bennie Wallace

ED_001369_00043850-00076

Address: 233 Sarecta Road, Kenansville, NC 28249

Addressee: Bennie Wallace

Map radius: Approximately 1 mile

Source: Google Maps

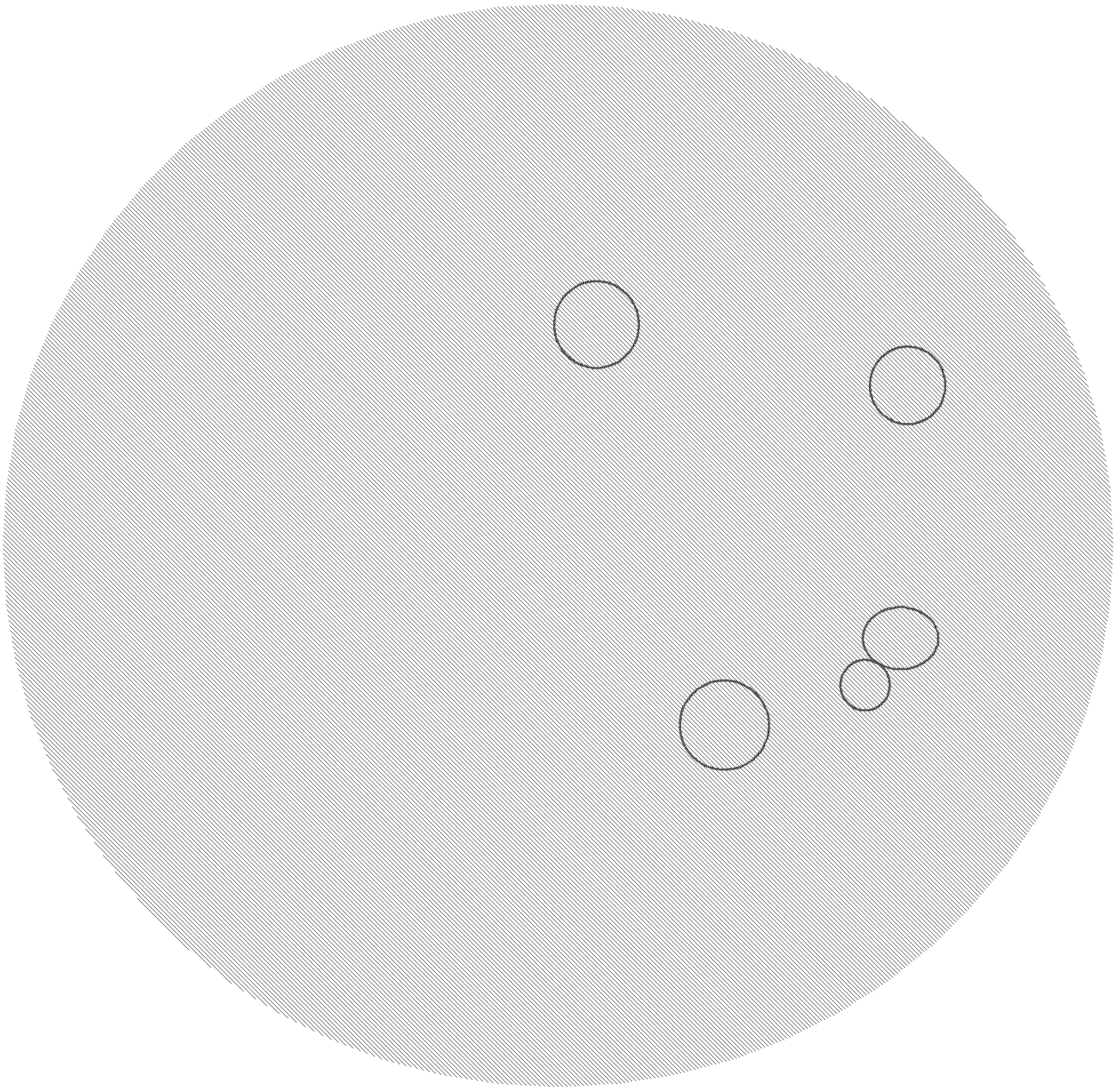

Exhibit 35

DECLARATION OF SANDRA WALLACE

1. My name is Sandra Wallace. I am of legal age and competent to give this declaration. All of the information herein is based on my personal knowledge unless otherwise indicated.

Background

2. I am a 47-year old African American woman.

3. I live at 65 Alexander Road in Clinton, North Carolina. I live with my daughter, Roxanne Carroll, and my partner William Carroll. My daughter is 25 and William is 52. I have lived here for 30 years. I own the land and my home.

4. I grew up in North Carolina and have lived in this area all of my life.

Experience Living Near Hog Facilities

5. There are at least one hog facility and two sprayfields very close to my home. The hog houses are across the street from my home. There is a sprayfield across the street and another in the woods behind my home.

6. A map showing my house and the surrounding hog facility and sprayfields is attached as Exhibit 1. Maps showing the many hog facilities near my house are attached as Exhibits 2-3.

7. My daughter was born early. She was about 2.4 pounds when she was born. She has cerebral palsy and asthma. Her sinuses are very bad and she has bad allergies. If she's around a hog facility, I can tell it is having an impact.

8. The odor from the hog facilities in this area is bad. The facility near me sprays two to three times a week. When I see the irrigation pump, I can smell the scent of hog waste. The more the pump moves down the road, away from us, the better off we are.

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9. I don't want to cook when they are spraying, even inside my house. The scent is so bad that I don't want to cook and eat.

10. My daughter likes to be outside, but I don't want her outside when it smells. I am afraid that it is not healthy for her to be exposed to the smell from the hog facilities.

11. Sometimes, when I drive in my car, like when I am taking my daughter to her school, the hog waste will fall on the windshield as I pass by the sprayfields.

I declare under penalty of perjury that the foregoing statements are true and correct to the best of my knowledge, information, and belief.

Executed in Sampson, North Carolina on 8/23/2014

Sandra Wallace

Sandra Wallace

ED_001369_00043850-00080

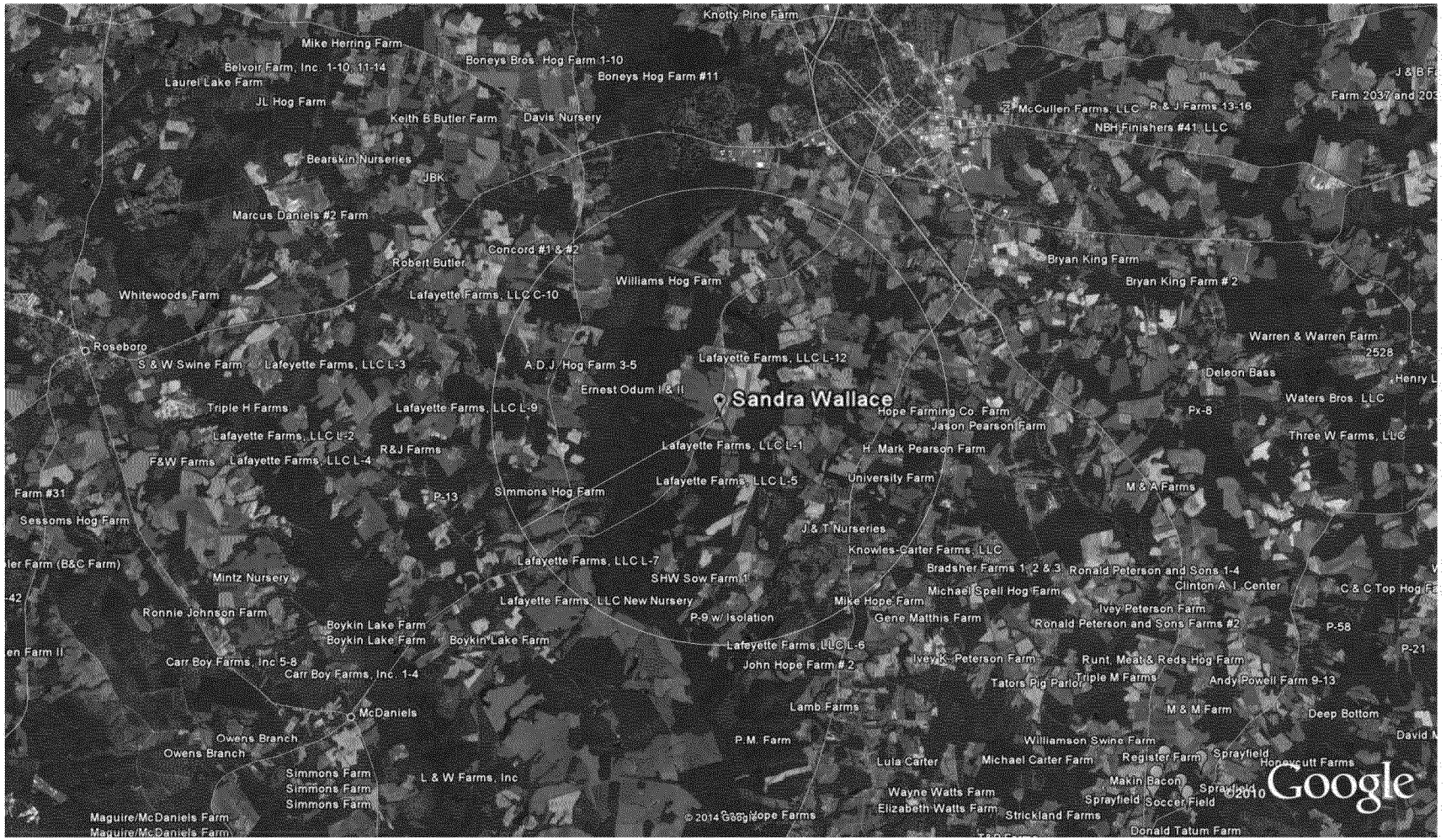
EXHIBIT 1

Sprayfield
Sprayfield
Sandra Wallace
©2010 Google
© 2014 Google

EXHIBIT 2

Lafayette Farms, LLC L-12
Sandra Wallace
Lafayette Farms, LLC L-1
© 2014 Google

EXHIBIT 3



NOTE: Map shows locations of swine facilities operating under the General Permit, as indicated in NCDENR's spreadsheet of permitted animal facilities, updated January 10, 2014. Circle shows permitted swine facilities within a 3 mile radius of Sandra's home, as calculated by Google Earth Pro.

Exhibit 36

DECLARATION OF LUBY C. WATERS

1. My name is Luby C. Waters. I am of legal age and competent to give this declaration. All of the information in this declaration is based on my own personal knowledge unless otherwise indicated.

Background

2. I am African-American. I am a member of the Rural Empowerment Association for Community Help, also known as REACH. I joined REACH in the fall of 2005 when I got involved with REACH's Duplin Environmental Health Awareness Project. Since November 2005, REACH has held monthly planning meetings for the Duplin Environmental Health Awareness Project. I decided to attend the meetings to learn about environmental health issues in my area, and to see if I could do something about the terrible smell from the industrial hog operations in the neighborhood. I also help cook and serve meals for the meetings. I have continued to attend the planning meetings from the beginning, whenever I can.

3. I live at 406 South Dobson Chapel Road in Kenansville, Duplin County, North Carolina. (See Attached Map). I live with my wife, Judy. I have lived here for more than 20 years, and my wife and I own our home. There are several farms within a half mile of my home.

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Problems living near Industrial Hog Farms

4. Since the day we moved in, we noticed the smell from the industrial hog operations. The closest hog facility to my house is less than a mile away. Within four miles, there are other large operations.

5. I think the smell comes from the facilities that are on the other side of Route 50 from my house. I can smell the hog waste while I'm driving to-and-from my home. Even if I have the windows up and the air conditioning or heating is off, the smell is intolerable.

6. The lagoons make the air smell terrible. It's much worse when the facilities scrape the bottom of the lagoons—I see it when they spray it in the fields and it looks blue. The smell is much stronger.

7. I can often see the spray when it's released. The sprayer shoots a stream of liquid in the air. The hog facility that is close by has a big operation. I can tell this because his lagoon is located right in front of his hog house, while most of them are behind the hog houses. This makes the smell stronger than the other hog facilities.

8. My wife and I don't hang out laundry to dry because we don't want the scent of the hog waste to get in the clothes. We keep the windows closed to

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keep out the smell, but even with the windows closed, the smell gets in the house. I'd like to have the windows open on nice days, but the smell is too unbearable. We also don't cookout very much either, because we don't want to be outside. Even if I keep the windows closed, the smell gets in my house.

9. We never know what days the smell is going to be at its worst. If the wind is blowing west-to-east, we are directly affected by it, but if the wind is blowing north-to-south, it won't affect us as much. We have noticed, however, that it smells worse right before it rains.

10. I like to garden. I plant all kinds of vegetables, including potatoes, onions, collards, turnips, and butter beans. But I can't spend as much time outside gardening as I'd like. Sometimes, when the wind is just right (blowing west-to-east), the smell from the hog facilities hits me and I have to go inside.

11. About 15 years ago, Duplin County officials came by our place and put us on a metered well. When we had the well, the water would often overflow. Water would bubble up out of the ground all day long because the ground was so saturated. We live right over a spring running under our house so if you were to put a hole in the ground, you'd get water coming out of it.

12. In 1999, Hurricane Floyd came through and the area flooded. After the flood, officials hooked us up to city water. During the flood, all the water came out of the lagoons and the spill over-contaminated the wells. There was talk about

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it in town. That's when county officials hooked us up to the city water supply. Even after Hurricane Floyd however, some people are still using their well water. I wanted to be hooked up to city water. I knew that sooner or later, the wells were going to get contaminated. Where my wife and I live now, we have well water access, but the county officials don't want us to drink it— they won't tell us why.

13. I enjoy spending time outdoors. I fish and hunt in the woods near where I live both for sport and for food for my family.

14. I used to enjoy fishing in Stocking Head Creek, near where the Creek flows beneath Stocking Head Road Bridge. There are industrial hog facilities all along Stocking Head Creek. I used to fish in Stocking Head Creek every week in the springtime. I used to catch pike, bass, perch, and blue gills. Then one day a few years ago, when I was fishing in Stocking Head Creek, I saw a dead hog caught in some of the bushes in the water. I was shocked and upset, and became concerned about water quality. Then I noticed that the water looked dirty and there was white foam on the surface. Then I remembered that I had caught fish here with sores on them. I had thought that the fish might have been bitten by other fish, but from talking with others at REACH, I now know that the fish were likely affected by lagoon wastewater runoff. After seeing the dead hog in the water, I decided I would never fish in Stocking Head Creek again.

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15. I also don't fish in the Cape Fear River anymore because the polluted creeks run into the river. I am concerned that there is hog waste contaminating the river so I stopped fishing here. I've also seen dead hogs in the river, which I know must contribute to the poor water quality.

16. I also used to enjoy hunting near Stocking Head Creek, close to where the Creek passes beneath Stocking Head Road Bridge. I used to catch squirrels, deer, and raccoons. But, when I saw a dead hog in Stocking Head Creek and realized how dirty the water was, I understood that the animals I hunted might also be sick and unsafe to eat. From that day forward, I decided I would stop hunting near the Creek. If I hunt anywhere else, I have to wear a mask because of the smell.

Health Issues

17. I have some health problems that I think might be affected by the hog facilities. In the early 1990s, I was hospitalized for 21 days for a bad case of pneumonia. While I was in the hospital, my lung collapsed. I'm worried about my lungs. I've been coughing on and off for the past three years, and I'm worried that my lung might collapse again. Sometimes my coughing keeps me up at night. I cough more when the smell from the hog operations is at its worst.

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18. I also have high blood pressure. I've been taking medicine for my high blood pressure for 10 years. I understand that living near hog facilities can increase my blood pressure, and this worries me.

19. My wife is not very well. She is on a lot of medicine and coughs a lot. I am worried that it is not good for her to live near these hog facilities.

20. I've never seen anything like these industrial hog farms before I moved here, to Duplin County. I think more African Americans are affected by the hog facilities because I see most of the hog facilities concentrated in mainly African-American communities. I wish it could be stopped altogether.

21. I used to do advocacy against the hog farms and I've done interviews about the hog farm smell. This was approximately eight or nine years ago.

I declare under penalty of perjury that the foregoing statements are true and correct to the best of my knowledge, information, and belief.

