Expert Report – Shane Rogers

1. I am qualified to talk about and give expert opinions on concentrated animal feeding operations (CAFOs), pollution caused by CAFOs, exposures of nearby residents of CAFOs to pollutants in manures and their residuals, treatment alternatives for CAFO manures, pathogenic microorganisms in manures, antibiotics and antibiotic resistant bacteria, host-associated genetic markers and DNA testing, and best management practices to reduce movement of pollutants from CAFOs and fields applied with their manures and residuals into the environment. Ongoing research in my laboratory investigates the fate, transport, and vectoring of pathogens, antibiotic resistant bacteria, and chemical stressors in agroecosystems, risks associated with exposure to these agents in air, water, soils, and produce grown for human consumption, and technology development to limit these risks.

A. Education
   (1) 1996, B.S. Civil Engineering, Iowa State University, Ames, IA
   (2) 1999, M.S. Civil (Environmental) Engineering, Iowa State University, Ames, IA
   (3) 2004, Ph.D Environmental Engineering (with honors), Iowa State University, Ames, IA

B. Experience
   (1) Positions held
      a. Associate Professor, Department of Civil and Environmental Engineering, Clarkson University, Potsdam, NY (2013 –current)
      b. Assistant Professor, Department of Civil and Environmental Engineering, Clarkson University, Potsdam, NY (2007-2013)

   (2) My research and development activities are varied, but focus on knowledge generation and development of technologies to improve farm systems and food production practices that support a healthy and growing population.

      a. My primary research activities since 2004 with the U.S. Environmental Protection Agency and at Clarkson University have centered upon agroecosystems engineering and biotechnologies for wastewater treatment and residuals management, including genome-enabled molecular technologies for monitoring soils, air, and water quality and host-source allocation. My research in these areas has been sponsored by the U.S. Environmental Protection Agency (U.S. EPA), the U.S. Department of Agriculture (USDA), and the U.S Geological Survey (USGS).
b. My recent research work related to livestock agriculture has focused on ammonia, nitrous oxide, and bioaerosols emission from dairy manure-amended fields, downwind transport, and associated risks to downwind receptors and produce grown for human consumption. This USDA-sponsored research was conducted on active dairy CAFOs in New York State with the collaboration of dairymen interested in development of good management practices to decrease potential exposures of manure pollutants to neighbors and downwind produce growing areas.

c. Some of my other livestock agriculture related research has focused on the performance of manure treatment practices and runoff management practices for limiting movement of manure stressors including nutrients, pathogens, host-associated DNA markers for source allocation of manure pollution, and antibiotic resistant bacteria from manure application areas to nearby waterways. This work includes investigations on the persistence of pathogens and host-associated genetic markers in soils environments to understand their decay once applied to land. This research has been conducted in several states and with varied partnerships including:

i. An active swine CAFO in North Carolina where Smithfield\(^1\) hogs were grown, in collaboration with the U.S. Geological Survey (USGS) and a grower interested in learning about potential pathways whereby stressors from the swine manure were loaded to surface waters as well as management practices to limit their movement.

ii. Livestock research farms at North Carolina State University, Iowa State University, and Purdue University in collaboration with USGS and University scientists. These projects were focused on understanding the role of grassed waterways, vegetative buffers, infiltration basins, surface flow constructed wetlands, and tile drainage in limiting movement of stressors to nearby waters, including during storm water runoff. These studies included swine, beef cattle, dairy cow and poultry sources of manure.

iii. An agronomic research site of the U.S. Department of Agriculture in Ohio, in collaboration with USDA-Agricultural Research Service Scientists. This project investigated the practice of manure application to frozen ground to understand runoff potential and the performance of land management practices including setbacks and grassed buffers under frozen conditions. Liquid swine manure, turkey litter, and beef cow manure solids were all used on the varied fields and treatment plots of this study.

\(^1\) I am advised that the legal entity owning the hogs at issue in these cases is Murphy-Brown, LLC d/b/a Smithfield’s Hog Production Division, which is owned by Smithfield Foods, Inc. and ultimately by WH Group Limited. For simplicity I call the company “Smithfield.”
d. I am deeply interested in the development of sustainable technologies to assist farmers in maintaining healthy and profitable operations and for assuring the highest quality food products that support their brand. To this end, my ongoing development activities include biosensors for rapid pathogen detection in food and water, anaerobic digester development and extension for small farms, and development of electrical discharge plasma reactors for rapid, energy-efficient, and sustainable sterilization of liquid foods. These projects have been sponsored by the USDA, U.S. EPA, and the New York State Pollution Prevention Institute.

e. I have recently gained interest in the development of a new and sustainable marine industry based on cultivated macroalgae feedstock designed to address issues at the forefront of the water, energy, and food security nexus. Macroalgae, which do not compete with land for food production, are a feedstock for a variety of products, a third-generation biofuel feedstock, and sink for nutrients in coastal environments impacted by anthropogenic activities. My current research is in collaboration with SINTEF Ocean in Norway.

(3) As an Associate Professor of Environmental Engineering at Clarkson University, I train future scientists and engineers through teaching and mentoring research activities.

a. I have mentored more than 60 undergraduate research students, graduate research students and post-doctoral scholars, many on agriculture-related research projects in my laboratory.

b. I teach courses in environmental biotechnology, water and wastewater engineering, livestock manure management, and sustainable water resources management, among others.

c. I am the primary investigator on several education programs, most of which focus on providing opportunities for financially needy students, women, and students of color. Of note, I manage a National Science Foundation (NSF) funded Research Experience for Undergraduates program and an NSF-funded program called ASPIRE: Academic Success Program to Improve Retention and Education of Underrepresented Students in STEM. These two programs engage >80 undergraduate students with otherwise limited opportunities each year in extended mentoring, undergraduate research, and professional development.

(4) Notable professional service includes:

a. Zone 1 Chair Elect, American Society for Engineering Education (ASEE)

b. Member of the Board of Directors, ASEE

c. Chair, ASEE St. Lawrence Section

d. Water Environment Federation Awards Committee

e. Associate Editor of Renewable Agriculture and Food Systems

(5) Awards and recognition:
a. Fulbright Scholar to Norway (2015-2016)
b. Tau Beta Pi Faculty Award (2013)
c. Martin Luther King Jr. Diversity Award (2011)
d. Clarkson University Student Association Outstanding Teacher Award (2010)
e. American Society for Engineering Education, St. Lawrence Section Outstanding Teaching Award (2009)
g. U.S. EPA, Superior Accomplishment Recognition Award (2007)
j. Iowa State University Research Excellence Award (2004)
l. Association of Environmental Engineering and Science Professors / Montgomery Watson Consulting Engineers M.S. Thesis Award (2000)
m. Phi Kappa Phi, Multidisciplinary Honor Society (1997)

(6) Patents

(7) Papers authored in the previous 10 years include


(8) I have not testified as an expert at trial or by deposition for any other case in the last four years.

2. I have reviewed materials for the eight subject sites as reflected in the reliance list of materials provided herewith.

A. Direct Owned Site
   (1) Sholar Farm Facility -- Permit No. AWS820034 -- 532 Moon Johnson Road, Rose Hill, NC 28458

B. Contract Grower Sites
   (2) Joey Carter Farms -- Permit No. AWS310259 -- 160 Howards Farm Road / 175 Joey Carter Lane, Beulaville NC 28518
   (3) Crooked Run Farm -- Permit No. AWS710012 -- 5920 NC Hwy. 11, Willard, NC 28478
   (4) Willow Creek Sow farm -- Permit No. AWS710008 -- 6486 NC Hwy. 11, Willard, NC 28478
   (5) Kinlaw Facility -- Permit No. AWS090133 -- 265 Porky’s Lane beyond Pearl Lloyd Road and Wright Lloyd Road, White Oak, NC 28399
   (6) Paul Stanley 7 -- Permit No. AWS710043 -- 4006 Piney Woods Rd., Watha, NC 28478
   (7) Greenwood 1 -- Permit No. AWS710090 -- 7448 Piney Woods Road, Watha NC 28478
   (8) Greenwood 2 -- Permit No. AWS710017 -- 6526 Piney Woods Rd., Watha, NC 28478.

3. I and/or other members of our team have toured seven of the eight subject sites, took measurements on site, and collected samples from the sites for testing, where permitted to enter the sites by the defendant. I would like to visit Crooked Run facility when it is restocked with hogs. Nonetheless, as discussed below, my study and findings from the other sites are sufficient for me to form opinions regarding Crooked Run.

A. Direct Owned Site
   (1) Sholar Farm Facility -- Permit No. AWS820034

B. Contract Grower Sites
   (2) Joey Carter Farms -- Permit No. AWS310259
   (3) Willow Creek Sow farm -- Permit No. AWS710008
   (4) Kinlaw Facility -- Permit No. AWS090133
   (5) Paul Stanley 7 -- Permit No. AWS710043
   (6) Greenwood 1 -- Permit No. AWS710090
(7) Greenwood 2 -- Permit No. AWS710017

4. I have reviewed some of the testimony of the Plaintiffs who live near these sites. Testimony I was provided is included in the reliance list.

5. I have collected physical samples from the outdoor air at, and exterior surface of, several houses of neighbors of the nine subject sites for DNA testing by analytical laboratories.

6. I have reviewed DNA data from physical samples collected from the outdoor air at, and from the exterior surfaces of, several houses of neighbors of the nine subject sites by personnel that I personally trained to collect the physical samples.

7. I along with our team conducted sampling and testing at each of the relevant sites as allowed under the site visit court order and the site visit protocol. This included air, manure, lagoon and other sampling and testing, the details of which the defendant is familiar with from attending all of the site visits. Our team has shared site visit photos, video, and testing and sampling information as required under the order and the protocol. In my reliance materials I include more information as to the sampling and testing done at each relevant site.

8. I have been provided with some of the testimony of the Smithfield hog production employees who manage/visit at the sites.

9. I have been provided with some of the testimony of the employees for the contract growers associated with the contract grower sites.

10. Operations at the subject CAFO sites generate odor and other harmful pollutants in the swine houses that get ventilated to the outside air. Poor management of the swine houses exacerbates malodor production and emission.

   **A.** There are three primary sources of odor production at swine facilities that include the production facility (swine houses), waste treatment and storage facilities, and land application. From a science and engineering perspective, the swine houses are the origin of the neighbors’ claims of nuisance. This where the hogs are confined and manure waste is first emitted. It is well recognized within the swine

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3 See Controlling Odor and Gaseous Emission Problems from Industrial Swine Facilities: A Handbook for All Interested Parties, Yale Environmental Protection Clinic, 1998, Section 2.2.1 ("In comparison to traditional swine housing on smaller-scale farms, swine buildings utilized in industrial swine facilities are more enclosed and tightly constructed ...."). Available at http://www.colorado.edu/economics/morey/8545/student/caforegs/ControllingOdor.pdf
production industry that odor problems from swine CAFOs come from the housing units. Swine house odors have been reported to account for approximately 30% of all odor complaints in some states. Swine odors generate due to anaerobic decomposition of swine manure, wastewater, and feed materials, and can be exacerbated when manures are held within the houses for more than 4 or 5 days, left on the floors without cleaning or scraping, and other factors. Swine odors can interfere with the quality of life of nearby residents and reduce property values in nearby communities.

B. Thousands of Smithfield hogs are being kept in the subject swine CAFOs as summarized in Table 1. It takes about 24 to 29 weeks for a hog to reach an average market weight of 283 pounds from birth, including about 3 weeks to wean, 6 weeks in a nursery stage, and then 16 to 20 weeks for the finishing stage. A typical finishing operation for Smithfield may have 2.5 sellouts (rotation of hogs) per year. As summarized in Table 1, mortalities reported by the subject swine CAFOs “dead truck” traffic to remove dead hogs from the farm for rendering for further processing and sale as products. According to the grower and Smithfield records, average weekly mortalities in the subject swine CAFOs range from .

