Mortality and health outcomes in North Carolina communities located in close proximity to hog CAFOs

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FALL FORUM 2018 ON HEALTH AND ENVIRONMENT,
NOVEMBER 1-2, 2018, DURHAM, NC
Income and life expectancy: unexpected finding?

- Even in high-income communities LE can be low.

- The differences in LE between same-income communities correlate with area-specific health behaviors and local area characteristics.

- This is also true for the low-income communities.

Race- and Ethnicity-Adjusted Life Expectancy by Income Quartile.
Differences in LE as one travels east on Route 64 from Raleigh.

Source: The Robert Wood Johnson Foundation and the Virginia Commonwealth University Center on Society and Health.
- 221 zip codes with hog CAFOs registered at the DWR, 2,260,000 residents.
- 56 zip codes with >215 hogs/km² (this is the upper quartile of hog density in NC), over 400,000 residents.
- Control Group: 601 zip codes without hog CAFOs, 7,200,000 residents.

Largest CAFOs in NC are located in Duplin, Sampson, Bladen, Wayne, Greene, Lenoir, Robeson, Pender, Columbus, Pitt, and Johnston counties.
Age-adjusted mortality rate (per 100,000), 2007-2016: NC areas with >215 hogs/km² and US and NC average, (±SE).

- All-cause mortality
  - US average: 881.0±4.6
  - NC average: 88.6±1.5
  - Communities with >215 hogs/km²: 22.0±0.7

- Infections (underlying+secondary)
  - US rank #1: 100.8±1.6

- Kidney disease (underlying)
  - US rank #2: 88.1±0.6

- Kidney disease (underlying+secondary)
  - US rank #3: 88.1±0.6

(official #1 West Virginia)

2018 EHSP Fall Forum
Age-adjusted mortality rate (per 100,000) (cont.), 2007-2016: NC areas with >215 hogs/km² and US and NC average, (±SE)

- Anemia (underlying+secondary) 30.8±0.9
- Cervical cancer (underlying+secondary) 1.9±0.2
- Uterine cancer (underlying+secondary) 7.0±0.5
- Asthma (underlying) 2.6±0.3
- Anemia (underlying) 3.3±0.4

“US rank” #2

“US rank” #7

“US rank” #1 (official #1 Mississippi 1.5±0.1)

“US rank” #1 (official #1 West Virginia 23.5±0.3)
Health issues in residential populations living near hog CAFOs: what other studies have reported

People who live near hog CAFOs have been reported to have more often:

- medium-to-low exposures to various infectious agents, diarrhea;
- respiratory symptoms;
- arterial hypertension;
- neurological symptoms (children);
- depression and fatigue.

(Source: Schiffman et al, 1995; Avery et al, 2004; Schiffman et al, 2000; Thu et al, 1997; Wing, Wolf, 2000; Wing et al., 2013; Chrischilles et al., 2004; Kilburn, 2012; Wing et al., 2008; Schinasi et al., 2011)
Hog CAFOs located within 3 miles of homes in North Carolina

Source: EWG, 2018
Weather factor in North Carolina

Total Precipitation (in.) Sep. 13-17, 2018

Source: http://www.nc-climate.ncsu.edu

Data from the National Weather Service and CoCoRaHS observers

Source: http://www.nc-climate.ncsu.edu
### Populations of NC communities adjacent to hog CAFOs

