No. 19-1019

IN THE UNITED STATES COURT OF APPEALS
FOR THE FOURTH CIRCUIT

JOYCE McKIVER, et al.,

Plaintiffs-Appellees,

v.

MURPHY-BROWN, LLC,
d/b/a Smithfield Hog Production Division,

Defendant-Appellant.

ON APPEAL FROM THE UNITED STATES DISTRICT COURT
FOR THE EASTERN DISTRICT OF NORTH CAROLINA,
NO. 7:14-CV-180-BR, HON. W. EARL BRITT, U.S. DISTRICT JUDGE

UNOPPOSED BRIEF OF AMICI CURIAE DR. LAWRENCE B. CAHOON, ELIZABETH CHRISTENSON, DR. BRETT DOHERTY, MIKE DOLAN FLISS, DR. JILL JOHNSTON, BOB MARTIN, DR. SARAH RHODES, DR. ANA MARÍA RULE, DR. SACOBY WILSON & DR. COURTNEY WOODS IN SUPPORT OF PLAINTIFFS-APPELLEES

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STATEMENT OF INTEREST[1]

Amici are scientists and public health practitioners with substantial expertise in environmental science, epidemiology, and community health. They include leading experts on concentrated animal feeding operations ("CAFOs") in North Carolina. *Amici* have a strong interest in assuring that the Court considers the substantial body of scientific and public health literature documenting the risks of living in close proximity to CAFOs.[2]

***Amicus* Dr. Lawrence B. Cahoon, Ph.D.**, is a Professor of Biology and Marine Biology at the University of North Carolina, Wilmington. Dr. Cahoon studies ocean and freshwater ecosystems, with particular emphasis on water quality analysis and remediation. He has published numerous articles connecting CAFOs to excessive nutrient enrichment in waterbodies.

***Amicus* Elizabeth Christenson, M.S.**, is a Ph.D. candidate in Environmental Sciences and Engineering at the University of North Carolina, Chapel Hill. Ms. Christenson's master's thesis assessed nutrient management practices at North Carolina swine CAFOs. Her doctoral research examines the

[1] All parties have consented to the filing of this brief. No party's counsel authored any part of this brief. Neither did any party, party's counsel, or any person other than *amici* and their counsel contribute money intended to fund the preparation or submission of this brief.

[2] An annotated bibliography summarizing much of this evidence is attached as Exhibit 1.

connection between swine CAFOs and microbial water quality in North Carolina surface waters, including concentrations of *E. coli*, antibiotic-resistant bacteria, and pig feces-specific bacteria.

***Amicus* Dr. Brett Doherty, Ph.D., M.S.P.H.**, is a Research Associate in the Department of Epidemiology at Dartmouth College's Geisel School of Medicine. Through his research, Dr. Doherty explores the health effects of a variety of anthropogenic environmental pollutants. He became familiar with health problems associated with environmental pollutants from CAFOs while studying with Dr. Steve Wing, a leading activist for environmental justice and advocate for human rights long employed as an Associate Professor of Epidemiology at the University of North Carolina, Chapel Hill.[3]

***Amicus* Mike Dolan Fliss, M.P.S., M.S.W.**, is a Ph.D. candidate in Epidemiology at the University of North Carolina, Chapel Hill. His current work explores the influences of social and environmental circumstances on health, including the risk of flooding at CAFOs located in close proximity to communities. As a student of Dr. Steve Wing, Mr. Fliss studied the public health consequences

[3] *Steve Wing, Beloved Teacher and Committed Activist, Dies at 64*, Gillings Sch. News (Nov. 10, 2016), https://sph.unc.edu/sph-news/steve-wing-beloved-teacher-and-committed-activist-dies-at-64/.

of swine CAFOs in North Carolina and assisted Dr. Wing in responding to threatened litigation from the pork industry.

***Amicus* Dr. Jill Johnston, Ph.D.**, is an Assistant Professor of Preventive Medicine at the University of Southern California's Keck School of Medicine. Dr. Johnston's research focuses on addressing unequal exposures to harmful contaminants that affect the health of communities of color and the working poor. Together with Dr. Steve Wing, Dr. Johnston demonstrated that swine CAFOs in North Carolina disproportionately harm communities of color.

***Amicus* Bob Martin** is the Director of the Food System Policy Program at the Johns Hopkins Center for a Livable Future, which works toward the development of a healthy, equitable, and resilient food system. Mr. Martin previously served as a senior officer at the Pew Charitable Trust's Environment Group and Executive Director of the Pew Commission on Industrial Farm Animal Production. In the latter role, Mr. Martin oversaw publication of the Commission's seminal report *Putting Meat on the Table: Industrial Farm Production in America*, which summarized scientific literature concerning the negative effects of CAFOs on public health and the environment.

***Amicus* Dr. Sarah Rhodes, Ph.D.**, is a Research Affiliate in the Department of Environmental Science and Engineering at the University of North Carolina,

Chapel Hill. Her doctoral research examined the connections between swine CAFOs and the occurrence of antibiotic-resistant *Staphylococcus aureus* in hogs, swine CAFO workers, community residents, and the environment in North Carolina. Dr. Rhodes' current research interests include partnering with communities to address persistent health inequities.

***Amicus* Dr. Ana María Rule, Ph.D., M.H.S.**, is an Assistant Professor of Environmental Health and Engineering and Director of the Exposure Assessment Lab at Johns Hopkins University. Through her research, Dr. Rule seeks to develop and evaluate novel strategies for assessing exposure to aerosols and particulate matter. Dr. Rule's field work has demonstrated that CAFOs expose neighbors and surrounding communities to aerosols that can act as vectors of antibiotic resistance.

***Amicus* Dr. Sacoby Wilson, Ph.D., M.S.**, is an Associate Professor with the University of Maryland's Department of Epidemiology and Biostatics and the Maryland Institute for Applied Environmental Health. An expert in exposure science, Dr. Wilson conducts environmental justice and community-based participatory research throughout the southeastern United States. Dr. Wilson has coauthored multiple articles pertaining to the emission of dangerous air pollutants from CAFOs.

***Amicus* Dr. Courtney Woods, Ph.D., M.S.**, is an Assistant Professor of Environmental Sciences and Engineering and MPH Program Director at the University of North Carolina, Chapel Hill. Dr. Woods's work focuses on aspects of environmental justice and community health. She has published research examining these concepts in the context of swine CAFOs in North Carolina.

INTRODUCTION

This brief is submitted by scientists and public health practitioners in diverse fields who have investigated the relationship between CAFOs and harm to human health and welfare, air and water quality, and other environmental systems. We write for the narrow purpose of bringing to the Court's attention the robust and widely available literature documenting the negative effects of industrial swine production and, particularly, of Murphy-Brown's reliance on open waste pits, also called "lagoons," as well as "sprayfields" for waste management. This literature undermines any claim that Murphy-Brown was not aware of the harms of swine CAFOs cause to neighbors, communities, and the environment in North Carolina.

As the U.S. Court of Appeals for the District of Columbia has recognized, "[a]nyone with a pet knows firsthand that raising animals means dealing with animal waste." *Waterkeepeer All. v. EPA*, 853 F.3d 527, 529 (D.C. Cir. 2017) (concluding that the U.S. Environmental Protection Agency lacked authority to

exempt CAFOs from reporting dangerous emissions and hazardous air pollutants). Nonetheless, many people without scientific training are not aware that animal waste emits dangerous pollutants as it decomposes. *Id.*; *see also Waterkeeper All. v. EPA*, 399 F.3d 486, 494 (2d Cir. 2005) (explaining that "[a]nimal waste includes a number of potentially harmful pollutants," not limited to disease-causing bacteria and viruses, odorous and volatile compounds like hydrogen sulfide and ammonia, antibiotics, pesticides, and hormones). "While those emissions are miniscule for pet owners, they can be quite substantial for farms that have hundreds or thousands of animals." *Waterkeepeer All.*, 853 F.3d at 529.

Murphy-Brown developed the industrial model of swine production in North Carolina and powered its rapid expansion over several decades.[4] Swine CAFOs in North Carolina now house more than 9.7 million pigs.[5] Together, these animals produce over 9.5 billion gallons of urine and feces each year—that is, *more than 500 times* as much waste as is generated by the entire human population of Washington, D.C.[6] Unlike cities, however, CAFOs rely on crude methods of

[4] *See* Owen J. Furuseth, *Restructuring of Hog Farming in North Carolina: Explosion and Imposion*, 49 Prof'l Geographer 391, 395 (1997).
[5] *See* N.C. Dep't. Envtl. Quality, *List of Permitted Animal Facilities* (2019), https://files.nc.gov/ncdeq/List_O_fPermitted_Animal_Facilities%201-26-2018.xls?SdODtHdc46AxmsgSZ0z_o0dLzRFbNgZs (recording the number and type of swine allowed at CAFOs in North Carolina).
[6] *See* Envtl. Working Grp., *Exposing Fields of Filth: Data and Methodology*

waste management and do not employ advanced, multi-stage procedures to disinfect waste prior to disposal. Instead, most swine CAFOs in North Carolina store urine and feces in vast uncovered pits before applying this waste to sprayfields from the backs of trucks or by spraying waste high into the air using mechanized sprinkler systems.

As described below, a longstanding and consistently growing body of widely available scientific and public health literature—including *amici*'s own work—makes clear that swine CAFOs harm the interests of neighbors and communities by, among other things, emitting odorous air pollutants, contaminating surface- and groundwater, and increasing the risk of infectious disease. In addition, published evidence shows that Murphy-Brown's allies in North Carolina's pork industry had actual knowledge of this evidence and sought to conceal it. For Murphy-Brown to deny knowledge of the harms caused by CAFOs is disingenuous, given the industry's longstanding efforts to discredit and stifle research detailing the negative effects of CAFOs.

(2016) https://www.ewg.org/research/exposing-fields-filth/data-and-methodology#.W5kdTaZKiUl; EPA, *Risk Assessment Evaluation for Concentrated Animal Feeding Operations (2004)* https://nepis.epa.gov/Exe/ZyPDF.cgi/901V0100.PDF?Dockey=901V0100.PDF; U.S. Census Bureau, *QuickFacts: District of Columbia* (last accessed Sept. 12, 2018), https://www.census.gov/quickfacts/fact/table/dc/PST045217 (In 2017, the population of Washington, D.C. was 693,972 people).

For these reasons, *amici* respectfully submit this brief in support of Plaintiff-Appellees.