5 See Department of Environmental Quality, State of Virginia. 2001. An Evaluation of Alternative Approaches to Reduce Odors from Intensive Swine Operations - Interim Report --Item #428, 1999 Appropriations Act (“A study showed that approximately 50% of all odor complaints were as a result of land application of waste, with the remaining complaints split 20% to waste storage and 30% to the production buildings.”) available at http://www.deq.virginia.gov/portals/0/deq/lawsandregulations/generalassemblyreports/swineodor.pdf
7 United States Department of Agriculture, Economic Research Service, web page, Hogs and Pork, available at http://www.ers.usda.gov/topics/animal-products/hogs-pork/background.aspx (chart showing that it may take 2 to 3 weeks to wean a pig, then nursery stage for 6 weeks, then 16 to 20 weeks for the finishing stage = 24 to 29 weeks total = 168 to 203 days).
8 Memo dated February 1, 2010 to Mitchell Norris and Interested Parties from Kraig Westerbeek, Assistant VP, EHS Compliance (Case 5:15-cv-00013BR Document 130-4 Filed 06/23/16), Mr. Westerbeek reports that the swine finishing operation known as Mitchell Norris has an “average of 2.5 sellouts per year”
Table 1. Production characteristics of the subject swine CAFOs

<table>
<thead>
<tr>
<th>Facility</th>
<th>Operation type</th>
<th>Permitted hog counts</th>
<th>Average Weekly Mortalities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Greenwood 1 Facility</td>
<td>Feeder to finish</td>
<td>3,672</td>
<td></td>
</tr>
<tr>
<td>Greenwood 2 Facility</td>
<td>Feeder to finish</td>
<td>3,672</td>
<td></td>
</tr>
<tr>
<td>Kinlaw Facility</td>
<td>Feeder to finish</td>
<td>14,688</td>
<td></td>
</tr>
<tr>
<td>Sholar Facility</td>
<td>Wean to finish</td>
<td>7,184</td>
<td></td>
</tr>
<tr>
<td>Joey Carter Facility</td>
<td>Feeder to finish</td>
<td>4,740</td>
<td></td>
</tr>
<tr>
<td>Crooked Run Facility</td>
<td>Feeder to finish</td>
<td>4,200</td>
<td></td>
</tr>
<tr>
<td>Willow Creek Sow Facility</td>
<td>Farrow to wean</td>
<td>1,446</td>
<td></td>
</tr>
<tr>
<td>Paul Stanley #7 Facility</td>
<td>Feeder to finish</td>
<td>1,800</td>
<td></td>
</tr>
</tbody>
</table>

Notes: (1) The permitted hog count is the allowable annual average count calculated pursuant to the permit. It is not the number of hogs present at any particular time. (2) Murphy-Brown noted in the defense fact sheet that for Sholar, the farm was permitted for wean-to-finish swine, but has housed only feeder-to-finish swine during the relevant period. (3) For December 2015 onwards, Crooked Run Farm was not in operation. (4) Paul Stanley Farm # 7 was depopulated by end of September 2015. (5) Willow Creek was depopulated by the end of January 2016.

C. The Smithfield hogs create a lot of manure in the subject swine CAFOs, which is a source of odor and other harmful pollutants of environmental and public health concern.

(1) To get from birth to 283 pounds in 200 days means that the hogs must gain weight rapidly; industry reports reflect average daily weight gains of as much as 1.95 pounds as of the year 2001. According to Smithfield company witness Terry Coffey, this required significant food and water intake and with that comes significant manure production. Based on reported manure production characteristics, hogs produce multiple times more waste than humans. As shown in Table 2, a 283 lb finishing hog can be expected to produce on average about 1.67 gallons (13.8 lbs) of manure each day.

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Table 2. Manure production characteristics of swine

<table>
<thead>
<tr>
<th>Life Stage</th>
<th>Animal size Pounds</th>
<th>Daily Manure Production Pounds</th>
<th>Gallons</th>
<th>Liters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nursery</td>
<td>25</td>
<td>1.9</td>
<td>0.23</td>
<td>0.87</td>
</tr>
<tr>
<td></td>
<td>40</td>
<td>3.0</td>
<td>0.37</td>
<td>1.40</td>
</tr>
<tr>
<td>Finishing</td>
<td>150</td>
<td>7.4</td>
<td>0.89</td>
<td>3.37</td>
</tr>
<tr>
<td></td>
<td>180</td>
<td>8.9</td>
<td>1.07</td>
<td>4.05</td>
</tr>
<tr>
<td></td>
<td>220</td>
<td>10.9</td>
<td>1.31</td>
<td>4.96</td>
</tr>
<tr>
<td></td>
<td>260</td>
<td>12.8</td>
<td>1.55</td>
<td>5.87</td>
</tr>
<tr>
<td></td>
<td>300</td>
<td>14.8</td>
<td>1.79</td>
<td>6.78</td>
</tr>
<tr>
<td>Gestating</td>
<td>300</td>
<td>6.8</td>
<td>0.82</td>
<td>3.10</td>
</tr>
<tr>
<td></td>
<td>400</td>
<td>9.1</td>
<td>1.10</td>
<td>4.16</td>
</tr>
<tr>
<td></td>
<td>500</td>
<td>11.4</td>
<td>1.37</td>
<td>5.19</td>
</tr>
<tr>
<td>Lactating</td>
<td>375</td>
<td>17.5</td>
<td>2.08</td>
<td>7.87</td>
</tr>
<tr>
<td></td>
<td>500</td>
<td>23.4</td>
<td>2.78</td>
<td>10.5</td>
</tr>
<tr>
<td></td>
<td>600</td>
<td>28.1</td>
<td>3.33</td>
<td>12.6</td>
</tr>
</tbody>
</table>

(2) Hog manure and its decomposition in swine houses and elsewhere on swine CAFO facilities generates a complex mixture of odorants and gases that comprise hundreds of chemical compounds including volatile organic compounds (VOCs), ammonia and hydrogen sulfide. Many of these compounds are odiferous at very low concentrations (have very low odor detection thresholds) in humans. In addition, significant levels of airborne dust (particles from feed, manure, dander, and other particles) are generated in swine houses. The dust can contain manure and absorb and concentrate gaseous odorants. Indeed, odorants can exist in much greater concentrations in the dust particles than in an equivalent volume of air (without the dust). These particles stick to surfaces in the swine houses and are ejected from swine houses through natural or forced ventilation and transported for significant distances downwind where their odorants are released. Inhalation of odorous dust and deposition of dust particles in the mucus overlying the olfactory mucosa by downwind receptors may be responsible for odor-related complaints by many swine CAFO neighbors. Swine manure odors in and of themselves are a public health concern. For example, they have been correlated to tension, depression, anger, loss of vigor, increased fatigue, and increased confusion.


14 Schiffman, S.S., Miller, E.A.S., Suggs, M.S. and Graham, B.G., 1995. The effect of environmental odors emanating from commercial swine operations on the mood of nearby residents. Brain research bulletin, 37(4), pp.369-375. (Persons living near the intensive swine operations who experienced the odors reported significantly more tension, more depression, more anger,
Hog manure can be expected to contain, among other things, microbes (including potentially pathogenic microorganisms), dander, hair, undigested and digested feed materials, salts, primary nutrients and trace elements, and other harmful pollutants of public and environmental health concern. The biological portion of airborne dusts generated in swine houses are referred to as bioaerosols. These can contain pathogens, endotoxins, allergens, and other pollutants of concern to downwind receptors. Detailed composition of swine manures including pathogenic microorganisms are provided in reported scientific literature and summarized elsewhere.

In general pathogenic microorganisms of public health concern commonly detected in swine manures and swine houses include *Salmonella*, *Staphylococcus aureus*, *Campylobacter*, *Yersina enterocolitica*, *Listeria*, and enteropathogenic *E. coli*, among others. These organisms are classified as zoonotic, meaning that they can be transmitted between vertebrate animals and humans. Zoonotic diseases in general are a major public health concern. Zoonoses infect billions of people worldwide, exhibit a considerable morbidity and mortality toll, are often followed by debilitating chronic sequelae, and are directly correlated with significant burdens in terms of veterinary medicine, agriculture, livestock production, and regional and national economics.

For instance, the CDC estimated in 1999 that foodborne diseases caused approximately 76 million illnesses, 325,000 hospitalizations and 5000 deaths in the U.S. annually. Zoonoses that are predominantly associated with livestock manure may have been responsible for as many as 90% of these infections where the causative agent was identified. Estimated medical costs, productivity losses, and costs of premature deaths associated with foodborne illness may have totaled as much as 6.9 billion per year. The zoonotic nature of a pathogen is also an influential factor that affects its potential for emergence or re-emergence, primarily through expanded routes of propagation. Sixty-one percent of the 1,415 infectious agents known to affect humans in 2001 were identified as zoonotic. "Persons who live near large hog operations have reported reduced quality of life as well as health problems related to airborne emissions from animal confinement houses, open waste lagoons, and spray fields.") See also Wing, S. and Wolf, S., 2000. Intensive livestock operations, health, and quality of life among eastern North Carolina residents. *Environmental health perspectives*, 108(3), p.233. ("Persons who live near large hog operations have reported reduced quality of life as well as health problems related to airborne emissions from animal confinement houses, open waste lagoons, and spray fields.");


zoonotic. The vast majority of novel human pathogens recognized since 2001 are also zoonotic, including the SARS coronavirus and the pandemic H1N1 influenza virus (swine flu).

(5) Hogs in CAFOs are purposefully engineered to grow fast and lean, which results in additional harmful pollutants of great concern in swine manure. Of particular concern is the use of antibiotics in livestock agriculture at subtherapeutic concentrations as prophylactic drugs and to increase feed efficiency and daily weight gain. Use of antibiotics at subtherapeutic concentrations promotes conditions by which microorganisms, including pathogens, have adapted to resist the antibiotics. For example, in a study of several swine farms in the United States, Tylosin use for growth promotion resulted in erythromycin-resistance in 59% of enterococci isolates, compared to 28% at a farm where Tylosin was used for treatment of disease only, and 2% at a farm that did not use Tylosin. Development of antibiotic resistance is a concern because when humans become infected with antibiotic-resistant pathogenic microorganisms, there are limited, if any, treatment options. Additionally, because antimicrobial resistance determinants are often co-located with virulence determinants on mobile genetic elements, treatment with antimicrobials for which resistance is conferred may result in the enrichment of more virulent bacterial strains.


21 The use of antibiotics for growth promotion did not begin until the 1950's, when researchers demonstrated that chlorotetracycline (aureomycin) used at low levels (i.e., 20 ppm or less) improved the rate of weight gain and the amount of feed per unit of weight gain in pigs. – see Jukes, T. H., Stokstad, E. L. R., Tayloe, R. R., Cunha, T. J., Edwards, H. M., & Meadows, G. B. (1950). Growth-promoting effect of aureomycin on pigs. Arch. Biochem., 26, 324-325.


24 For example, carbapenem-resistant Enterobacteriaceae (CRE) was recently detected in a swine farrow to finish operation in the United States. See Mollenkopf, D. F., Stull, J. W., Mathys, D. A., Bowman, A. S., Feicht, S. M., Grooters, S. V., Daniels, J. B. and Wittum, T. E., 2016. Carbapenemase-producing Enterobacteriaceae recovered from the environment of a swine farrow-to-finish operation in the United States. Antimicrobial Agents and Chemotherapy, pp.AAC-01298. (Carbapenem antimicrobials are considered “last line of defense drugs in human medicine…” “The emergence of carbapenem-resistant Enterobacteriaceae (CRE) has been described as heralding the end of the antibiotic era with their global expansion presenting an urgent threat to public health.”)

25 Epidemiological evidence from reported Salmonella and Campylobacter infections suggest that resistant strains are somewhat more virulent than susceptible strains, exhibiting prolonged or more severe illness – see Barza, M. (2002). Potential mechanisms
The capacity for human care workers, their families, and residents of nearby communities to become infected with antibiotic-resistant microorganisms from swine CAFOs has long been documented. The U.S. Food and Drug Administration reported that 13.5 million kilograms (29.8 million pounds) of antibiotics were sold for use in domestic animals in 2011, compared to 3.3 million kilograms (7.3 million pounds) for treatment of human illness. Use in domestic livestock agriculture has increased since that time. The rise in agricultural use of antimicrobial agents is certainly related to changes in their production and availability, a perceived need for prophylactic use due to close confinement and increased risk of the spread of disease, and realization of the financial benefits of shortening the time to reach market weight.

D. The design and operation of the swine houses in which the Smithfield hogs are grown exacerbate odor problems.

(1) Our inspections confirmed that the facilities used

of increased disease in humans from antimicrobial resistance in food animals. Clinical Infectious Diseases, 34(S3), S123-S125; In a study of 67 individuals not treated with antimicrobials, diarrhea lasted longer when the isolates were ciprofloxacin-resistant (12 days) than when they were ciprofloxacin-susceptible (6 days) (P=0.02). see Marano, N., Vugia, D., Fiorentino, T., et al. (2000). Fluoroquinolone-resistant Campylobacter causes longer duration of diarrhea than fluoroquinolone-susceptible Campylobacter strains in FoodNet sites [abstract]. In: Program and abstracts of the International Conference on Emerging Infectious Diseases 2000 (Atlanta). Atlanta, GA: Centers for Disease Control and Prevention; The likelihood of hospitalization and average length of hospital stay are significantly higher in those infected with antimicrobial-resistant organisms than those with susceptible strains. See Lee, L. A., Puhr, N. D., Maloney, F. K., Bean, N. H., & Tauge, R.V. (1994). Increase in antimicrobial-resistant Salmonella infections in the United States, 1989-1990. J. Infect. Dis., 170, 128-34.


28 Of note, farmers with large operations are much more likely than those with small farms to use antibiotics in feed supplements for growth promotion and prophylaxis. Of the large confinement operations, those working with veterinary consultants are twice as likely to use such feed additives. See Dewey, C. E., Cox, B. D., Straw, B. E., Budh, E. J., & Hurd, H. S. (1997). Association between off-label feed additives and farm size, veterinary consultant use, and animal age. Preventative Veterinary Medicine, 31, 133-146.