Executed in Duplin County North Carolina on August 30, 2014

Signed: Luby C Waters
Luby C. Waters

ED_001369_00043850-00090

Address: 406 S. Dobson Chapel Road, Kenansville, NC 28349

Addressee: Luby Waters

Map radius: Approximately 2 miles

Source: Google Maps

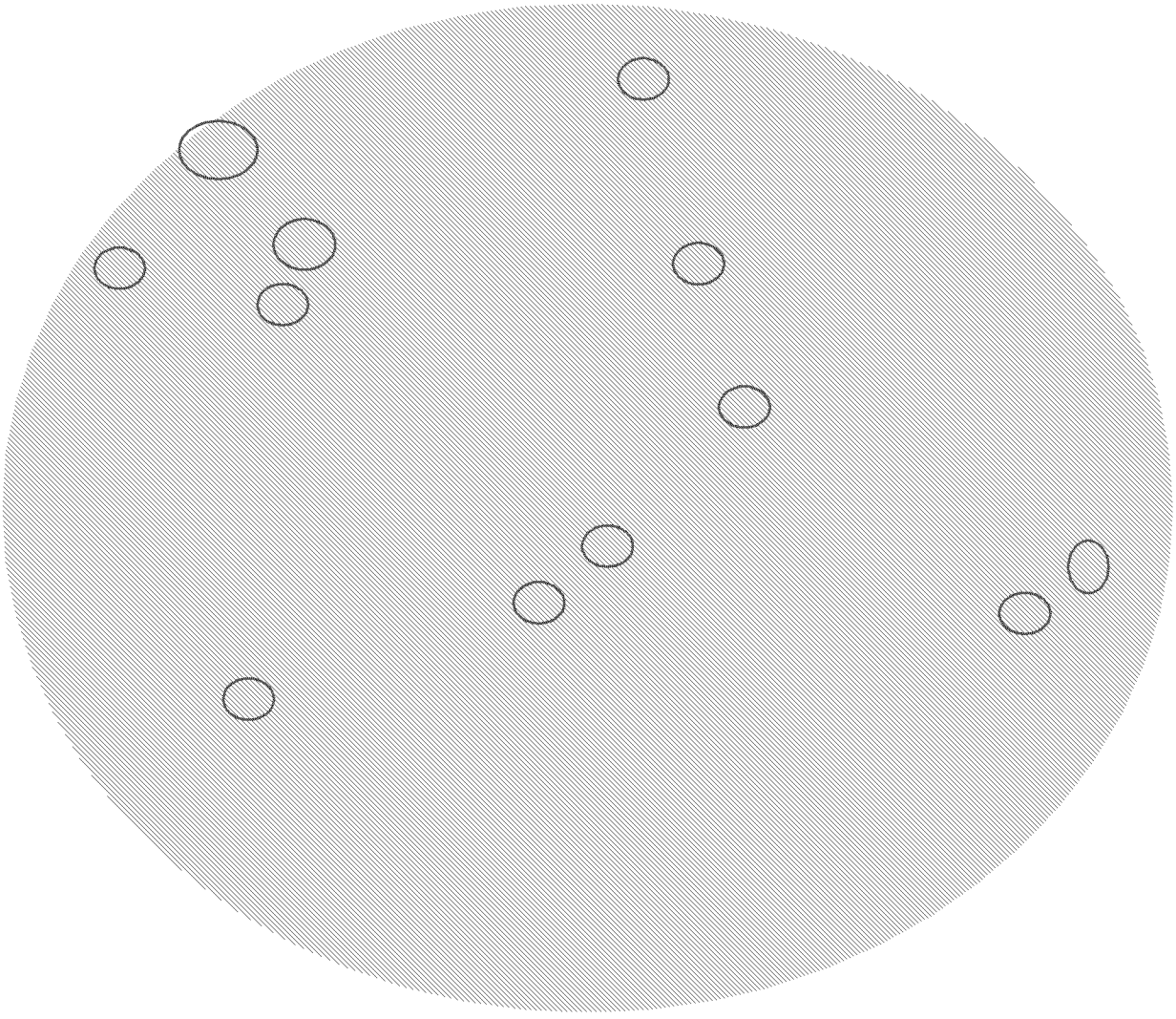

Exhibit 37

Detection and occurrence of antimicrobially resistant E. coli in groundwater on or near swine farms in eastern North Carolina

M.E. Anderson and M.D. Sobsey

University of North Carolina at Chapel Hill, School of Public Health, Rosenau Hall CB#7400, Chapel Hill, NC 27599-7400, USA (E-mail: meanders@oddpost.com)

Abstract The use of antibiotics for growth promotion and disease treatment by the commercial swine industry has led to high proportions of multiple antibiotic-resistant enteric bacteria being shed by these animals and concerns about the environmental spread of these bacteria. A study was conducted to quantify the extent of release of antibiotic-resistant E. coli from swine farms into groundwater. Four study sites, two swine farms and two reference sites (crop farms), with known groundwater flow paths were screened for E. coli four times over the course of one and a half years. A total of 100 biochemically-confirmed E. coli were collected from the four sites. There were statistically significantly higher E. coli levels at the two swine farm sites than at the reference sites. The bacterial isolates were tested for antibiotic resistance using a panel of 17 drugs that are typical of human and veterinary use. There were 19 and 71 E. coli isolates from swine farms #1 and #2, respectively, with most (68%) being resistant to 1–6 antimicrobials. Only one E. coli isolate from each of the reference sites showed antimicrobial resistance traits. The results of this study demonstrate that antibiotic-resistant E. coli strains are present in groundwaters of swine farms with a typical lagoon and land application system for waste management.

Keywords Antibiotic resistance; E. coli; groundwater; lagoon; land application; swine

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Introduction

The commercial swine industry and other sectors of animal agriculture use antibiotics for growth promotion and disease treatment, which has led to high proportions of multiply antibiotic-resistant enteric bacteria being shed by these animals. There are growing concerns about the spread of these bacteria through the food production chain and into the environment (Tollefson et al., 1999; Teale, 2002). North Carolina is second in swine production in the USA with nearly 10 million animals raised on more than 3,000 farms (predominantly in the eastern coastal plain regions of the state). The porous soils and seasonally high water tables of this region can cause underlying groundwater to be vulnerable to surface contamination from a variety of sources including human and animal wastes. Previous studies have documented groundwater contamination by nitrates in the vicinity of swine farms, especially near the anaerobic lagoons in which swine waste is stored prior to periodic land application of the lagoon liquid (Stone et al., 1998). Little is known about the extent to which swine farm wastes pose enteric microbial contamination risks to groundwater.

E. coli bacteria are universally present in faeces of all mammals at levels of over one billion/g faeces and the most faecal-specific member of the coliform group (Edberg et al., 1997). Hence, E. coli is considered the definitive organism for demonstrating faecal pollution in water at least in temperate climates (Anon, 1987). Because E. coli provides evidence of a public health risk from enteric pathogens, there is zero tolerance for them in 100 mL volumes of drinking water. E. coli is considered a practical microbial indicator for public health protection and is

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recommended by the WHO (Edberg et al., 1997; WHO, 2004). The half-life of E. coli is conservatively estimated to be at least 8 d under groundwater conditions. Therefore, the recovery of E. coli from a contamination event should be possible for weeks although the large dilution factor of aquifers must be taken into consideration (Edberg et al., 1997).

Bacterial multi-drug and pan-resistance to antimicrobials is an important emerging public health issue. Resistant bacteria are spreading outside of hospitals, which are the traditional USA reservoir (CDC, 2002). Approximately half of the antibiotics produced globally flow into the agriculture industry and are used for infections and as growth promoters. High percentages of antimicrobial resistant bacteria in livestock waste and human exposure to agricultural animal faecal bacteria via food and occupational exposure have been documented (McDermott et al., 2002). The range of pathways of exposure to these resistant bacteria must be established. Waterborne exposure is a possibility through drinking and recreational water that is contaminated with farm-origin antimicrobial resistant bacteria. The stability of resistant strains of bacteria in the environment has been demonstrated (Marshall et al., 1990). Pigs were inoculated with an antimicrobial resistant strain of swine E. coli and the resistant strain was found in water, bedding materials, mice, flies and a human caretaker during the 4-month follow up period. Mathew et al. (1999) determined that resistance patterns differed between farm types and pigs of differing ages, indicating that pig age and degree of antibiotic use affect the resistance of faecal E. coli. Therefore, as antibiotic use changes, so do bacterial patterns of antibiotic resistance.

The purpose of this study was to quantify the presence of antibiotic-resistant E. coli in groundwater on commercial swine farms and to determine if there was a relationship between current swine waste management practices in eastern North Carolina and microbial impacts on groundwater quality.

Materials and methods

The four study sites, located in the Neuse River Basin in eastern North Carolina and having US Geological Survey (USGS) monitoring wells and known groundwater flow paths (Spruill, 2000), were screened for E. coli in groundwater. Swine farm #1 had swine from the feeder to finish stages and a design capacity for 5,000 animals. The swine waste was flushed from the barns with water and entered an anaerobic lagoon at the end of the barns, via pipes, where it was stored and partially treated prior to land application. The lagoon liquid was applied to fields surrounding the lagoons via pumps taking material directly from the upper level of the lagoon and applying it with a sprayer. There were 25 groundwater wells at this site including those located up and down gradient of the lagoon and in the middle of the sprayfields. Swine farm #2 was a farrow to finish swine operation with a design capacity for 1,500 animals. This facility had an alternative swine waste treatment technology in which the waste solids were removed from the barn flush and de-watered by compaction. The solids were applied to the field and the liquid stored in a lagoon prior to land application. There were 12 groundwater wells at this site, all located down-gradient of the swine barns and lagoon in relation to groundwater flow. The third site (reference #1) had crops such as corn, soybeans, and wheat growing on the field that formed the groundwater recharge area for the wells. Commercial fertiliser of unknown quantity was applied on two dates prior to the onset of sampling,and a small herd of beef cattle were allowed to graze approximately 25 m up gradient from the location of the wells. There were a total of seven groundwater wells at this site. The fourth site (reference #2) was a crop farm where there was no land application of swine waste or any agricultural animals present. The study site consisted of an upland field

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where corn, soybeans, wheat and tobacco were grown and there were a total of six groundwater wells.

Groundwater samples were collected aseptically as grab samples in sterile 4 L bottles and placed in coolers with freezer packs. The collection pump tubing was cleansed with 70% ethanol between samples to prevent cross-contamination of the water samples from well-to-well. Water samples were analysed for E. coli within 30 h of collection. Four seasonal rounds of groundwater samples at each site were collected and analysed for E. coli over the course of one and a half years. Water samples were filtered (47 mm, 0.45mm cellulose ester filters in sterile membrane filter apparatus) with each membrane being placed on mFC agar and, after overnight incubation, transferred to nutrient agar with MUG (NA-MUG) and incubated according to standard procedures (APHA, 1998).

Selected E. coli colonies from NA-MUG were picked and streaked onto tryptic soy agar for purification and subsequent biochemical characteriation by Enterotube II (Becton Dickenson, Sparks, MD) using E. coli (ATCC 25922) as positive control for the confirmation tests. Confirmed E. coli isolates were subjected to antibiotic susceptibility testing using customised commercially prepared plates (Sensititre 18–24 Hour Susceptibility System, TREK Diagnostics Inc., Westlake, OH). Minimum inhibitory concentrations (MIC) were determined for 17 antimicrobials encompassing those commonly specified for human therapy and for veterinary use in swine and cattle (Table 1). E. coli isolates were first grown on tryptic soy agar and 3–5 colonies were picked and resuspended in 4 mL sterile deionised water to give a turbidity of 0.5 MacFarland units. This suspension (10mL) was transferred to 50 mL Mueller Hinton broth. After vortexing, 50mL were transferred to each well of the custom plate. The plate was then sealed and incubated at 378C for 18–24 h. The plates were read by scoring for a collection of bacteria at the bottom of a well as positive. Three positive control wells were included within the plate for quality control of the test; including E. coli (ATCC strain 25922).

Table 1 Antimicrobials, dilution ranges, and MIC breakpoints

Antimicrobial	Approved for use in			Abbreviation	Dilution range (*m*g/mL)	MIC breakpoints
	f	d	h			
Streptomycin	X		X	STR	32–1024	R $ 64; S $ 32
Vancomycin				VAN	8–256	R $ 32
Chlortetracycline	X			CTET	0.5–64	R $ 16; S $ 4
Tetracycline	X		X	TET	0.5–64	R $ 16; S $ 4
Trimethoprim			X	TMP	2–64	R $ 4; S $ 2
Sulfamethoxazole	X		X	SMX	32–1024	R $ 512; S $ 256
Chloramphenicol			X	CHL	4–128	R $ 32; S $ 8
Tiamulin	X			TIA	8–64	R $ 32
Erythromycin		X	X	ERY	4–32	R $ 8
Enrofloxacin				ENRO	1–16	R $ 4
Ciprofloxacin			X	CIP	1–16	R $ 4; S $ 1
Neomycin	X			NEO	16–128	R $ 32
Gentamicin		X		GEN	4–256	R $ 16; S $ 4
Ampicillin		X		AMP	8–128	R $ 32; S $ 8
Florfenicol				FFN	4–128	R $ 16
Tylosin Base	X			TYLB	5–80	R $ 16
Clindamycin			X	CLI	1–32	R $ 4

f ¼ approved for use in swine feed (growth promotion); d ¼ approved for use as injection or water soluble (disease treatment); h ¼ approved for use in humans

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Results

E. coli occurrence in groundwater

A total of 134 presumptive E. coli were collected from the four sites with 100 confirmed as E. coli through biochemical testing. Swine farm #1 yielded 19 E. coli colonies in the groundwater. Only one E. coli colony was found in two wells each in the first round of sampling (March/May 2001): one well was located in the middle of a land application sprayfield and one well was located down gradient of the swine waste lagoon. The second round of sampling (February/April 2002) had higher E. coli concentrations with five positive wells and concentrations of 1–6 CFU/100 mL. The positive wells were two shallow wells located in the middle of sprayfields, two wells located at the edge of a sprayfield and one well located down gradient from the swine waste lagoon. The third round of sampling (May/June 2002) yielded only one E. coli colony that was located in one of the control wells up gradient of the swine farm. The fourth round (September 2002) yielded no E. coli colonies in the groundwater at all due to continuing drought conditions and several wells were unable to be sampled due to a lack of water in the wells. Overall, E. coli were found more often, and in higher concentrations, in areas associated with the land application of swine waste (sprayfields) and in wells located down gradient from the swine waste lagoon than in the control wells at swine farm #1.

Swine farm #2 gave 71 E. coli colonies in groundwater. The first round (May/June 2001) had one well and two piezometers positive for E. coli out of the 12 total. The well averaged 16.4 CFU/100 mL and one piezometer yielded only one E. coli colony (0.5 CFU/100 mL). The second piezometer had 1,045 CFU/100 mL and inspection of the piezometer proved that it might be a conduit for contamination in the aquifer. This piezometer was sampled again in the fourth round and yielded no E. coli. The second round (December 2001) had four wells and one piezometer positive for E. coli (0.5–32.7 CFU/100 mL). The piezometer was close to the sprayfield and stream, two positive wells were in the sprayfield and the other two wells were located down gradient from the swine waste lagoon. The third round (April 2002) yielded only one well positive for E. coli (1.8 CFU/100 mL) and the final round of sampling (September 2002) had three wells positive with E. coli at low levels (1.0–1.8 CFU/100 mL). Round one showed higher E. coli concentrations in groundwater than all other rounds. Round two also revealed positive E. coli colonies in the groundwater samples, but by rounds three and four the E. coli concentrations were at non-detectable levels in all wells due to summer and drought conditions similar to the findings at swine farm #1.

Low E. coli concentrations (4.5 CFU/100 mL) appeared in only 1/7 wells at reference site #1 during the first round of sampling (June/August 2001) and none were detected in the subsequent three sampling rounds (February 2002, May 2002, August 2002). The positive well was located off to the east of the rest of the wells and was not in line of the groundwater flow path that the rest of the wells represented. There was the potential for cattle manure to penetrate through the soil matrix from a small herd of beef cattle (approximately 10 animals) that were allowed to graze approximately 25 m up gradient from the location of the wells. Therefore, the results from this site may have indicated bacteria from cattle sources but the absence of detectable E. coli bacteria in groundwater samples from down gradient wells suggested that their waste did not have a major impact on groundwater microbial quality during the study period. This site was considered to be an agricultural reference site because it did not contain swine or their waste material. Most of the wells at reference site #1 were deeper (10–40 ft; 3–12 m) than at reference site #2 (7–18 ft; 2–6 m). The deeper wells on this site were located below an aquiclude and were not representative of the shallow groundwaters that were yielding positive

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results at the other sites. However, the shallower wells at 10 ft (3 m) at this site were representative of the surficial aquifer but were not positive for bacteria.

Only one E. coli isolate (0.5 CFU/100 mL) appeared in 1/6 wells at reference site #2 during the first round of sampling (September/October 2001) and not in the subsequent three rounds (April/May 2002, June 2002, August 2002). The one positive well was 8.9 ft (2.7 m) deep and was located only a few metres from the surface water on the site. A prior study at this site (Fanuel, 1999) revealed that the chemistry in this well was under reducing conditions, and this study confirmed low pH (4.5–5.2) and very low dissolved oxygen levels (, 0.1 mg/L). The previous study also found that water samples from this well were chemically distinct from the other wells with significantly lower concentrations of calcium, magnesium, dissolved oxygen and more dissolved organic carbon, ammonium, and iron.