ARGUMENT

Under North Carolina law, liability for private nuisance reflects an assessment of the interests of the defendant, balanced against the interests of the plaintiffs and the interests of the community. *See Watts v. Pama Mfg. Co.*, 124 S.E.2d 809, 814 (N.C. 1962). Analysis of liability for nuisance should consider the decades of scientific study demonstrating that CAFOs adversely affect the interests of surrounding communities.

The scientific record is also relevant to the basis for punitive damages. Under North Carolina law, punitive damages are appropriate to punish a defendant liable for private nuisance who has engaged in "willful or wanton conduct"—that is, "the conscious and intentional disregard of and indifference to the rights and safety of others, which the defendant knows or should know is reasonably likely to result in injury, damage, or other harm." N.C. Gen. Stat. § 1D-5(7); *id.* § 1D-15(a)(3). Among other factors, punitive damage awards may reflect "[t]he degree of the defendant's awareness of the probable consequences of its conduct," *id.* § 1D-35(2)(c), and "[a]ny concealment by the defendant of the facts or consequences of its conduct." *Id.* § 1D-35(2)(f). Punitive damages are appropriate

where, as here, defendants were—or should have been—aware of an extensive body of widely available literature linking their conduct to serious harm to plaintiffs, surrounding communities, and the environment.

I. IN LIGHT OF WELL-ESTABLISHED AND WIDELY AVAILABLE SCIENTIFIC EVIDENCE, MURPHY-BROWN KNEW OR SHOULD HAVE KNOWN THAT SWINE CAFOS IN NORTH CAROLINA HARM NEIGHBORS AND SURROUNDING COMMUNITIES.

A. Well-Established and Widely Available Scientific Evidence Demonstrates that Odors and Associated Air Pollutants from CAFOs Harm Neighbors.

Even before CAFOs came to dominate swine production in North Carolina, scientific evidence indicated that odors and associated air pollutants from swine CAFOs threaten human health. Beginning in the 1970s, a series of studies revealed that CAFO workers experience a common pattern of health problems, including symptoms such as headaches, stuffy nose, sore throat, nagging cough, chest tightness, wheezing, and fatigue.[7] Other early reports demonstrated that exposure to environmental odors can harm people's physical health and psychological well-being,[8] while exposure to livestock odors in particular can

[7] *See* Kendall M. Thu, *Public Health Concerns for Neighbors of Large-Scale Swine Production*, 8 J. Agric. Safety & Health 175, 176 (2002).
[8] *See* Susan S. Schiffman et al., *The Effect of Environmental Odors Emanating from Commercial Swine Operations on the Mood of Nearby Residents*, 37 Brain Research Bull. 369 (1995).

induce respiratory problems and exacerbate pre-existing conditions, such as asthma.[9]

In 1995, Dr. Susan Schiffman and colleagues connected this early research to the experience of North Carolina residents living near CAFOs, finding that CAFO neighbors regularly subjected to livestock odors experience significantly higher rates of tension, depression, anger, confusion, and fatigue, as compared with otherwise similar people who do not live near CAFOs.[10] As Dr. Schiffman explained, these negative moods are concerning not only because they reflect CAFO neighbors' diminished quality of life, but also because "mood has been found to play a role in immunity . . . and can potentially affect subsequent disease."[11] Dr. Schiffman concluded her study with a warning: unless swine CAFOs employed methods to reduce odors, they would continue to take a toll on their neighbors' emotional lives.[12]

Less than two years later, Dr. Kendall Thu and colleagues determined that residents living within two miles of a 4,000-sow CAFO experience significantly elevated rates of symptoms consistent with the pattern of health problems already

[9] *See* Thu, *supra* note 7 at 178.
[10] *See* Schiffman, *supra* note 8 at 371.
[11] *Id.* at 370.
[12] *See id.* at 372.

well-established among CAFO workers, including nausea, headaches, dizziness, runny nose, scratchy throat, burning eyes, coughing, wheezing, and shortness of breath.[13] By 1998, a group of nearly fifty scientists participating in an expert workshop convened in part by the U.S. Environmental Protection Agency agreed that "odorous emissions from animal operations . . . have an impact on physical health."[14] That same year, air quality experts at a workshop organized by the Centers for Disease Control concluded that "adequate evidence currently exists to indicate airborne emissions from large-scale swine facilities constitute a public health problem."[15]

More recent research, much of which has been conducted near swine CAFOs in North Carolina, has consistently reinforced the conclusion that odors and air pollutants from swine CAFOs threaten neighbors' health and well-being. For instance, in 2000, Drs. Steve Wing and Susanne Wolf determined that people living near swine CAFOs in North Carolina experience a higher prevalence of health problems, including those common among CAFO workers, even when compared with rural residents living near industrial cattle operations.[16] Subsequent

[13] *See* Thu, *supra* note 7 at 179.
[14] *Id.*
[15] *Id.* at 180.
[16] *See* Steve Wing & Susanne Wolf, *Intensive Livestock Operations, Health, and Quality of Life Among Eastern North Carolina Residents*, 108 Envtl. Health Persp.

studies repeatedly confirmed that neighbors' complaints are consistent with objective scientific evidence. For example, researchers have concluded that neighbors' assessments of odor accord with measurements of CAFO-related odorous air pollutants.[17] Similarly, neighbors' reports of stress and negative mood correspond to increases in CAFO-related air pollutants and increases in blood pressure, a quantifiable physical indicator of stress.[18]

Air pollutants from swine CAFOs pose a special threat to vulnerable individuals. In 2009, Dr. Stacy Sneeringer found that infant mortality rates increase along with local concentrations of industrial livestock facilities, including

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233 (2000).

[17] *See, e.g.*, 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) (finding that the concentration of atmospheric ammonia in North Carolina communities increases as distances to swine CAFOs decrease); Sacoby M. Wilson & Marc L. Serre, *Use of Passive Samplers to Measure Atmospheric Ammonia Levels in a High-Density Industrial Hog Farm Area of Eastern North Carolina*, 41 Atmospheric Env't 6074 (2007) (concluding that neighbors who live approximately 2 kilometers from swine CAFOs risk exposure to atmospheric ammonia); Steve Wing et al., *Air Pollution and Odor in Communities Near Industrial Swine Operations*, 116 Envtl. Health Persp.1362 (2008) (determining that CAFO neighbors' subjective assessments of odor severity accord with objective measurements of hydrogen sulfide and other CAFO-associated air pollutants).

[18] *See* Rachel Avery Horton et al., *Malodor as a Trigger of Stress and Negative Mood in Neighbors of Industrial Hog Operations*, 99 Am. J. of Pub. Health Suppl. S610, S614 (2009); *see also* Steve Wing et al., *Air Pollution from Industrial Swine Operations and Blood Pressure of Neighboring Residents*, 121 Envtl. Health Persp. 92, 94 (2013).

swine CAFOs.[19] Based on a review of causes of death associated with industrial livestock production, Dr. Sneeringer concluded that this increase in infant mortality can be attributed to "air-based pollution in the proximity of livestock farming operations."[20] Other studies have shown that air pollution related to swine CAFOs reaches rural North Carolina schools,[21] and children attending rural schools within three miles of swine CAFOs in North Carolina suffer significantly increased rates of asthma symptoms, comparable to those associated with well-established risk factors for asthma, such as exposure to second-hand smoke.[22]

In addition to confirming neighbors' reports of negative effects on health and well-being attributable to air pollutants and odors from swine CAFOs, scientific evidence shows that these air pollutants and odors significantly diminish neighbors' quality of life. For instance, children who suffer from asthma—including those whose symptoms coincide with exposure to CAFO-related air

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[19] Stacy Sneeringer, *Does Animal Feeding Operation Pollution Hurt Public Health? A National Longitudinal Study of Health Externalities Identified by Geographic Shifts in Livestock Production*, 91 Am. J. Agric. Econ. 124 (2009).
[20] *Id.* at 125.
[21] *See* Virginia T. Guidry et al., *Hydrogen Sulfide Concentrations at Three Middle Schools Near Industrial Livestock Facilities*, 27 J. Exposure Sci. & Envtl. Epidemiology 167 (2017).
[22] *See* Maria C. Mirabelli et al., *Asthma Symptoms Among Adolescents who Attend Public Schools that are Located Near Confined Swine Feeding Operations*, 118 Pediatrics e66, e72 (2006).

pollutants and odors—miss opportunities to engage in social, recreational, and physical activities.[23] Similarly, studies show that odor from swine CAFOs prevents neighbors from participating in activities like "barbequing, . . . socializing with neighbors [and family], gardening, working outside, playing, drying laundry outside, opening doors and windows for fresh air and to conserve energy, . . . growing vegetables," and even sleeping through the night.[24]

These effects are particularly concerning because many neighbors of CAFOs "cannot afford air conditioning, clothes dryers, membership at a gym, [or] entertaining in restaurants."[25] As a result, they rely "on opening their windows for ventilation, drying their clothes outside, exercising in their yards, and entertaining family and friends in and around their homes."[26] When odor from swine CAFOs interrupts these activities, neighbors forgo opportunities to "positively affect health, improve overall well-being, reduce stress, and strengthen social networks,"

[23] *Id.* at e71.
[24] M. Tajik et al., *Impact of Odor from Industrial Hog Operations on Daily Living Activities*, 18 New Solutions 193, 201 (2008); *see also* Wing & Wolf, *supra* note 16 at 237 (finding that CAFO neighbors reported that odor from swine CAFOs prevented them from opening windows and going outside during nice weather).
[25] Horton et al., *supra* note 18 at S614.
[26] *Id.*

thus compounding the negative effects on their health and well-being that result directly from exposure to odors and air pollution.[27]

B. Well-Established and Widely Available Scientific Evidence Demonstrates that Swine CAFOs in North Carolina Adversely Affect the Interests of Communities.

1. CAFOs Impair Water Quality.

As early as 1979, scientists documented seepage of contaminants from CAFO waste storage pits into nearby surface- and groundwater.[28] In the 1990s, Drs. Rodney Huffman and Phillip Westerman found that the majority of lagoons studied in North Carolina leached moderate to significant amounts of pollutants, including fecal bacteria and nutrients, into the soil, groundwater, and superficial aquifer.[29] Seepage was especially severe in the state's sandy Coastal Plain.