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>NC communities with &gt;215 hogs/km²</th>
<th>NC communities with hog CAFOs</th>
<th>NC communities without CAFOs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Race, %</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>White</td>
<td>58.3%**</td>
<td>63.9%**</td>
<td>73.7%</td>
</tr>
<tr>
<td>African-American</td>
<td>31.3%**</td>
<td>28.8%**</td>
<td>19.3%</td>
</tr>
<tr>
<td>American Indian</td>
<td>4.1%**</td>
<td>2.4%*</td>
<td>0.8%</td>
</tr>
<tr>
<td>Median household income, US$</td>
<td>$36,520**</td>
<td>$39,005**</td>
<td>$46,414</td>
</tr>
<tr>
<td>Bachelor or higher degree, %</td>
<td>13.7%**</td>
<td>16.5%**</td>
<td>24.2%</td>
</tr>
<tr>
<td>Primary care providers, per 100,000</td>
<td>51**</td>
<td>54**</td>
<td>76</td>
</tr>
<tr>
<td>Uninsured individuals, %</td>
<td>18.5%</td>
<td>18.2%</td>
<td>17.8%</td>
</tr>
<tr>
<td>Smokers among aged 24+, %</td>
<td>25.9%*</td>
<td>24.4%</td>
<td>24.0%</td>
</tr>
</tbody>
</table>

Note: *p<0.05; **p<0.001.
Co-factors:

- age
- median household income,
- education level,
- availability of primary care providers,
- health insurance coverage,
- smoking prevalence.
Methods of analysis developed for the study

- The propensity score was used for matching zip codes without CAFO to zip codes with >2,150 hogs/km² by socioeconomic and demographic characteristics.

- The greedy matching algorithm (Austin et al., 2010) was used for matching.
The Distance from the Source of potential Contamination (DiSC)

- There is a drop of exposure with increasing distance from the CAFO location.
- Population in rural NC areas (where hog CAFOs are located) is unevenly distributed.
- We developed an approach in which zip-code-specific CAFO’s exposure was evaluated by averaging the contributions of all census blocks in a given zip-code.

**Figure**: The map of Duplin county, NC with zip code boundaries.

- The point of the highest density of population living in each zip code: 😊
- The circles represent potential exposures from each hog farm.
<table>
<thead>
<tr>
<th>Hazardous Air Pollutants and other pollutants in emissions from CAFOs (Rumsey et al., 2012; 2014)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Acetaldehyde</strong></td>
</tr>
<tr>
<td><strong>Ammonia</strong></td>
</tr>
<tr>
<td><strong>Benzene</strong></td>
</tr>
<tr>
<td><strong>Butyric acid</strong></td>
</tr>
<tr>
<td><strong>Carbon disulfide</strong></td>
</tr>
<tr>
<td><strong>Chloroform</strong></td>
</tr>
<tr>
<td><strong>1-Chloro-3-methylbenzene</strong></td>
</tr>
<tr>
<td><strong>Cresols</strong></td>
</tr>
<tr>
<td><strong>Cyclohexane</strong></td>
</tr>
<tr>
<td><strong>Dichlorobenzene</strong></td>
</tr>
<tr>
<td><strong>1,2-Dichloroethane</strong></td>
</tr>
<tr>
<td><strong>Diethlybenzene</strong></td>
</tr>
<tr>
<td><strong>Dimethyl sulfide</strong></td>
</tr>
<tr>
<td><strong>Dimethyl disulfide</strong></td>
</tr>
<tr>
<td><strong>Dimethyl trisulfide</strong></td>
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</tbody>
</table>
Exposure from each hog farm can be represented as a "bell" with the maximum of pollutants situated directly over the farm.

Literature showed that air pollutants from hog CAFO can be detected up to 10-15 miles from the farm.

Radius-specific analyses within:
- 2 km (1.24 miles),
- 5 km (3.11 miles),
- 10 km (6.21 miles), and
- 20 km (12.43 miles) from each hog CAFO.
Sensitivity analysis

- When excluded zip codes of the cities of Charlotte and Raleigh.

- When excluded 18 urbanized areas (114 zip codes) that are defined in the US Census Bureau criteria for urban-rural areas as having 50,000 or more residents.

- Using the generalized estimating equation (GEE) method to account for possible correlations between disease-related records in specific zip codes.
NC residents living near hog CAFOs had higher rates of all-cause mortality, infant mortality, mortality of patients with multimorbidity (e.g., kidney disease+septicemia+anemia), mortality from anemia, kidney disease, tuberculosis, and septicemia, and higher rates of ED visits and hospital admissions for low birth weight.