The Kruskall–Wallis x^2 test was employed to determine if there were statistically significant differences in bacteria occurrence and concentrations in all of the groundwater samples among the four study sites. The analysis was applied to all groundwater samples for all farms including samples that were negative for E. coli. These analyses revealed that there were statistically significant differences in the E. coli concentrations between the two swine farms ($p \approx 0.003$). This was attributable to the higher E. coli concentrations present at swine farm #2 and may have been due to differences in numbers of animals, waste management practices and geo-hydrological or other environmental conditions. There were also statistically significant differences in E. coli concentrations between swine farm #2 and the reference sites (#1: $p \approx 0.003$; #2: $p \approx 0.005$). However, there were no statistically significant differences in E. coli concentrations when comparing the swine farm #1 to the references sites (#1: $p \approx 0.36$; #2: $p \approx 0.41$).

E. coli antimicrobial resistance

Knowing the antimicrobial usage at the two swine farms would facilitate efforts to determine if there was a direct positive association between antimicrobial use and the presence of antimicrobial resistant E. coli isolates in groundwater on or near these farms. However, information on antimicrobial usage was unavailable and even deemed proprietary when it comes to what antibiotics are included in the swine feed. What was known was that the following antimicrobials in the Sensititre panel used for antimicrobial testing were approved for use in swine feed – streptomycin, tetracycline, chlortetracycline, sulfamethoxazole, neomycin, tiamulin, and tylosin base and that the following antimicrobials were approved for use as a water soluble diet additive or for injection to treat disease – erythromycin, gentamicin and ampicillin.

Of the 19 E. coli isolates from swine farm #1, two were resistant to two antimicrobials, three were resistant to one antimicrobial and the rest were non-resistant. Hence, 7/19 isolates (37%) had antimicrobial resistance. Of the 71 E. coli isolates from swine farm #2, 56 (79%) had resistance with nine resistant to 4–6 antimicrobials, 47 resistant to 2–3 antimicrobials and 15 non-resistant. Only 1/10 E. coli isolates from reference site #1 (10%) and the only E. coli isolate from reference site #2 displayed antimicrobial resistance traits (Figure 1).

The Wilcoxon Exact Scores test was used to compare frequencies of occurrence of antimicrobial resistance traits in individual E. coli isolates. The null hypothesis was that there would be no differences in antimicrobial resistance trait frequencies in E. coli isolates based on their sites. There were not quite statistically significant differences (at the 5% confidence level or $p \approx$, 0.05) in E. coli antimicrobial resistance trait frequencies between the two swine farms ($p \approx 0.06$). There were significant differences between the swine farms pooled together versus those at the reference sites (#1: $p \approx 0.01$; #2:

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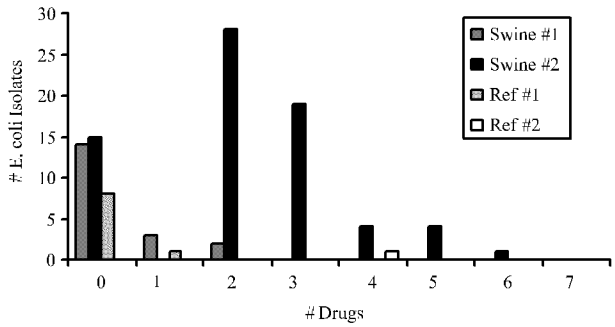

Figure 1 Frequency distribution of antibiotic resistance of groundwater E. coli isolates

p ¼ 0.003). There were also significant differences between swine farm #2 and the reference sites (#1: p ¼ 0.03; #2: p ¼ 0.009). There was no significant difference in frequency of resistance traits/isolate between swine farm #1 site and the reference sites (#1: p ¼ 0.29; #2: p ¼ 0.11) and also with the two reference sites (p ¼ 0.37). Overall, frequencies of antimicrobial resistance traits per E. coli isolate were significantly higher at swine farms than at reference sites.

MICs were generated for 17 antimicrobials of which it was expected that isolates would be inherently resistant to vancomycin, erythromycin, tiamulin, tylosin base, and clindamycin (Table 1). E. coli isolates from swine farm #1 had resistance to chlortetracycline, tetracycline and sulfamethoxazole (all approved for use in swine) (Figure 2). E. coli isolated from swine farm #2 site also had predominant resistance to tetracycline and chlortetracycline. The isolates were also resistant to ampicillin, streptomycin, chloramphenicol, sulfamethoxazole and trimethoprim, as well as florfenicol and neomycin. Of the antimicrobial resistance traits found in E. coli isolates, only chloramphenicol was an antibiotic not permitted for use in swine feed or to treat swine disease (it is a drug of last resort for human therapy). However, florfenicol is a derivative of chloramphenicol that is approved for use in cattle by the US FDA-CVM (Purdue Research Foundation, 1996). Cross-resistance between florfenicol and chloramphenicol has been seen in bovine E. coli isolates. The E. coli isolates in the study were resistant to florfenicol mediated by the flo gene, which specifies non-enzymatic cross-resistance to both florfenicol and chloramphenicol (White et al., 2001). Trimethoprim can be used to treat sick animals (but is also used for humans) and sulfamethoxazole is primarily used in combination with

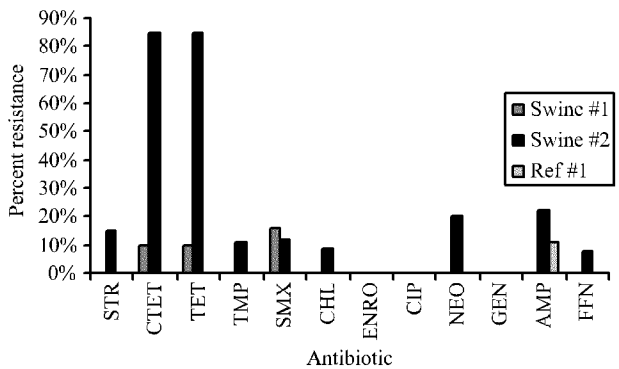

Figure 2 Drug resistance (%) of biochemically speciated groundwater E. coli isolates

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trimethoprim which might explain the presence of this resistance trait in bacteria associated with this swine farm. One in ten E. coli isolates found at reference site #1 was resistant but only to ampicillin. Reference site #2 yielded only one E. coli isolate from groundwater which was resistant to four antimicrobials – tetracycline, chlortetracycline, trimethoprim and ampicillin. This isolate came from a well near a surface water sampling site that was under reducing and low pH conditions.

Discussion

The information obtained from this study revealed that E. coli was found more frequently in groundwater on or near swine farms than on crop farms with no swine in eastern North Carolina. E. coli were found on a farm with a conventional anaerobic lagoon and sprayfield land application system, as well as on a farm with alternative technology consisting of separating, compacting and land applying the swine waste solids along with anaerobic lagoon liquid. These findings provided evidence of faecal contamination of the groundwater by swine farms. Swine farm #2 had higher concentrations of E. coli in the groundwater than swine farm #1. Swine Farm #2 was a smaller operation (design capacity for 1,500) with farrow to finish swine that separated/compacted swine waste solids and applied them to land without further treatment along with returning the separated liquid to the lagoon for subsequent storage and land application. The lack of lagoon storage of swine waste solids prior to land application at swine farm #2 may have resulted in higher loads of land applied E. coli that could penetrate into groundwater.

Swine farm #1 had sandy soils while swine farm #2 had well drained loamy sandy soils with moderate permeability. Differences in soils and in geo-hydrological conditions may also have contributed to differences in bacteria infiltration and transport through the soil matrix to groundwater on the different study sites. However, it was not possible to specifically investigate this. The detection of fewer E. coli bacteria at swine farm #1 site than at swine farm #2 could also be related to other factors that were not systematically investigated in this study (such as differences in timing/magnitude of land application of swine wastes and soil moisture content).

There were only very low levels of E. coli found in one well each during the first round of sampling at the reference sites. The one positive well at reference site #2 may have been due to (i) the combination of unique chemical constituents, (ii) vulnerability to surface water contamination and (iii) the presence of vegetation all of which may be factors contributing to E. coli presence and its possible persistence and growth. There were statistically significant differences among the E. coli frequencies and concentrations in groundwater between swine farm #2 and the other three sites and temporal variability was seen among the different sampling periods.

The results from this study showed that the frequency of occurrence of antimicrobial resistance traits in E. coli isolates from groundwater at swine farms was significantly higher than at the reference sites studied. Multi-drug resistance was present in E. coli isolates from groundwater near swine farm sites having lagoons and sprayfields with isolates resistant to 4–6 antimicrobials. This magnitude and frequency of multi-resistance was not seen in E. coli isolates at the reference sites. The antimicrobials to which resistance was observed in bacteria were generally consistent with the antimicrobials approved for use in swine feeding operations.

Conclusions

Overall, the results of this study demonstrated that antibiotic-resistant E. coli were present in groundwaters associated with commercial swine farms that have anaerobic lagoons and land application systems for swine waste management. Therefore, groundwater on or

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near swine farms may be a potential environmental reservoir for both antimicrobial resistant bacteria and antimicrobial resistance genes. It is clear that swine farms are negatively impacting the shallow groundwater in eastern North Carolina. The extent to which such contamination of groundwater with multiple antibiotic-resistant E. coli poses risks to human health is uncertain and deserves further investigation.

References

Anon (1987). Drinking water microbiology, Committee on the Challenges of Modern Society (NATO/CCMS). J. Environ. Pathol. Toxicol. Oncol., 7, 1–365.

APHA (1998). Standard Methods for the Examination of Water and Wastewater, 20th edn, APHA, AWWA, WEF, Washington, DC.

CDC (2002). Surveillance summaries: surveillance for waterborne disease outbreaks–United States 1999–2000. MMWR, 51(SS–8).

Edberg, S.C., LeClerc, H. and Robertson, J. (1997). Natural protection of spring and well drinking water against surface microbial contamination. II. Indicators and monitoring parameters for parasites. Crit. Rev. Microbiol., 23, 179–206.

Fanuel, M. (1999). Modeling of Groundwater Flow Through Riparian Buffers Masters Thesis, Dept. of Marine, Earth and Atmospheric Sciences, North Carolina State University, Raleigh N.C.

Marshall, B., Petrowski, D. and Levy, S.B. (1990). Inter- and intra- species spread of Escherichia coli in a farm environment in the absence of antibiotic usage. Proc. Nat. Acad. Sci. USA, 87, 6609–6613.

McDermott, P.F., Zhao, S., Wagner, D.D., Simjee, S., Walker, R.D. and White, D.G. (2002). The food safety perspective of antibiotic resistance. Anim. Biotechnol., 13, 71–84.

Purdue Research Foundation (1996). Chemotherapy – Drug Groups. Cited August 19, 2002, http://www.vet.purdue.edu/depts/bms/courses/bms514/chmrx/chmrxtit.htm#Protein%20Synthesis%20Inhibitors

Spruill, T.B. (2000). Statistical evaluation of effects of riparian buffers on nitrate and ground water quality. J. Env. Qual., 29, 1523–1538.

Stone, K.C., Hunt, P.G., Humenik, F.J. and Johnson, M.H. (1998). Impact of swine waste application on ground and stream water quality in an eastern coastal plain watershed. Trans. ASAE, 41, 1665–1670.

Teale, C.J. (2002). Antimicrobial resistance and the food chain. J. Appl. Microbiol., 92(Suppl), 85S–89S.

Tollefson, L., Fedorka-Cray, P.J. and Angulo, F.J. (1999). Public health aspects of antibiotic resistance monitoring in the USA. Acta Vet. Scand. Suppl., 92, 67–75.

White, D.G., Hudson, C.R., Maurer, J.J., Ayers, S., Zhao, S., Lee, M.D., Bolton, L., Foley, T. and Sherwood, J. (2001). Characterisation of chloramphenicol and florfenicol resistance in Escherichia coli associated with bovine diarrhoea. Cited 3/9/2003: http://www.nal.usda.gov/ttic/tektran/data/000012/11/0000121170.html, Agricultural Research Service.

WHO (2004). Guidelines for Drinking-water Quality: Vol 1 – Recommendations, 3rd edn, World Health Organization, Geneva.

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Exhibit 38

BLUE RIBBON STUDY COMMISSION
ON
AGRICULTURAL WASTE

REPORT TO THE

1995 GENERAL ASSEMBLY

OF NORTH CAROLINA

1996 REGULAR SESSION

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May 16, 1996

TO THE MEMBERS OF THE 1995 GENERAL ASSEMBLY (REGULAR SESSION 1996):

The Blue Ribbon Study Commission on Agricultural Waste submits to you for your consideration its final report on agricultural waste. The report was prepared by the Blue Ribbon Study Commission on Agricultural Waste pursuant to Part IV of chapter 542 of the 1995 Session Laws.

Respectfully submitted,

Tim Valentine

The Honorable Tim Valentine

Ernest A. Carl

Dr. Ernest A. Carl

CoChairmen
The Blue Ribbon Study Commission on Agricultural Waste

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PREFACE

The Blue Ribbon Study Commission on Agricultural Waste was authorized by Part IV of Chapter 542 of the 1995 Session Laws. The relevant portions of chapter 542 are included in Appendix A. The Commission Notebook Containing the Commission minutes and all information presented to the Commission in filed in the Legislative Library. The Commission was Chaired by the Honorable Tim Valentine and Dr. Ernest A. Carl. The Full membership of the Commission is filed in Appendix B of this report.

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I. INTRODUCTION

The Blue Ribbon Study Commission on Agricultural Waste was created by the 1995 General Assembly to study "the effect of agriculture waste on groundwater, drinking water, and air quality". The driving force behind its formation was the rapid growth of swine farming in the State, particularly in Eastern North Carolina. The expansion of these farms has brought tremendous economic growth to areas of the State that have long suffered from stagnant economies and marginal job opportunities. As the numbers of intensive livestock operations have increased, however, so have concerns about their impact on water quality and on the quality of life for those living in close proximity to the farms. The Commission looked long and hard at these environmental and socioeconomic issues. To appreciate the context of the Commission's analysis, it is useful to consider several trends that have brought North Carolina agriculture to its present state.

Trends in Agriculture. The major trends evident in recent decades can be summed in three words: depopulation, capitalization, and consolidation. Since 1945 the population engaged in farming has continuously diminished, falling to less than two percent of the population. As the number of farms has fallen, acres of cultivated cropland also have declined. During this same period, farm operations have become more capital intensive, and productivity has increased dramatically. Average farm size has continued to grow, reaching 160 acres in 1995. By 1992, seventy-five percent of the value of North Carolina agricultural products were coming from ten percent of the farms. But many states have participated in these background trends. What distinguishes North Carolina's experience are the simultaneous changes in the composition of its agriculture. During the mid 1980s, animal agriculture surged past crop production to reverse the historic relationship of these two sectors. The growth in animal agriculture is owed to two subsectors: swine and poultry.

In contrast, dairy's share of agricultural production has continued a long-term decline, while beef has been a relatively stable performer in recent years. North Carolina broiler production, which has climbed steadily since the late 1950s, reached 644 million in 1994, when it surpassed tobacco sales to become the State's number one agricultural commodity.

Hog production expanded rapidly between 1991 and 1995, when the swine inventory rose from 2.7 million head to 7.5 million head: an average annual growth rate of nearly thirty percent. This record propelled North Carolina from a rank of sixth among the states to a number two ranking behind only Iowa. Production growth has been concentrated, both in the sense that a limited number of counties have been affected and in the sense that a limited number of producers have accounted for a lion's share of the increased production. During this period, the number of hog farms actually declined, while large, intensive operations raising thousands of animals in confined areas expanded. The economic effect in impacted areas was tremendous.

Sampson County raised its per capita income level from eighty-three percent of the State average to one hundred two percent (102%) of the State average in just the five years between 1988 and 1992. Duplin County went from seventy-eight percent to ninety-two percent over the same interval. The economic performance of the livestock and poultry sectors is cause for enthusiasm among beneficiaries. However, the increased animal inventory has been accompanied by a concomitant increase in animal waste. Complaints about the effects of increasing numbers of swine farms triggered the introduction of legislation in both the 1993 and 1995 Sessions of the General Assembly. A lagoon failure in June 1995 focused the public's attention on the attendant water quality issues.

Water Quality Regulations. Until recently, animal waste was a topic that occupied only a few paragraphs from the thousands of pages of State and federal environmental regulation. Federal rules specifically define large "concentrated animal feedlots" (inventories greater than 1,000 cattle; 2,500 swine; 10,000 sheep) as point sources, implying that they should be regulated under the same National Pollution Discharge Elimination System (NPDES) that issues permits for industrial and municipal wastewater discharges.

Beyond that specific mention, farms at a lesser scale are presumably prohibited along with all other enterprises from introducing pollutants to navigable waters through "discrete conveyances" that is, point sources, except under color of a permit. However, the environmental impact of farming is generally believed to be from runoff from pastures, fields, and feedlots, rather than from the point source discharge of pollutants.

Federal law largely leaves the regulation of these nonpoint sources to the states. Agriculture's potential impact was only recognized when states began to look seriously at "nonpoint source" pollution as a cause of persistent water quality problems.