During the 1980s and 1990s, scientists demonstrated links between swine CAFOs, degraded surface water quality, and excessive nutrient levels in waterbodies. Excessive nutrient levels, in turn, lead to toxic algal blooms and low-

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[27] Tajik et al, *supra* note 24 at 201.
[28] *See* T.G. Ciravolo et al., *Pollutant Movement to Shallow Ground Water Tables from Anaerobic Swine Waste Lagoon*, 8 J. Envtl. Quality 126 (1979).
[29] *See* R.L. Huffman & Phillip W. Westerman, *Seepage and Electromagnetic Terrain Conductivity Around New Swine Lagoons*, 47 Transactions Am. Soc'y Agric. Eng'rs 1507 (1991); *see also* R.L. Huffman & Phillip W. Westerman, *Estimated Seepage Losses from Established Swine Waste Lagoons in the Lower Coastal Plain of North Carolina*, 38 Transactions Am. Soc'y Agric. Eng'rs 449 (1995).

oxygen conditions that imperil wildlife and degrade or destroy habitat. Numerous studies show that CAFOs apply more waste to fields than crops can absorb, leading to toxic levels of nutrients in hay and excessive nitrogen and phosphorus in soils, groundwater, and surface water.[30] Indeed, contamination from swine CAFOs has been a chronic problem resulting in degraded water quality over the past four decades,[31] even in streams not historically at risk of nutrient over-enrichment.[32]

Elevated nutrient levels from seepage and spills from waste pits and excessive spraying can fuel harmful algal blooms[33] and contribute to the spread of *Pfiesteria* and other potentially toxic organisms.[34] For example, in 1997,

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[30] *See* J. C. Burns et al., *Swine Lagoon Effluent Applied to 'Coastal' Bermudagrass: I. Forage Yield, Quality, and Element Removal*, 14 J. Envtl. Quality 9 (1985); *see also* Philip Wayne Westerman et al., *Swine Manure and Lagoon Effluent Applied to a Temperate Forage Mixture: II. Rainfall Runoff and Soil Chemical Properties*, 16 J. Envtl. Quality 106 (1987).

[31] *See* Michael A. Mallin et al., *Industrial Swine and Poultry Production Causes Chronic Nutrient and Fecal Microbial Stream Pollution*, 226 Water, Air, Soil & Pollution 407 (2015); *see also* Christopher D. Heaney et al., *Source Tracking Swine Fecal Waste in Surface Water Proximal to Swine Concentrated Animal Feeding Operations*, 511 Sci. Total Env't 676 (2015).

[32] *See* Michael A. Mallin et al., Water Res. Research Inst., Univ. of N.C., *Effect of Organic and Inorganic Nutrient Loading on Photosynthetic and Heterotrophic Plankton Communities in Blackwater Rivers* (1998).

[33] *See* Michael A. Mallin, *Impacts of Industrial-Scale Swine and Poultry Production on Rivers and Estuaries*, 88 Am. Scientist 26 (2000).

[34] *See* JoAnn M. Burkholder & Howard B. Glasgow, *History of Toxic Pfiesteria in North Carolina Estuaries from 1991 to the Present*, 51 Bioscience 827, 833 (2001).

Dr. JoAnn Burkholder and colleagues found extremely high levels of potentially toxic microbes, including toxic *Pfiesteria*, in an estuary about twenty miles downstream from a CAFO waste pit.[35] Dr. Burkholder and other researchers also documented abundant potentially toxic cyanobacteria in surface waters and wetlands contaminated by waste pit spills.[36]

In addition to impairing surface- and groundwater quality, swine waste from CAFOs poses a significant threat to well water and human health.[37] Data indicate

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[35] *See* JoAnn M. Burkholder et al., *Impacts to a Coastal River and Estuary from Rupture of a Large Swine Waste Holding Lagoon*, 26 J. Envtl. Quality 1451 (1997).

[36] *See id*., *see also* Matthew S. Schwarz et al., U.S. Fish & Wildlife Serv., *Environmental Contaminants Associated with a Swine Concentrated Animal Feeding Operation and Implications for McMurtrey National Wildlife Refuge* (2004); *see also* Giorgos Markou & Dimitris Georgakakis, *Cultivation of Filamentous Cyanobacteria (Blue-Green Algae) in Agro-Industrial Wastes and Wastewaters: A Review*, 88 Applied Energy 3389 (2011) (Swine wastes are rich in nutrients that fuel cyanobacteria growth.).

[37] *See* JoAnn Burkholder et al., *Impacts of Waste from Concentrated Animal Feeding Operations on Water Quality*, 115 Envtl. Health Persp. 308 (2007); *see also* Mallin, *supra* note 33; Wendee Nicole, *CAFOs and Environmental Justice: The Case of North Carolina*, 121 Envtl. Health Persp. A182, A186 (2013) (Contaminants from CAFOs include chloride, NH_4^+N, NO_3-N, phosphorus, fecal coliform, and antibiotic-resistant bacteria.); I.G. Krapac et al., *Impacts of Swine Manure Pits on Groundwater Quality*, 120 Envtl. Pollution 475 (2002); Amy R. Sapkota et al., *Antibiotic-Resistant Enterococci and Fecal Indicators in Surface Water and Groundwater Impacted by a Concentrated Swine Feeding Operation*, 115 Envtl. Health Persp. 1040 (2007); R.L. Huffman, *Seepage Evaluation of Older Swine Lagoons in North Carolina*, 47 Transactions Am. Soc'y Agric. Eng'rs 1507 (2004); Kenneth C. Stone et al., *Impact of Swine Waste Application on Ground and Stream Water Quality in an Eastern Coastal Plain Watershed*, 41 Transactions

that many of North Carolina's swine waste pits cause nitrate pollution to infiltrate nearby wells at levels that exceed the drinking water standard,[38] posing an elevated health risk to infants, pregnant women, children, the elderly, and others with weakened immunological states living close to hog farms.[39] Even much lower concentrations of nitrate pollution can decrease immune response and cause disease and death of beneficial aquatic life.[40]

Extreme weather events exacerbate the risk of significant water contamination from CAFOs.[41] Over the past two decades, hurricanes in North Carolina have caused severe flooding of swine CAFOs, leading to waste pit failure and the overflow of waste into creeks, rivers, and streams.[42] These events have

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Am. Soc'y Agric. Eng'rs 1665 (1998).

[38] *See* Huffman, *supra* note 37.

[39] *See* Burkholder et al., *supra* note 37.

[40] *See* Julio A. Camargo et al., *Nitrate Toxicity to Aquatic Animals: A review with New Data for Freshwater Invertebrates*, 58 Chemosphere 1255 (2005); *see also* Julio A. Camargo & Álvaro Alonso, *Ecological and Toxicological Effects of Inorganic Nitrogen Pollution in Aquatic Ecosystems: A Global Assessment*, 32 Envtl. Int'l 831 (2006); *see also* Louis J. Guillette, Jr. & Thea M. Edwards, *Is Nitrate an Ecologically Relevant Endocrine Disruptor in Vertebrates?*, 45 Integrative & Comp. Biology 19 (2005).

[41] *See* Huffman, *supra* note 37.

[42] *See* JoAnn M. Burkholder et al., *supra* note 35; *see also* R.L. Huffman & Phillip W. Westerman, *supra* note 29.

disproportionately harmed communities of color, low-income communities, and communities that depend on wells for drinking water.[43]

The scientific literature makes clear that swine CAFOs threaten North Carolina's waterways,[44] and these threats continue today. A 2015 study, for example, confirmed that watersheds affected by CAFOs in North Carolina have significantly higher concentrations of ammonium, nitrate, and total nitrogen in surface water than those without CAFOs.[45] As recently as 2018, researchers found seasonal increases in surface water contaminants and nutrients tied to seasonal applications of waste.[46] By multiple means—including insufficient crop absorption on sprayfields and waste pit seepage and spills, for example—methods of waste management at CAFOs fail to protect nearby and downstream water quality, directly harming communities.

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[43] *See* Steve Wing et al., *The Potential Impact of Flooding on Confined Animal Feeding Operations in Eastern North Carolina*, 110 Envtl. Health Persp. 387 (2002).

[44] *See* F. Liu et al., *Phosphorus Recovery in Surface Runoff from Swine Lagoon Effluent by Overland Flow*, 26 J. Envtl. Quality 995 (1997) (nutrient loading at rates associated with accelerated nutrient over-enrichment); *see also* Mallin et al., *supra* note 32 (potential nutrient over-enrichment in blackwater stream systems).

[45] *See* Stephen L. Harden, *Surface-Water Quality in Agricultural Watersheds of the North Carolina Coastal Plain Associated with Concentrated Animal Feeding Operations* (2015).

[46] *See* Michael A. Mallin & Matthew R. McIver, *Season Matters When Sampling Streams for Swine CAFO Waste Pollution Impacts*, 16 J. Water & Health 78 (2018).

2. CAFOs are Associated with Other Harms to the Interest of Communities, Including Increased Exposure to Pathogens and Antibiotic Resistance.

In addition to degrading water quality, CAFOs adversely affect other community interests—reducing property values,[47] for example, and increasing exposure to antibiotic-resistant, potentially pathogenic microorganisms. CAFOs can put surrounding communities at risk of infectious disease by releasing harmful pathogens into the air and water.[48] A growing body of scientific evidence connects swine CAFOs to the spread of antibiotic-resistant bacteria.[49] As early as 1956,

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[47] *See* Raymond B. Palmquist et al., *Hog Operations, Environmental Effects, and Residential Property Values*, 73 Land Econ. 114 (1997); *see also* Joseph A. Herriges et al., *Living with Hogs in Iowa: The Impact of Livestock Facilities on Rural Residential Property Values*, 81 Land Econ. 530 (2005) (finding statistically significant relationships between proximity to hog CAFOs and lower property values and finding worse effects on property value for residences downwind of operations).

[48] *See, e.g.*, Dana Cole et al., *Concentrated Swine Feeding Operations and Public Health: A Review of Occupational and Community Health Effects*, 108 Envtl. Health Persp. 685 (2000) (environmental dispersion of pathogens by air and water); *see also* Michael Greger & Gowri Koneswaran, *The Public Health Impacts of Concentrated Animal Feeding Operations on Local Communities*, 33 Family & Community Health 11, 13 (2010) (links between overflowing lagoons, runoff from waste application to fields, and the spread of pathogens in the environment); Jennifer Gentry-Shields et al., *Hepatitis E Virus and Coliphages in Waters Proximal to Swine Concentrated Animal Feeding Operations*, 505 Sci. Total Env't 487 (2015) (risks of dissemination of Hepatitis E virus).