Because we were allowed inside the confinement buildings, we were able to take photos and videos of what the interior looked like.

As noted above, several of the facilities have been shut down or “depopulated” since these lawsuits were brought. Thus, our team was unable to observe them in active hog growing operation or make measurements or take samples of from active operations, emissions, etc. However, I have been able to review available information on those facilities that lets me understand how they worked in active operation. Based on the information showing that when they were previously operation, the now-inactive sites also had hundreds and thousands of hogs just like those still active today, and used the same lagoon and spray waste handling as those still active today. Accordingly, it is reasonable to conclude that when they were in active operation, those sites produced manure and emissions similar to the manner in which the still-active sites do.

The nature of the ventilation for the hog sheds varies between natural or roof ventilation and tunnel fan ventilation. Hog sheds that have natural or roof ventilation do not have exhaust fans at the end of the shed. Instead, they

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30 The Defendant Fact Sheets at response number 46 describes each site’s system. For Kinlaw Farm, Crooked Run, Greenwood 1, Greenwood 2, and Sholar: each “utilizes a flush tank system for removing effluent from the gutters and moving it to the treatment lagoon. The system operates by way of a float switch that is automatically triggered when effluent levels reach a certain point. When in operation this system flushes approximately 4-6 times a day.” For Joey Carter: “Barns 1-5 utilize a pit recharge system for removing effluent from the gutters and moving it to treatment lagoons. The system works by way of a holding valve that is opened approximately every seven days to allow draining. Barns 6 and 7 utilize a flush tank system. This system works by using a float switch that is automatically triggered when effluent levels reach a certain point. When in operation this system flushes approximately 4-6 times a day.” The Willow Creek and Paul Stanley 7 facilities are empty.
have vents in the roof and they may have louvers or panels that can raise or lower on their sides. Hog sheds with tunnel ventilation have large electric-powered fans at the end of the long narrow hog sheds.

(5) It is obvious from a survey of available media that pork integrators have historically allowed a variety of individuals into the CAFO sheds, and have promoted and publicized photos and videos taken inside of sheds. Thus, Smithfield has a video library it makes available for the general public. However, a comparison of those videos with the ones our team took reflects that.

(6) The design of the hog sheds allows the noises of hogs to be audible on the outside. Also, when hogs are being loaded or unloaded onto or off of trucks there may be noise. I am informed that some Plaintiffs complain that they hear the hogs from their homes from time to time.

(7) Manure from the hogs is deposited onto the floor. Some of it falls through open “slats” in the floor, and some of it accumulates on the floor in the small pens where hogs live, eat, and sleep, forcing hogs to be covered in their own manure. Many hogs are kept close together. Pigs have a natural instinct to wallow in the mud and root


33 See M.B.M. Bracke, Review of Wallowing in pigs: Description of the behaviour and its motivational basis, Applied Animal Behaviour Science, Vol. 132, Issues 1-2, June 2011, Pages 1-13, abstract available online at http://www.appliedanimalbehaviour.com/article/S0168-1591(11)00021-9/abstract. Wallowing, i.e. coating the body surface with mud, is a natural behavior of pigs, commonly observed in feral pigs and wild boar, but rarely provided for in current housing systems for food produced pigs. Wallowing is observed in related species including rhinos, elephants and bison. Pigs also share several characteristics with water-loving mammals such as water buffalos and hippos. Pigs wallow mainly for cooling because they lack functional sweat
in the earth. However, these hogs never contact the dirt or earth. They have no room to defecate in one area and live in another as hogs instinctively do. Therefore, they get coated with feces. These physical circumstances relate to the amount of odor, gas and particulate emissions that are occurring.\textsuperscript{34}

\begin{figure}
\centering
\includegraphics[width=\textwidth]{image.png}
\caption{Figure 1.}
\end{figure}

\textsuperscript{34} See the North Carolina Swine Farm Waste Management Odor Control Checklist of the Senate Bill 1217 Interagency Group’s ninth guidance document, which lists dirty manure-covered animals as a cause of odors in swine houses and indicates that dry floors are a best management practice to help control odor production and keep animals from becoming dirty and manure-covered. \url{www.ncagr.gov/SWC/tech/documents/AppenzSwineOdor_111196.pdf}; see also Barker, James C., 1996, Swine Production Facility Manure Management: Underfloor Flush – Lagoon Treatment, North Carolina Cooperative Extension Service, Publication Number EBAE 129-88, March, 1996. (Page 2- "An orderly system for manure collection and storage or treatment reduces potential pockets of odor production. All manured surfaces on which animals are maintained should be as clean and dry as possible. Dirty manure-covered animals promote accelerated bacterial growth and odorous gases which are quickly vaporized by animal heat"); see also Controlling Odor and Gaseous Emission Problems from Industrial Swine Facilities: A Handbook for All Interested Parties, Yale Environmental Protection Clinic, 1998, Section 2.2.1 (There are two main sources of odors within these buildings; the actual hogs, and the manure and urine, which is excreted at two to four times the daily rate of a 70-kilogram man. In the tight confines of these buildings, swine become soiled with manure, urine and feed dust, their body heat radiating the odor of the culmination of these substances."). Available at \url{http://www.colorado.edu/economics/morey/8545/student/caloregs/ControllingOdor.pdf}
The North Carolina Swine Farm Waste Management Odor Control Checklist indicates that wet manure-covered floors are a cause of odor from floor surfaces in swine houses. They indicate that scraping of manure buildup from floors is a best management practice to help control odor production in swine houses.

Below the slatted floors are shallow holding pits. the attached still images from a news video of a site tour of what is represented in the video to be a hog confinement facility in North Carolina. At about three minutes in, the reporter lifts up the slat floorboard and videos into the waste holding pit. Manure makes its way under the floor by spilling through or being pushed or trampled through slits cut into the floor, after which it sits generating gases and odors until it is transported from the swine houses to the lagoon, much like odors can be generated when a porta-potty is left without servicing and accumulating waste. A review of the literature describes that odor may be a product not just of decomposing waste over time, but also, waste as soon as it is produced. Flushing is accomplished using wastewater that is recycled from the poorly functioning anaerobic lagoons. Waste can gather at edges and corners that are not reached or cleaned by flushing/draining. In facilities with partially slatted floors, approximately 2/3 of the floor space of the pens has no slats. Yet the hogs are so densely packed that they cannot/do not move through the rest of the hogs to defecate over the slats. As a result, hogs necessarily and frequently excrete over a cement floor without slats and the waste accumulates over the hours. When the hogs then lay down, they lay down in the feces as there is nowhere else to lay. Most surfaces are covered with excrement including the walls. The hog sheds thus have features conducive to producing air emissions and fumes, as well as breeding flies and insects.

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37 The video is available at https://www.youtube.com/watch?v=HnNVB61soAU.
38 The North Carolina Swine Farm Waste Management Odor Control Checklist recognizes urine and microbial decomposition of manure that occurs in manure collection pits to be a source of odor from swine houses; see also Argo, J., Westerman, P.W. and Heber, A.J., 2003. A review of ammonia emissions from confined swine feeding operations. Transactions of the ASAE, 46(3):805-817 - at 808 (“Ammonia emitted from buildings originates from decomposition of nitrogen in feces, urine, and wasted feed on the floor. In addition, NH3 originates from under-floor manure storage in slatted floor systems ...Some manure remains on the floor, slats, and walls of the pens, and ammonia losses from these sources can be significant.”); see also Controlling Odor and Gaseous Emission Problems from Industrial Swine Facilities: A Handbook for All Interested Parties, Yale Environmental Protection Clinic, 1998, Section 2.2.1 (“In most large-scale facilities, the manure and urine that do not collect on the swine pass through slatted floors into a holding area beneath the building, where they remain until the next removal date. These holding areas often generate a large portion of the odors associated with housing facilities, especially when ventilation devices are utilized, pumping the odorous by-products of decomposition outdoors ...”). Available at http://www.colorado.edu/economics/morey/8545/student/caforegs/ControllingOdor.pdf
41 See The Pig Site, web page on flies (“Waste feed that accumulates in and around pens, particularly where there is moisture, provides an ideal environment for flies to lay eggs. Crust on top of slurry becomes a major breeding grounds especially if slurry tanks are not completely emptied. Cracks and crevices in walls are an attractive area for flies to breed in, as are solid manure heaps.”). http://www.thepigsite.com/pighealth/article/433/flies/.

Ventilation air from swine confinement buildings, as described above, are known sources of odors and other pollutants that can affect public health and the quality of life of neighbors of swine CAFOs. See Schiffman et al., “The effect of environmental odors emanating from commercial swine operations on the mood of nearby residents,” Brain Res Bull. 37(4):369-75 (1995) - (“The sources of the odors from swine operations include ventilation air released from swine buildings, waste storage and handling systems including lagoons, and land application of manure to fertilize fields.”, emphasis added); See also Wing et al., “Intensive livestock operations, health, and quality of life among eastern North Carolina residents,” Environmental Health Perspectives, 108: 233-38 (2000) (“Persons who live near large hog operations have reported reduced quality of life as well as health problems related to airborne emissions from animal confinement houses, open waste lagoons, and spray fields.”); Rule et al., “Assessment of an Aerosol Treatment to Improve Air Quality in a Swine Concentrated Animal Feeding Operation (CAFO),” Environ. Sci. Technol. 39 (24), pp 9649-55 (2005) (“Poor air quality within swine concentrated animal feeding operations (CAFOs) poses a threat to workers, the surrounding community, and farm production ... Many of the public health concerns stem from elevated concentrations of respiratory hazards found in swine CAFOs because of their high animal density and enclosed characteristics. These respiratory hazards include chemical and biological (immunogenic and infectious) aerosols (i.e., bioaerosols). Among the biological components of these aerosols are molds, bacteria, feed, bedding particles, animal hair, and dried manure. These organic aerosols, combined with inflammatory agents including ammonia and endotoxins, have been associated with the development of respiratory illness among swine workers, the community surrounding the CAFO, and the pigs themselves.”).
In a study of odor remediation technologies at swine farms in North Carolina, the highest concentration of VOCs measured in the study using a similar PID instrument at 10.6eV was 191 ppm in fans ventilating swine confinement buildings.47

47 see Schiffman, S.S., Graham, B.G. and Williams, C.M., 2008. Dispersion modeling to compare alternative technologies for odor remediation at swine facilities. Journal of the Air & Waste Management Association, 58(9), pp.1166-1176. (pg 1173 – “The highest level of VOCs measured by the ppbRAE were at the house fans (191,000 parts per billion [ppb]),...”)

48 see Bottcher, R.W., 2001. An environmental nuisance: odor concentrated and transported by dust. Chemical senses, 26(3), pp.327-331. (pages 327-328 – “Although quantifying oors and air pollutant concentrations are important in judging air quality, the emission rate of pollutants is also significant in determining potential impacts downwind. The emission rate of an air pollutant from a building is the product of the air pollutant concentration in the exhaust air multiplied by the airflow rate.”

49 For comparison, see Schiffman, S.S., Graham, B.G. and Williams, C.M., 2008. Dispersion modeling to compare alternative technologies for odor remediation at swine facilities. Journal of the Air & Waste Management Association, 58(9), pp.1166-1176. (pg 1173 – “The highest hydrogen sulfide measurements obtained with the Jerome of VOCs measured by the ppbRAE were at the house fans (191,000 parts per billion [ppb]),...”; “the highest particulate values for PM10 obtained with the EPAM were at a house edge (3.16 mg/m³)...”)
The DNA marker we chose is pig2bac because it is a highly specific and sensitive DNA marker for pig feces, owing that it detects DNA from a bacterium that is only known to grow in a pig intestine. This DNA marker has been successfully applied in the past for tracking sources of fecal pollution to swine CAFOs in North Carolina.  

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50 Heaney, et al., Source tracking swine fecal waste in surface water proximal to swine concentrated animal feeding operations, Science and the Total Environment, 2015 Apr 1; 511: 676-683 available at http://www.ncbi.nlm.nih.gov/pmc/articles/PMC4514616/ ("Microbial source tracking (MST) methods are designed to improve the identification of sources of fecal contamination.").
Rogers, et al., Decay of Bacterial Pathogens, Fecal Indicators, and Real-Time Quantitative PCR Genetic Markers in Manure-Amended Soils, Applied and Environmental Microbiology, July 2011, p. 4839-4848 ("Cultivation-based methods for fecal indicator bacteria (FIB) such as Escherichia coli and Enterococcus spp. have long been used to indicate potential public health risks associated with water impacted by human and other animal feces. FIB cultivation methods are simple to perform and inexpensive."). Available at http://pubmedcentralcanada.ca/pmcc/articles/PMC3147375/pdf/zam4839.pdf.
A. One method to reduce odor generation is to simply reduce the number of hogs, thus reducing the volume of wastes produced. Simple housekeeping measures can reduce potential for odor generation in swine confinement buildings. Better initial siting decisions with larger buffers between swine confinement buildings and neighbors could also have reduced odor complaints.