Historically, animal waste management systems in North Carolina were "deemed permitted" so long as they were operating without discharging pollutants to surface waters. However, rapid expansion of the swine industry in Eastern North Carolina, together with water quality problems attributed to the dairy industry in the Piedmont and mountain areas, pointed to the need for additional regulatory control. In the early 1990s, North Carolina regulators deftly bypassed practical arguments about whether animal agriculture should be regulated as a point source or a nonpoint source or both, and legal arguments about the limits of federal law by including animal waste management as a category of activity requiring a "nondischarge permit".

The nondischarge program is a State government innovation. It requires State permission to handle or dispose of waste that cannot legally be discharged into a waterway on grounds that, if a discharge did occur, it would be injurious to water

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quality. Farms raising livestock were made subject to State nondischarge rules (see 15A NCAC 2H. 0200, popularly known as the .0200 rules). Animal farming operations that have fewer than 100 head of cattle, 75 horses, 250 swine, 1,000 sheep, or 30,000 birds using wet waste management systems are simply deemed to be permitted without meeting any new requirements. Those operations with stocks above those thresholds are also deemed permitted, but only if they develop and follow approved waste management plans that incorporate best management practices promulgated by the North Carolina Soil and Water Conservation Commission or the United States Department of Agriculture.

To retain deemed permitted status after December 31, 1997, farmers must have supplied the Division of Environmental Management (DEM), a State agency, with a form assuring that their plan has been reviewed and certified. New or expanding livestock facilities must obtain certified animal waste management plans prior to stocking animals. Animal operations that were functioning prior to February 1, 1993, referred to as "existing operations", are treated differently than those that came on line after that date. Existing animal waste management systems must meet operating and maintenance standards. They are not required, however, to meet facilities design and construction standards.

Obviously, the animal waste management plan is the keystone in this regulatory system. The animal waste management plan includes four basic elements that are prepared on a site-specific basis. The elements are: (1) waste collection, (2) waste storage, (3) waste treatment, and (4) waste application. Each element of the plan requires the implementation of one or more agricultural "Best Management Practices" or "BMPs".

BMPs are a set of measures believed on the basis of field experience and scientific measurement to reduce nonpoint pollution. BMPs include such items as grassed waterways, filter strips, and terracing: traditional conservation techniques that have been subsidized by the State through some form of cost-sharing. Agricultural BMPs are not generally defined; however, the Soil and Water Conservation Commission has been charged with developing a list of acceptable BMPs that may be used in developing certifiable plans under the .0200 rules. It is worth noting that North Carolina has funded BMPs aggressively since 1984, when the Agriculture Cost Share Program for Nonpoint Source Pollution Control was created with a $2.0 million appropriation to encourage soil loss prevention and minimize sedimentation. By 1995 funding had grown to $8.2 million, and more than 2,000 farmers were receiving reimbursement of up to seventy-five percent of the cost of practices designed to protect soil and water, including improved animal waste management.

Qualified technical specialists designated by the Soil and Water Conservation Commission must certify that each element of the animal waste management plan meets standards set forth in the Technical Guide published by the Natural Resource

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Conservation Service, United States Department of Agriculture. BMPs approved for use in the Agriculture Cost Share Program for Nonpoint Source Pollution Control are also approved for use. The standards cover both the design of facilities, like lagoons or storage pits, and the operating specifications, such as "agronomic" waste application rates that avoid overloading the absorptive capacity of spray fields. Buffers must separate both the spray fields and storage of treatment facilities from perennial streams.

The preparation and certification of animal waste management plans to meet the nondischarge rules has been a troublesome exercise. Technical specialists include representatives from the Soil and Water Conservation District Offices, Cooperative Extension agents, staff of the Natural Resources Conservation Service, and professional engineers. Interpretations of the rules and rule requirements vary among the agency representatives. The result has been confusion among the regulated community and delays, both by farmers in seeking assistance to obtain certification of animal waste management systems and by local technical specialists who are reluctant to certify that plans meet the no discharge standards.

Other Laws and Regulations. In addition to water quality regulations, there are other requirements scattered throughout the North Carolina General Statutes that impact on the operation of livestock facilities. During the 1995 Session, Senate Bill 974 was ratified, adding a new Part to Article 21 of Chapter 143 of the General Statutes. Senate Bill 974 requires the Division of Environmental Management, in cooperation with the Cooperative Extension Service, to develop and administer a training and certification program for animal waste management operators on swine farms. Each applicant is required to complete at least six hours training and pass an examination. As of January 1, 1998, only a certified operator may apply animal waste to the land.
As is indicated by the descriptions above, the livestock industry is regulated largely at the State level. Resources available to local governments to control the burgeoning livestock industry are limited. County public health departments may enact ordinances affecting the operation of livestock farms; however, such ordinances must have a public health basis. A few counties have imposed moratoriums on the construction of new swine farms. These moratoriums are grounded in the general police power delegated to the counties by the General Assembly.

One of the primary tools a county may use to plan for orderly growth within its limits is zoning. Bona fide farms, however, are exempt from county zoning authority. The General Assembly has attempted to deal with the issues spawned by the proliferation of swine farms by enacting legislation during the 1995 Session that provides statewide minimum setbacks for swine farms. The General Statutes now provide that swine houses and lagoons on farms sited after October 1, 1995, must be situated at least 1,500 feet from any residence, 2,500 feet from any church, school, or hospital, and 100 feet from any residential property line. The statutes further require a minimum

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50-foot buffer for land application of wastes from the boundaries of residential property and perennial streams.

The North Carolina General Statutes also contain "right to farm" provisions. These statutes were enacted in recognition of the conflicts that arise when nonfarm uses extend into agricultural areas. Their intent is to reduce the loss of agricultural resources by limiting the circumstances under which they can be declared a nuisance. No agriculture or forestry operation that was not a nuisance at the time it was begun, may become a private or public nuisance by virtue of changed conditions in the area after it has been in operation for one year. The exception does not apply where nuisance results from the negligent operation of the facility.

Issues Addressed By the Commission. The Commission spent several months identifying and sorting issues that appeared most central to its charge. Generally, those issues fell into four categories. The first area of concern was **the adequacy of program management.** For example: Is there coordination and consistency among the several State and federal agencies that have roles in the regulation of animal agriculture? Are agencies dedicating sufficient manpower and other resources? Do they have realistic plans for completion of the certification process by the 1997 deadline?

The second broad issue was **the adequacy of the standards** that are being applied through the nondischarge program. For example: Do the specifications for lagoon design realistically address the potential for emergencies? Should land or buffer requirements be explicitly based on risk of environmental damage? Are there satisfactory safeguards against groundwater contamination from seeping storage pits? Should animal operations be subjected to local zoning control as well as State environmental regulations?

The third general category was **the adequacy of enforcement and compliance.** For example: Should the "deemed permitted" approach be replaced with a more aggressive regulatory design? Should animal waste management systems be inspected? If so, how often?

The last area of concern was the necessity for **future research initiatives.** As has been noted above, there is a serious lack of data on the impact of intensive livestock operations on groundwater supplies. Further information is also needed to identify nonpoint sources of nitrates and to direct regulatory efforts toward nutrient control in a cost-effective manner. Finally, it is clear that vigorous efforts need to be undertaken to develop new animal waste management technologies to protect the environment and improve the quality of life for those living in close proximity to livestock farms.

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The findings and recommendations adopted by the Commission do not exhaust all of the issues that were taken up under the cited categories. In some cases, members felt that they had insufficient information to reach conclusions. In other cases, members became well informed but could not reach agreement. Responding to public opinion, members focused upon animal waste as opposed to the more general topic of agricultural waste, and discussion naturally gravitated toward swine farming because of the controversy attending their rapid growth during recent years.

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II. FINDINGS AND RECOMMENDATIONS

As noted in the introduction, the Commission made extensive findings and recommendations in four areas: The adequacy of program management, the adequacy of standards, the adequacy of compliance and enforcement, and future research initiatives. The following contains a narrative of the findings made by the Commission on each issue, followed by the recommendations based upon those findings.

A. ADEQUACY OF PROGRAM MANAGEMENT

Through testimony received in public hearings and evidence presented by State and federal personnel, the Commission learned that issues of program management continue to plague government agencies involved in regulation of intensive livestock operations. Many of the problems are routine travails of bureaucracy that would be overlooked in other circumstances, however, the urgency and scale of public concern about agricultural waste policy magnifies administrative weaknesses. Unless steps are taken to address these weaknesses, confidence will erode both among interested citizens and among members of the regulated community.

Agencies from all three levels of government have some hand in the regulatory system. From the federal level, the Natural Resource Conservation Service (NRCS) within the Department of Agriculture (USDA) has a direct role as a provider of technical assistance to farmers, while the Environmental Protection Agency (EPA) has an indirect role as administrator of federal environmental programs. At the State level, the Division of Environmental Management (DEM) and the Division of Soil and Water Conservation (DSWC), both agencies within the Department of Environment, Health, and Natural Resources (DEHNR), have direct roles: the first as an environmental regulatory agency and the second as a provider of both technical and financial assistance to farmers.

The North Carolina Department of Agriculture (NCDA) and the North Carolina State University Cooperative Extension Service (CES) are State-level agencies that provide technical assistance, training, and laboratory services to farmers. At the local level, Soil and Water Conservation Districts (SWCDs) allocate cost-sharing resources and provide technical assistance to farmers.

At present there is no single deliberative or authoritative body that represents the combined efforts of these agencies. Attempts to harmonize policy information being distributed to farmers have been partially successful, however, contradictions remain. Obvious confusion and disagreement over the meaning of such key concepts as "no discharge of pollutants" gives the regulations a tentative quality not encouraging to

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farm operators, for whom compliance may mean a long-term investment in equipment or land.

A-1. "ZERO DISCHARGE" STANDARD

The interpretation of the zero discharge requirement under the .0200 rules is significant and has important implications. "No discharge of pollutants" is often confused with and used interchangeably with "no discharge of water". "Animal waste management system" is defined under the .0200 rules as "a combination of structural and nonstructural practices which will properly collect, treat, store, or apply animal waste to the land such that no discharge of pollutants occurs to surface waters of the State by any means except as a result of a storm event more severe than the 25-year, 24-hour storm".[1] This language is interpreted by some technical specialists as establishing a performance standard rather than a technology standard. Technical specialists justifiably are reluctant to sign the certification statement for an animal waste management plan because of the lack of clarity regarding the interpretation of the zero discharge requirement and their concern regarding potential legal liability. The current slow pace of certification of animal waste management plans is in part caused by the confusion surrounding the meaning of "no discharge".

Recommendations

1. The "no discharge" requirement under the .0200 rules should be clarified by the Environmental Management Commission as to whether it is a performance standard or a technology standard so that technical specialists can determine what discharge limitation the animal waste management plans they certify must satisfy.

2. The Environmental Management Commission should amend the definition of animal waste management system under the .0200 rules as necessary to give "no discharge" a meaning that is economically practical and technologically achievable.

A-2. REGULATORY CONSISTENCY

An animal waste management plan must be certified by a technical specialist. Some technical specialists are employees of the Soil and Water Conservation Districts (SWCD), some are employees of the Natural Resources Conservation Service (NRCS), some are employees of the Agronomic Division of the North Carolina

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1 15 NCAC 2H.0203(3).

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Department of Agriculture (AgrD). and others work for the North Carolina State Cooperative Extension Services (CES). (Private professional engineers also can serve as technical specialists.) AgrD also provides technical assistance to farmers in developing waste utilization plans.

Involvement by these various agencies can easily lead to uncertainty and confusion within the regulated community. Currently, personnel from NRCS, DSWC, AgrD, and CES do not provide uniform interpretation of the .0200 requirements for certification of animal waste management plans. A single reliable source of information and assistance is vital. Operators and technical specialists need to be kept informed of new interpretations and revised procedures that affect the certification process. Interagency training is needed in some instances.

Further, interagency teams are needed to provide uniform strategies for operators to meed the certification deadline. Communication among operators, technical specialists, NRCS, DSWC, CES, AgrD, and DEM is often inadequate to facilitate the certification process. Industry can and should assist the education and communication processes.

Recommendations

1. This Commission endorses the interagency group formed in February 1996, which consists of two representatives from each of four agencies: NRCS, DEM, DSWC, and CES. Two representatives from the North Carolina Department of Agriculture should be added to that group. The interagency group should address questions from technical specialists, publish its decision on a regular basis, and remain in existence until such time after December 31, 1997, that the Secretary of Environment, Health, and Natural Resources determines the interagency group is no longer needed to resolve issues related to certification of animal waste management plans.

2. Establish a county team in each Soil and Water Conservation District (SWCD). Each team should consist of a technical specialist from each of three agencies: NRCS, DSWC, and CES.

3. Establish regional animal waste teams that include representatives from the following agencies: NRCS, DSWC, CES, and NCDA. The regional teams should analyze county needs and coordinate whatever assistance regarding the .0200 rules is needed.

4. The Natural Resource Conservation Service, the Division of Environmental Management, the Division of Soil and Water Conservation, the Agronomic Division, NCDA, and the Cooperative Extension Service should update the Guidance Document, a memorandum from NRCS, DEM, DSWC, and CES, and

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circulate the updated version to all technical specialists, including private and industry technical specialists.

5. Before June 1, 1996, NRCS, DSWC, CES, and the NCDA should conduct joint on-site animal waste training for all technical specialists to ensure consistent, quality work. Leadership for NRCS, DEM, DSWC, CES, and NCDA should be present to explain what is expected of the technical specialists and to empower them to use their best judgment in designing animal waste management systems without fear of being second guessed or overruled.

A-3. .0200 CERTIFICATION DEADLINE

Many operators subject to the .0200 rules are unsure that the December 31, 1997, deadline to have an approved animal waste management plan will be enforced. A perception exists among operators that public pressure will force more changes that will render today's certification invalid. If a large number of operators wait until shortly before the December 31, 1997 deadline to initiate the certification process, Natural Resources Conservation Service, Division of Soil and Water Conservation, and Cooperative Extension Service will be unable to provide adequate or timely technical assistance. Lack of engineering assistance is a particular concern of operators. There is little incentive to encourage operators to initiate the certification process well before the deadline.

Current funding for technical support for design, inspection of construction, and testing of animal waste management systems is adequate.

Current funding for the Agriculture Cost Share Program for Nonpoint Source Pollution Control is inadequate to accomplish the certification of animal waste management plans by December 31, 1997. The current limitation on the disbursement of agriculture cost-share funds is not justified and hinders the certification process.

Recommendations

1. Do not relax the .0200 rules by postponing the December 31, 1997 certification deadline. Communicate this position to all operators of intensive livestock operations.

2. All operators should be advised to contact their SWCD by September 1, 1996, and initiate the certification process. Those who meet this deadline should be given high priority to receive technical assistance; those who do not should not be assured technical assistance by the December 31, 1997 deadline. The Environmental Management Commission should be authorized to enter into

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special agreements or special orders so that operators who register by the September 1, 1996 deadline and make a good faith effort to meet the certification requirements by December 31, 1997 will not be held in violation of the .0200 rules. The special agreement should set forth an enforceable schedule that would bring the operator into compliance. The Environmental Management Commission should strictly enforce the penalties available against those operators who fail to sign up or otherwise fail to make a good faith effort to be certified by the deadline.

3. The assigned technical specialist should present the operator with a timetable to accomplish the steps of certification. This timetable should be specific to the circumstances of each operator. The timetable should include a deadline for the technical specialists to arrive at design alternatives for that operation and a deadline for the operator to make a design decision. The same process should follow until implementation is complete.

4. Appropriate funds to the Division of Soil and Water Conservation for technical support to producers. These funds should be used for design, inspection of construction, or testing of animal waste management systems that are needed for certification under the .0200 rules.

5. The animal agriculture industry should be more aggressive in education and coordination efforts on certification under the .0200 rules.

6. Appropriate $3,800,000 to DEHNR for the Agriculture Cost Share Program for Nonpoint Source Pollution Control and remove the current $15,000 annual cap and substitute a $75,000 total cap for funds received by a recipient under this program. Consider other incentives, including tax incentives, that will encourage farmers to adopt environmentally sound animal waste management practices. Funds for animal waste management should be allocated to projects in river basins in order that the funds will have the greatest impact on improving water quality.

7. The Natural Resources Conservation Service and Cooperative Extension Service should allocate resources such that tasks related to the certification process under the .0200 rules are given priority.

A-4. LOCAL ZONING/PUBLIC NOTICE

Counties may enact ordinances that affect swine operations under the counties' authority to regulate conditions detrimental to the health, safety, or welfare of its

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citizens.[2] Also, local boards of health may adopt rules necessary to protect the public health.[3] However, counties are prevented from enacting zoning ordinances that affect bona fide farms.[4]

Senate Bill 1080,[5] enacted in the 1995 Session, placed restrictions on the siting of intensive livestock operations. Intensive analysis of data from Pitt County, which is representative of a swine-producing area of North Carolina with respect to its population, population density, land area, and geography, shows that the impact of Senate Bill 1080 is substantial. Senate Bill 1080 essentially operates as a statewide land-use planning law. It is in the best interest of the State that siting limitations be uniform throughout the State and that siting limitations be established by the General Assembly rather than by local governments.