[49] *See, e.g.*, Engeline van Duijkeren et al., *Transmission of Methicillin-Resistant Staphylococcus Aureus Strains Between Different Kinds of Pig Farms*, 126 Veterinary Microbiology 383 (2008); Tushar Khanna et al., *Methicillin Resistant Staphylococcus Aureus Colonization in Pigs and Pig Farmers*, 128 Veterinary

scientists learned that pigs harbor strains of bacteria resistant to common antibiotics.[50] Subsequent studies have found an association between the use of antimicrobials in swine CAFOs and detection of drug-resistant bacteria.[51] These bacteria and resistance genes can travel downwind of CAFOs and enter groundwater near swine facilities and sprayfields.[52] Since 2006, multiple studies have linked swine CAFOs to the spread of Methicillin-Resistant *Staphylococcus*

Microbiology 298 (2008); Amy Chapin et al., *Airborne Multidrug-Resistant Bacteria Isolated from a Concentrated Swine Feeding Operation*, 113 Envtl. Health Persp. 137 (2005) (multi-drug resistant bacteria at levels dangerous to human health in the air within a swine CAFO).

[50] *See* H. Williams Smith, *Antibiotic-Resistant Escherichia Coli in Market Pigs in 1956-1979: The Emergence of Organisms With Plasmid-borne Trimethoprim Resistance*, 84 J. Hygiene 467 (1980).

[51] *See*, e.g., van Duijkeren et al., *supra* note 49 (using antimicrobials is a risk factor for MRSA-positive pigs on a farm); Cole et al., *supra* note 48 at 692 (review of studies on how antimicrobial resistance increases "with increasing antimicrobial use on farms").

[52] *See* Shawn G. Gibbs et al., *Isolation of Antibiotic-Resistant Bacteria from the Air Plume Downwind of a Swine Confined or Concentrated Animal Feeding Operation*, 114 Envtl. Health Persp. 1,032, 1,036 (2006); *see also* Joanne C. Chee-Sanford, *Occurrence and Diversity of Tetracycline Resistance Genes in Lagoons and Groundwater Underlying Two Swine Production Facilities*, 67 Applied Envtl. Microbiology 1494 (2001); *see also* 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, 217 (2006); *see also* Sapkota, *supra* note 37.

aureus ("MRSA"),[53] a major antibiotic-resistant threat in the United States.[54] MRSA originating in swine CAFOs have been able to colonize and infect humans, including people who have not direct contact with livestock.[55] Additionally, according to a 2013 study, residential "proximity to swine manure application to crop fields and livestock operations each was associated with MRSA and skin and tissue infection."[56]

II. BY ATTEMPTING TO INTIMIDATE RESEARCHERS AND STUDY PARTICIPANTS, MURPHY-BROWN AND ALLIES SOUGHT TO CONCEAL THE HARM THAT CAFOS CAUSE TO NEIGHBORS AND COMMUNITIES.

As explained above, a considerable body of scientific evidence demonstrates that Murphy-Brown *should have known* that CAFOs harm neighbors and communities. Additional evidence demonstrates that Murphy-Brown and its allies

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[53] *See* Gibbs et al., *supra* note 52; *see also* van Duijkeren et al., *supra* note 49; *see also* Noah Rosenblatt-Farrell, *The Landscape of Antibiotic Resistance*, 117 Envtl. Health Persp. A244 (2009).

[54] *See* CDC Office of Infectious Diseases, Antibiotic Resistance Threats in the United States 77 (2013), https://www.cdc.gov/drugresistance/threat-report-2013/pdf/ar-threats-2013-508.pdf (MRSA infected over 80,000 people and killed 11,285 in 2011).

[55] *See* Jesper Larsen et al., *Methicillin-Resistant Staphylococcus Aureus CC398 is an Increasing Cause of Disease in People With no Livestock Contact in Denmark, 1999 to 2011*, 20 Euro Surveillance (2015).

[56] Joan A. Casey et al., *High-Density Livestock Operations, Crop Field Application of Manure, and Risk of Community- Associated Methicillin-Resistant Staphylococcus Aureus Infection in Pennsylvania*, 173 J. Am. Med. Ass'n: Internal Med. 1980 (2013).

in North Carolina's pork industry had *actual knowledge* of studies documenting harm from CAFOs, and that they sought to conceal that harm by attempting to intimidate scientists and derail future research. Given the industry's economic and political power, these attempts at concealment have met with some success.

Pork industry representatives have sought to intimidate scientists directly by publicly impugning their motives, threatening aggressive legal action, and attempting to undermine employment and research funding. For example, in response to a study by Dr. Steve Wing demonstrating that CAFOs are disproportionately located in low-income communities and communities of color, the North Carolina Pork Council issued a press release levelling several *ad hominem* attacks. These "sweeping and sometimes vitriolic claims," presented without meaningful explanation or evidence, constitute textbook "intentional efforts to manufacture doubt," a tactic of confronting unfavorable research long employed by the tobacco industry.[57] The Pork Council also contacted Dr. Wing's employer and federal funder, actions Dr. Wing understood to be efforts at "harassment and intimidation."[58]

[57] S. Holly Stocking & Lisa W. Holstein, *Manufacturing Doubt: Journalists' Roles and the Construction of Ignorance in a Scientific Controversy*, 18 Pub. Understanding Sci. 23 (2009).
[58] *See* Wing et al., *supra* note 43.

Dr. JoAnn Burkholder experienced similar harassment after discovering a toxic organism linked to water pollution from CAFOs. According to Dr. Burkholder, on the day her research was released, her employer—North Carolina State University—received over "160 messages sent in by various representatives of the concentrated swine industry demanding that [she] be fired."[59] Dr. Burkholder also received multiple death threats.[60] She has expressed concern that "the backlash that resulted from her research on swine pollution has damaged her reputation and hurt her ability to receive grants."[61]

Pork industry representatives have also exercised influence behind-the-scenes, to deter CAFO neighbors from participating in public health studies and otherwise derail scientific research. In 2002, Dr. Wing reported that "[i]n some areas, community members have been fearful of participating in the research because of the influence of the hog industry in local affairs."[62] Several *amici* confirm that the fear of retaliation continues to deter some CAFO neighbors and

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[59] Alicia Allen, *ISU Graduate Claims Backlash Hurt Career*, Iowa State Daily (Dec. 4, 2002), http://www.iowastatedaily.com/news/isu-graduate-claims-backlash-hurt-career/article_00fd4c47-7e9b-5b6f-b86c-52c88a99afcd.html

[60] Perry Beeman, *Ag Scientists Feel the Heat*, Inst. Agric. & Trade Pol. (Feb. 2, 2003), https://www.iatp.org/news/ag-scientists-feel-the-heat.

[61] Allen, *supra* note 62.

[62] *See* Wing et al., *supra* note 43 at 443.

workers from participating in public health studies.[63] Indeed, the North Carolina Pork Council has fueled these fears—for example, by demanding that researchers disclose the identities of study participants.[64]

According to published reports and *amici*'s experience, the pork industry's efforts to intimidate scientists and potential study participants have met with some success.[65] Scientists who might otherwise study the effects of CAFOs on public health have chosen to pursue other research interests, in part to avoid the character assassination and career impediments that Drs. Wing, Burkholder, and others have suffered.[66] In the words of one CAFO worker, who left her job after intimidation

[63] Residents have raised fears of industry retaliation affecting not only their participation in research but also the exercise of their civil rights. *See* Letter from Lilian Dorka, EPA to William G. Ross, Jr., N.C. Dept. of Envtl. Quality (2017), https://www.epa.gov/sites/production/files/2018-05/documents/letter_of_concern_to_william_g_ross_nc_deq_re_admin_complaint_11r-14-r4_.pdf (expressing "grave concerns" about reports of "a potential hostile and intimidating environment" for members of the community seeking to provide information about the industry).

[64] *See* Wing et al., *supra* note 43 at 441, 443.

[65] *See, e.g.*, Stocking & Holstein, *supra* note 59, at 36 (concluding, with respect to the North Carolina pork industry's attacks on Dr. Wing, that claiming ignorance about scientific evidence "became a viable tool for [this] economically powerful but threatened industry . . . even though a respected scientist at a high-status institution, someone who had won state and federal funding for his work, produced the science").

[66] *See* Wing et al., *supra* note 43 at 440, 442.

from Murphy Farms: "It's a mind game. The pork industry has got people scared thinking that they're so big and strong that we can't do without them."[67]

CONCLUSION

For the foregoing reasons, *Amici* respectfully submit this brief in support of the Plaintiffs-Appellees.

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[67] *See id*. at 441.

CERTIFICATE OF COMPLIANCE

This brief complies with the type-volume limitations of Fed. R. App. P. 29(a)(5) because it contains 5,749 words, as determined by Microsoft Word 2016, excluding the parts of the brief exempted by Fed. R. App. P. 32(f).

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I hereby certify that on May 6th, 2019, I electronically filed the foregoing Brief of Amici Curiae in Support of Plaintiffs-Appellees using the Court's CM/ECF system, which will serve notice of the filing to all registered users.

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Exhibit 1

ANNOTATED BIBLIOGRAPHY[1]

Peer Reviewed Literature

1970s

T.G. Ciravolo et al., *Pollutant Movement to Shallow Ground Water Tables from Anaerobic Swine Waste Lagoon*, 8 J. Envtl. Quality 126 (1979). All lagoons tested seeped fecal coliforms, nutrients, and ion contaminants into the surrounding groundwater.

1980s

J. C. Burns et al., *Swine Lagoon Effluent Applied to 'Coastal' Bermudagrass: I. Forage Yield, Quality, and Element Removal*, 14 J. Envtl. Quality 9 (1985). Medium to high application rates of swine lagoon effluent to bermudagrass can increase the concentration of nitrates in the forage to levels nearing concentrations unsafe for ruminants and result in levels of nitrogen and phosphorus four and ten times higher, respectively, than normally recommended for fertilizer applications, leading to environmental impacts on soil, groundwater, and surface runoff.

H. Williams Smith, *Antibiotic-Resistant Escherichia Coli in Market Pigs in 1956-1979: The Emergence of Organisms with Plasmid-Borne Trimethoprim Resistance*, 84 J. Hygiene 467 (1980). Pigs can harbor strains of bacteria resistant to common antibiotics.

Philip Wayne Westerman et al., *Swine Manure and Lagoon Effluent Applied to a Temperate Forage Mixture: II. Rainfall Runoff and Soil Chemical Properties*, 16 J. Envtl. Quality 106 (1987). Swine lagoon effluent and swine manure slurry can supply excess nitrogen to crops like tall fescue, resulting in surface and groundwater pollution hazards, especially when rainfall occurs soon after application.