53 See Barker, James C., 1996, Swine Production Facility Manure Management: Underfloor Flush – Lagoon Treatment, North Carolina Cooperative Extension Service, Publication Number EBAE 129-88, March, 1996. (Page 3 – “Exhaust fans and shutters should regularly be cleaned of dust. Building sidewall screens should periodically be cleaned of debris such as dust, spider webs and vines to allow maximum warm season cross ventilation. All components of the total production and waste treatment system should be operated and maintained in good functional order. Accumulations of solids and wastewater should be removed from these systems expeditiously. Proper disposal of dead animals and good fly and rodent control programs are essential.”); see also Rahman, S. and Borhan, M.S., 2012. Typical odor mitigation technologies for swine production facilities-a review. Journal of Civil & Environmental Engineering, 2(4). (Page 4 – “The most promising and widely used practical system until now is the frequent scraping of manure, which can reduce NH3 emissions by approximately 50%. However, in the real world, producers don’t remove manure that frequently, which facilitates odor causing bacteria to work on manure and generate odor.”)

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B. Several reviews of odor control technologies for swine CAFOs, including technologies for swine confinement buildings, have been produced.\textsuperscript{57} Summaries of several technologies have been published on state extension websites such as the Iowa State University Extension and Outreach Air Management Practices Assessment Tool.\textsuperscript{58} This assessment tool summarizes information on mitigation practices by air pollutant alongside relative cost information for their implementation at livestock production facilities. Simple engineered mitigation measures include proprietary additives or oils applied as a mist to reduce dust or breakdown waste and lower odor; physical barriers, chimneys, and landscaping controls to break odors up near the houses. These technologies have been applied to varying degrees of success, but generally their performance is low relative to alternative technologies for odor control. Some of these technologies such as engineered physical barriers and chimneys require the use of tunnel ventilation systems for their implementation, and their effectiveness for odor reduction is primarily realized near the confinement buildings, diminishing with distance downwind from the confinement buildings.

C. Engineered technologies for swine manure handling and air pollution control technologies can be used to significantly reduce odors from swine confinement buildings.\textsuperscript{59} Separation of urine and feces for separate treatment has been shown to reduce odors generated in swine confinement buildings.\textsuperscript{60} Belt systems can facilitate manure separation, but lead to the production of two waste streams for handling. One innovative way to recover value from the solid waste stream is to convert the separated manure thermally to a combustible gas stream to produce fuel-grade ethanol.\textsuperscript{61}


\textsuperscript{58} Air Management Practices Assessment Tool, Iowa State University, Extension and Outreach, available online at http://www.agronext.iastate.edu/ampat/homepage.html


\textsuperscript{60} see Rahman, S. and Borhan, M.S., 2012. Typical odor mitigation technologies for swine production facilities-a review. \textit{Journal of Civil & Environmental Engineering}, 2(4)

D. There are several technologies that have been used to remove odor and other manure pollutants successfully from the air in swine confinement buildings. For example, Electrostatic Particle Ionization (EPI® Technology) uses basic concepts of electrostatic precipitation to remove particles from the air by partitioning to nearby grounded surfaces of the barn. The technology was demonstrated in several performance trials in the Murphy Brown Circle 4 Farms to remove approximately 50% of dust particles from confinement building air, and reduce H₂S by 58%, ammonia by 55%, and odors by 19%. The technology resulted in a 12% increase in average daily gain, a 9% increased weight of hogs by day 45 and 26% reduction in mortalities. The technology has also been demonstrated through peer reviewed scientific literature to decrease airborne pathogens in swine production facilities including Influenza A virus (IAV), porcine reproductive and respiratory syndrome virus (PRRSV), porcine epidemic diarrhea virus (PEDV) and Staphylococcus aureus, which could decrease exposure and health risks for hogs and swine workers. Gas scrubbers have also been used to trap pollutants from confinement building air. Acid scrubbers trap alkaline materials such as ammonia in an acid solution that is circulated over a packed bed at low pH. These systems are highly efficient at removing ammonia, and odor reductions can be about 30%. Hydrogen sulfide removal would require a second stage alkaline scrubber owing that it is acidic in water. Bioscrubbers use the action of microorganisms to convert ammonia to nitrogen gas. Water scrubbers are less effective for ammonia removal than acid scrubbers or bioscrubbers, but require less maintenance and less hazardous materials. Scrubbers can be excepted to remove between 70 to 90% of ammonia, 30-60% of odors, 60-90% of particulate matter, and 50-90% of volatile organic compounds from confinement facility air. Biofilters are another technology that have been demonstrated to be particularly effective in the removal of odors (80-95%), H₂S (up to 95%), dust and particulates (80%), VOCs (up to 93%), and ammonia (up to 75%) from swine confinement building forced ventilation exhaust air. However, they cannot be installed on confinement buildings with passive ventilation systems.

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64 See http://www.agronext.iastate.edu/ampat/animalhousing/biofilters/homepage.html
12. Operations at the grower sites emit odor and other harmful pollutants from anaerobic lagoons into the air. Improper / negligent operation of the lagoons exacerbates odor problems.

A. Manure from the Smithfield hogs is being flushed into open-air anaerobic lagoons at each of the nine subject CAFO sites (or was when the facilities were in operation). Lagoons are constructed to receive hog feces, wastewater, feed particles, urine, and other materials that are periodically is drained or flushed from out of the below-floor holding pits in the hog confinement buildings. Lagoons store these materials until they can be land applied or otherwise disposed of. During storage, anaerobic bacteria in well functioning anaerobic lagoons break down and stabilize the organic fraction of materials. When this process is upset due to a number of potential factors such as overloading with wastes, solids accumulation and reduction of treatment volume, pH changes or other upsets, the stabilization process is greatly reduced or eliminated. Anaerobic decomposition in anaerobic lagoons generates significant quantities of methane gas, carbon dioxide, ammonia, nitrous oxide, and other gases in the process that are emitted to the atmosphere at the lagoon surface. Methane is a significant component of this biogas produced (up to 60% or more). It is a powerful greenhouse gas (more than 20 times as potent as CO$_2$) and significant contributor to global warming.\(^{65}\)

B. All anaerobic lagoons regardless of how well they are functioning generate odorous compounds during the process of anaerobic decomposition of swine manure, wastewater, and feed materials from the confinement buildings. Some of these compounds are extremely powerful odorants, and their production is exacerbated when lagoons are improperly managed (causing process upsets), or if they are overloaded. Odors from anaerobic lagoons often increase during winter periods when the lower temperatures slow microbial processes and lead to less stabilization of waste materials. During spring and fall when atmospheric temperatures are changing, lagoons may experience turnover due to variable water temperatures between the lagoon surface and deeper water. This process agitates solids and brings them to the surface where odors can be more readily emitted. It is well recognized within the swine production industry that odor problems from swine CAFOs come from anaerobic lagoons;\(^{66}\) odors from waste storage, including anaerobic lagoons, may account for 20% of all odor complaints.

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\(^{65}\) see The Humane Society of the United States, An HSUS Report: The Impact of Animal Agriculture on Global Warming and Climate Change. Available at [http://www.hsi.org/assets/pdfs/farming_climate_impact.pdf](http://www.hsi.org/assets/pdfs/farming_climate_impact.pdf) (page 7 – “Storing and disposing vast quantities of manure can produce anthropogenic methane and nitrous oxide emissions. According to the Pew Center on Global Climate Change, farm animal manure management currently accounts for 25% of agricultural methane emissions in the United States and 6% of agricultural nitrous oxide emissions. As noted above, methane has 23 times the GWP of carbon dioxide, and its concentrations have increased by approximately 150% since 1750. Globally, farm animals are the most significant source of anthropogenic methane, responsible for 35-40% of methane emissions worldwide.”

in some states.\textsuperscript{67} Swine odors interfere with the quality of life of nearby residents and reduce property values in nearby communities.\textsuperscript{68}

C. Typical anaerobic lagoons used in swine production industry are one-stage, meaning that all waste is put into the lagoon and taken out of the same lagoon for land application. Because material is not evenly loaded and drawn, residence times in one-stage lagoons are variable and subject to application activity. Two stage lagoons are less frequently used. They operate by loading all wastes from the confinement buildings into the first stage lagoon. Effluent from the first stage lagoon, drained near the surface where solids are expected to be low, passes to the second stage for further treatment. This allows for the total volume of the first stage lagoon to remain constant. Because lower waste load enters the second stage lagoon, less anaerobic decomposition and overloading issues occur, and odors generated from the second stage lagoon are typically reduced. Effluent for land application is drawn from the second stage anaerobic lagoon. Of note, use of two stage lagoons does not necessarily imply lower odor generation from the lagoons as a whole. The first stage of the lagoon system may still generate substantial odors. These lagoons may be reduced in volume relative to a one stage anaerobic lagoon treating the same waste load, and thus may be prone to issues with solids accumulation and associated upsets in anaerobic decomposition and odor generation. In a properly functioning two-stage lagoon system where solids are well managed, the residence time of waste materials for treatment in the first stage is stable and equal to the volume of the lagoon divided by the loading rate of wastes from the confinement buildings. However, with significant solids accumulation, the effective volume of the lagoon becomes reduced, and thus the residence time for treatment also reduced. This condition can lead to substantial odor generation. Table 3 summarizes the characteristics of the anaerobic lagoon systems at each of the subject swine CAFOs.

Table 3. Lagoon characteristics at each of the subject swine CAFOs

<table>
<thead>
<tr>
<th>Facility</th>
<th>Number of Lagoons</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Greenwood 1 Facility</td>
<td>1</td>
<td>One stage</td>
</tr>
<tr>
<td>Greenwood 2 Facility</td>
<td>1</td>
<td>One stage</td>
</tr>
<tr>
<td>Kinlaw Facility</td>
<td>3</td>
<td>One stage</td>
</tr>
<tr>
<td>Sholar Facility</td>
<td>1 primary, 1 secondary</td>
<td>Two-stage</td>
</tr>
<tr>
<td>Joey Carter Facility</td>
<td>2</td>
<td>One stage</td>
</tr>
<tr>
<td>Crooked Run Facility</td>
<td>1</td>
<td>One stage</td>
</tr>
<tr>
<td>Willow Creek Sow Facility</td>
<td>1</td>
<td>One stage</td>
</tr>
<tr>
<td>Paul Stanley #7 Facility</td>
<td>2</td>
<td>One stage</td>
</tr>
</tbody>
</table>

\textsuperscript{67} See Department of Environmental Quality, State of Virginia. 2001. An Evaluation of Alternative Approaches to Reduce Odors from Intensive Swine Operations - Interim Report --Item #428, 1999 Appropriations Act (“A study showed that approximately 50\% of all odor complaints were as a results of land application of waste, with the remaining complaints split 20\% to waste storage and 30\% to the production buildings.”) available at http://www.deq.virginia.gov/portals/0/deq/lawsandregulations/generalassemblyreports/swineodor.pdf

D. Improper / negligent operation of the anaerobic lagoons and overloading can exacerbate odor problems. With time, anaerobic lagoons accumulate solids and sludge at the bottom of the lagoon. If care is not taken to assure that solids that accumulate in the lagoons are removed frequently, for example through agitation prior to pumping for land application or by frequent dredging, the lagoons will fill with sludge and poorly degradable solids. Their accumulation reduces the effective volume of the lagoon available for treatment by microbial processes. The function of the lagoon becomes impaired, waste materials are not effectively stabilized prior to land application (which can cause further odor issues on land application), and excessive odors are emitted from the lagoon. Further, when these solids and sludge become so great that they fill the lagoon, they can emerge from the lagoon surface and emit excessive odors directly to the atmosphere. Similarly, if the lagoon is excessively pumped out, too little liquid may remain for effective biological treatment and stabilization of manure wastes, and again lead to excessive odor generation. Many swine CAFOs, discharge their liquid wastes from swine confinement buildings into the lagoon via pipes located above the lagoon surface. As this waste material falls through the air and splashes into the lagoon, it releases odors into the air and can create mists with associated pollutants such as bioaerosols that can be transported downwind.

E.

1. [Redacted]
The sludge is composed of settled manure solids, nonorganic constituents of manure, active and dead microbial cells, and other materials (such as debris and sand) that entered the manure collection system and settled to the bottom. Sludge is black, moderately viscous, typically about 10 percent solids and 90 percent liquid, and high in nutrients, bacteria, and organic matter. Biological anaerobic degradation activity occurs in the sludge, as can be evidenced by the biogas that periodically floats sludge to the liquid surface.

Midwest Plan Service, 2004, "Manure Characteristics," Manure Management Systems Series, MWPS-18 Section 1, second edition, Iowa State University, Ames, IA, at p. 5 ("Agitation of manure is one of the most critical operations to perform before taking a manure sample. Nitrogen and potassium can be adequately sampled from pits by obtaining a vertical profile sample without agitation, but phosphorus requires agitation. Agitation homogenizes the manure mixture and provides a more consistent nutrient analysis as the manure is being removed.").