Adjoining property owners should be informed of plans to construct a new swine farm, or expansion of an existing swine farm beyond the capacity of its current animal waste management system, before a permit is issued by the Division of Environmental Management. Adjoining property owners should not be able to block the siting of a swine operation that otherwise complies with all applicable laws and rules. Neighbors should have an opportunity to bring to the Division's attention any reasons known to the neighbors that the proposed operation would violate an applicable law or rule. The intent of the notice requirement is to establish a dialogue between swine farmers and their neighbors and to assure that neighbors will have an opportunity to have written input to the permit process.

Recommendation:

1. Do not extend the authority of counties to adopt zoning ordinances that affect intensive livestock operations.

2. After completing the site evaluation and before the farm site is modified, a person who intends to construct a swine operation shall attempt to notify all adjoining property owners and all property owners who own property located across a public road, street, or highway from the swine farm that the person intends to construct the operation. This notification shall be by certified letter sent to the addresses on record at the property tax office. The letter shall include:

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2 153A-121

3 130A-39

4 G.S. 153A-340

5 Article 67, Chapter 106 of NC General Statutes

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(1) The name and address of the person intending to site the swine operation.

(2) The type of swine operation and the design capacity of the animal waste management system.

(3) The name and address of the technical specialist preparing the animal waste management plan.

(4) The address of the local Soil and Water Conservation District Office.

(5) Information informing the adjoining property owners and all property owners who own property located across a public road, street, or highway from the swine farm that they may submit written comments to the Division of Environmental Management.

This recommendation applies to new swine operations and to those operations expanded beyond the design capacity of the existing animal waste management system.

A-5. SITING LIMITATIONS FOR SWINE FARMS

The interpretation of the language in Senate Bill 1080[6] is not consistent with the original intent of the legislation due to the use of ambiguous language. Senate Bill 1080 was intended to apply to the siting of swine houses or lagoons that are located only on new swine farms, that is, farms for which a site evaluation is completed on or after October 1, 1995. It was intended to affect new swine operations and certain expansions of swine farms that had swine houses or lagoons constructed before October 1, 1995. Senate Bill 1080 was not intended to apply to expansions that were anticipated before October 1, 1995. The registration or the approved waste management plan indicated whether the expansion was anticipated before October 1, 1995. Further, Senate Bill 1080 was not intended to apply to expansions that are necessary for compliance with the animal waste management rules but are not for the purpose of increasing the animal population.

As the agency that issues permits for intensive livestock operations, DEM is the appropriate agency to enforce Senate bill 1080. The enforcement mechanism for Senate Bill 1080 should be explicitly stated in the legislation.

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6 Ibid

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Recommendation

Amend the Swine Farm Siting Act to clarify ambiguous language and to add an enforcement mechanism as provided in the Commission's legislative proposal.

A-6. BASINWIDE PLANNING

Basinwide planning is a systems approach to planning. Basinwide plans consider all point sources and nonpoint sources of pollutants in surface water and groundwater. The extent of the contribution of animal waste to nonpoint sources of pollution, if any, cannot be calculated at this time. The Department of Environment, Health, and Natural Resources already has the authority to develop basinwide management plans for the 17 river basins in the State. The basinwide management approach to protecting the waters of the State is a desirable approach.

Recommendation

The Commission endorses the basinwide approach to water quality protection and encourages the accelerated development of basinwide management plans.

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B. THE ADEQUACY OF STANDARDS

A second broad group of concerns heard by the Commission revolves around the standards and requirements being applied to intensive livestock operations through the regulatory processes. The Commission concluded that requirements being imposed through the .0200 rules are adequate to protect the environment. The Commission was apprized that the current standards in the NRCS Technical Guide were in the process of being revised by a group consisting of three subcommittees, charged to revise the technical standards related to animal waste. Problems may exist now, testimony suggested, but they will disappear as the rules are implemented. This opinion was offered by both the Department of Environment, Health, and Natural Resources and by representatives of the swine industry. The set of recommendations that follows represent what the Commission considered to be improvements to the .0200 rules.

B-1. POULTRY DRY WASTE

Although poultry farms are currently subjected to the nondischarge rules, they are also required by those rules to prepare waste management plans only in those rare cases where the flock exceeds 30,000 birds and wet litter disposal systems are employed. Dry litter poultry operators retain a deemed permitted status that continues so long as three conditions are satisfied. These conditions include: (1) spreading dry litter on the land at no greater than agronomic rates, (2) retaining litter disposal records for one year, and (3) siting litter stockpiles more than 100 feet from perennial streams.

Poultry litter is particularly high in such conservative elements as copper and zinc, and the cumulative effect of many years of land application may be soil toxicity. The Commission observed that the current level of regulation does not acknowledge the potential long-term damage to the environment that may occur due to metals buildup. The only practical way to avoid this result is application at carefully computed agronomic rates, coupled with regular analysis of soil and litter samples to monitor soils concentrations.

Recommendations

1. No sooner than December 31, 1997, and no later than December 31, 1999, all poultry operations utilizing dry litter should have an animal waste management plan that includes a soil test to be performed at least annually and a waste analysis as close to the time of application as possible and at least within 60 days of the date of the waste's application. These records should be maintained for no less than three years.

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2. Effective as soon as possible, extend the dry litter application records retention period from one year to three years.

B-2. ODOR CONTROL

Odor control is a legitimate public policy issue, even though uncertainty about health effects, the variability observed with odor measurement techniques, and the unpredictable nature of odor causation make reasonable regulation difficult. Commission members reviewed the Swine Odor Task Force report and heard further public testimony confirming the significance of odor as a nuisance factor associated with intensive swine operations. Farmers argue that some odor is a natural and inevitable by-product of animal-raising activity. However, odor can be minimized by using a variety of recognized best management practices that range from air scrubbing systems to simple housekeeping. These practices are not now required as an element of waste management planning nor are they eligible for reimbursement under the State's Agriculture Cost Share Program for Nonpoint Source Pollution Control.

Recommendations

1. Animal waste management plans submitted under the .0200 rules should include a checklist of potential odor sources and a choice of site-specific, cost-effective practices that will minimize those sources. The Soil and Water Conservation Commission should adopt odor control best management practices. These practices should be an enforceable element of the approved plan.

2. Odor management practices should be made eligible for agriculture cost-share funds.

3. Research into economically feasible odor control technology should be accelerated, anticipating that new methods will be developed and that these new methods may be considered for inclusion as a regulatory requirement as they are proven effective. This research should be jointly funded through private and public sources.

4. Odor Best Management Practices requirements should become effective September 1, 1996 and apply to animal waste management systems for which an approved animal waste management plan is obtained on or after that date. The requirements should apply to all other animal waste management systems as of January 1, 1998.

B-3. DEAD ANIMAL DISPOSAL

Representative poultry mortality rates are 10% for turkeys and 5% for chickens. At these rates, given current North Carolina production, operators must dispose of some

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45 million poultry carcasses annually. Annual swine mortality, based on similar calculations, is approximately 3.6 million. Although mortality can be regarded as part of the waste stream generated by livestock farms, carcass disposal is not covered in the animal waste management planning requirements of the .0200 rules. Instead, disposal of dead animals is governed by law and regulation aimed at preventing the spread of livestock diseases. North Carolina statutes require that animals be buried at three feet beneath the ground or otherwise disposed of in a manner approved by the State Veterinarian.[7] The Veterinary Division of the Department of Agriculture has issued rules accepting as alternative methods incineration, rendering at a rendering plant, and, in the case of poultry only, composting or placement in a disposal pit.

The problems associated with improper carcass disposal include threats to human health, spread of animal disease, odor, and water contamination. The latter risk is addressed to a degree in the statute allowing burial, inasmuch as that option is not allowed within 300 feet of a flowing stream or public water body. The Commission concluded that the potential for harm has weight sufficient to merit regulatory action.

Recommendation

Provisions for dead animal disposal, setting forth legally acceptable methods whereby mortality will be addressed, should be required as a component of an approved animal waste management plan. These provisions should become effective September 1, 1996 and apply to animal waste management systems for which an approved animal waste management plan is obtained on or after that date and to all other animal waste management systems as of January 1, 1998.

B-4. RIPARIAN BUFFERS

Riparian buffers are cost-effective measures that protect State waters from animal waste runoff. They are thought to reduce nitrogen levels in such runoff by as much as seventy percent. Buffers are one of a few available means to effectively control runoff for dairies.

The width and type of riparian buffer needed varies according to the particular conditions presented. Therefore, buffer requirements should apply site specific standards. The interagency group recommended in A-2 above includes persons with sufficient expertise to determine an appropriate and reasonable standard for mandatory buffers and to decide whether to make this standard site specific, uniform for each river basin, or uniform statewide.

Recommendations

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7 G.S. 106-403; see also G.S. 106-549.70

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1. Direct the interagency group to develop a standard for the use of riparian buffers or equivalent controls as a best management practice, particularly along streams designated as "perennial streams" on the United States Geological Survey quadrangle sheets. The interagency group must decide whether a uniform State standard, a basinwide standard, or a site specific standard would best protect water quality.

2. Requirements for riparian buffer best management practices or equivalent controls should become effective September 1, 1996 and apply to animal waste management systems that are constructed or expanded beyond their design capacity on or after that date. Other systems should implement these practices or equivalent controls to the extent that land is available.

B-5. EMERGENCY MANAGEMENT

The .0200 rules consider a 25-year, 24-hour storm event the only emergency sufficient to suspend the no discharge requirement. Frequent heavy rains for an extended period of time, or chronic rainfall as was experienced in eastern North Carolina the summer of 1995 preceding the lagoon spill at Oceanview Farms, can lead to emergency conditions that threaten the environment as much as those created by the 25-year, 24-hour storm event. The environment cannot be protected adequately without requiring the development of emergency procedures that must be followed during emergency conditions, including emergencies caused by chronic rainfall. Likewise, animal waste management plans do not adequately address the potential for emergency conditions nor explicitly set forth steps to minimize environmental damage under such conditions.

Recommendations

1. Require emergency spillways for all new and expanding lagoon facilities. Allow existing facilities to use agriculture cost share funds to add optional spillways.

2. Include site-specific emergency management elements in all animal waste management plans, detailing operating procedures that must be followed in times of emergency situations in order to minimize the environmental damage of catastrophic events.

3. Amend the definition of "animal waste management system", which currently appears in the .0200 rules, so that chronic rainfall is treated the same as the 25-year, 24-hour storm event.

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4. Emergency spillway requirements should become effective September 1, 1996 and apply to animal waste management systems that are constructed or expanded beyond their design capacity on or after that date.

B-6. WASTE UTILIZATION PLANS/RECORD KEEPING

Balancing nitrogen produced by intensive livestock operations with the nitrogen utilized by the crops to which the waste is applied is critical to avoiding runoff of nutrients. A waste utilization plan that is site specific and based on actual nutrient uptake is the best way to assure nitrogen balance. Waste utilization plans are critical for the protection of water quality. Current agronomic rates for application of wastes onto land are based on nitrogen as the limiting factor. Monitoring waste products and soils for heavy metals and phosphorous in addition to nitrogen is advisable. Currently, testing of waste products and testing of soils are not required under the .0200 rules.

Record keeping plays an essential role both in best management practices and in compliance monitoring. Although the existing .0200 rules provide that animal waste be applied to the land at agronomic rates,[8] no records are required to be kept to demonstrate adherence to the rule. While the NRCS and DSWC have forms to guide farmers in preparation of waste utilization plans, a standard set of forms would provide certainty as to what is required and assist DEM inspectors with their work.

Recommendations

1. Require record keeping as a component of animal waste management plans under the .0200 rules.

2. Record-keeping requirements should be established by the Environmental Management Commission, Natural Resource Conservation Service, and the Soil and Water Conservation Commission, with technical assistance from the Cooperative Extension Service.

3. For both wet and dry systems, require periodic testing of soils at crop sites and of waste products that will be used as nutrient sources. Soils should be tested annually. Lime should be applied to maintain pH in the optimum range for crop production. Waste products should be tested as close to the time of application as possible and at least within 60 days before or after the date of waste application. Nitrogen should be used as the rate determining element, but buildup of zinc and copper in the soils should be monitored and alternative sites used when these elements approach excessive levels.

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8 15A NCAC 2H.0217(a)(1)(H)(iv).

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4. Require waste utilization plans to assure a balance of nitrogen application rates and crop requirements for nitrogen. Yield data and plant analysis should serve as the mechanism for maintaining this balance of nitrogen.

5. Testing and recordkeeping requirements should become effective September 1, 1996 and apply to animal waste management systems for which an approved animal waste management plan is obtained on or after that date. The requirements should apply to all other animal waste management systems as of January 1, 1998..

B-7. INSECT CONTROL

The Commission considered complaints from the public related to the impact of intensive animal farming on insect populations in the local area, and observed that a potential for nuisance conditions does exist. Like odor, fly infestation can be decreased by recognized site management practices. Many of these can be applied at minimal cost.

Recommendations

1. A list of insect control best management practices should be adopted by the Soil and Water Conservation Commission.

2. Insect control best management practices should be made eligible for agriculture cost share funds.

3. Animal waste management plans should include a checklist of potential insect sources and a choice of site-specific, cost-effective practices that will minimize the sources. These practices should be an enforceable element of an approved animal waste management plan.

4. Insect control best management practices should become effective September 1, 1996 and apply to animal waste management systems for an approved animal waste management plan is obtained on or after that date and to all other animal waste management systems as of January 1, 1998.

B-8. APPLICATOR TRAINING REQUIREMENTS

During the 1995 Session, the General Assembly enacted legislation requiring all persons operating animal waste management systems for swine farms to be certified by DEM.[9] To be certified, each operator must take six hours of instruction and pass

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9 Part 9A, Article 21 of Chapter 143 of the General Statutes.

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a test. DEM and CES were directed to develop the program of instruction. The law requires each operator to pay an initial fee of $10 and an annual renewal fee of $10 for certification.

During its review of the applicator training program, DEM brought to the Commission's attention the fact that the Water Pollution Control Systems Operators Certification Commission, established pursuant to Chapter 90A of the General Statutes, might be a more appropriate commission under which to place the certification program. The Certification Commission is charged with the training and certification of operators of systems that collect, treat, or dispose of waste for which a permit is required under rules adopted by the Environmental Management Commission or the Commission for Health Services.[10] All other livestock waste management operators would be certified under this Commission if they were to be regulated. The new law makes swine an exception to the existing statutory scheme.

DEM also indicated that six hours instruction was insufficient to adequately cover the materials that needed to be presented. Moreover, in addition to classroom instruction, some hands-on-training in the field is advisable. To arbitrarily limit the amount of time for training to less than required would likely thwart the overall goal of enhanced water quality protection through use of properly trained waste system operators.

Questions about the potential impact of requiring each producer to pass a test as a certified operator were raised by several Commission members. The Commission concluded that farmers should have the option to hire a certified operator to oversee the farmer's waste management operations and that alternative testing procedures be available to farmers with learning difficulties.

Recommendations

1. Part 9A, Article 21 of Chapter 143 of the General Statutes should be repealed.

2. The program of certification of swine waste management system operators should be placed under the Water Pollution Control Systems Operators Certification Commission.

3. Two persons representing the animal agriculture industry should be added to the Certification Commission.

4. Farmers should have the option to hire a certified operator to manage their waste systems.

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10 G.S. 90A-39

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5. The number of hours of required training for certification should be limited to eight hours of classroom instruction and four hours of field training.

6. Upon request, alternate methods of instruction shall be provided for persons with reading or learning difficulties.

7. Make all operator training materials user friendly, taking into account the educational level of the applicant.

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C. ADEQUACY OF ENFORCEMENT AND COMPLIANCE

One of the questions placed squarely before the Commission by those seeking enhanced restraints upon the growth of the livestock industry was "Why should agriculture be treated differently from other waste-generating industries?" To address this question, the Commission reviewed the existing exemptions for agriculture or animal operations in the water quality statutes and the basis for granting each exemption. The Commission learned that changes in production techniques and farm size, coupled with the advent of corporate and contract farming, have changed the nature of agriculture. Nowhere is this more clear than in intensive livestock production. The bucolic picture of pastured livestock has given way to a technically advanced system of raising thousands of animals in confined facilities. Typically, millions of gallons of waste produced by each intensive livestock operation are treated and stored in lagoons and disposed of by land application of the waste. Such methods of agriculture are proving extremely efficient and profitable, but they also have created an increased potential for serious water quality problems. It is worth noting that lagoon and land application of waste is a preferred method of waste treatment. The State's nondischarge program has been in effect for at least 20 years. Nondischarge systems, however, must obtain permits under the nondischarge rules and their operators must be certified by the Water Pollution Control System Operators Certification Commission. Not until 1992, however, were the waste management systems for animal agriculture operations formally addressed in the rules and they currently hold a deemed permitted status.