1990s

JoAnn M. Burkholder et al., *Impacts to a Coastal River and Estuary from Rupture of a Large Swine Waste Holding Lagoon*, 26 J. Envtl.

[1] Asterisk indicates studies authored or co-authored by one or more of *amici*.

Quality 1451 (1997). Hurricanes in eastern North Carolina have led to severe flooding of industrial swine facilities, the rupture of lagoons, and the overflow of waste into North Carolina's creeks, rivers, and streams.

∗ Lawrence B. Cahoon et al., *Nitrogen and Phosphorus Imports to the Cape Fear and Neuse River Basins to Support Intensive Livestock Production*, *33* Envtl. Sci. & Tech. 410 (1999). The quantities of "new" nitrogen and phosphorus added to watersheds due to industrial livestock operations in North Carolina's Cape Fear and Neuse River basins were more than an order of magnitude greater than the annual loads of these nutrients in each river during the 1990s, posing significant threats of nutrient over-enrichment.

Bahman Eghball et al., *Phosphorus Movement and Adsorption in a Soil Receiving Long-Term Manure and Fertilizer Application*, 25 J. Envtl. Quality 1339 (1996). Phosphorus from long-term manure or fertilizer application and from heavy loading of manure can leach into groundwater in areas with shallow water tables or coarse-textured soils.

R.L. Huffman & Phillip W. Westerman, *Estimated Seepage Losses from Established Swine Waste Lagoons in the Lower Coastal Plain of North Carolina*, 38 Transactions Am. Soc'y Agric. Eng'rs 449 (1995). Of 11 lagoons studied, 54% demonstrated moderate or severe seepage into the superficial aquifer.

A.W. Jongboeld & N.P. Lenis, *Environmental Concerns About Animal Manures*, 76 J. Animal Sci. 2641 (1998). Swine manure application can lead to soil accumulation of minerals such as P, Cu, Zn; nitrate leaching into ground and surface water; and emissions of odors, ammonia, and dust above tolerable levels.

F. Liu, *Phosphorus Recovery in Surface Runoff from Swine Lagoon Effluent by Overland Flow*, 26 J. Envtl. Quality 995 (1997). Phosphorus from swine lagoon effluent applications to bermudagrass and ryegrass resulted in dissolved P and total P concentrations exceeding critical values associated with accelerated eutrophication, especially when applied to slopes greater than 5%.

Raymond B. Palmquist et al., *Hog Operations, Environmental Effects, and Residential Property Values*, 73 Land Econ. 114 (1997). There is a statistically significant relationship between the decline of property values and proximity to hog facilities.

Stephen J. Reynolds et al., *Air Quality Assessments in the Vicinity of Swine Production Facilities*, 4 J. Agromedicine 37 (1997). Air around swine sites contained concentrations of hydrogen sulfide and ammonia that exceeded U.S. Environmental Protection Agency and Agency for Toxic Substances and Disease Registry recommendations.

Susan S. Schiffman et al., *The Effect of Environmental Odors Emanating from Commercial Swine Operations on the Mood of Nearby Residents*, 37 Brain Res. Bull. 369 (1995). People living near swine operations experienced odors and reported significantly more tension, depression, anger, fatigue, confusion, and mood disturbance.

Kenneth C. Stone et al, *Impact of Swine Waste Application on Ground and Stream Water Quality in an Eastern Coastal Plain Watershed*, 41 Transactions Am. Soc'y Agric. Eng'rs 1665 (1998). When a facility increased its number of hogs from 3,300 to over 14,000, nitrate concentrations in groundwater increased significantly in three of seven wells tested near a sprayfield.

Kendall M. Thu et al., *A Control Study of the Physical and Mental Health of Residents Living Near a Large-Scale Swine Operation*, 3 J. Agric. Safety & Health 13 (1997). Neighbors living within a two-mile radius of a 4,000-sow swine facility had higher rates of toxic or inflammatory respiratory effects, which were similar to health problems documented among swine confinement workers.

Philip Wayne Westerman et al., *Swine-Lagoon Seepage in Sandy Soil*, 38 Transactions Am. Soc'y Agric. Eng'rs 1749 (1995). Swine manure anaerobic lagoons in sandy soils without clay liners demonstrate significant seepage of contaminants into groundwater even after 3.5-5 years of receiving waste, despite assumptions that animal manures physically seal the lagoons.

Steve Wing et al., *Community Based Collaboration for Environmental Justice: South-East Halifax Environmental Reawakening*, 8 Env't & Urbanization 129 (1996). CAFOs are disproportionately located in communities of color and poverty and thus among populations more susceptible to the exposures and more likely to experience detrimental health consequences.

James A. Zahn et al., *Characterization of Volatile Organic Emissions and Wastes from a Swine Production Facility*, 26 J. Envtl. Quality 1687 (1997). 27 Volatile Organic Compounds are linked to decreased air quality in the vicinity of a swine production facility.

2000s

André J.A. Aarnink & Martin W. A. Verstegen, *Nutrition, Key Factor to Reduce Environmental Load From Pig Production*, 109 Livestock Sci. 194 (2007). Dietary composition and odor production and emission related to swine production have a cause-and-effect relationship, and altering the sources and levels of crude protein and fermentable carbohydrates can be a promising approach to reduce odor nuisance.

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). Antibiotic-resistant E. coli is present in groundwater near swine farms using lagoons and sprayfields.

Rachel C. Avery et al., *Odor From Industrial Hog Operations and Mucosal Immune Function in Neighbors*, 59 Archives Envtl. Health 101 (2004). Neighbors of swine CAFOs experienced impaired immune function during periods of odor.

Julia R. Barrett, *Hogging the Air: CAFO Emissions Reach into Schools*, 114 Envtl. Health Persp. A241 (2006). Children living closer to CAFOs had higher risks of asthma symptoms.

Susan Bullers, *Environmental Stressors, Perceived Control, and Health: The Case of Residents Near Large-Scale Hog Farms in Eastern North Carolina*, 33 Human Ecology 1 (2005). Residents

living near industrial hog farms experienced increased psychological distress, nausea, and respiratory and sinus problems.

JoAnn M. Burkholder & Howard B. Glasgow, *History of Toxic Pfiesteria in North Carolina Estuaries from 1991 to the Present*, 51 Bioscience 827 (2001). The adverse environmental and health effects caused by *Pfistiera* are linked to water pollution from swine facilities.

JoAnn Burkholder et al., *Impacts of Waste from Concentrated Animal Feeding Operations on Water Quality*, 115 Envtl. Health Persp. 308 (2007). CAFO contaminants find pathways into the environment from leaky lagoons, heavy rainfalls that cause overflow, and runoff from waste fields, posing a public health threat, particularly for infants, pregnant women, children, elderly, and others with weakened immunological states living close to hog farms.

Enzo R. Campagnolo et al., *Antimicrobial Residues in Animal Waste and Water Resources Proximal to Large-Scale Swine and Poultry Feeding Operation*, 299 Sci. Total Env't 89 (2002). There can be high levels of antimicrobial compounds in lagoons, and sprayfields may spread antimicrobial residues into water sources.

∗ Amy Chapin et al., *Airborne Multidrug-Resistant Bacteria Isolated from a Concentrated Swine Feeding Operation*, 113 Envtl. Health Persp. 137 (2005). Multi-drug resistant bacteria are present at levels dangerous to human health in the air within a swine CAFO.

Joanne C. Chee-Sanford, *Occurrence and Diversity of Tetracycline Resistance Genes in Lagoons and Groundwater Underlying Two Swine Production Facilities*, 67 Applied Envtl. Microbiology 1494 (2001). Antibiotic-resistant genes from hog farms can be traced in local groundwater.

Dana Cole et al., *Concentrated Swine Feeding Operations and Public Health: A Review of Occupational and Community Health Effects*, 108 Envtl. Health Persp. 685 (2000). The human health threats posed by intensive swine production include patterns of antimicrobial resistance, the spread of pathogens, and the impacts of airborne contaminants.

Kelley J. Donham et al., *Community Health and Socioeconomic Issues Surrounding Concentrated Animal Feeding Operations*, 115 Envtl. Health Persp. 317 (2007). Due to factors like low income, inadequate housing, low health status, and insufficient access to medical care, racial discrepancies compound the negative impacts that hog farms create.

Kelley J. Donham et al., *Assessment of Air Quality at Neighbor Residences in the Vicinity of Swine Production Facilities*, 11 J. Agromedicine 15 (2006). The air surrounding homes near swine facilities had hydrogen sulfide levels exceeding federally recommended limits, posing potential health risks.

Kelley J. Donham, *The Concentration of Swine Production—Effects on Swine Health, Productivity, Human Health, and the Environment*, 16 Veterinary Clinics: Food Animal Prac. 559 (2000). The impacts of swine CAFOs on water, air, soil, and health have been documented and discussed since the early- and mid-1970s and is relevant to effective veterinary practice.

Engeline van Duijkeren et al., *Transmission of Methicillin-Resistant Staphylococcus Aureus Strains Between Different Kinds of Pig Farms*, 126 Veterinary Microbiology 383 (2008). The use of standard antimicrobials for pigs is a likely risk factor for finding MRSA-positive pigs on a farm; MRSA-colonized personnel are found more often at MRSA-positive farms, indicating that farmers/personnel on MRSA-positive farms have a greater chance of being colonized with MRSA than farmers/personnel on MRSA-negative farms.

Bob Edwards & Anthony E. Ladd, *Environmental Justice, Swine Production and Farm Loss in North Carolina*, 20 Soc. Spectrum 263 (2000). Swine CAFOs are disproportionately located in communities of color and poverty and recent patterns of farm loss were more pronounced in Black communities, regardless of income, and low-income communities, regardless of race.

Miquel B. Ekkelenkamp et al., *Endocarditis Due to Methicillin-Resistant Staphylococcus Aureus Originating from Pigs*, 150 Nederlands Tijdschrift Voor Geneeskunde 2,442, 2,442-47(2006).

There was a life-threatening infection in a hospital patient from a strain of pig MRSA.

Shawn G. Gibbs et al., *Airborne Antibiotic Resistant and Nonresistant Bacteria and Fungi Recovered from Two Swine Herd Confined Animal Feeding Operations*, 1 J. Occupational & Envtl. Hygiene 699 (2004). Dangerously high levels of multi-drug resistant bacteria are present both within and downwind of swine CAFOs.