See Westerman, Sludge Survey Methods article.
North Carolina has only 16 inspectors to visit more than 2000 swine CAFOs with more than 9 million hogs in the state at least once per year. There is simply not enough time for thorough inspections to occur.
Note that in 1996, the recommendation from the state of North Carolina was to allow for 2 cubic feet of lagoon volume for each steady state live weight of animal in the facility. See Barker, James C., 1996, Swine Production Facility Manure Management: Underfloor Flush – Lagoon Treatment, North Carolina Cooperative Extension Service, Publication Number EBAE 129-88, March, 1996. (Page 4 – “North Carolina recommendations currently are 2 cubic feet of liquid volume per pound of live animal weight for a single anaerobic lagoon... A two-stage lagoon would have 1.5 cubic feet of volume per pound live weight in the first stage and..."
another 0.5 cubic feet in the second stage.") However, the minimum allowable permanent liquid treatment volume of 1 cubic foot per SSLW was used. See North Carolina State University, A&T University Cooperative Extension, Sludge Management & Closure Procedures for Anaerobic Lagoons, available at https://www.bae.ncsu.edu/extension/ext-publications/waste/animal/ag-604-sludge-mgmt.pdf (Page 3 – “The permanent liquid treatment volume in most lagoons should provide at least 1 cubic foot of liquid for every pound of steady state live weight of animals on the farm.”) (Emphasis added). Further, the designer of these lagoons made the decision to not account for storage volume for sludge accumulation (assumed zero in the designs).


88 Schiffman, S.S., Graham, B.G. and Williams, C.M., 2008. Dispersion modeling to compare alternative technologies for odor remediation at swine facilities. Journal of the Air & Waste Management Association, 58(9), pp.1166-1176. (page 1174 – range of D/T for anaerobic swine waste lagoons tested in this study were 2 – 350 D/T)
B. Samples of waste, wastewater, sludge and solids from lagoons are readily taken if someone wants to measure various parameters of a lagoon.\textsuperscript{89} Indeed, nutrient management planning requires samples of the lagoon be taken regularly. Thus it would not be hard to determine if a lagoon has too much sludge or other problems if someone wanted to check.

\textsuperscript{89} Campagnolo et al., “Antimicrobial residues in animal waste and water resources proximal to large-scale swine and poultry feeding operations,” Sci Total Environ. 299(1-3):89-95 (Nov. 2002) (noting how “A total of 23 samples were collected from or near participating swine farms, including manure waste lagoon samples (seven) and water samples (16) from or immediately proximal to the farm”). Available at https://www.academia.edu/13481299/Antimicrobial_residues_in_animal_waste_and_water_resources_proximal_to_large-scale_swine_and_poultry_feeding_operations.
C. Better siting decisions with larger buffers between anaerobic swine waste lagoons and neighbors could also have reduced odor complaints.\textsuperscript{91} For example, it has long been known that good practice is to site anaerobic swine waste lagoons at least 1000 feet from the nearest residence, yet the Smithfield-owned Sholar facility itself operates with their solids-overloaded stage 1 lagoon less than half that distance to the Mary Tatum residence (see Figure 6.). I visited her home only a few weeks prior on November 22 and was met at the road in front of her house with exceptionally malodorous air. There are other examples of poor siting and site controls such as lack of wind breaks around the lagoons that I observed personally and are evident from satellite imagery and aerial photography of the subject CAFO sites.

\textsuperscript{91} see Miller, Dale, 10 steps to manage odor, National Hog Farmer, Available online at http://www.nationalhogfarmer.com/mag/10_steps_manage_odor; see also See Liu, Z., Powers, W. and Mukhtar, S., 2014. A Review of Practices and Technologies for Odor Control in Swine Production Facilities. \textit{Applied Engineering in Agriculture}, 30(3), pp.477-492 (page 479 – “Setback distances adopted by Ontario, Iowa, and Illinois for livestock facilities depend roughly on animal type, land use, and total animal body weight and range from 0.23 to 2.4 km…”); see also Barker, James C., 1996, Swine Production Facility Manure Management: Underfloor Flush – Lagoon Treatment, North Carolina Cooperative Extension Service, Publication Number EBAE 129-88, March, 1996. (Page 5 – “It is suggested that a lagoon be located at least 1000 feet from any residence or inhabited dwelling not owned by the producer.”)
Figure 6. Satellite Imagery from Google Earth showing that the Smithfield-owned Sholar CAFO anaerobic swine waste lagoon is sited approximately 450-ft from the residence of Mary Tatum.

D. Engineered control technologies can be used with anaerobic lagoons to help reduce odor and emissions of other harmful pollutants. Table 6 summarizes different technologies and their performance characteristics for ammonia (NH$_3$), hydrogen sulfide (H$_2$S), volatile organic compounds (VOCs), greenhouse gases (GHGs), odors and pathogens. For example, aeration of a lagoon can significantly reduce odors. An alternative is surface aeration of an anaerobic lagoon with the objective to reduce odors where proper loading cannot be achieved. This reduces the energy requirements of aeration, and can achieve 50-90% odor reduction.  

Permeable covers of varying types have been used successfully to reduce odors from lagoons between 40-90%. In 2005, permeable fabric covers were reported to yield 52% odor reduction on anaerobic lagoons in Missouri as installed by Smithfield / Premium Standard Farms, who praised them as “the most effective

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feasible option for odor control” for lagoons.\textsuperscript{93} Floating permeable geotextile covers are inexpensive, and last from 3-5 years.\textsuperscript{94} There is absolutely no reason from a scientific or technical standpoint why these covers could not be implemented in North Carolina as well, aside from lack of will. Notably, microbial additives perform relatively poorly for odor reduction, stabilization, and emissions control compared to other technologies.\textsuperscript{95}

E. Considerable progress has been made in manure treatment technology development in the last 20 years. Several environmentally superior technologies for manure treatment have long been available, and are working on swine farms to significantly reduce odors, gaseous emissions, and other pollutants. For example, anaerobic digestion is a rapidly growing technology for farm waste management in the United States. The process of anaerobic digestion produces biogas, which is a mixture of methane, carbon dioxide, and trace gases. In this case, the methane, a powerful greenhouse gas with high emissions from anaerobic lagoons, is captured rather than emitted to the atmosphere, thus reducing emissions that contribute to global warming. Because of its high methane content (usually 60-80%), biogas can be burned directly for heating purposes or can be used directly in a cogeneration system to produce both heat and electricity. The biogas can also be upgraded by removing carbon dioxide and trace gases for other uses where higher grade methane is required. Anaerobic digesters can be designed so that they can accept other waste materials such as food wastes or other agricultural wastes; such co-digestion can greatly increase biogas production rates in in manure digesters and has been used successfully. Although most agricultural waste biogas digesters in the U.S. are at dairy farms, there are several examples of successful hog waste

\textsuperscript{93} see Odor Control Plan, Revised and Updated, Premium Standard Farms, Inc. dated February 18, 2005 ("In section 6.2 of the original Plan, the Companies identified permeable fabric covers as the most effective feasible option for odor control. Now, more than ever, the Companies continue to believe permeable covers and the most effective options for lagoons.")
\textsuperscript{95} See memo dated February 1, 2010 to Mitchell Norris and Interested Parties from Kraig Westerbeek, Assistant VP, EHS Compliance (Case 5:15-cv-00013BR Document 130-4 Filed 06/23/16), Mr. Westerbeek reports that "Over the past five years, Murphy Brown LLC has focused research funds on the use of microbial supplementation to control lagoon odor and building odor, as well as to improve lagoon activity and reduce sludge levels"
biogas plants as well. For example, one swine waste anaerobic digester system installed at the "Barham Farm" and operated by Full Circle Recycle is simply an anaerobic swine waste lagoon with an impermeable cover and gas recovery system. In this system, biogas recovered from their ambient temperature anaerobic digester heats greenhouses in which they produce vegetables. Anaerobic digestion virtually eliminates all odors from manure treatment and produces a sanitary product that can be more safely used for fertilization. Another process called Terra Blue (formerly Super Soils) combines solids separation and advanced wastewater treatment including nitrification and denitrification, and soluble phosphorus removal to produce a high quality and sanitary waste effluent. When operated with a pH of 10, this technology also meets pathogen reduction requirements of the State of North Carolina’s Swine Waste Management System Performance Standards in 15A NCAC 02T.2010. Of concern is the fact the Smithfield has not informed its growers of the available alternatives for dealing with Smithfield’s hogs’ waste. Nor is Smithfield implementing these alternatives or compensating growers enough to implement alternatives themselves.

F. For more examples and details on alternative technologies such as biogas and covered lagoons, see attached exhibit, “Alternative technologies summary.”

97 see Odor Control Plan, Revised and Updated, Premium Standard Farms, Inc. dated February 18, 2005 ("Certain technologies identified as ‘next generation’ do not utilize anaerobic treatment lagoons. Therefore, some lagoons may be taken out of service. This is already happening at the Valley View farm where construction of the Crystal Peak fertilizer plant will result in the manure being treated in covered, in-ground anaerobic digesters rather than in anaerobic lagoons.")

98 see Full Circle Recycle website at http://fullcirclerecyclenc.com/

99 C.M. (Mike) Williams, Evaluation of Generation 3 Treatment Technology for Swine waste, August 19, 2013, Animal and Poultry Waste Management Center, Raleigh, NC.

100 My understanding is that other experts including Dr. Taylor and Dr. Aneja may comment on economic costs and benefits of advanced treatment options. While it is not entirely in my own area of expertise, I have also appended some background information on treatment alternatives in an exhibit.
Table 6. Example engineered controls for anaerobic manure lagoons and environmentally superior technologies available for swine manure treatment that can significantly reduce odors and other harmful pollutants in manure relative to anaerobic manure lagoons at the subject CAFO facilities.\(^{101}\)

<table>
<thead>
<tr>
<th>Technology</th>
<th>NH(_3)</th>
<th>H(_2)S</th>
<th>VOCs</th>
<th>GHGs</th>
<th>Odors</th>
<th>Pathogens</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Engineered controls</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Surface Aeration</td>
<td>Medium</td>
<td>Medium</td>
<td>Medium</td>
<td>High</td>
<td>50-90%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>-20-70%</td>
<td>-10-70%</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Landscaping / vegetative barriers</td>
<td>Medium</td>
<td>---</td>
<td>---</td>
<td>Low</td>
<td>Low</td>
<td>6-15%</td>
</tr>
<tr>
<td></td>
<td>&lt;50%</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Permeable covers</td>
<td>Medium</td>
<td>High</td>
<td>Medium</td>
<td>Medium</td>
<td>Medium</td>
<td>40-90%</td>
</tr>
<tr>
<td></td>
<td>30-90%</td>
<td>40-95%</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Microbial additives</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
<td>0-20%</td>
</tr>
<tr>
<td></td>
<td>0-60%</td>
<td>0-80%</td>
<td>10-40%</td>
<td>0-10%</td>
<td>0-20%</td>
<td></td>
</tr>
<tr>
<td><strong>Environmentally Superior Technology</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Impermeable covers / ambient temperature</td>
<td>High</td>
<td>High</td>
<td>High</td>
<td>High</td>
<td>High</td>
<td>85-99%</td>
</tr>
<tr>
<td>anaerobic digestion (e.g., AgriClean)</td>
<td>85-99%</td>
<td>85-99%</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mesophilic anaerobic digestion (e.g., ORBIT High Solids Anaerobic Digester)</td>
<td>Low</td>
<td>Low</td>
<td>High</td>
<td>High</td>
<td>High</td>
<td>50-85%</td>
</tr>
<tr>
<td></td>
<td>0-30%</td>
<td>0-10%</td>
<td>60%</td>
<td>70%</td>
<td>50-85%</td>
<td>99%-99.9%</td>
</tr>
<tr>
<td>Thermophilic anaerobic digestion (e.g., ORBIT High Solids Anaerobic Digester)</td>
<td>Low</td>
<td>Low</td>
<td>High</td>
<td>High</td>
<td>High</td>
<td>99%-99.99%</td>
</tr>
<tr>
<td></td>
<td>0-30%</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Urine / feces separation and thermal conversion</td>
<td>Medium</td>
<td>High</td>
<td>High</td>
<td>High</td>
<td>70-80%</td>
<td>60-80%</td>
</tr>
<tr>
<td></td>
<td>40-80%</td>
<td>80-90%</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Terra Blue (formerly Super Soils)</td>
<td>High</td>
<td>High</td>
<td>High</td>
<td>High</td>
<td>High</td>
<td>99.98%</td>
</tr>
<tr>
<td>Solids separation, nitrogen, &amp; phosphorus removal</td>
<td>99%</td>
<td>100%</td>
<td></td>
<td>100%</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

14. **Operations at the grower sites emit odor and other harmful pollutants into the air during application of anaerobic manure lagoon effluents to land. Negligent and improper land application practices leads to greater odor and other harmful pollutant emissions into the air and into the environment.**

A. Liquids drawn from the anaerobic lagoons are applied or have been applied to land at each of the subject CAFO sites. Land application of manures is permitted in North Carolina so long as it is done in accordance with a certified animal waste management plan (CAWMP). The purpose of the CAWMP is to assure that manure is applied at a rate to meet, but not exceed, the nutrient requirements of the crop to receive the manure as a nutrient source. In general, CAWMPs consider application history and nutrients contents of the soil, nutrient content of manure, infiltration rates and application equipment used (effect on nutrient delivery to the plants), and land area over which the crop(s) will be grown. Table 7 summarizes the land application practices used by each of the subject CAFO facilities. Details of the CAWMPs for each of the subject CAFO sites were reviewed.
B. It is well recognized in the industry that odor problems from swine CAFOs come from land application of anaerobic manure lagoon effluents and solids. Land application of these materials has been reported to account for 50% of all odor complaints in some states. When anaerobic manure lagoon effluents and solids are land-applied, odors, particulates, endotoxins, bacteria, and other harmful pollutants are released into the environment and into the air where they can drift. The aerial photo in Figure 7 was captured in a flyover of Greenwood 2. Jimmy Jacobs, a neighbor of this facility, reports repeatedly being sprayed with mists that drift into his yard during spraying at Greenwood 2. It is unreasonable to believe a recurrent condition like this, where extremely malodorous anaerobic

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104 See Department of Environmental Quality, State of Virginia. 2001. An Evaluation of Alternative Approaches to Reduce Odors from Intensive Swine Operations - Interim Report -- Item #428, 1999 Appropriations Act (“A study showed that approximately 50% of all odor complaints were as a results of land application of waste, with the remaining complaints split 20% to waste storage and 30% to the production buildings.”) available at [http://www.deq.virginia.gov/portals/0/deq/lawsandregulations/generalassemblyreports/swineodor.pdf](http://www.deq.virginia.gov/portals/0/deq/lawsandregulations/generalassemblyreports/swineodor.pdf).