In zip codes with >215 hogs/km² mortality OR after adjustment by 6 cofactors was
- for anemia 1.50 (p<0.0001),
- for kidney disease 1.31 (p<0.0001),
- for septicemia 2.30 (p<0.0001),
- for tuberculosis 2.22 (p=0.0061).
### All-cause mortality

**Age-Adjusted Mortality Rates (Per 100,000) in NC Communities with > 215 hogs/km² (Study Group 2) Compared to the NC and US Average, 2007-2013. (95% Confidence Intervals are Shown in the Parentheses)**

<table>
<thead>
<tr>
<th>Disease</th>
<th>Age and race group</th>
<th>The US average&lt;sup&gt;a&lt;/sup&gt;</th>
<th>The NC average&lt;sup&gt;a&lt;/sup&gt;</th>
<th>NC communities with &gt; 215 hogs/km²</th>
</tr>
</thead>
<tbody>
<tr>
<td>All-cause mortality</td>
<td>All ages, all races</td>
<td>750 (749.5-750.2)</td>
<td>803&lt;sup&gt;a&lt;/sup&gt; (801.3-805.6)</td>
<td>934&lt;sup&gt;ab&lt;/sup&gt; (922.7-944.8)</td>
</tr>
<tr>
<td></td>
<td>White, all ages</td>
<td>745 (744.5-745.2)</td>
<td>780&lt;sup&gt;a&lt;/sup&gt; (777.9-782.6)</td>
<td>858&lt;sup&gt;ab&lt;/sup&gt; (844.7-871.2)</td>
</tr>
<tr>
<td></td>
<td>AA,² all ages</td>
<td>903 (901.6-904.1)</td>
<td>923&lt;sup&gt;a&lt;/sup&gt; (917.4-928.4)</td>
<td>969&lt;sup&gt;ab&lt;/sup&gt; (947.9-989.4)</td>
</tr>
<tr>
<td></td>
<td>Age ≤ 24 years old, all races</td>
<td>62.2 (62.0-62.4)</td>
<td>69.8&lt;sup&gt;a&lt;/sup&gt; (68.7-70.9)</td>
<td>92.7&lt;sup&gt;ab&lt;/sup&gt; (86.3-99.1)</td>
</tr>
</tbody>
</table>

<sup>a</sup>Statistically significant difference compared to the US average.

<sup>b</sup>Statistically significant difference compared to NC average.

Source: Kravchenko et al., 2018
Table: Mortality ORs in NC communities with >215 hogs/km², 2007-2013, adjusted by 6 cofactors.

<table>
<thead>
<tr>
<th>Disease</th>
<th>Underlying cause</th>
<th>Underlying+ secondary cause</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kidney disease (N00-N19)</td>
<td>1.23***</td>
<td>1.27***</td>
</tr>
<tr>
<td>Glomerular kidney disease (N00-N08)</td>
<td>2.22***</td>
<td>2.08***</td>
</tr>
<tr>
<td>Septicemia</td>
<td>1.21***</td>
<td>1.22***</td>
</tr>
<tr>
<td>Anemia</td>
<td>1.39*</td>
<td>1.44***</td>
</tr>
</tbody>
</table>

Notes: *p<0.05, **p<0.001, ***p<0.0001;

Figure: Age-adjusted mortality rates (per 100,000) from combination of septicemia, anemia, and kidney disease: communities with >215 hogs/km² compared to NC and US average, 2007-2013.
Chronic Kidney Diseases in Agricultural Communities

Bethesda Marriott
5151 Pooks Hill Road
Bethesda, MD

View Meetings & Workshops
The presence of several *Staphylococcus* species was detected near the hog farm and in the spray field.

Antibiotic-resistant bacteria in air samples showed a predominance of *Proteobacteria* in both hog farm and spray field air (includes a variety of pathogens such as *Escherichia, Salmonella, Yersinia*, etc.).