Shawn G. Gibbs et al., *Isolation of Antibiotic-Resistant Bacteria from the Air Plume Downwind of a Swine Confined or Concentrated Animal Feeding Operation*, 114 Envtl. Health Persp. 1032 (2006). Bacteria with multidrug and multiple antibiotic resistances can be found both inside and downwind of a swine CAFO, posing potential health risks for residents nearby such facilities.

Mary J. Gilchrist, *The Potential Role of Concentrated Animal Feeding Operations in Infectious Disease Epidemics and Antibiotic Resistance*, 115 Envtl. Health Persp. 313 (2006). Swine CAFOs encourage antibiotic resistance, raising risks of infectious disease epidemics.

Christopher F. Green et al., *Bacterial Plume Emanating from the Air Surrounding Swine Confinement Operations*, 3 J. Occupational & Envtl. Hygiene 9 (2006). Bacteria from a swine CAFO traveled both upwind and downwind from the facility.

Dick Heederik et al., *Health Effects of Airborne Exposures from Concentrated Animal Feeding Operations*, 115 Envtl. Health Persp. 298 (2007). Health impacts from air pollutants emitted by CAFOs include psychophysiologic changes due to odor.

Joseph A. Herriges et al., *Living with Hogs in Iowa: The Impact of Livestock Facilities on Rural Residential Property Values*, 81 Land Econ. 530 (2005). Proximity to livestock operations has a statistically significant negative effect on property value, particularly for properties located downwind of operations.

Alan R. Hirsch, *Hydrogen Sulfide Exposure Without Loss of Consciousness: Chronic Effects in Four Cases*, 18 Toxicology & Indus. Health 51 (2002). Exposure to hydrogen sulfide, which is

produced by the breakdown of animal waste, can lead to neurological damage, even at low levels.

Rachel Avery Horton et al., *Malodor as a Trigger of Stress and Negative Mood in Neighbors of Industrial Hog Operations*, 99 Am. J. Pub. Health Suppl. S610 (2009). Individuals living in African-American communities in southeastern North Carolina near hog farms reported high rates of stress and negative mood, which were associated with hydrogen sulfide concentrations.

Tushar Khanna et al., *Methicillin Resistant Staphylococcus Aureus Colonization in Pigs and Pig Farmers*, 128 Veterinary Microbiology 298 (2008). MRSA is common in pigs in Ontario, Canada, and that there is a strong correlation between MRSA presence in humans and pigs on farms, providing further support to concerns about transmission of MRSA between pigs and humans.

Jungik Kim & Peter Goldsmith, *A Spatial Hedonic Approach to Assess the Impact of Swine Production on Residential Property Values*, 42 Envtl. & Res. Econ. 509 (2009). Craven County home property values declined on a per hog basis.

I.G. Krapac et al., *Impacts of Swine Manure Pits on Groundwater Quality*, 120 Envtl. Pollution 475 (2002). Fecal bacteria from swine manure pits can enter shallow groundwater, indicating possible threats to human health through drinking water contamination.

Hannah C. Lewis et al., *Pigs as Source of Methicillin-Resistant Staphylococcus Aureus CC398 Infections in Humans, Denmark*, 14 Emerging Infectious Diseases 1383 (2008). An emerging subtype of methicillin-resistant *Staphylococcus aureus* (MRSA) that was found in humans came from swine confinement pigs.

∗ 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). Industrialized animal production causes phosphorus and nitrogen to enter the environment, contributing to eutrophication in nutrient sensitive watersheds.

James A. Merchant et al., *Asthma and Farm Exposures in a Cohort of Rural Iowa Children*, 113 Env't Health Persp. 350 (2005). There is a positive association between rural children's exposure to raising hogs and their rates of asthma.

Katherine Milla et al., *Evaluating the Effect of Proximity to Hog Farms on Residential Property Values: A GIS-Based Hedonic Model Approach*, 17 J. Urban & Regional Info. Sys. Ass'n 1 (2005). Proximity to hog farms adversely affects residential property values.

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). High rates of wheezing among schoolchildren in North Carolina are correlated with proximity to swine CAFOs and noticeable odor.

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 Persp. 591 (2006). There is noticeable odor in North Carolina schools located near swine CAFOs, indicating potential exposure of students to air-borne pollutants.

A.J. de Neeling et al., *High Prevalence of Methicillin Resistant Staphylococcus Aureus in Pigs*, 122 Veterinary Microbiology 366 (2007). There are high levels of MRSA among hogs at slaughterhouses and swine facilities.

Katja Radon et al., *Environmental Exposure to Confined Animal Feeding Operations and Respiratory Health of Neighboring Residents*, 18 Epidemiology 300 (2007). Adults living in rural German towns with a high density of CAFOs experience asthma, nasal allergies and odor annoyance.

Noah Rosenblatt-Farrell, *The Landscape of Antibiotic Resistance*, 117 Envtl. Health Persp. A244 (2009). Pig-specific MRSA strains are detectable among farmworkers, and air- and waterborne CAFO emissions can be contaminated with antibiotic-resistant microbes such as MRSA.

Amy R. Sapkota et al., *Antibiotic-Resistant Enterococci and Fecal Indicators in Surface Water and Groundwater Impacted by a Concentrated Swine Feeding Operation*, 115 Envtl. Health Persp. 1040 (2007). There are elevated levels of fecal indicators and antibiotic-resistant enterococci in water sources situated down gradient from a swine facility compared with up-gradient sources, which provides additional evidence that water contaminated with swine manure could contribute to the spread of antibiotic resistance.

Susan S. Schiffman et al., *Potential Health Effects of Odor from Animal Operations, Wastewater Treatment, and Recycling of Byproduct*, 9 J. Agromedicine 397 (2004). People living near swine sites reported more tension, depression, anger, fatigue, confusion, and less vigor.

Susan S. Schiffman et al., *Quantification of Odors and Odorants from Swine Operations in North Carolina*, 108 Agric. & Forest Meteorology 213 (2001). Air pollutants emitted from industrial swine facilities include hydrogen sulfide, ammonia, and other respiratory irritants.

Susan S. Schiffman et al., *Symptomatic Effects of Exposure to Diluted Air Sampled from a Swine Confinement Atmosphere on Healthy Human Subjects*, 113 Envtl. Health Persp. 567 (2005). Those exposed to diluted swine air were more likely to report eye irritation, nausea, and headaches than a control group exposed to clean air.

Charles W. Schmidt, *Swine CAFOs and Novel H1N1 Flu*, 117 Envtl. Health Persp. A394 (2009). One potential source of the H1N1 influenza virus that led to a global swine flu pandemic was swine in CAFOs; swine flu is more likely to persist in larger farms with higher pig densities.

Sigurdur T. Sigurdarson & Joel N. Kline, *School Proximity to Concentrated Animal Feeding Operations and Prevalence of Asthma in Students*, 129 Chest 1486 (2006). There is a higher prevalence of asthma among elementary school children attending schools near CAFOs in Iowa.

Stacy Sneeringer, *Does Animal Feeding Operation Pollution Hurt Public Health? A National Longitudinal Study of Health Externalities Identified by Geographic Shifts in Livestock Production*, 91 Am. J. Agric. Econ. 124 (2009). Living near livestock production facilities is linked to increased infant mortality due to respiratory disease.

M. Tajik et al., *Impact of Odor from Industrial Hog Operations on Daily Living Activities*, 18 New Solutions 193 (2008). Within 1.5 miles of CAFOs, hog odor limits activities of daily living that participants either enjoyed doing the most or expected to be able to perform inside and outside their homes, including social interactions, physical activities, energy- and cost-saving activities, relaxing outside or indoors, and sleeping, which can have secondary adverse impacts on health and well-being.

Kendall M. Thu, *Public Health Concerns for Neighbors of Large-Scale Swine Production*, 8 J. Agric. Safety & Health 175 (2002). CAFOs and the odors they produce adversely impact quality of life in rural communities and produce health effects similar to those experienced by workers in facilities, which occupational health studies have documented extensively.

Andreas Voss et al., *Methicillin-Resistant Staphylococcus aureus in Pig Farming*, 11 Emerging Infectious Diseases 1965 (2005). MRSA rates were 760 times higher among pig farmers studied than among regular hospital patients, suggesting potential hog-to-human transmission of drug-resistant disease.

John T. Walker et al., *Atmospheric Transport and Wet Deposition of Ammonium in North Carolina*, 34 Atmospheric Env't 3407 (2000). Swine operations are the primary domestic animal source of NH3, accounting for 48% of all North Carolina NH3 emissions.

∗ 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). There are high weekly average ammonia concentrations near hog CAFOs in Eastern North Carolina, suggesting dangerous levels of exposure for populations living or attending school near CAFOs.

* Sacoby M. Wilson & Marc L. Serre, *Use of Passive Samplers to Measure Atmospheric Ammonia Levels in a High-Density Industrial Hog Farm Area of Eastern North Carolina*, 41 Atmospheric Env't 6074 (2007). Populations living close to hog CAFOs have higher exposure to ammonia.

Steve Wing & Susanne Wolf, *Intensive Livestock Operations, Health, and Quality of Live Among Eastern North Carolina Residents*, 108 Envtl. Health Persp. 233 (2000). Residents located near CAFOs are more likely to experience detrimental health consequences, are more likely to have reduced quality of life indicators, and are more susceptible to illness, stress, depression and physical injury.

Steve Wing et al., *Air Pollution and Odor in Communities Near Industrial Swine Operations*, 116 Envtl. Health Persp.1362 (2008). Study participants living within 1.5 miles of swine factory farms altered or ceased normal daily activities when hydrogen sulfide concentrations, and associated hog odor, were the highest.

Steve Wing et al., *Environmental Injustice in North Carolina's Hog Industry*, 108 Envtl. Health Persp. 225 (2000). The excess of hog operations is greatest in areas with both high poverty and high percentage nonwhites, and operations run by corporate integrators are more concentrated in poor and nonwhite areas than are operations run by independent growers.

Steve Wing et al., *The Potential Impact of Flooding on Confined Animal Feeding Operations in Eastern North Carolina*, 110 Envtl. Health Persp. 387 (2002). African Americans were more likely than Whites to live in areas with flooded CAFOs during storms, according to satellite estimates.