105 See Testimony of Jimmy Jacobs, Pg. 252 and 263:

p.252
1· ·lawsuit that the spraying blows on to you?
2· · · · A· · They spray it right in the field, right
3· ·across the ditch.
4· · · · Q· · But are you claiming that the spray like
5· ·physically lands on you?
6· · · · A· · Yeah, yeah.· That wind will blow that
7· ·little fine foggy mix from that goon, it'll blow it
8· ·right over there on you.

p.263
9· · · Q· · But just so I can understand what your
10· ·claim is, I mean, is this something that's happened
11· ·to you a dozen times or more?
12· · · · A· · Yeah.
13· · · · Q· · So you personally --
14· · · · A· · Yeah.
15· · · · Q· · have been sprayed with mist from the
16· ·sprayers on Greenwood 2 over a dozen times?
17· · · · A· · Yeah.· Yeah.
18· · · · Q· · On your body, the mist is sprayed onto
19· ·your body?
20· · · · A· · Yes, that mist -- that mist is coming
21· ·through the air, yeah.
22· · · · Q· · And you can feel it?
23· · · · A· · I can feel it.· When they be spraying it
hog manure lagoon effluent is set adrift next to neighbor homes to land on people and their property, would not substantially interfere in an unreasonable manner with the neighbors enjoyment of their property, their health and wellbeing, and their dignity. This practice is unreasonable and inexcusable.

**Figure 7.** Aerial photo of manure application adjacent to neighbor properties at the Greenwood 2 facility. Note the height of the arc on the irrigation equipment spraying anaerobic hog manure lagoon effluent through the air, aerosolizing and setting adrift gases, particles, endotoxins, and fecal material adjacent to neighbor properties.

C. Improper land application practices lead to excessive odor emissions and release of other harmful pollutants during and following land application. Exposure of people in nearby communities to CAFO manures and pollutants can cause a nuisance and harm the health and wellbeing of neighbors. I have reviewed evidence that clearly demonstrates poor land application practices at the subject CAFO sites that in my best judgment are have led to excessive odor problems for neighbors and also clearly demonstrate improper or negligent application of

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Merchant, J.A., J. Kline, K.J. Donham, D.S.Bundy. C. J. Hodne 6.3 Human Health Effects Available online at [https://www.public-health.uiowa.edu/ehsrc/CAFOstudy/CAFO 6-3.pdf](https://www.public-health.uiowa.edu/ehsrc/CAFOstudy/CAFO_6-3.pdf);
waste materials. I have viewed aerial and satellite imagery, testimony, waste application records, and other records that demonstrate improper operation / negligent management through poor land application practices. It is worthwhile to note that Smithfield / Murphy Brown tracks these notices of violations of their growers, effectively overseeing their waste management. These improper or
negligent operations and practices substantially interfere with the enjoyable use of neighbor property and wellbeing of residents, and include deficient waste utilization plans, application during times such as the evenings, weekends, and holidays likely to affect neighbors or exacerbate odor problems, application in low wind speeds and when wind is blowing towards neighbor residences, application in the night hours, which traps odors and harmful pollutants closer to the ground, weekend/evening applications likely to disturb enjoyable use of property and spraying too close to neighbor’s properties as to reasonably expect that there will not be odor issues or believe that manure pollutants will not likely drift to neighbor homes. Applying manures with only sparse or nonexistent vegetative barriers between application areas and neighbor properties as can be seen in several satellite photos including in Figure 7 above.

D. Other improper and negligent application practices are apparent in several aerial images that demonstrate spray application into standing water or at a rate that exceeds the infiltration capacity of the soils and application into drainage

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111 For example – see video titled IMG_3459.mp4-2.mov of manure spreading at the boundary of a neighbor property, approximately 30 feet from their back door. Also see video of spraying in windy conditions at Sholar farm and spray records showing spraying on weekends.
structures, which increases the chances of runoff. Application onto saturated land can increase odor emissions from the field and chances of manure runoff. An example is shown in Figure 8.

Figure 8. Examples of improper manure application practices that can cause excess odor as well as threaten environmental and public health. In this image of the Joey Carter facility, application to saturated ground has caused ponding and runoff.

15. **There are land application options to reduce the release of odors and harmful pollutants relative to spray systems**. Failure to use these techniques or to require these techniques when there is every reason to know that the effect is to likely cause nuisance to the neighbors is negligent or improper conduct and willful behavior.

A. Manure application follows manure treatment. Properly managing the anaerobic lagoons as discussed above will reduce odors and harmful pollutants in the materials when land applied. Use of any of the manure treatment alternatives known to reduce odor and harmful pollutants in treated effluent will further reduce odor and harmful pollutant emissions when the material is land applied.

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Use of manure treatment alternatives that preserve nitrogen rather than emit it as ammonia will result in lower manure application rates per land area where nutrient management planning is based on a nitrogen-limited agronomic rate. The lower application rate will correspond to lower odors emissions and less release of harmful pollutants into the environment.

B. Managing land application of manures correctly can reduce odors and emissions of pollutants during application to land at the subject CAFO facilities. Simple practices include:

1. Reduce the number of hogs to reduce the overall waste load that must be applied to land. Grow different crop types that require less manure application per land area. The resulting lower manure mass applied per land area will produce lower odors and reduce emission of harmful pollutants to the environment.

2. Irrigate on days with low humidity and when breezes are blowing away from neighboring residences. Irrigate in the mornings and early in the week when odors are less apt to be offensive.\(^\text{113}\)

3. Do not spray anaerobic lagoon effluents into standing water or into drainage structures that convey runoff to waters of the State of North Carolina. Eliminate ponding while land-applying anaerobic lagoon materials by reducing the application rate or duration such that the infiltration capacity of the soil is not overwhelmed.

4. Do not land apply during periods when the soils are saturated, such as following rainfall. Better manage anaerobic lagoon levels and solids contents so that there is less pressure to apply before rainfall or to spray to simply maintain freeboard.

5. Avoid application of manures during evening or nighttime hours, which may result in trapping of odors and other pollutants lower in the atmosphere where they will be a greater problem for neighbors.\(^\text{114}\)

6. Avoid application of manures near property lines, and especially near neighbor residences.

7. Don't spray on the weekends, evenings, or holidays

C. Direct injection of manure, such as can be accomplished with Aerway spreaders, is one alternative to spray irrigation that can reduce the odor impact of manure application for nearby residents as well as reduce potential for off-site transport of harmful pollutants in manures or anaerobic digester effluents, provided that the manure is applied in a manner that is not improper or negligent like the that shown in the video attached.\(^\text{115}\) Reduction in odors can be up to 90%, but is


\(^{114}\) Schiffman, S.S., Graham, B.G. and Williams, C.M., 2008. Dispersion modeling to compare alternative technologies for odor remediation at swine facilities. *Journal of the Air & Waste Management Association*, 58(9), pp.1166-1176. (page 1174 – range of D/T for anaerobic swine waste lagoons tested in this study were 2 – 350 D/T)

\(^{115}\) IMG_3459.mp4-2.mov of manure spreading at the boundary of a neighbor property, approximately 30 feet from their back door.
generally reported to be 50 to 75% for liquid manure\textsuperscript{116}. Reduction in hydrogen sulfide emissions are estimated to be between 50-75\%, but there may be a slight increase in greenhouse gas emissions (up to 10\%) owing a slight increase in nitrous oxide emissions from decomposition by soil microbes. The technology also results in greater preservation of nutrients (up to 90\% reduction in ammonia volatilization compared to spray application), which reduces the amount of anaerobic lagoon effluent that must be applied to land to meet crop nutrient requirements. Lower mass of anaerobic lagoon effluent applied per land area means less odor per land area. The subject CAFOs may need to reduce numbers of hogs if insufficient cropland is available to account for the improved nitrogen conservation, but this would perpetuate benefits in reduction of odor in swine houses and the anaerobic lagoons described above. When used in conjunction with other practices to reduce odors from swine houses and lagoons described above, odors and releases of harmful pollutants from the subject CAFOs could be greatly diminished. Again, Smithfield has neglected to inform their growers of the available alternatives for dealing with their hogs’ waste, has not implemented such alternatives as standard operating procedures where manure application is likely to affect neighbors with odors and other harmful pollutants, or compensated growers sufficiently to implement better practices that lower nuisance burdens on neighbors.\textsuperscript{117}

\textsuperscript{116} National Hog Farmer, 2007, 10 steps to manage odor; available online at http://www.nationalhogfarmer.com/mag/10_steps_manage_odor

\textsuperscript{117}
16. **Smithfield has benefitted and continues to benefit, at the expense of their neighbors and the environment, from emissions of odor and other harmful pollutants from the anaerobic lagoon and spray systems at the subject CAFOs**

A. Anaerobic lagoons are not a good odor management technology relative to other manure treatment options that are available, as demonstrated above. Also demonstrated above, spray irrigation is not a good odor management technology. It mobilizes pollutants to a greater extent than other application options that are available. What they are good at is releasing a lot of ammonia into the atmosphere.

B. Anaerobic lagoons are a low cost treatment alternative relative to other options on a per pig basis. They have traditionally had lower installation costs, and less requirements and costs for operation and maintenance than more complicated systems that better treat manure pollutants. Their improper and continued use in a degraded condition rather than replacement with appropriate 21st century technology serves as a cost savings as well. Note that the reluctance to modify these existing systems with cost being the justification while Smithfield continues to turn large profits may be an admission in and of itself that they are willing to profit at the expense of neighbors (the residents of North Carolina) that are affected by the pollution externalities of their facilities.

C. Similarly, spray irrigation systems are a low cost land application alternative relative to other options on a per pig basis. Capital and maintenance costs of these systems to effectively spread manure wastes is proportional to the land area over which these materials must be spread to meet requirements of their waste utilization plan, which is based on crop nutrient requirements.

D. Both anaerobic lagoons and spray irrigation systems release high amounts of nitrogen in the form of ammonia, as well as other pollutants, to the atmosphere. In anaerobic lagoons, microbial processes convert organic nitrogen contained in manure to ammonia nitrogen, which then volatilizes to a great

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119 For example, in a memo dated February 1, 2010 to Mitchell Norris and Interested Parties from Kraig Westerbeek, Assistant VP, EHS Compliance (Case 5:15-cv-00013BR Document 130-4 Filed 06/23/16), Mr. Westerbeek reports that annual operating costs of Aerway applicators are “approximately 40% higher (or more) than the use of regular applicators.”

120 See Massey, R.E., J.A. Lory, J. Hoehne, and C. Fulhage, Economies of Scale in Swine Manure Utilization, Available at http://infohouse.p2ric.org/ref/21/20986.htm (“Lagoons require less land for manure spreading than earthen pits or concrete or glass-lined steel tanks because lagoons promote volatilization of nitrogen (N), reducing the nutrients available for land application. Surface application of manure with a traveling gun or tank spreader further reduces land requirements by promoting the loss of N by ammonia volatilization after application. Surface application of lagoon effluent results in the lowest land requirements; injection of slurry from a tank system results in the greatest land requirements.”)
extent into the atmosphere through the open lagoon surfaces. About 75% of nitrogen in the manure is lost during this process.