In the past two decades environmental efforts have focused primarily on eliminating point source pollution. Recently, however, there has been an increasing awareness of the role of nonpoint source pollution in the State's water quality problems. Animal waste management systems utilized by intensive livestock operations are both potential point sources of pollution as well as contributors of nonpoint source pollution. Failure to properly construct and manage lagoons and related storage and treatment structures can result in point source pollution as was seen by the failure of several lagoons in eastern North Carolina during the summer of 1995. Failure to properly manage the land application of wastes may result in excess nutrients reaching surface water through means such as runoff.

Based upon the recognition of the increased potential for environmental harm and the increasing industrialization of animal agriculture, the Commission found that many of agriculture's exemptions from the operations of the environmental statutes are no longer warranted. The Commission recommends that differential treatment for agriculture be eliminated where it cannot be justified. The specific recommendations, set forth below, cover a wide range of issues and include replacing the "deemed permitted" status of intensive livestock facilities with a standardized, or "general" permit, setting penalties for errant farming operations equivalent to those

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for other environmental violators, requiring annual inspection of intensive livestock facilities and their waste handling operations and the payment of fees for general permit applications.

C-1. PERMITS AND PERMITTING

Under the existing rules, animal waste management systems that meet the appropriate criteria are "deemed permitted" and it is not necessary that owners of these systems apply for and obtain an individual permit.[11] At the suggestion of the Division of Environmental Management, the Commission considered replacing the "deemed permitted" approach to regulation with a general permit model.

The current "deemed permitted" system is based upon each facility obtaining a certified site specific animal waste management plan that incorporates best management practices for waste collection, treatment, storage, and disposal. Other criteria a facility must meet include maintaining minimum riparian buffers and setbacks, and providing adequate land to accommodate the application of animal waste at agronomic rates. The Commission found that the concept of using site specific waste management planning incorporating best management practices is an efficient and effective method of providing protection for the State's surface waters.

There have been difficulties, however, in implementing the current system under the .0200 rules. Under the current rules, all facilities subject to the rules must have obtained an approved animal waste management plan that is certified by a technical specialist by December 31, 1997. As has been noted in detail in A-3 above, many of the producers have not initiated efforts to obtain plan approval. This has been due in part to the confusion among the agencies charged with providing technical assistance and certification. Varying interpretations abound as to what is necessary for certification as well as to what standards apply.

DEM does not participate in the creation of the animal waste management plans but only receives notification that a certified plan has been obtained. Its role in the current certification process is reactive, limited to enforcing the waste management plans. DEM does not review an animal waste management plan except when investigating in response to a complaint.

A shift in regulatory approach to a general permit model would have several significant advantages to the current system. Notably, it would centralize the authority for the permitting, inspection, and enforcement process within DEM. Interpretation of the requirements of the rules would come from a single source. Further, DEM would have a greater level of scrutiny over the waste management

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11 15A NCAC 2H .0217

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plans being submitted. DEM would receive the permit application and either approve or disapprove its conformance with the general permit.

As envisioned by the Commission, the general permit model would retain the positive features of the deemed permitted rule. It would allow DEM to issue a permit to a class of activity, here an animal waste management system, based upon compliance with a general set of requirements. The core of the general permit requirement would be the site specific animal waste management plan based upon best management practices determined to be most suitable for that operation. Thus the implementation of a general permit could be accomplished without disturbing the ongoing process of certification. Finally, the issuance of a general permit would have the advantage of placing in the producer's hands a document that spelled out clearly the regulatory requirements applicable to that facility.

Recommendations

1. The deemed permitted approach should remain in place for livestock operations beneath the .0200 thresholds: less than 100 cattle, 250 swine, 75 horses, 1,000 sheep, and 30,000 birds with a liquid waste system.

2. General permits, one for each species of livestock, should replace the deemed permitted status for all animal waste operations equal to or above the .0200 thresholds. (Sample general permits may be found in the appendices to this report.)

3. The animal waste management plans now required under the .0200 rules should be a central component of the general permit.

4. Individual permits may be required for noncompliant facilities and for facilities proposing to use alternative animal waste treatment systems.

C-2. SPECIAL ORDERS

North Carolina's water quality statutes provide the Environmental Management Commission authority to issue special orders compelling persons found to be causing or contributing to water pollution to take or refrain from taking action to eliminate the pollution.[12] This statute also provides the Commission the authority to enter into special consent orders and assurances of voluntary compliance with persons responsible for causing water pollution. This particular compliance "tool" provides needed flexibility in fostering compliance with environmental rules. It allows DEM to provide violators with a schedule of actions to bring their activities into

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12 G.S. 143-215.2

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compliance within a specified time frame, with specific stipulated fines for nonperformance. Except in extreme cases, the public interest is served when those in violation of environmental standards are required to correct deficiencies in compliance with a reasonable schedule. Agricultural operations, however, currently are excluded from the operation of these statutes.

As has been noted throughout this report, agriculture has come under increasing regulatory scrutiny and control due to its potential contribution to both point and nonpoint source pollution. As the regulatory burden has grown, the costs of acquiring pollution control technology and implementing environmentally sound management practices have placed an economic burden on agriculture that cannot be shifted to consumers as can be done in other industries. The Commission believes that the use of special orders and special consent orders would benefit the agricultural community by allowing DEM, where necessary, to set a reasonable schedule to obtain compliance with the water quality rules. The Commission also found that the inability to use special orders has hampered the certification process under the .0200 rules, particularly in the case of the dairy industry, by limiting the Department's ability to work with farmers who are attempting to implement best management practices but are limited by time and financial constraints and weather.

Recommendation

Amend the statutes to give the Environmental Management Commission authority to enter into special orders and special consent orders with agricultural operations in violation of the water quality statutes.

C-3. PENALTIES

Current law provides that fines and penalties for the construction of conveyances, such as pipes or ditches, on livestock or poultry farms for the willful discharge of wastes to the waters of the State may not exceed $5,000 for the first offense.[13] Other environmental violations, however, may carry civil penalties of up to $10,000.[14] The Commission could find no compelling reason for limiting the penalties that may be imposed upon livestock and poultry producers for willful violation of the water quality statutes.

Recommendation

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13 G.S. 143-215(e)

14 G.S. 143-215.6A

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Penalties for constructing conveyances on livestock and poultry farms for the purpose of willfully discharging pollutants to the waters of the State should be set at $10,000, consistent with the civil penalties imposed for other environmental violations.

C-4. INSPECTION AND ENFORCEMENT

Inspections are a part of the everyday compliance monitoring done by the Division of Environmental Management and a fact of everyday life for the regulated community. Major permitted facilities are usually subject to annual inspection, while smaller operations may be inspected as infrequently as every five years. Animal waste management systems, however, have never been subject to routine inspections. Historically, the Division of Environmental Management has inspected such facilities only in response to complaints.

Recommendations

1. A systemic monitoring and inspection program should be applied to intensive livestock operations. The program should involve technical assistance from the Division of Soil and Water Conservation, the Natural Resources Conservation Service, the Agronomic Division of NCDA, and the Cooperative Extension Service. Regulatory inspections should be conducted by the Division of Environmental Management.

2. Each intensive livestock operation may be subjected to an annual operations review to assure full compliance with applicable laws and regulations. This review may be carried out by qualified staff from Soil and Water Conservation Districts. Operators should be advised of minor deficiencies found during the review and should be given reasonable opportunity to correct those deficiencies before enforcement action is taken. In the event of major deficiencies posing an immediate threat to the environment or in cases of operator intransigence, Division of Environmental Management enforcement personnel should be directly and immediately involved.

3. Each intensive livestock operation and its animal waste management system that is required to obtain an approved animal waste management plan should be inspected annually. Additional inspections should be scheduled for facilities found to be noncompliant.

C-5. FEES FOR PERMITTING AND INSPECTION OF ANIMAL WASTE MANAGEMENT SYSTEMS

The collection of fees from regulated industries to offset the costs of implementing environmental programs is established policy in North Carolina. As agriculture becomes increasingly subject to environmental regulation, the question arises whether

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agriculture should also pay a like share for the programs required to ensure their compliance with water quality statutes and rules. After considerable debate, the Commission agreed that the animal agriculture industry should contribute to the cost of implementing the permitting and inspection program recommended in this report. The fee would be imposed upon each swine, cattle, and poultry operations required to obtain a permit for its animal waste management system from DEM. As recommended by the Commission, this fee would be tiered and assessed on a live weight basis. No fee would be assessed on those facilities that operate on a deemed permitted basis. The total amount of the fees collected by DEM should not exceed 40% of the total cost of the regulatory program. This is consistent with the limitations on fees that may be assessed other industries that are required to obtain water quality permits.

Recommendations

1. DEM should be authorized to collect an annual fee to cover up to 40% of the cost of its permitting and inspection program for animal waste management systems.

2. The fees shall be structured on a tiered basis as follows:
    a. For each animal waste management system with a design capacity of at least 38,500 pounds steady state live weight and less than 100,000 pounds steady state live weight, the annual fee shall be $50.
    b. For each animal waste management system with a design capacity of at least 100,000 pounds steady state live weight and less than 800,000 pounds steady state live weight, the annual fee shall be $100.
    c. For each animal waste management system with a design capacity of 800,000 pounds or greater steady state live weight, the annual fee shall be $200.

3. The fees recommended in this section should be assessed on swine, cattle, and poultry facilities meeting the size thresholds for obtaining a general or individual permit. No fee should be assessed on animal agricultural operations that fall within the "deemed permitted" category.

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D. FUTURE RESEARCH INITIATIVES

From the evidence presented to the Commission, it was obvious that additional research is needed in several critical areas in order to develop a regulatory approach based upon scientific fact. The impacts of older lagoons on groundwater quality is not yet known. Sources of nonpoint nitrate pollution in our surface waters have not been specifically identified. Alternate innovative technologies must be pursued and made available to the livestock industry to supplement lagoon and sprayfield technology as part of the overall effort to ensure that their impact upon the environment is minimized.

D-1. ALTERNATIVE TREATMENT METHODS

In the intermediate to long run, exclusive reliance upon lagoon technology as the permitted method of animal waste disposal is not prudent. New and innovative waste management technologies that are proven to be viable should be encouraged. When adequate data exists to indicate the reliability of the technology, backup waste management systems should not be required.

At present, State government does not appear to be actively encouraging the development and use of alternative technologies. A major reason for the failure to accept alternative technologies is the absence of a satisfactory institutional arrangement for testing such technologies.

Recommendations

1. As a matter of State policy, encourage the development of alternative treatment and disposal technologies. Provide incentives to producers to participate in the evaluation of new and innovative animal waste management technologies. Direct the Division of Environmental Management to ensure that the regulatory process is not limiting the use of innovative technologies and that the evaluation of technologies is made in a timely manner.

2. Appropriate funds to the North Carolina Agricultural Research Service for a collaborative venture between the Service and DEHNR, that would serve as a focal point for experimentation with and testing of alternative animal waste disposal technologies for use in agriculture.

3. Encourage the N.C. State University Animal and Poultry Waste Management Center to increase their current efforts to establish and monitor farms for demonstrating alternative technologies.

D-2. GROUNDWATER QUALITY

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Some lagoons constructed prior to February 1, 1993, were not required to satisfy Natural Resources Conservation Service design and construction criteria that went into effect February 1, 1993, for all lagoons pursuant to the .0200 rules.

Seepage of wastewater beyond 200 feet of the lagoon as occurred in some instances, in most cases for "old lagoons". According to testing conducted by the Fayetteville Regional Office of Division of Environmental Management pursuant to the Governor's free drinking water well testing program for persons who reside in close proximity to hog farms, of 109 wells sampled, 30 have had nitrate levels in excess of 10 parts per million and 29 have had nitrate levels between 1 and 10 parts per million. To date, it is the opinion of the Division of Environmental Management that at least one hog farm is the cause of the contamination of nearby drinking water wells. The results of the drinking water wells tests to date are a reason for concern and warrant close monitoring.

Groundwater studies currently being conducted include only lagoons constructed according to current Natural Resource Conservation Service standards. More data concerning groundwater quality in the area surrounding hog farms is needed. Additional data regarding the quality of groundwater is needed. A groundwater study should be carefully designed to assure that the best scientific approach is taken in order to provide reliable results.

Recommendations

1. Direct a research institution to design and implement a scientifically based study for the purpose of determining the extent to which lagoons pose a threat, if any, to the groundwater of this State. Select for study lagoons that are representative of soil types and hydrologic conditions in North Carolina.

2. For purposes of this study, a lagoon is posing a threat to groundwater if nitrate levels exceed 10 parts per million outside the compliance boundary of 250 feet.

3. An environmental interest group, a regulatory agency, and a commodity group representing the pork industry should participate in the study.

D-3. WATER QUALITY

Water quality can be degraded by a number of point sources and nonpoint sources of contaminants. Nonpoint sources of nitrates are diverse and potentially include municipal wastewater treatment systems, industrial systems, golf courses, commercial residential lawns, fertilizers, pesticides, animal waste and the natural ecosystem. The nonpoint sources of nitrates should be identified so that operators of intensive livestock operations know the contribution their industry makes to the degradation of

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water quality. The technology exists to determine the nonpoint sources of nitrates in the waters of the State.

Recommendation

Fund research designed to identify sources of nitrogen in the surface and groundwaters of the State.

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III. PROCEEDINGS

The Blue Ribbon Study Commission on Agricultural Waste met 14 times on the following dates: October 11, 1995; October 25, 1995; November 8 and 9, 1995; November 30 and December 1, 1995; December 13 and 14, 1995; January 10, 1996; January 24, 1996; February 7 and 8 1996; February 20, 1996; March 6, 1996; April 10, 1996; April 24, 1996; May 1, 1996; and May 8, 1996. For a complete record of the Commission proceedings, including minutes for each meeting, refer to the Commission notebooks on file in the Legislative Library in the Legislative Building. A brief summary of the Commission meetings follows:

October 11, 1996

After opening remarks by the Cochairmen Dr. Ernest Carl and The Honorable Tim Valentine and introductory remarks by each on the Commission members, Kelly Zering, Ph.D. Department of Agriculture and Resource Economics, College of Agriculture and Life Sciences, North Carolina State University, provided the Commission with information regarding the historical and economic background of agriculture in North Carolina, emphasizing the poultry and swine industries. Historically, the main North Carolina crop was tobacco, a high value crop that requires relatively small acreage. According to one report, twenty-eight percent of the economy in North Carolina is dependent on agribusiness. In the last seven years, the number of farms in North Carolina that sell at least $1,000,000 in agricultural commodities has dropped from 70,000 to 58,000. In the 1980s the average size farm in this State grew significantly to approximately 150 acres by 1987 and to 160 acres by 1994. Now the average size farm in North Carolina is about one-quarter the average size farm in the Midwest. Like tobacco farms, poultry and hog farms do not require large amounts of acreage. Production contracts are unique to North Carolina and provide a small farmer with a low-risk way to become profitable. On the one hand, poultry production and swine production have provided some small farmers with an economically viable alternative to raising tobacco and a way to stay on the farm and earn a livelihood. On the other hand, increased farm size and increased specialization lower production costs and increase efficiency. Accordingly, the number of hog farms in North Carolina has decreased since 1988, while the number of hogs produced has increased over the same period.

Dr. Zering estimated the total economic impact of the swine industry in North Carolina, including the multiplier effect, at more than $3 billion dollars, over $1 billion dollars of which stays in the pockets of North Carolinians. At present, Iowa is the largest pork producing state with approximately 14,000,000 hogs. North Carolina is second with approximately 8,100,000 hogs. Packing capacity limits the growth of the industry.

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Dewey Botts, Director, Division of Soil and Water Conservation, DEHNR, informed the Commission of the Division's role with respect to the regulation of intensive livestock operations and the role of the federal Natural Resources and Conservation Service (NRCS) in both implementing the .0200 rules and providing technical assistance to operators. The N.C. State Cooperative Extension Service and the North Carolina Department of Agriculture (NCDA) also provide technical assistance. Through the Agriculture Cost Share Program for Nonpoint Source Pollution Control, as provided in Part 9 of Article 21 of Chapter 143 of the General Statutes, funding may be provided to assist farmers in implementing certain best management practices or for certain other expenditures that lead to the reduction of agricultural nonpoint source pollution in the waters of the State. The State contributes seventy-five percent of these funds; the farmer is required to provide twenty-five percent. Between now and December 31, 1997, 2,400 to 2,600 intensive livestock operations have to be brought into compliance with the .0200 rules. The dairy operations in the western part of the State have the greatest and most costly problems to address before they are in compliance. It is anticipated that one-fourth to one-third of the dairy operations will have to go out of business due to their inability to afford the cost of coming into compliance.