Existence of opportunistic pathogens and antibiotic resistant bacteria in airborne contaminants evidences potential health risks to farmers and other residents.

Source: Arfken et al., 2015
Asthma

There are two most vulnerable age groups:

- Age <9 years old – the highest OR of hospital admissions and ED visits compared to other ages:
  - hospital admissions OR=1.23, p<0.001,
  - ED visits OR=1.30, p<0.001.

- Age 45-64 years old – the highest mortality OR compared to other ages:
  - mortality OR=1.36, p<0.05,
  - hospital admissions OR=1.10, p<0.0001,
  - ED visits OR=1.23, p<0.001.
Low birth weight in NC communities with >215 hogs/km²:

- Hospital admissions OR=1.44, p=0.0663
- ED visits OR=2.45, p<0.0001.

Low birth weight – health risks later in life:

- impaired glucose tolerance and diabetes mellitus,
- cardiovascular diseases (arterial hypertension, ischemic heart disease),
- depression (e.g., in adolescent girls in NC study),
- respiratory diseases,
- chronic kidney disease,
- hypothyroidism, etc.

(Gluckman et al., 2007; Huxley et al., 2007; Costello et al., 2007; Hanson, Gluckman, 2014)
Maternal health

- Complications of pregnancy, childbirth, and the puerperium:\n  - Mortality OR in NC communities with >215 hogs/km$^2$ 2.75, p<0.05.
  - Mortality from pre-eclampsia OR up to 3.55, p=0.0008.

- More often hospital admissions and ED visits in both white and African-American females for:
  - Complications of pregnancy, childbirth, and puerperium,
  - Threatened preterm labor,
  - Diabetes mellitus and anemia during pregnancy.

1Puerperium - the period of adjustment after childbirth during which the mother's reproductive system returns to its normal pre-pregnant state. It lasts six to eight weeks.
Cervical cancer

- Mortality OR in communities adjacent to hog CAFOs was 1.54 (p<0.005).

- Increased ORs of hospital admissions (1.25; p<0.005) and ED visits (1.32; p<0.005).

Age-adjusted mortality rates (per 100,000) for cervical cancer, 2010-2016.
African-Americans have the most pronounced differences between the groups.

The differences in mortality rates start at age 20 years old.

Lower socioeconomic status and poorer access to medical care substantially contribute to increased HIV risk in these communities.

Additional factors could contribute to increased HIV morbidity and mortality, especially among AAs living in NC zip codes with hog CAFOs.

### Human Immunodeficiency Virus (HIV) infection

**Table:** HIV outcomes, underlying+secondary cause/primary+secondary diagnosis, 2007-2013: OR in communities with >215 hogs/km² vs. Control group, multivariable analysis.

<table>
<thead>
<tr>
<th>Health outcome</th>
<th>White</th>
<th>African-American</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mortality</td>
<td>1.43**</td>
<td>1.66**</td>
</tr>
<tr>
<td>Hospital admissions</td>
<td>1.18**</td>
<td>1.27**</td>
</tr>
<tr>
<td>ED visits</td>
<td>1.57**</td>
<td>1.99**</td>
</tr>
</tbody>
</table>

Note: **p<0.001.
Increasing risk of mortality with closer proximity to hog CAFO. Patterns remained after adjustment for co-factors.

White females aged 65+ had the highest mortality OR within 5km from the GAFO.

The Distance from the Source of potential Contamination (“DiSC”): uterine cancer as underlying cause of death, multivariable analysis, 2007-2013.
Note: *p<0.05; **p<0.001; ***p<0.0001.
Other studies showed that elevated levels of estrogens (due to organic waste) were detected in surface runoff, receiving waters and ground waters surrounding hog CAFOs in NC (Sackett et al., 2015).

Involvement of white females in swine industry seems to be higher than of AA females: e.g., in Duplin and Sampson counties, NC, up to 89.3% of working in farming females were whites and 10.7% were AAs (Census, 2000).