2010s

Ann M. Arfken et al., *Assessing Hog Lagoon Waste Contamination in the Cape Fear Watershed Using Bacteroidetes 16S rRNA Gene Pyrosequencing*, 99 Applied Microbiology & Biotechnology 7283 (2015). Pig fecal markers—a typical method of isolating hog contamination—detect moderate to significant hog lagoon water contamination but not low levels of hog lagoon contamination; a new methodology employing bacteroidetes 16S rRNA gene

pyrosequencing allows for more accurate assessment of waterways in which contamination previously could not be detected.

Joan A. Casey et al., *High-Density Livestock Operations, Crop Field Application of Manure, and Risk of Community-Associated Methicillin-Resistant Staphylococcus Aureus Infection in Pennsylvania*, 173 J. Am. Med. Ass'n: Internal Med. 1980 (2013). People living near industrial swine facility liquid waste application sites in Pennsylvania receive treatment for more skin and soft tissue infections and infections caused by MRSA than people living further away from application sites.

∗ Meghan F. Davis et al., *Occurrence of Staphylococcus aureus in Swine and Swine Workplace Environments on Industrial and Antibiotic-Free Hog Operations in North Carolina, USA: A One Health Pilot Study*, 163 Envtl. Res. 88 (2018). Workers at industrial hog operations are exposed to Staphylococcus aureus, including MRSA, through indirect, airborne transmission, as well as direct contact with animals.

Jennifer Gentry-Shields et al., *Hepatitis E Virus and Coliphages in Waters Proximal to Swine Concentrated Animal Feeding Operations*, 505 Sci. Total Env't 487 (2015). Current waste management practices for industrial swine operations may be associated with the dissemination of viruses of public health concern in waters proximal to CAFO sprayfields.

Michael Greger & Gowri Koneswaran, *The Public Health Impacts of Concentrated Animal Feeding Operations on Local Communities*, 33 Family & Community Health 11 (2010). There are demonstrable links between 1) waste spilled from overflowing lagoons and runoff from application of the waste to fields and 2) outbreaks of harmful pathogens, such as salmonella and E. coli in the environment.

Virginia Guidry & Steve Wing, *A Longitudinal Study of Exposure to Livestock Odor and Symptom Reports in Children*, Envtl. Health Persp. (2011). Reported presence of livestock odor within the previous 24 hours is associated with increased symptom reports of respiratory and irritation issues among children.

* Virginia T Guidry et al., *Hydrogen Sulfide Concentrations at Three Middle Schools Near Industrial Livestock Facilities*, 27 J. Exposure Sci. & Envtl. Epidemiology 167 (2017). Off-site migration of pollutants like H2S from industrial livestock operations can decrease air quality at nearby schools in North Carolina.

* Virginia T. Guidry et al., *Connecting Environmental Justice and Community Health Effects of Hog Production in North Carolina*, 79 N.C. Med. J. 324 (2018). Hog CAFOs, which are associated with adverse health effects, including respiratory conditions, irritation symptoms, mental health problems, and infectious disease risk, disproportionately impact communities of color and low-income communities in North Carolina. Physicians can improve patient care by recognizing how environmental injustices influence health.

Sarah M. Hatcher et al., *Occurrence of Methicillin-Resistant Staphylococcus Aureus in Surface Waters Near Industrial Hog Operation Spray Fields*, 565 Sci. Total Env't 1028 (2016). Antibiotic-resistant Staphylococcus aureus, of which industrial hog operations are a known source, including MSSA, MRSA, and MDRSA, are present in surface waters adjacent to hog lagoon waste spray fields in southeastern North Carolina.

* Sarah M. Hatcher et al., *The Prevalence of Antibiotic-Resistant Staphylococcus aureus Nasal Carriage Among Industrial Hog Operation Workers, Community Residents, and Children Living in Their Households: North Carolina, USA*, 125 Envtl. Health Persp. 560 (2017). Children under the age of seven living in households with industrial hog operation workers are more likely to carry ABR S. aureus (particularly MRSA and MDRSA) intra-nasally than children in a reference community, especially if industrial hog operation workers take their personal protective equipment home with them.

Christopher D. Heaney et al., *Source Tracking Swine Fecal Waste in Surface Water Proximal to Swine Concentrated Animal Feeding Operations*, 511 Sci. Total Env’t 676 (2015). Surface waters where

swine CAFO density is high have diffuse and overall poor sanitary quality.

Mariëtte Hooiveld et al., *Odour Annoyance in the Neighborhood of Livestock Farming – Perceived Health and Health Care Seeking Behaviour*, 22 Annals Agric. & Envtl. Med. 55 (2015). The number of pigs, poultry, and cattle are equally associated with odor annoyance, which in turn is associated with reduced general health.

Carrie Hribar & Marita Sommer, Nat'l Ass'n of Local Bds. of Health, *Understanding Concentrated Animal Feeding Operations and Their Impact on Communities* (2010). The impacts of CAFO odors include: preventing children from playing outside or going to school; causing negative mood states, tension, anger, and depression; increasing asthma rates in neighboring communities; and elevating levels of fly populations in homes close to the feeding operations.

Alexander P. Keil et al., *Suitability of Public Records for Evaluating Health Effects of Treated Sewage Sludge in North Carolina*, 72 N.C. Med. J. 98 (2011). Eastern North Carolina communities near industrial hog farms that apply waste to land demonstrate human exposure to airborne pollutants and dose-response relationships between pollutant levels, symptoms of illness, and stress levels.

Kaye H. Kilburn, *Human Impairment from Living near Confined Animal (Hog) Feeding Operations*, 2012 J. Envtl. & Pub. Health 56,5690 (2012). Neighbors around manure lagoons and massive hog confinement buildings who complained of offensive odors and symptoms had impaired neurobehavioral and pulmonary functions, and these effects extended to nearby people thought to be the study control group.

Julia Kravchenko et al., *Mortality and Health Outcomes in North Carolina Communities Located in Close Proximity to Hog Concentrated Animal Feeding Operations*, 79 N.C. Med. J. 278 (2018). North Carolina residents living near hog CAFOs had higher all-cause mortality, infant mortality, kidney disease, septicemia, tuberculosis, and higher hospital and emergency department visits for low-birth weight infants.

Gopi Krishna Kafle & Lide Chen, *Emissions of Odor, Ammonia, Hydrogen Sulfide, and Volatile Organic Compounds from Shallow-Pit Pig Nursery Rooms*, 39 J. Biosystems Eng'g 76 (2014). The gas and odor concentrations of emissions including NH3, H2S, CO2, and VOCs indicate an acute need for using gas and odor mitigation technologies in pig facilities.

Jesper Larsen et al., *Meticillin-Resistant Staphylococcus Aureus CC398 Is an Increasing Cause of Disease in People with No Livestock Contact in Denmark, 1999 to 2011*, 20 Euro Surveillance (2015). The spatial and temporal distribution of MRSA infections among patients with and without livestock exposure suggests that MRSA spreads from livestock facilities into surrounding communities.

Zifei Liu et al., *Ammonia and Hydrogen Sulfide Emissions from Swine Production Facilities in North America: A Meta-Analysis*, 92 J. Animal Sci. 1656 (2014). Swine hoop houses have significantly higher NH3 emissions and deep-pit houses have the highest H2S emissions compared to other manure-handling systems.

David C. Love et al., *Dose Imprecision and Resistance: Free-Choice Medicated Feeds in Industrial Food Animal Production in the United States*, 119 Envtl. Health Persp. 279 (2010). Providing antibiotics to industrial food animals, including swine, for purposes besides treating disease can result in the development of antimicrobial-resistant microorganisms.

Michael A. Mallin & Matthew R. McIver, *Season Matters When Sampling Streams for Swine CAFO Waste Pollution Impacts*, 16 J. Water & Health 78 (2018). Seasonal spraying of CAFO animal waste on fields in North Carolina aligns with seasonal differences in adjacent stream water quality for concentrations of conductivity, nitrate, total nitrogen, total organic carbon, and fecal bacteria.

Michael A. Mallin et al., *Industrial Swine and Poultry Production Causes Chronic Nutrient and Fecal Microbial Stream Pollution*, 226 Water, Air, Soil & Pollution 407 (2015). Industrial-scale swine and poultry production leads to chronic surface and groundwater pollution that is both a human health and ecosystem hazard, and current US waste management protocols for this form of livestock

production fail to protect freshwater and estuarine ecosystems along the US Mid-Atlantic, Southeast and Gulf coasts.

Maya Nadimpalli et al., *Persistence of Livestock-Associated Antibiotic-Resistant Staphylococcus Aureus Among Industrial Hog Operation Workers in North Carolina over 14 Days*, 72 Occupational & Envtl. Med. 90 (2015). Workers at swine CAFOs had persistent nasal carriage of MRSA, including after a period of 96 hours away from work.

Maya Nadimpalli et al., *Face Mask Use and Persistence of Livestock-Associated Staphylococcus aureus Nasal Carriage Among Industrial Hog Operation Workers and Household Contacts, USA*, 126 Envtl. Health Persp. 127005 (2018). Industrial hog operation workers may persistently carry antibiotic-resistant, livestock-associated Staphylococcus aureus in their nasal cavities. Consistent face mask use was associated with reduced exposure to antibiotic-resistant, livestock-associated S. aureus among IHO workers and their household members.

Wendee Nicole, *CAFOs and Environmental Justice: The Case of North Carolina*, 121 Envtl. Health Persp. A182 (2013). The pervasive presence of odors in communities on North Carolina's coastal plain affects quality of life, use of property, water quality, and public health. Even without spills, ammonia and nitrates may seep into groundwater, especially in North Carolina's coastal plain where the water table is near the surface.

Yelena Ogneva-Himmelberger et al., *CALPUFF and CAFOs: Air Pollution Modeling and Environmental Justice Analysis in the North Carolina Hog Industry*, 4 Int. J. Geo-Info. 150 (2015). At locations downwind of hog CAFOs, modeled ammonia concentrations are up to 3 times higher than the average concentration in the entire watershed, exposing around 3,500 people in the study area to ammonia concentrations greater than the minimal risk level.

Patrick T. O'Shaughnessy & Ralph Altmaier, *Use of AERMOD to Determine a Hydrogen Sulfide Emission Factor for Swine Operations by Inverse Modeling*, 45 Atmospheric Env't 4617

(2011). Hydrogen sulfide emitted from large industrial swine facilities can travel up to 6 km (3.7 miles).

Brian T. Pavilonis et al., *Relative Exposure to Swine Animal Feeding Operations and Childhood Asthma Prevalence in an Agriculture Cohort*, 122 Envtl. Res. 74 (2013). There is a significant relationship between poor respiratory health among children and environmental exposure to the cumulative impacts of all industrial hog operations within 4.8 km (2.98 miles) of their homes.