Mr. Steve Tedder, Chief, Water Quality Section, Division of Environmental Management (DEM), DEHNR and David Harding, staff for the Water Quality Section, spoke of the division's role in enforcing the animal waste management plans required under the .0200 rules and the requirement that operators register with DEM by December 31, 1993. Because intensive livestock operations are deemed permitted pursuant to the .0200 rules, the Division finds itself in a reactive position with respect to enforcement. It responds to complaints brought to its attention. Following the various lagoon spills that occurred beginning in June 1995, the Governor issued an Executive Order that required, in part, that DEM inspect all of the approximately 4, 600 animal waste lagoons in the State. When the final report of the inspections is complete, it will be presented to the Commission.

Susan Iddings, Commission Counsel, informed the Commission of legislation enacted by the 1995 General Assembly regarding intensive livestock operations.

October 25, 1995

This meeting provided an opportunity for various interest groups to express their positions regarding the recent rapid growth of intensive livestock operations in North Carolina. The following persons spoke before the Commission: Walter Cherry, Director, North Carolina Pork Producers' Association (he noted that the major hog counties are in the eastern part of the State, Duplin County is the number one hog-producing county in the nation and the number one turkey-producing county in the nation, and Sampson county is the number two hog-producing county in the nation); Kristin Rowles, Executive Director, Pamlico-Tar River Foundation (she expressed the

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Foundation's concern of the adverse environmental impacts of large-scale hog production and recommended a moratorium on the I.B.P. processing plant being considered in the Pamlico-Tar River Basin); Bill Moser, P.E., Law Engineering and Environmental Services (he stated that his firm had submitted a proposal to the North Carolina Pork Producers' Association to produce a report containing their recommendations for any changes to current regulations of the industry); Rick Dove, Neuse Riverkeeper, Neuse River Foundation) he gave a slide presentation to illustrate his assertion that the Neuse Rive is one of the twenty most threatened rivers in all of North America); Roger Bone, Lobbyist, North Carolina Pork Producers' Association (he appeared in lieu of Marion Howard, who was scheduled to speak at this place in the agenda); Bill Holman, Lobbyist, North Carolina Conservation Council and the North Carolina Chapter of the Sierra Club (he acknowledged the contribution of other sources of water pollution in addition to the swine and poultry industries and presented a number of recommendations to the Commission); Jimmy Vincent, Environmental Resources Manager, Browns of Carolina (he assured the Commission that producers are eager to protect the environment and willing to comply with the .0200 rules); Don Webb, President, Alliance For A Responsible Swine Industry (he stated that his citizens' organization seeks to stop the odor associated with swine operations and to stop the pollution of air and water resources).

Michael Williams, Ph.D., Commission member, spoke in his capacity as Director of the Animal and Poultry Waste Management Center, North Carolina State University. The Center is conducting research to determine a means by which animal waste can be used as a valuable resource. Members of the public made remarks from the floor.

<u>November 8 and 9, 1995</u>

The Commission traveled to Duplin County for its next meeting. On November 8, guided by Michael Suggs, District Conservationist, NRCS, the Commission toured the following facilities: Oceanview Farms, the site of the June 21, 1995, lagoon failure; the Joey Carter Farm, site of an experimental waste treatment system that is designed to eliminate the need for a typical waste treatment lagoon; the Gerald Knowles Farm, site of a constructed wetland used to treat animal waste; the David Summerlin Farm, site of a turkey mortality composting facility; and the Circle Q Farms, site of a well-managed, conventional waste treatment lagoon and spray irrigation system for a 4,000 sow farrow to wean facility. At 7:00 p.m. the evening of November 8, the Commission conducted a public hearing at the James C. Sprunt Community College in Kenansville, North Carolina. Approximately 400 people attended this hearing.

On November 9, 1995, the Commission held a meeting in the Board Room of the James C. Sprunt Community College Administration Building. The meeting consisted of discussion among the members of the Commission. No formal presentations were given; members of the public made remarks from the floor.

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November 30 and December 1, 1995

This two-day meeting in Raleigh was devoted to water quality issues and focused on the receipt of scientific evidence presented by scientists recognized as experts in their respective fields of study. First, Steve Tedder, Chief, Water Quality Section, DEM, DEHNR, explained the complex issues associated with animal waste management for the swine industry and reported the results of the inspections of animal waste lagoons that were ordered by the Governor after the June 21 lagoon spill at Oceanview Farms. The .0200 rules were adopted by the Environmental Management Commission on December 10, 1992, and became effective February 1, 1993. Pursuant to these rules, all animal operations having equal to or more than the threshold numbers of animals are required to have an approved animal waste management plan by December 31, 1997. At this time, only eight to ten percent of the operations affected by this requirement have an approved plan in place. Mr. Tedder characterized current record-keeping requirements as "woefully inadequate" to protect water quality. Agriculture cost share funds are available to farmers for certain costs associated with coming into compliance with the .0200 rules (G.S. 143-215.74(b)(5) provides that funding may be provided to assist certain practices and for grade control structures, water control structures, and animal waste management systems and application to farmers who volunteer to participate in the program). Mr. Tedder is concerned that farmers who wait will find these funds no longer available.

By November 28, 1995, 4,619 intensive livestock operations had been inspected by DEM staff. Most are located east of Raleigh. Of the total inspected: fifteen percent had inadequate freeboard, four percent exhibited seepage from lagoons, six percent had inadequate cover crops, twenty-six percent kept inadequate records, three percent had inadequate acreage set aside for irrigation with wastewater. Mr. Tedder concluded that the inspections had been extremely informative; previously DEM staff had not been available to conduct inspections. He expressed concern regarding operations that had gone out of business. Closure plans are needed. As a result of the inspections, DEM had initiated a number of enforcement actions. Enforcement options are: the imposition of civil penalties, injunctions filed by the Attorney General's Office, loss of an operator's deemed permit status, or a criminal action. Mr. Tedder made a number of recommendations to the Commission. Dewey Botts, Director, Division of Soil and Water conservation, DEHNR, added that the .0200 rules are inadequate with respect to resources, recordkeeping, and training requirements for applicators of wastewater.

Dr. J. Wendell Gilliam, Professor of Soil Science, NCSU, explained how nutrients leave the soil and get into water. Run off from an individual's house, garden, or from agricultural land contains some nutrients, mainly nitrogen (N) and phosphorus (P). Those nutrients are necessary for life in the water; however, excess nutrients cause problems. If harvested, coastal Burmuda grass removes N from the farm site, but if the grass is used for grazing by livestock, high concentrations of N will be left

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at the farm as waste deposited by the grazing animals, and the N eventually gets into shallow groundwater. Phosphorous reacts with soil; therefore, phosphorous stays in surface soil. When used correctly and according to recommendations, animal waste is just as good a fertilizer as inorganic fertilizer. However, it is more difficult to correctly use animal waste as inorganic fertilizer. However, it is more difficult to correctly use animal waste as a fertilizer than it is to correctly use commercial, inorganic fertilizer. The amount of N and P can be adjusted in commercial fertilizer. More P has been added to Coastal Plain soils over the years. Coastal Plain soils are generally higher in P than Piedmont soils. But, when Piedmont soils do become high in P, there is potentially a larger problem with regard to water quality. More N is lost to surface waters from Coastal Plain soils than from Piedmont soils.

Senator Albertson urged the increased use of riparian buffers. Dr. Gilliam stated that at the coast, buffers of 30-50 feet are sufficient; 100 foot buffers consisting of ½ grass and ½ trees are ideal.

Dr. Frank J. Humenik, Professor and Associate Head and Departmental Extension Leader, Biological and Agricultural Engineering, NCSU, assessed animal waste treatment systems. He has been working with these systems in North Carolina since 1969. Dr. Humenik stated that lagoons with land irrigation systems provide cost-effective treatment. The key to that is that they must be properly designed, constructed, operated, and maintained. There are many cost-effective lagoon irrigation systems in North Carolina. The .0200 rules need to address chronic rainfalls in addition to the catastrophic rainfalls that are currently recognized as being outside the "zero discharge" requirement. Dr. Humenik said that he would like to see the Commission direct its attention to how to best handle discharges resulting from catastrophic and chronic rainfall beyond the .0200 rules, either through an emergency spillway or by irrigating onto land, depending upon the site.

Dr. Hans W. Paerl, Kenan Professor of Marine and Environmental Sciences, Institute of Marine Science, Morehead City, UNC-Chapel Hill, gave a detailed slide presentation on issues and problems of waste generated and treated by land application, specifically the atmospheric deposition of N in estuaries and coastal waters. Animal waste contains a variety of N compounds which can be used by algae. Nitrogen is very mobile and can move in a variety of ways to end up in our estuaries and coastal zones. Obvious sources of discharge to surface waters are via pipelines, runoff, and groundwater, but the atmospheric deposition of nitrogen is still another way N gets into estuaries. The atmospheric deposition of N has been the focus of Dr. Paerl's research. The atmospheric deposition of N constitutes about ¼ to 1/3 of N loading.

Dr. Paerl said that a certain amount of N is needed to sustain a healthy food chain, but the problem with excessive N loading is that too many algae are grown for the

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rest of the food chain to be able to use. Algae blooms take up oxygen in the water that fish need, leading to fish kills.

Dr. Bill Showers, Associate Professor of Marine, Earth, and Atmospheric Sciences, NCSU, provided a slide presentation regarding a scientific technology that is available now in the State. This technology is able to determine the source of N nutrients found in water. Dr. Showers and Dr. Paerl did a study of the Neuse River in 1980 using a mass spectrometer. This study concluded that there is a difference over time in the source of nitrates. Based on data from the Neuse from 1986-1989, during years of excessive rain, nonpoint sources dominate as the source of nitrates. In dry years, point sources dominate as the source of nitrates. The sources can be discriminated, because the isotopes can be discriminated. Then the isotopic signals for cattle, poultry, and swine waste are determined, the contribution of each of these sources to the N in the surface waters of our State can be determined. This technology, for the first time, provides a means of allocating each sector's contribution to the nutrient loading of our waters.

Dr. Joe Zublena, Assistant State Program Leader, Agriculture, Natural Resources, and Community and Rural Development at NCSU, began the second day. His activities at NCSU have been primarily in the Soil Science Department, with responsibilities in agronomy and waste management. To properly manage nutrients, we must find the balance between nutrients generated from the animal waste and nutrients taken up by the plants being grown in the soil where the waste is applied. A positive balance indicates there are more nutrients used by crops than nutrients generated from manure. A potential problem is indicated by a surplus of nutrients generated by animal waste. Fifty-seven percent of the manure generated in the State can be collected and utilized by the crops that receive the manure. Too much N in the soil can get into wellwater and cause "blue baby" syndrome. Excess N can result in algae blooms, which in turn leads to fish kills. Phosphorous build up is a long-term problem. Other concerns arise when copper or zinc reach unacceptable levels in the soils. Crop needs for these heavy metals are very low; excess levels can cause long-term plant toxicity. A potential solution to avoiding excess nutrients in the future is diet manipulation, involving enzymes that can be fed to the animals. A longer term solution is the export of manure.

Dr. R. Wayne Skaggs, William Neal Reynolds Professor and Distinguished University Professor, and Dr. Robert O. Evans, Jr., Extension Assistant Professor, Biological and Agricultural Engineering at NCSU, provided a slide presentation on the hydrology of the land application of wastewater, specifically swine wastewater. The application of wastewater to land is a final treatment process of many different kinds of wastewaters: municipal wastewater, industrial wastewater, as well as agricultural wastewater. Using computer simulated modeling methods, the amount of N lost in runoff was followed. The properties and disposition of the soil affects the ability of the wastewater to be treated by application to that soil.

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Dr. R. L. Huffman, Associate Professor, Biological and Agricultural Engineering at NCSU. Dr. Huffman's field of study is wastewater seepage from animal waste lagoons. For the past six years he had been involved in site investigations at lagoons. If lagoons are constructed according NRCS standards, there should be little or no seepage. Some to the approximately 4,600 lagoons were not constructed according to these standards. It is documented that a drinking well in Robeson County contains excess nitrates caused by an old lagoon nearby. Dr. Huffman said that old lagoons need to be assessed, but that monitoring wells do not provide the most direct or cost-effective assessment. He advocated the use of emergency spillways to avoid lagoon failures, such as the one at Oceanview Farms in June 1995.

Dr. Patrick G. Hunt, Research Leader with the Coastal Plain, Soil, Water, and Plant Center, Agricultural Research Service of the USDA, spoke about the multiagency water quality demonstration project in Duplin County that was initiated as part of the Presidential Water Quality Initiative. The purpose of the project was to demonstrate improvements in water quality that could be made through the voluntary actions of the landowners, such as the use of nutrient management plans, fencing, and riparian borders. Approximately 100 monitoring wells were installed in one subwatershed on farms that were willing to participate. Seventy-seven percent of the wells did not contain excessive nitrates. One project used a constructed wetland to treat wastewater.

Mr. M. Carl Bailey, Assistant Chief for Planning, Groundwater Section, DEM, DEHNR, spoke about a study that the Groundwater Section is performing related to potential groundwater contamination around animal waste lagoons. Data is not available at this time.

Dr. Kenneth H. Reckhow, Assistant professor, School of the Environment, Department of Civil and Environmental Engineering, Institute of Statistics and Decision Science, Duke University, urged the Commission to use a methodology called decision analysis in trying to solve complex environment management problems. Decision analysis is a method that is historically used more in the private sector than in the public sector. Decision analysis provides a logical structure for study and analysis, beginning with the complete identification of management objectives and attributes.

Members of the public made remarks from the floor.

December 13 and 14, 1995

The Commission members met in Statesville, North Carolina on December 13 to tour dairy facilities in Iredell County. Mr. Kenneth Vaughn, Agricultural Extension Agent in Iredell County, and Representative Frank Mitchell guided the tour of the following

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facilities: the Jeff Maness Farm, a dairy farm that employs a lagoon waste management system; the Holland farm, a land-locked farm in need of extensive renovation due to its location and the presence of streams and valleys surrounding the property; the Robertson Farm, which employs a lagoon for waste treatment and, after the waste has formed a crust on the lagoon, the waste is piled to dry and subsequently used as a dry fertilizer; the Hill Farm, which was in the process of constructing a waste lagoon; and the Leamon Farm, a dairy farm that is using the "dry stack" method of treating its animal waste. That evening at 7:00 p.m., the Commission held its second public hearing at the Iredell County Agricultural Center in Statesville. Approximately 250 persons attended and 28 spoke of the problems particular to the dairy industry.

On December 14 at 9:00 a.m. at the Holiday Inn in Statesville, the Commission held a meeting. The Commission discussed the tour of the previous day. The Commission voted to create a working group consisting of Commission members: Dick Gallo, Dr. Wohlegant, Dr. Barker, Dennis Loflin, and David Harris to consider the current slow pace of certification of animal waste management systems under the .0200 rules and to report its recommendations for corrective action to the full Commission. Steve Levitas, Deputy Secretary, DEHNR submitted a letter containing a list of Department recommendations to the Commission for its consideration.

January 10, 1996

The Commission reviewed and adopted a report prepared by Commission staff summarizing and categorizing issues to be considered by the Commission. This list was based upon the lists of issues that each member of the Commission had prepared and submitted to staff at the Statesville meeting in December. Discussion during the morning session centered on these issues. The Commission recognized the importance of the operators expediting certification of intensive livestock operations pursuant to the .0200 rules. To send a clear message on this point, the Commission, by motion, concluded that the basic thrust of the .0200 rules is to establish an appropriate set of requirements for animal waste management systems, and this Commission will recommend that the December 31, 1997, deadline for compliance with these rules not be extended.

Steve Levitas, Deputy Secretary, DEHNR, reviewed Department recommendations on animal waste issues that are in addition to those recommendations submitted to the Commission at the Statesville meeting. He made the following statements: DEHNR supports addressing water quality problems with a site-specific basin wide systems approach; good scientific evidence supports the conclusion that there is thirty percent more nitrogen in the Neuse river than the river can assimilate. The excess nitrogen comes from all sources, but a substantial portion comes from nonpoint sources of which a large portion is animal waste; other sources of nitrogen include

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municipal wastewater treatment plants, industrial wastewater, gold courses, residential lawns, and agriculture fertilizers.

Dr. Barker stated that farms in existence at the time the .0200 rules went into effect February 1, 1993, have to comply with the operation and maintenance requirements of those rules, but not the design and construction requirements, so long as DEM has not found these operations discharging pollutants to the waters of the State. The agronomic rates that had to be followed before 1992 were based on the amount of nutrients associated with maximum yield capacity for certain crops. The soil capacity and the soil type of the soil at a particular site were not taken into account to establish these earlier agronomic rates. If an operation is fond in violation of the .0200 rules, the operator is required to upgrade his waste management plan to one that is based on the agronomic rates that do take soil capacity and soil type into account.

Dr. Wohlegant pointed out that the animal agriculture industries are price takers, that is, industries whose products cannot be priced higher and passed on to consumers in order to absorb any increased costs of doing business. Mr. Bodley added that animal products, such as pork and dairy products, are commodity products whose prices are set at the national and international levels. Mr. Weaver pointed out that producers' profits go down when the cost of seed grains increases. The cost of feed corn in April 1995 was $2.67/bushel; today it is $4.06/bushel. Mr. Gallo said that the special economics of the agriculture industry is the justification for the voluntary Agriculture Cost Share Program, whereby the public provides seventy-five percent of the cost of certain expenses incurred by the farmer, who must provide the remaining twenty-five percent of the costs.