(2) Spraying lagoon effluent into the air yields small droplets of water with high surface area to volume ratio. The large increase in mass transfer surface area results in a high rate of volatilization of remaining ammonia, as well as volatile organic compounds, hydrogen sulfide, and other gases from the effluent. Approximately 50% of the nitrogen that remains in anaerobic lagoon effluents is plant available following spray application.

E. Growers of Smithfield hogs can not only discharge freely this ammonia and other pollutants, but are allowed to account for ammonia volatilization as a loss of fertilizer nitrogen from their effluents when determining land application rates to meet plant agronomic needs. This allows them to apply 8 times more manure to the same land area than they would otherwise be able to apply if they were to preserve their ammonia nitrogen.

F. Smithfield might claim that manure nitrogen is a valuable fertilizer, and that they are interested in its preservation. However, it should be noted that the value of the additional crops that would be fertilized with this manure nitrogen is outweighed by the value of the additional hogs that can be grown on each of the subject CAFO sites if ammonia volatilization practices are maintained. Also, there is insufficient land on the subject CAFO sites to grow sufficient additional crops to account for the additional nitrogen that would be available lacking volatilization.

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121 Ammonia volatilization in anaerobic swine manure lagoons may reduce nitrogen contents sufficiently such that land application requirements are only 10-12% that of manure stored in pits or tanks. See Massey, R.E., J.A. Lory, J. Hoehne, and C. Fulhage, Economies of Scale in Swine Manure Utilization, Available at http://infohouse.p2ric.org/ref/21/20986.htm ("Six finishing buildings required 74 acres for surface application of lagoon effluent, 113 acres for injection of lagoon effluent, 620 acres of land for injection of pit slurry, and 744 acres for injection of tank slurry.").

122 Approximately 20-30% of the total nitrogen produced by swine remains following nitrogen losses from anaerobic lagoon storage. see Worley, John W. Manure Storage and Treatment Systems, Table 1. Available online at http://aware.uga.edu/wp-content/uploads/2009/08/Manure-Storage-and-Tre195.pdf

123 First year nitrogen availability coefficient for anaerobic lagoon liquid is 0.5 for broadcast or irrigation land application methods and 0.9 for injection methods. see North Carolina Cooperative Extension Service, Soil Facts: Swine Manure as a Fertilizer Source. Available online at https://content.ces.ncsu.edu/swine-manure-as-a-fertilizer-source

124 For example, direct injection of anaerobic swine waste lagoon effluent may increase land application requirements by 150% over that of spray application owing less loss in ammonia volatilization. See Massey, R.E., J.A. Lory, J. Hoehne, and C. Fulhage, Economies of Scale in Swine Manure Utilization, Available at http://infohouse.p2ric.org/ref/21/20986.htm ("Six finishing buildings required 74 acres for surface application of lagoon effluent, 113 acres for injection of lagoon effluent, 620 acres of land for injection of pit slurry, and 744 acres for injection of tank slurry.").

Thus, any additional manure nitrogen retained would result in a requirement of trucking it offsite for disposal on other fields and associated costs.

G. Importantly, the ammonia that volatilizes to the atmosphere during each of these processes is an air pollutant; it can cause lung irritation to exposed individuals, odors, particulates, and deposition of nutrients downwind among other problems. Additionally, the aerodynamically-sized droplets of effluent produced by spray irrigators and their associated pollutants can be carried downwind from spray application areas.

H. With greater manure application rates (8 times greater per land area), greater emissions of other pollutants that do not volatilize can be expected with associated increases in exposure to nearby residents.

I. The subject swine CAFOs are not held responsible for emitting ammonia or other air pollutants. Ammonia emission standards do not apply to swine CAFOs in North Carolina that existed prior to the moratorium on new swine farms using anaerobic lagoon and spray systems (G.S. 143-215-101). The moratorium in and of itself is recognition by the State of North Carolina that anaerobic lagoon and spray systems cause unwarranted and excessive ammonia emissions as well as other pollutant discharges.

J. When Smithfield grows their hogs in these facilities that have been grandfathered around the modern performance standards that new facilities must face, they enjoy many compounding benefits at the expense of the environment (which receives a higher pollution load) and neighbors who are exposed to excess pollution from these activities.

(1) Direct benefits that Smithfield enjoys include:
   a. Reduced cost of manure treatment and lagoon effluent spreading.
      i. Smithfield does not have to cover the cost of controlling ammonia that they would otherwise have to according to G.S. 143-215-101 if they were to raise their hogs in a new CAFO facility.
      ii. Smithfield does not pay for potential environmental or public health externalities associated with ammonia and other emissions from the anaerobic lagoons and the spray irrigators at these facilities so long as they follow their nutrient management plans and avoid accidental releases.

   b. Reduced cost of land application.
      i. Because there is less nitrogen in the lagoon effluent that reaches the fertilized plants, they can spread more effluent over smaller land areas than otherwise possible.
      ii. A smaller land area for application means reduces piping, transportation costs, and energy costs per hog produced.
c. A greater number of hogs can be grown on the same land area than otherwise would be possible.
   i. This is because they can spread greater amounts of lagoon effluents onto smaller land areas than would be possible if they did not emit their ammonia from the lagoons and spray irrigation equipment.
   ii. An important factor in the size of CAFO operations in terms of numbers of hogs is the land area available for application of manure produced. Manure must be applied at no greater than the agronomic requirements of the crops grown on the land based on its nutrients content. Nitrogen is a primary nutrient of concern. If greater manure is produced than can be applied at the agronomic rate to the land onsite, the grower must contract additional land for application.

d. Aggregating a greater number of hogs in smaller land spaces and fewer facilities than otherwise would be possible allows for cost efficiencies of scale. These include things like transportation associated with trucking live hogs, dead hogs, and food to their production sites (more hogs on less sites equals less hauling costs) among other efficiencies. 126

(2) The benefits enjoyed by Smithfield when they choose to grow their hogs in these facilities comes at the expense of neighbors who must live with the increased nuisance, which include, among other things:
   a. Increased truck traffic and associated noise, odors, dust, road deterioration, and road traffic for moving hogs and feed into and out of the facility,
   b. Increased odors and noise from more densely populated hog farms
   c. Increased dead hog handling and associated problems such as odors, insects, and truck traffic
   d. Increased releases of gases, particulates, odors and other pollutants than ammonia generated from anaerobic decomposition of greater amounts of manure present on the site than would otherwise be possible to accommodate, as described above.

(3) The benefits enjoyed by Smithfield when they choose to grow their hogs in these facilities comes at the risk of the environment, which receives manure pollutants at a greater rate than would otherwise be allowed. 127

126 See Massey, R.E., J.A. Lory, J. Hoehne, and C. Fulhage, Economies of Scale in Swine Manure Utilization, Available at http://infohouse.p2ric.org/ref/21/20986.htm ("Concentrating swine finishing facilities at a single site reduces overhead costs such as feed storage, manure storage and infrastructure costs such as roads; "When using lagoon storage for swine finishing facilities, manure fertilizer value never exceeded storage and application costs. Concentrating the facilities on a single site and using sprinkler application of the effluent minimized net manure cost. Scale economies exist.")
127 Although the focus below is on the externalities that are inherent to the system of growing hogs in an anaerobic lagoon and spray system, additional externalities may certainly be realized by deliberate improper application practices as documented above for several of the subject swine facilities. See Keplinger, K.O. and Hauck, L.M., 2006. The economics of manure utilization: model and application. Journal of Agricultural and Resource Economics, pp.414-440. (Page 415 – “When supplies of manure become large, its value falls and an incentive is created to apply manure at rates exceeding crop requirements or to otherwise dispose of manure as inexpensively as possible, despite negative externalities.”)
a. Many manure pollutants are not similarly reduced like ammonia is through emissions before land application. Therefore, increased application rates mean increased loading of these pollutants onto land (e.g., phosphorus, oxygen demanding materials, antibiotics, pathogens, etc.) or into the air (e.g., bioaerosols) and associated risks of environmental damage. There is no agronomic value of manure pollutants such as pathogenic microorganisms, antibiotics, and antibiotic resistant bacteria. New CAFO performance standards of G.S. 143-215-10I located at 15A NCAC 02T .1307 mandate annual average concentrations of fecal coliforms in land-applied effluent should not exceed 7000 MPN / 100 mL.

b. With increased manure mass maintained on site and increased manure mass applied comes increased risks of unintentional environmental damage caused by accidental spills, flooding of manure storage structures or swine houses, flooding of manure-amended fields, runoff of manure during rainfall, greenhouse gas emissions, air pollutant emissions, antibiotic emissions, release of antibiotic resistant bacteria to the environment and other insults. I have seen recent aerial imagery taken during Hurricane Matthew in October of 2016 that devastated the region, flooded manure application areas at the subject sites, and encroached upon their lagoons evidencing the realization of these risks. When manure amended fields are flooded, they release the manure particles and their associated pollutants into waterways of the state, where they can deplete oxygen, kill aquatic life, introduce antimicrobial resistance to the environment, and cause diseases to receptors downstream, among other issues. Lagoon breaches have caused catastrophic environmental damages in North Carolina.

c. 

(4) The exploitation of the overall system of ammonia volatilization to increase manure application rates and reduce land requirements for manure application was by design and continues by choice. If the subject sites were to manage their manure to preserve ammonia, and were no longer able to account for ammonia volatilization from spray irrigation in their manure management plans, they would have insufficient land available to receive the volume of manure produced by the large number of Smithfield hogs on the subject CAFO sites.
Figure 9. Aerial image of Joey Carter property flooded during Hurricane Matthew. Flooding that occurred in Hurricane Matthew threatened several of the lagoons of the subject swine CAFOs and inundated manure application fields.
17. The subject swine facilities (i) are the source of frequent and persistent unreasonable odors at neighbor houses, and (ii) have resulted in direct and repeated exposure to pig feces bioaerosols at neighbor houses. This condition substantially interferes in an unreasonable manner with the health and welfare of the plaintiffs and their families, and the enjoyment of their property.

A. During the course of my investigation, I visited several neighbor homes. This includes homes that I randomly requested that we visit on the day of visitation. At every visit and every home, I experienced offensive and sustained swine manure odors to varying intensity, from moderate to very strong. If the swine manure odors were an infrequent event, the probability of experiencing these odors at each of the homes would be low. A 100 percent occurrence supports the likelihood of problematic odors at these homes.128

B. On the day prior to the one we sampled the Sholar facility, we sampled downwind off the property of the Sholar facility towards the house where Allen Johnson and his son lived and Gwen Pickett’s residence. This ad-hoc measurement came while we were waiting to go onto the Sholar facility, only to learn that they were experiencing a PED outbreak -- we needed to reformulate our sampling plan for the day. Getting out of the vehicle, we had a puff of odor hit us that was very strong. We turned on the Jerome hydrogen sulfide meter and caught another puff, noting a hydrogen sulfide measurement of 124.8ppb. While we were waiting for the defense council to organize to accommodate our negotiated change in sampling plan, we decided to walk around the neighbors’ properties to see if we could record what was happening. Figure 10 shows the results of our measurements while we walked around. A light wind was blowing in the direction of the Pickett residence, and strong odors were hitting us in waves and puffs. You can see in the measurements where the hydrogen sulfide meter was collecting data. We started collecting VOCs data and at about 9:15 and began taking VOCs measurements side by side. We did this until about 9:20, when we separated, but by no more than about 50-100 feet. Note that the readings on the instruments when together were well coordinated, but even a short separation distance resulted in very different conditions. We decided to take a walk along the road that borders the two properties; at that point, we were carrying a GPS system and were measuring VOCs. It was possible for me to log a GPS coordinate when I smelled a strong puff of odor, and then I saw the VOC instrument spike. We got to the end of our walk at 9:25 and turned around, returning to the road in front of the Pickett residence by about 9:28. I then decided to walk a line to the front porch of Gwen Pickett. From about 9:33 until about 9:42, I recorded VOCs from a stationary point on Gwen's porch. As seen in the VOCs data, the odor comes in puffs and gusts, and can peak with quite strong odors. I walked back to the vehicle at 9:42 to leave.

128 Plaintiffs’ homes range from 615 feet to 5190 feet from the hog houses; 458 feet to 5386 feet from the lagoons; and 71 feet to 3731 feet from sprayfields.
C. There are two important concepts about this data to understand. One is that in an outdoor environment with complex air movement and localized conditions, odors are not experienced as one long and even smell. Second, odors can be experienced quite locally, even over short distances of only a few feet or a few yards. Odors can ride on a puff or gust and affect one location while another location nearby may not have coincident experience. Odors can come in waves that are unpredictable. Wafting occurs which makes odors variable and sometimes powerfully surprising. This is related to atmospheric mixing that occurs even on a localized scale. Wind is complex and not as linear as one might expect. It can mix and move around obstacles causing surprising effects. Local microclimates, differences in source air temperatures (for example in a hog confinement buildings or above a lagoon) and air temperature or even variations in atmospheric conditions from stable to unstable or temperature inversions can lead to surprising plume behavior whereby a plume may become trapped and flow long distances from the source (e.g. at night129) or may lift into the air and jump over one house, only to deposit particulates and odors on receptors further downwind from the site (see the looping plume in Figure 11). Thus, to believe that an air plume should be experienced linearly in intensity from the source may not be accurate. Odors can travel several feet to several miles.130

![Graph](image)

**Figure 10.** Measurements taken on December 14 near Gwen Pickett’s residence, downwind the Sholar facility.

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Figure 11—an unstable looping plume looking down from the top and looking from the side. Notice how someone close to the source may not experience much of the smoke, but someone further away may be inundated.