For addition to residential exposure, white females likely have occupational exposure.
Top 10 U.S. states by inventory of hogs and pigs in 2018 (in 1,000s)*

- **Iowa**: 22,500
- **North Carolina**: 8,900
- **Minnesota**: 8,500
- **Illinois**: 5,300
- **Indiana**: 4,050
- **Nebraska**: 3,450
- **Missouri**: 3,450
- **Ohio**: 2,650
- **Oklahoma**: 2,160
- **Kansas**: 1,970

This statistic shows the top 10 U.S. states based on the number of hogs and pigs in 2018. Iowa came in first place, where the inventory stood at around 22.6 million hogs and pigs, as of March 1, 2018. The total number of hogs and pigs in the U.S. amounted to about 72,908 thousands in 2018.
Hog farms in North Carolina, Iowa and Minnesota

The max number of hogs per county:
- NC - 2,353,933,
- IA - 1,394,130,
- MN - 755,622.

The average number of hogs per farm:
- NC – 1,583,
- IA – 955,
- MN – 727.
### NC, IA, and MN: All-cause mortality, age-adjusted, 1999-2016, per 100,000

<table>
<thead>
<tr>
<th>Disease</th>
<th>Areas with hog CAFOs with &gt;215 hogs/km²</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>IA</td>
</tr>
<tr>
<td>All-cause mortality, White</td>
<td>704.4 (699.5-709.4)</td>
</tr>
<tr>
<td>All-cause mortality, African-Americans</td>
<td>543.0 (396.0-726.5)</td>
</tr>
<tr>
<td>All-cause mortality, American Indian</td>
<td>364.4 (249.3-514.5)</td>
</tr>
<tr>
<td>All-cause mortality, age &lt;24</td>
<td>59.0 (56.0-62.0)</td>
</tr>
<tr>
<td>All-cause mortality, age 65+</td>
<td>4,277.3 (4,245.3-4,309.4)</td>
</tr>
<tr>
<td>Infant mortality (crude rate)</td>
<td>5.2 (4.8-5.7)</td>
</tr>
</tbody>
</table>
### NC, IA, and MN: disease-specific mortality, age-adjusted, 1999-2016, per 100,000

<table>
<thead>
<tr>
<th>Disease</th>
<th>Areas with hog CAFOs with &gt;215 hogs/km²</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>IA</td>
</tr>
<tr>
<td>Infections</td>
<td></td>
</tr>
<tr>
<td></td>
<td>9.4 (8.9-10.0)</td>
</tr>
<tr>
<td>Septicemia</td>
<td>5.0 (4.6-5.4)</td>
</tr>
<tr>
<td>HIV</td>
<td>0.3 (0.2-0.5)</td>
</tr>
<tr>
<td>Conditions of perinatality</td>
<td>3.0 (2.6-3.4)</td>
</tr>
<tr>
<td>Acute kidney failure</td>
<td>1.3 (1.1-1.5)</td>
</tr>
<tr>
<td>Chronic kidney failure, nephritis/nephrotic syndrome</td>
<td>2.6 (2.3-2.9)</td>
</tr>
</tbody>
</table>

¹ Perinatality – a period immediately before and after birth. Depending on the definition, it starts at the 20th to 28th week of gestation and ends 1 to 4 weeks after birth.
Note: Preventable Hospital Rate is a number of hospital stays for ambulatory-care sensitive conditions per 1,000 Medicare enrollees.
Acknowledgements

- Duke Environmental Health Scholars Program

- We thank Igor Akushevich (Duke SSRI, Duke University) for his help in analysis.

- We thank Fred and Alice Stanback for supporting this study with a philanthropic donation.

Team:
- H Kim Lyerly
- Julia Kravchenko
- Sung Han Rhew
- Pankaj Agarwal
THANK YOU!

"I like pigs.
Dogs look up to us.
Cats look down on us.
Pigs treat us as equals."
- Winston Churchill