Pranay R. Randad et al., *Comparison of Livestock-Associated and Community-Associated Staphylococcus Aureus Pathogenicity in a Mouse Model of Skin and Soft Tissue Infection*, 9 Sci. Rep. 6774 (2019). Industrial hog operation workers are at increased risk of carrying Staphylococcus aureus in their nostrils, particularly strains that are livestock-associated (LA) and multidrug-resistant. The observed pathogenicity suggest that more attention should be placed on preventing the spread of LA-S. aureus into human populations.

Miranda M. L. van Rijen et al., *Livestock-Associated MRSA Carriage in Patients Without Direct Contact with Livestock*, 9 PLoS ONE e100294 (2014). There is a significant association between individuals residing in communities with pigs and livestock associated MRSA; pig-associated MRSA is present even in people without direct contact with swine.

Jessica L. Rinsky et al., *Livestock-Associated Methicillin and Multidrug Resistant Staphylococcus Aureus Is Present Among Industrial, Not Antibiotic-Free Livestock Operation Workers in North Carolina*, 8 PloS ONE e67641 (2013). Nasal swabs from individuals exposed to industrial livestock operations tested positive for livestock-associated MRSA and MDRSA, while those from people exposed to antibiotic-free livestock operations did not.

Günther Schauberger et al., *Empirical Model of Odor Emission from Deep-Pit Swine Finishing Barns to Derive a Standardized Odor Emission Factor*, 66 Atmospheric Env't 84 (2013). Odors from swine finishing operations create public nuisance concerns,

particularly due to their odor, which could be reduced in part through animal diet.

Leah Schinasi et al., *A Case Control Study of Environmental and Occupational Exposures Associated with Methicillin Resistant Staphylococcus Aureus Nasal Carriage in Patients Admitted to a Rural Tertiary Care Hospital in a High Density Swine Region*, 13 Envtl. Health 54 (2014). MRSA carriers identified at a local hospital had a higher odds of reporting being able to smell odor from farms while at home and of living in areas with medium densities of swine.

Leah Schinasi et al., *Air Pollution, Lung Function, and Physical Symptoms in Communities Near Concentrated Swine Feeding Operations*, 22 Epidemiology 208 (2011). The odor and chemicals emitted from industrial swine operations, including hydrogen sulfide and endotoxins, lead to acute eye, nose, and throat irritation, increased incidents of difficulty breathing, increased wheezing, chest tightness, and nausea among adults living in eastern North Carolina.

Jochen Schulz et al., *Longitudinal Study of the Contamination of Air and of Soil Surfaces in the Vicinity of Pig Barns by Livestock-Associated Methicillin-Resistant Staphylococcus Aureus*, 78 Applied & Envtl. Microbiology 5666, (2012). MRSA can be detected 300 feet from a pig barn in which animals, air, and workers' plastic boots tested positive for MRSA.

Steve Wing et al., *Air Pollution from Industrial Swine Operations and Blood Pressure of Neighboring Residents*, 121 Envtl. Health Persp. 92 (2013). Malodors from industrial swine operations may be associated with acute blood pressure increases and, in turn, could contribute to chronic hypertension.

Sample of Grey Literature Supplementing Peer-Reviewed Publications

1990s

R.L. Huffman & Phillip W. Westerman, *Seepage and Electromagnetic Terrain Conductivity Around New Swine Lagoons*, 47 Transactions Am. Soc'y Agric. Eng'rs 1507 (1991). Unlined lagoons built in deep sands in North Carolina's coastal region seep significantly into the soil and ground water.

∗ Michael A. Mallin et al., Water Res. Research Inst., Univ. of N.C., *Effect of Organic and Inorganic Nutrient Loading on Photosynthetic and Heterotrophic Plankton Communities in Blackwater Rivers* (1998). Pollution from lagoons could contribute to toxic algae outbreaks in Blackwater stream systems in the Coastal Plain of North Carolina.

James P. Murphy & Joseph P. Harner, *Lagoon Seepage Through Soil Liners*, in Swine Day 1997 Report of Progress 1, 3 (1997). Lagoons can leach wastewater into soil, potentially leading to groundwater contamination.

Melva Okun, Univ. of N.C., *Human Health Effects Associated with the Hog Industry* 2 (1999). Health effects of swine sites include odors, waste, resulting flies, poor air quality, and the contamination of drinking water supplies.

Susan S. Schiffman et al., *Mood Changes Experienced by Persons Living Near Commercial Swine Operations*, in *Pigs, Profits, and Rural Communities* 84 (Kendall M. Thu & E. Paul Durrenberger eds., 1998). Odor can have a deleterious health effect, including a physiological pathway between the olfactory lobe and the immune system, which directly implicate odor as a health risk.

Understanding the Impacts of Large-Scale Swine Production: Proceedings from an Interdisciplinary Scientific Workshop, June 29-30, 1995, Des Moines, Iowa (Kendall M. Thu & Kelley J. Donham eds., 1996). Research has found that CAFOs adversely impact water and air quality and harm residents' quality of life.

2000s

Policy Statement, Am. Pub. Health Ass'n, *Precautionary Moratorium on New Concentrated Animal Feed Operations* (2003), https://www.apha.org/policies-and-advocacy/public-health-policy-statements/policy-database/2014/07/24/11/17/precautionary-moratorium-on-new-concentrated-animal-feed-operations. A precautionary moratorium on new CAFOs may be necessary based on evidence of the health hazards from over 400 volatile compounds emitted by manure.

Br. David Andrews & Timothy J. Kautza, Pew Comm'n on Indus. Farm Animal Prod., *Impact of Industrial Farm Animal Production on Rural Communities* (2008). CAFOs produce recurrent strong odors, degrade water bodies, and increase fly populations, making it intolerable for neighbors and their guests to participate in normal outdoor recreational activities or normal social activities in and around their homes.

Joanne Chee-Sanford, U.S. Dep't of Agric., *Distribution of Tetracycline- and Tylosin-Resistance Genes in Bacteria from Soils Exposed to Swine Effluent*, Presentation at the ASA-CSSA-SSSA International Annual Meetings (Nov. 13, 2006). There is evidence of drug-resistant bacteria traveling from a hog facility into groundwater 250 meters downstream.

Adam Driscoll & Bob Edwards, *From Farms to Factories: The Social and Environmental Consequences of Industrial Swine Production in North Carolina*, in *Twenty Lessons in Environmental Sociology* 153 (Kenneth A. Gould & Tammy L. Lewis eds., 2009). In North Carolina, the industrialization of hog CAFOs has led to a range of externalities, including farm loss, reduced quality of life, adverse impacts on health, and environmental degradation.

Rolf U. Halden & Kellogg J. Schwab, Pew Comm'n on Indus. Farm Animal Prod., *Environmental Impact of Industrial Farm Animal Production* (2008). All industrial animal operations impact public health and quality of life in rural America due to odors and interference with neighbors' ability to spend time outdoors.

Iowa State Univ. & Univ. of Iowa Study Grp., *Iowa Concentrated Animal Feeding Operations Air Quality Study* (2002). Air emissions from CAFOs cause odor of major concern to residents living in proximity to CAFOs and may constitute a public health hazard. The report calls for recognition of the effects of CAFOs on surrounding communities in permitting decisions.

Michael A. Mallin, *Impacts of Industrial-Scale Swine and Poultry Production on Rivers and Estuaries*, 88 Am. Scientist 26 (2000). Lagoons and sprayfields located near aquatic environments can harm public health and degrade water quality.

James Merchant et al., Pew Comm'n on Indus. Farm Animal Prod., *Staff Summary of Occupational and Community Public Health Impacts* (2008) http://www.pcifapia.org/_images/PH_FINAL.pdf. Bacterial agents that spread contagious diseases between animals and humans can travel downwind as spray aerosols and infect local populations, as can disease-transmitting flies and pests.

N.C. Council of Churches, Hog Lagoons Policy Statement (Nov. 9, 2000), https://www.ncchurches.org/2000/11/hog-lagoons/. Contaminated water supplies and air emissions from hog operations adversely affect the health of those who live in the surrounding neighborhoods, causing respiratory problems, exposure to disease-causing bacteria, and psychological problems.

Brian C. Murray et al., RTI Int'l, *Benefits of Adopting Environmentally Superior Swine Waste Management Technologies in North Carolina: An Environmental and Economic Assessment* (2003). The costs of health effects and premature deaths linked to ammonia emissions from swine production sites total hundreds of millions of dollars.

James A. Zahn et al., *Air Pollution from Swine Production Facilities Differing in Waste Management Practice*, 2000 Odors & Emission Conf. Proc. 1. Odor intensity and the air concentration of volatile organic compounds (VOCs) emitted from swine manure management systems are strongly correlated. The concentration of VOCs in air samples was highest with high-load, outdoor swine manure management systems.

2010s

Thijs Bosch & Leo M. Schouls, *Livestock Associated MRSA: Innocent or Serious Health Threat?*, 10 Future Microbiology 445 (2015). A review of past studies links the spread of MRSA to hog facilities and finds that livestock-associated MRSA can successfully colonize human hosts, pointing to a potentially serious health threat and the possibility that livestock-associated MRSA could persist and spread in communities without contact with hogs.

Univ. of N.C. at Chapel Hill, *Identifying Opportunities and Impacts for New Uses of Hog Waste in Eastern North Carolina* (2013). Proximity to a hog CAFO lagoon in Sampson County resulted in a $10,382 decline per lagoon in the value of residential parcels with homes and an assessed property value loss of anywhere from $5,443-$15,563, depending on the type of residential parcel.

Stephen L. Harden, U.S. Geological Survey, Sci. Investigations Rep. 2015-5080, *Surface-Water Quality in Agricultural Watersheds of the North Carolina Coastal Plain Associated with Concentrated Animal Feeding Operations* (2015). North Carolina watersheds with CAFOs have significantly higher concentrations of ammonium, nitrate, and total N than those without CAFOs.

∗ Steve Wing & Jill Johnston, *Industrial Hog Operations in North Carolina Disproportionately Impact African-Americans, Hispanics and American Indians*, N.C. Policy Watch (Aug. 29, 2014), http://www.ncpolicywatch.com/wp-content/uploads/2014/09/UNC-Report.pdf. Hog CAFOs in North Carolina disproportionately affect Black, Hispanic and American Indian residents, and NC's hog CAFOs are relatively absent from low-poverty White communities.