D. Additionally, odors from swine CAFOs sorb to dust or manure particulates, causing the particles to become powerful odorants themselves owing their ability to deposit in the olfactory mucosa. Once they are transported and deposited onto surfaces downwind, they remain a constant source of powerful odor for a long time. Examples to aid in understanding this effect abound. Consider a non-smoker being placed in a hotel room that has allowed smokers in the past. Consider a person who loses a loved one yet holds onto a favored piece of their clothing because it carries their smell. We observed and recorded just such an effect, which is well known among those who live near or work on swine operations. After sampling all day in the swine houses, we brought that same odor back with us on our clothing. We were able to document powerful levels of VOCs coming from our cameraperson and experts, RV, and clothes using a photoionization detector set to 10.6eV, long after we had returned home from sampling. I personally suffered on an airplane after sampling Greenwood 1 in the barns because I smelled like pig manure all the way home to the Adirondack region of New York following sampling. The important lesson is that the wind does not have to be blowing constantly in the direction of your home to have odors constantly present. The particles from the swine CAFO facilities can be an ever-present source of nuisance for the communities near these facilities.

Figure 12. VOCs measurement taken from the clothing of one of our team, far away from facilities and more than an hour after leaving.

E. Anaerobic lagoon and spray systems result in ammonia volatilization. This allows producers to apply more manure to the same area of land than otherwise possible. More manure means greater loading of associated pollutants such as odors, pathogens, antibiotics, antibiotic resistant bacteria, organic matter, etc.

F. There are three primary sources of nuisance odors on swine CAFOs, which are detailed above, and include the swine houses, manure storage and treatment (in the case of all of the subject CAFO sites, anaerobic lagoons), and manure application to land. None of the subject CAFO sites employ the best technologies
H. During the course of my investigations, I collected air samples and physical samples from the exterior of houses of neighbors of the subject CAFO sites for DNA testing. I also trained personnel in the appropriate sterile techniques to collect additional samples for DNA testing. The purpose of this DNA testing was to determine whether there was evidence to demonstrate an undue nuisance at the neighbors' homes as evidenced by exposure to pig feces by either its impaction onto their houses, or presence in the air where it could be breathed in. It is well known that particulates from swine CAFOs are of the most important contributors of odors experienced from these facilities because they absorb and concentrate odorous compounds at the facility and they deposit in the olfactory mucosa when breathed in where their sensory effects are intensified. As described below, the DNA we tested for is present only in a bacterium in pig feces, and a bacterium and DNA are both particulates. Therefore, presence of this DNA reasonably serves as a surrogate for particulate transport and deposition of particulates (and associated odor) from the subject CAFO facilities. It is a direct measure of fecal particles.

(1) The DNA collected was scrutinized for the presence of the genetic sequence known as pig2bac. This DNA signature is unique to pig feces, and was first described by a scientific team in France in 2009. This host-associated genetic marker detects DNA from the 16S rRNA gene of obligate anaerobic bacteria of the phylum Bacteroidetes and order Bacteriodales that inhabit the intestinal microflora of pigs. These bacteria are shed in pig feces, and they are not known to replicate in the environment, largely because of their high specialization to the swine gut environment from which they originate. The DNA marker has been demonstrated to have very high specificity for pig feces, high sensitivity for pig feces, high repeatability and reproducibility in laboratory testing, and excellent cross-laboratory validity.
(2) Pig2bac is an established DNA marker for identifying the presence of pig feces. It has been used in many scientific studies to allocate sources of fecal pollution in environmental samples and in human exposure studies. For example, researchers from Johns Hopkins University and the University of North Carolina at Chapel Hill were able to demonstrate pig2bac as a reliable marker for occupational exposure of industrial hog operation workers to *Staphylococcus aureus* originating in swine feces that were subsequently found in the nasal passages of the workers.

(3) The pig2bac marker is conservative for the presence of pig feces. This means that pig feces have to be in relatively high concentrations to facilitate its detection. In other words, this marker does not establish the aerial extent

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(the leading edge) of the plume of pig fecal material that may be transported off of a site. Rather, it establishes that the plume of pig fecal material extends beyond the position that the marker was detected. Factors that contribute to this fact are provided below.

a. Bacteria of the phylum Bacteroidetes and order Bacteriodales represent approximately 40% of the total bacteria present in pig feces. Bacteriodales that harbor DNA specific to pig2bac marker comprise only about 2.5% of the total Bacteriodales in pig feces. Considering these factors together, only about 1% of the bacteria in pig feces harbor DNA that can be detected by the pig2bac marker. Bacteria in pig feces likely constitutes only half or less of the total solid matter in pig feces based on measurements of bacteria as a fraction of human fecal matter.

b. Although studies regarding the decay of pig2bac in air have not been reported, Pig2bac has been demonstrated to decay faster in water and soils environments than other fecal indicator bacteria and pathogenic microorganisms in pig feces. That means that our ability to detect this marker in the environment diminishes with time faster than other fecal bacteria, potential pathogens, and manure particles.

c. It has been clearly demonstrated that Gram negative and non-spore forming bacteria can survive in aerosols and infect nearby receptors (for example, Salmonella). However, improved survival of bacteria in aerosols is associated with the ability to respire oxygen, the ability to form spores, and the presence of Gram positive cell wall chemistry. Of note, Bacteriodales that harbor the DNA for pig2bac are obligately anaerobic (cannot respire oxygen), Gram negative, non-spore forming bacteria. They are unlikely to survive in air for as long as other bacteria in

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manure aerosols such as antibiotic-resistant *Enterococcus* and *Staphylococcus aureus*.

d. Detection of DNA in an environmental sample requires that a lot of DNA be present. DNA losses during extraction from a sample are commonly 50% or more. These losses are associated with the protocols used to acquire the highest quality DNA possible from a sample. When DNA is recovered from a sample, usually only 5-20% of the recovered DNA is used for each test. This allows for replication of the test (quality control), or for testing for other DNA markers from the same sample (for example, other bacteria of interest). At least one template copy of the DNA of interest must be present in each test for it to be detected. However, 10 template copies of DNA is generally considered the lowest reliable detection threshold that can be achieved without running many tests of the same sample. Most operators will calibrate their instrumentation to detect 10 or more template DNA copies in a test. Considering all factors, it usually requires a bare minimum of about 50 - 200 template copies of DNA containing the pig2bac marker to be present in a sample to be detected.

e. Considering the above, the detection of pig2bac in a sample drawn from a location or the environment in aerosols or following aerosol transport and deposition implies the presence of a much greater mass of fecal material and other fecal bacteria, which may include pathogenic microorganisms. It also strongly implies transport of fecal material further downwind from the areas where it was detected because it can be expected to diminish to undetectable levels faster than other manure particles. In other words, because it is a conservative marker for fecal material, it does not establish the aerial extent of the plume of fecal material that may be transported offsite. Rather, it establishes that the plume extends past that position for some distance that may be better indicated by other markers.

(4) Three procedures were used to test for the presence of swine feces DNA at the homes.

a. DNA swab samples were collected from either 1-inch square or 12-inch square areas of the exterior walls of neighbor homes at least four feet in elevation from the ground surface. Care was taken to limit sampling from surfaces that receive high exposure to sunlight.

b. Air samples were collected onto 49-mm diameter, 0.2 micrometer pore size polycarbonate filters under vacuum at approximately 24 - 30 L / min flowrate. Sampling intervals ranged from about 12 to 24 hours.

c. High volume air samples were collected onto 0.45 micrometer pore size, 25.4 cm x 20.3 cm cellulose acetate filters using Tisch TE 5170V Total Suspended Particulates High Volume Air Samplers at a flowrate of approximately 1000 - 1700 L / min. Sampling intervals ranged from about 12 to 24 hours.
d. For some samples, a Kestrel 5500 pocket weather meter with rotating vane and mount were attached to a camera stand and used to monitor wind speed and direction during air sampling at homes downwind of the subject swine CAFOs. The Kestrel automatically logs time, wind speed, and direction as well as temperature and relative humidity.

(5) Thirty-one samples collected from surfaces of the homes of the clients were submitted for DNA testing. Table 9 presents the results. In total, 14 of 17 homes tested positive, indicating a recent history of impaction of hog feces onto their homes. Further, all six dust samples collected from the air using vacuum filtration devices at the yards of four clients as far as 0.47 miles from the CAFO properties contained tens of thousands to hundreds of thousands of hog feces DNA particles, demonstrating exposure to hog feces bioaerosols for clients who breathe in the air at their homes. Considering the facts, it is far more likely than not that hog feces also gets inside the clients homes where they live and where they eat.

(6) Importantly, odors were experienced at these houses coincident with the measurement of pig feces bioaerosols in the air. Their coincident detection is not surprising since hog odors are known to be associated with particulates from hog CAFOs. Their detection at half a mile is not surprising because we know that hog feces and odors can travel several miles from the swine CAFOs. However, the ability to detect the DNA signature of the hog feces at these distances and in such high concentrations from the hog CAFOs was surprising. In my own experience, this DNA does not persist well in the environment relative to pathogens or other biological particles of concern. Because we detected this DNA in such high concentrations, it is clear that we were still well within the plume of fecal material extending from these facilities. Within sound scientific reason, it is reasonable to say that these conditions are likely experienced by all of the clients fairly evenly, the furthest of which lives only 0.72 miles from one of the subject swine CAFOs, and provided sampling on the right day, we would identify it. Such exposures to swine CAFO pollutants have been linked to negative health consequences.

141 North Carolina Cooperative Extension, North Carolina State University, “Understanding Livestock Odors,” available at https://www.bae.ncsu.edu/extension/ext-publications/air_quality/ag589-livestock-odors.pdf. (pg. 6 - “Depending on specific conditions, odorous gases and dust may travel several miles or several feet.”)


143 See Mirabelli, M.C., S. Wing, S. W. Marshall, T.C. Wilcosky (2006) Asthma Symptoms Among Adolescents Who Attend Public Schools That Are Located Near Confined Swine Feeding Operations. *Pediatrics*, 118(1):e66-e75, and Mirabelli, M.C., S. Wing, S. W. Marshall, and T. C. Wilcosky (2006) Race, Poverty, and Potential Exposure of Middle-School Students to Air Emissions from Confined Swine Feeding Operations. *Environmental Health Perspectives*, 114(4):591-596. These authors report that reported that exposure to airborne pollution from confined swine feeding operations is associated with adolescents’ wheezing symptoms. The prevalence of wheezing during their one-year study in North Carolina was slightly higher at schools that were estimated to be exposed to airborne effluent from confined swine feeding operations. For students who reported allergies, the prevalence of wheezing was 5% higher at schools that were located within 3 miles of an operation relative to those beyond 3 miles.
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I.

and 24% higher at schools in which livestock odor was noticeable indoors twice per month or more relative to those with no odor.
J. The presence of feces on the side of these people’s homes is a physical representation of odor. Because it is on the side of their houses, and because it is in their air, they are breathing it in. Because of the way that air exchanges between the indoor and the outdoor environment, scientifically we can understand that the odor and that the feces is getting inside of their houses. We were not able to search everyone’s homes, but it is my opinion, based on what we did find, that I would find this condition present at all of the plaintiff’s homes.

K. I have been provided what I understand to be the basis for a nuisance claim under North Carolina Law. Considering that, for all of the reasons stated above, it is my opinion, within a reasonable degree of scientific certainty, that each of these Smithfield hog operations have the ability to cause and the effect of causing a substantial interference with the Plaintiffs’ use and enjoyment of their property in the form of significant annoyance and material physical discomfort. (in my own experience on and near these operations, and in my experience inspecting these operations, I myself have witnessed conditions which in my opinion would substantially interfere with the average person’s use and enjoyment of their property). I also believe that to the extent Plaintiffs are concerned or fearful of breathing the foul odors from the hog operations, considering the constituents of the odors and the pollutants present in conjunction with the odors, they have a scientifically justified reason for concern.

L. For all of the reasons stated above, it is my opinion, within a reasonable degree of scientific certainty, that the substantial interference likely suffered by the Plaintiffs is unreasonable. The interference, for the reasons above, is excessive and inappropriate given due consideration to the interests of the Plaintiffs, the Defendant, and the community. None of these operations is a suitable location for the defendant’s operations as they are currently operated. The substantial interference is also unreasonable given the surroundings and conditions under which the defendant’s interference occurs, the character of the locations, the extent nature and frequency of the harm to the plaintiffs’ interest, and the nature, utility and social value of the Plaintiffs’ use and enjoyment that has been invaded.

M. All of my opinions are expressed to a reasonable degree of scientific certainty.

Signed:

[Signature]