Members of the public made remarks from the floor.

January 24, 1996

The Commission voted to establish four subcommittees and to assign each subcommittee a set of issues to address during today's Session and again in February and to report back to the full Commission on the second day of the next meeting, February 8, 1996. The Cochairman assigned issues to each subcommittee based on the list of issues adopted by the Commission at its meeting January 10, 1996. The membership of the four subcommittees is as follows: Subcommittee I: Sen. Charlie Albertson (Chair), Jeff Turner, Dr. Robert Cook, and Dr. Michael Williams; Subcommittee II: Dr. James Barker (Chair), David Harris, Nick Weaver, Dr. Michael Wohlgenant; Subcommittee III: Dick Gallo (Chair), John Adams, Rep. John Brown, and Loyd Godley; Subcommittee IV: Robert Ivey (Chair), Cleveland Simpson, Dennis Loflin, and Dr. William Caviness. The Commission discussed the benefits of requiring general permits for intensive livestock operations. The Commission reached a consensus on the desirability of a general permit regulatory structure as

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preferable to the current regulatory structure whereby operations are deemed permitted until found to be in serious violation of the .0200 rules. Before breaking up for subcommittee meetings, the Commission discussed the desirability of authorizing local governments to regulate intensive livestock operations and the desirability of imposing a moratorium on new swine operations. Both discussions were lively, but resulted in no formal action by the Commission. The Commission appeared to be in agreement that a moratorium was not justified at this time.

The afternoon session was devoted to presentations by the following: Dr. Steve Hoard, Edgecombe County Commissioner, and Jim Bayless, Edgecombe County Health Director, both of whom spoke in favor of local governments having the authority to regulate intensive livestock operations; Marvin Horton from Nashville, North Carolina, who spoke against locating an I.B.P. slaughterhouse in Edgecombe County; Frank Tyndall, a consulting engineer for Kimley-Horn and Associates, Inc., who presented the report on the swine industry requested and paid for by Murphy Family Farms; and William Mosher, Chief Engineer and Assistant Vice President for Law Engineering and Environmental Services, Inc., who presented the Law Engineering Report requested and paid for by the North Carolina Pork Producers' Association.

Members of the public made remarks from the floor.

February 7 and February 8, 1996

The full day, February 7, was spent in separate meetings by each of the four subcommittees designated by the Cochairmen at the last meeting. On February 8, the full Commission met, and the Chair of each subcommittee presented its report to the full Commission. In its report, a subcommittee addressed each issue it had been assigned. A subcommittee had been directed to take some action on each issue as follows: (1) make a recommendation (2) decide to take no action, or (3) decide more information was needed and defer action until the information was obtained. The Commission took up one recommendation at a time. A recommendation was presented for discussion by the Commission. The Commission then voted on whether to adopt a recommendation for approval by the Commission. Cochairman Tim Valentine emphasized that a vote of approval by the Commission was not a final action on any recommendation. The Commission approved some recommendations as presented, approved several as amended by the full Commission, and tabled others for later action by the subcommittee that had considered the issue. Senator Albertson's Subcommittee I deferred action on two issues: local zoning and a rewrite of Senate Bill 1080 of the 1995 Session (enacted as Chapter 420 of the 1995 Session Laws) until more data was obtained. Dr. Barker's Subcommittee II decided it needed more information before it could address the role of local health departments in regulating intensive livestock operations. The Commission approved a recommendation made by Subcommittee IV chaired by Robert Ivey to replace the

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deemed permitted approach to regulation of intensive livestock operations with a system of general permits based on the animal waste management plans currently required under the .0200 rules, but tabled the following recommendations of that same Subcommittee: that the costs of the inspection and enforcement program should be borne by the State, all recommendation's concerning changes to the application training requirements, the issue of integrator liability, and that a public comment period should be incorporated into the permit process for intensive livestock operations. The later recommendation was the recommendation contained in a minority report from the Ivey Subcommittee.

Members of the public made remarks from the floor.

February 20, 1996

Steve Tedder, Chief, Water Quality Section, DEM, DEHNR, presented the Draft Interim Plan for the Neuse River Basin. The document has been presented to the Environmental Management Commission (EMC) at its February meeting, is subject to written comments, and provides the basis for proposed rules. The interim plan establishes a thirty percent reduction of the nitrogen levels in the Neuse River over a five-year period as a goal, requires cities to elicit a connections program for stormwater sewers, recommends a tiered permit program for intensive livestock operations, and requires 50 feet buffers for intermittent and perennial streams.

Dennis Loflin, Commission member and member of the EMC, expressed his objections to the interim plan, saying that, in his opinion, the buffer requirements represent a flagrant violation of private property rights.

Mr. Tedder reminded the Commission that DEM is flexible and presents the interim plan as embodying a concept that is subject to refinement. DEM staff considers that the most important component of the plan for the Neuse is general permits.

Dick Gallo, Commission member appearing in his capacity as State Director, Natural Resources Conservation Service (NRCS), introduced the report to the Commission regarding the revision of NRCS standards as related to animal waste. Jim Canterberry, State Resource Conservationist, NRCS, gave the Commission background information. NRCS is a federal agency under the United States Department of Agriculture that was created in 1935 to provide on site technical assistance to farmers. NRCS works with local Soil and Water Conservation Districts through a memorandum of agreement. NRCS contends the main problem with respect to intensive livestock operations is improper management. Starting November 1995, NRCS convened a series of three subcommittees consisting of a broad range of interested parties to improve the NRCS technical standards and to attempt to strengthen lagoon technology. Harry Gibson, State Engineer, NRCS, related the key revisions to the waste treatment lagoon technical standards. A new

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standard addresses closure of abandoned lagoons or ponds. Emergency action plans will be required for every lagoon. Approximately 15 years' worth of sludge storage is now required rather than the five years worth currently required. Odor control measures will be required, which include precharging lagoons with water before loading, the use of inlet pipes, and installation of windbreaks, if applicable. Emergency spillways are mandated to allow effluent to escape. More comprehensive site evaluations will be required pursuant to the revised standards. Liners will be required where conditions may present limestone deposits. The lagoon bottom and site must be scarified and compacted to standard.

Bill Harrell, Resource Conservationist, NRCS, presented the key revisions with respect to waste utilization standards. The major revisions address the nutrient management standards. The object of the nutrient management plan is to assure that the nutrients, including nitrogen, are removed through crop harvest. Nitrogen is the limiting nutrient. Phosphorous is immobile in the soil; phosphorous leaves through erosion. Erosion is controlled through the use of best management practices. Nitrogen goes into solution readily and leaves through runoff or volatilization. Copper and zinc are toxic to plants. Crops vary in sensitivity to these heavy metals. The revised nutrient management plans will inform farmers of concerns regarding heavy metal loading. Irrigation plans will be a required component of a waste utilization plan. For five years, operators will be required to maintain records indicating the date and amount of waste applied to crops. Soils where waste is applied must be tested every two years. Agronomic rates will be based on realistic yield expectations rather than maximum yields used previously. Agronomic rates for grasslands are based upon an assumption of a fifty percent N reduction, whereas the previous assumption was for a twenty-five percent N reduction. The direct result of these revisions is that more land will be needed on which to land apply animal waste. The revised NRCS technical standards become effective March 1, 1996.

During the afternoon session, Dick Gallo, speaking in his capacity as Chair of the Commission subcommittee established in Statesville at the December 14, 1995 Commission meeting, gave the subcommittee's report. That subcommittee was charged to consider the current slow pace of certification of animal waste management systems under the .0200 rules. The Commission took up each recommendation in turn for discussion and voted on whether to adopt the recommendation.

Members of the public made remarks from the floor.

March 6, 1996

Sen. Albertson, Chair of Subcommittee I, reported progress by that group on the two issues remaining before it. The subcommittee had met on three occasions to review GIS maps of portions of certain counties for the purpose of determining the impact of

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the siting limitations enacted by the 1995 General Assembly under Senate Bill 1080. On the first two occasions, sufficient gaps in the data existed to make any judgments on the potential impact of Senate Bill 1080 inconclusive. Sufficient data was available for only Pitt County and, on the third occasion, the subcommittee studied maps for Pitt County. Tim Johnson, Technical Services Manager, and Jeff Brown, Project Developer, both with the Center for Geographic information and Analysis, Office of the Governor, brought these maps of Pitt County to the full Commission. The first sets of maps showed all of Pitt County, and the second showed a southeastern portion of Pitt County. Areas restricted for siting new swine farms pursuant to the siting limitations contained in enacted Senate Bill 1080 (Chapter 420 of the 1995 Session Laws) were shaded. Property boundaries were shown as well. The subcommittee concluded that Senate Bill 1080 substantially limited the siting of new swine farms and, accordingly, operated as a statewide zoning law. The subcommittee's recommendations to not broaden the authority of counties to adopt ordinances that affect swine operations and to rewrite Senate Bill 1080 to clarify ambiguous language and add an enforcement provision were adopted by the Commission. A working group to consist of representatives for the Farm Bureau, DEHNR, NCDA, the Attorney General's Office, and an environmental group was appointed the task of working with Commission staff and providing a draft rewrite of Senate Bill 1080.

The Commission broke into its Subcommittees I - IV, which met to review a compilation of the tentative recommendations of the Commission and to consider any issues before them. The Commission reconvened after lunch to receive further reports from the subcommittees. Robert Ivey's Subcommittee IV presented its recommendations on their issues remaining before it. As to the issue of applicator training, the subcommittee recommended placing a 16-hour cap on the required training class. Current law (G.S. 143-215.74E) enacted by the 1995 General Assembly, Chapter 544 of the 1995 Session Laws, requires a person who performs the land application of animal waste from swine production to be certified and, in order to be certified, that person must have a six-hour training program and pass an examination. Ron Ferrell, DEM, DEHNR, explained that a training manual had been developed since August 1995, following the enactment of Senate Bill 974 of the 1995 Session (enacted as Chapter 544 of the 1995 Session Laws), the legislation requiring swine waste applications to be certified. The training manual was developed with input from NRCS, N. C. State Cooperative Extension Service, the Farm Bureau, the New River Foundation, the North Carolina Pork Producers' Association, and others. It is a good and thorough manual. Applicators must be able to perform certain mathematical calculations to complete the training and pass the examination. In order to protect water quality, it is critical that the land application of waste is performed correctly. Sen. Albertson pointed out that farmers who apply their own pesticides are only required to take a three-hour course or pass an examination, not both. After full discussion, the Commission voted to raise the current training cap of six hours to twelve hours. Eight hours of training is to be in

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the classroom; four hours is to be in the field. The Commission voted to amend the recommendation to add that alternate instruction and testing methods will be made available for those with reading or learning difficulties. The subcommittee's recommendation that the fees for certification be $75.00 for the examination and certification and $30.00 for an annual renewal fee failed. The other recommendations of the subcommittee were approved, including the recommendations that the costs of the inspection and enforcement program be borne by the State and that responsibility for violations of environmental statutes and rules should remain with the permittee.

Members of the public made remarks from the floor.

April 10, 1996

Dr. Carl brought up the issue of public notice for reconsideration for the Commission. Dr. Carl stated that the previous vote by the Commission against requiring operators to give public notice of a new operation was addressed as a requirement for a public hearing. The Commission discussed providing notice by publishing notice in a newspaper of general circulation. After voting against a notice requirement in concept, Dr. Carl appointed a subcommittee consisting of Representative John Brown (Chairman), Jeff Turner, Cleveland Simpson, and David Harris to discuss a notice requirement.

The Commission considered for the first time the issue of insect control and voted to include in the final report a requirement to establish odor control best management practices which would be a mandatory component of an animal waste management plan.

The Commission turned its attention to a thorough review of the draft and final report to the General Assembly, proceeding page by page. The Commission directed the rewrite of the introduction to the report and voted to modify several recommendations as they appeared in the draft report.

The Cochairmen directed the Division of Environmental Management, DEHNR, to present the Commission with its proposals in writing for a general permit system for animal operations, one general permit for each species of animals: swine, dairy, cattle, and poultry.

The Commission received comments from the public.

April 24, 1996

Dick Gallo, Commission member and State Director, NRCS, updated the Commission regarding the revision of the NRCS technical standards related to

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animal waste. After receiving comments, the group working on revising the standards made a number of changes to the revisions. The next stop in the process is to submit the revised NRCS standards to the Soil and Water Conservation Commission for adoption. If the Soil and Water Conservation Commission takes no action, the standards are adopted automatically. The effective date for the revised standards was changed from March 1 to June 1, 1996.

The Commission broke into subcommittees so that the subcommittees could address any outstanding issues and later reconvened with subcommittee reports. The newest subcommittee consisting of Representative Brown (Chair), Jeff Turner, Cleveland Simpson, and David Harris returned with a motion regarding public notice to post a sign at the property on which an animal operation is proposed, stating pertinent information whereby the public could submit written comments to DEHNR. After full discussion and amendments to the motion the Commission voted to adopt the motion.

Senator Albertson's subcommittee and Dr. Barker's subcommittee jointly recommended a rewriting of the Commission's Recommendation B-6 in the draft report on waste utilization plan and record keeping. The commission adopted alternate language, which states the recommended requirements for waste and soils testing with fuller, more accurate scientific language.

After lunch, the Commission reconsidered its motion regarding public notice and passed a motion in lieu of that motion. The Commission adopted a form of notice whereby the person intending to site a new swine farm or to expand an animal waste management system beyond its design capacity is required to attempt to notify all adjoining property owners by certified mail at the address for the adjoining property owner on file at the property tax office. The motion specified the contents of the notice, including information that the adjoining property owners may submit written comments to DEM. Adjoining property owners will not be able to block the siting of an operation that complies with all applicable laws and rules; however, the adjoining property owners may inform DEM of information that indicates the proposed operation fails to comply with an applicable law or rule. The Commission seemed in accord on wanting to establish a dialogue between operators and neighbors and to remove the possibility of neighbors being caught unaware that a hog farm was coming next door or substantially increasing its size.

The Commission turned its attention to reviewing and revising three proposed types of general permits for animal waste management systems prepared by DEM: one for swine, one for dairy cattle, and one for poultry. Then the Commission considered and adopted additional language submitted by David Harris regarding recommendation C-4 in the draft report regarding annual inspections of animal waste management systems by DEM. Noting the success of cooperative efforts of staff from various agencies in the Sedimentation Control Program in DEHNR, the Commission

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considered a similar approach with respect to monitoring and reviewing animal waste management systems. David Harris stated it was his intent to spread the work among the agencies, all of whom have trained, qualified staff to do the work so that the work gets done. Dr. Barker and Mr. Gallo urged the Commission to preserve the nature of the relationship between Cooperative Extension agents and NRCS staff with farmers. After modifying the language to the satisfaction of Dr. Barker and Mr. Gallo, the new language was adopted.

The Commission discussed imposing fees on the operators for the cost of an inspection and enforcement program for animal waste management systems. Unable to ascertain the projected cost of such a program from DEHNR, the Commission delayed discussion on this subject.

The Commission sought comments from members of the public.

May 1, 1996

Senator Albertson's subcommittee gave its final report on the rewriting of Senate Bill 1080, the Swine Farm Siting Act, and submitted a draft bill to be included in the Commission's final report as part of an omnibus legislative proposal. The Commission adopted the draft bill, then turned its attention to the last issue outstanding before the Commission: What level of funding is needed for permitting, inspections, and enforcement programs within DEM and how to fund these programs, through the General Fund or by imposing fees upon producers or a combination of the two. DEHNR provided the members of the Commission with a chart indicating the Department's proposal on funding. Steve Tedder, Chief, Water Quality Section, DEM, DEHNR, reviewed these figures and responded to questions. According to Mr. Tedder, the cost of permitting inspections, compliance inspections, and enforcement activities is one million one hundred eighty-three thousand twenty-three dollars ($1,183,023) for the 1996-97 fiscal year. This would provide for 18 new staff positions. The cost of permit application analysis, compliance and enforcement activities, and training, certification, and technical assistance is six hundred thirty-three thousand one hundred fourteen dollars ($633,114) for the 1996-97 fiscal year. This total includes funding for 10 new staff positions. The total for both the permitting program and the inspection and enforcement program is one million eight hundred sixteen thousand one hundred thirty-seven dollars ($1,816,137) for 28 other positions. DEHNR proposed imposing fees to raise at least thirty percent (30%) of the total costs to DEHNR of the water quality programs with the balance to come from appropriations from the General Fund. Under G.S. 143-215.3, water quality programs are funded in this way. EMC develops a fee schedule, which goes through the rule-making process. These figures do not take inspections of dry poultry litter operations, as recommended by the Commission, into account. Dr. Cook reminded the Commission that DEM had received funding for the 1995-96 fiscal year for eight new positions. Mr. Tedder stated that before last session, DEM had had no

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