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CENTER *for* A LIVABLE FUTURE

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Illinois Department of Agriculture
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Members of the Fulton County Board
C/O: John Young, Clerk
Fulton County Courthouse
100 N. Main Street Room 100
Lewistown, Illinois 61542

Disclaimer: The opinions expressed herein are our own and do not necessarily reflect the views of The Johns Hopkins University.

Re: Memory Lane Acres, LLC and Runway Ridge Farms, LLC swine breeding facilities

Dear state and local officials,

We are researchers at The Johns Hopkins Center for a Livable Future, an academic center based at the Bloomberg School of Public Health in the Department of Environmental Health and Engineering. The Center engages in research, policy analysis, education, and other activities guided by an ecologic perspective that diet, food production, the environment, and public health are interwoven elements of a complex system. We recognize the prominent role that food animal production plays in regard to a wide range of public health concerns within and associated with that system.

Our Center was contacted by an Illinois resident concerning Professional Swine Management's plans for Memory Lane Acres, LLC and Runway Ridge Farms LLC, two proposed 20,000-head swine breeding facilities. We understand that Professional Swine Management has submitted applications for these facilities and that the Illinois Department of Agriculture is preparing to review the permit applications. In response to community concerns and in an effort to serve as a resource, we provide the following summary of public health concerns associated with large-scale swine operations below, along with an annotated bibliography on pages 7-18.

Summary of Public Health Concerns Associated with Swine Operations

Based on evidence from numerous scientific studies of swine operations, the proposed facility may present a range of serious health risks to members of the surrounding community. Our public health concerns regarding the proposed swine breeding facility include the following:

1. The spread of infectious diseases to communities
2. Groundwater and surface water pollution, and associated health impacts on community members
3. Air pollution, odors, and associated health and social impacts on communities

These concerns are detailed below, along with supporting evidence from the peer-reviewed scientific literature. We value the opportunity to comment on this important issue and we appreciate you taking this information into consideration.

1. Industrial swine production has been linked to the spread of pathogens to surrounding communities.

The poor conditions characteristic of industrial livestock operations—such as the proposed swine operation—present frequent opportunities for the transmission of viral and bacterial pathogens (infectious agents that cause disease or illness) among animals, and between animals and humans. [1] Many of these pathogens live in the digestive tracts of animals and are passed in their waste. [2-4]

A growing body of evidence points to the potential pathways by which pathogens (antibiotic-resistant or otherwise) might spread from industrial livestock operations into communities. [5] Studies suggest, for example, that pathogens may be transmitted by workers into their homes and communities, [6-9] conveyed by runoff into ground and surface waters, [4] blown out of barns by ventilation systems, [10-12] and spread to consumers via contaminated meat. [13,14] Pathogens may also be transported by flies, [15] wild birds, [16,17] and animal transport vehicles. [18]

Further evidence for disease transmission risks was documented in a 2013 study of nearly 450,000 Pennsylvania residents, in which living near larger swine operations or cropland where swine manure is spread was significantly associated with elevated rates of infection with methicillin-resistant *Staphylococcus aureus* (MRSA) and non-resistant skin and soft tissue infections. [19] MRSA is an antibiotic-resistant pathogen that can be challenging and expensive to treat. [20] In a similar study in Iowa, persons living closer to swine operations had a greater risk of colonization with MRSA.[21]

Industrial swine operations also present opportunities for the replication, mutation, and recombination of viruses—including novel influenza viruses. [22] Swine, susceptible to both human and avian strains of influenza, can serve as "mixing vessels" in which human, avian (bird), and porcine (pig) strains exchange genetic material in a process called viral reassortment. The resulting novel virus may then be transmissible from swine to humans. [23,24] Increased contact among large populations of swine, particularly if there are birds and humans nearby, offer ample opportunities for this phenomenon to occur. Workers in swine operations face a greater risk of infection and may also increase the risk of influenza virus transmission to their surrounding communities.[25,26]

2. Industrial swine operations can contaminate ground and surface waters, potentially leading to health impacts

Confining large numbers of animals indoors presents the challenge of how to collect, store, and dispose of the massive quantities of manure they generate. When such quantities are applied to nearby fields (the usual method of disposal), the amounts often exceed what surrounding land can absorb. When manure is over-applied, the excess—along with chemical and bacterial contaminants—is transported by runoff into surface waters and may leach into groundwater. [27] A 2015 study traced fecal microbes specific to swine in surface water upstream and downstream of swine operations and found that swine specific microbes were nearly 2.5 times as prevalent in surface water downstream than upstream of swine operations, indicating poor sanitary quality of surface waters near industrial swine operations.[28]

The proposed facility is expected to have an inventory of 8,000 sows and 12,000 piglets. A 440 lb. gestating sow generates an average of 11 lbs of wet manure daily, or roughly four times the mass of excreta generated by a human; a 423 lb. lactating sow generates an average of 25 lbs of wet manure daily, or roughly ten times the excreta generated by a human; and a nursery pig generates an average of 2.4 lbs of wet manure daily, or roughly the same amount as a human. [29] Assuming that the proposed facility has an average inventory of 6,000 gestating sows, 2,000 lactating sows, and 12,000 piglets, the facility would generate 144,800

lbs of wet manure daily, or about 1.6 times the waste generated daily by the human population of Fulton County. The proposed facility would be comparable, in terms of waste generated, to the addition of nearly 58,000 humans to Fulton County, without the benefit of a wastewater treatment plant to treat microbial pathogens and chemical toxins.

Communities living near or downstream from confinement operations may be exposed to a range of waterborne contaminants, including nitrates, bacterial and viral pathogens, heavy metals, and veterinary pharmaceuticals. [30] People may be exposed to these contaminants through the recreational use of contaminated surface water and the ingestion of contaminated drinking water, placing them at greater risk for adverse health outcomes. [30] Chronic exposure to nitrates (naturally occurring in animal waste), for example, has been associated with increased risks for thyroid conditions, [30,31] birth defects and other reproductive problems, [30-33] diabetes, [31] various cancers, [31,34-36] and methemoglobinemia (blue baby syndrome), a potentially fatal condition among infants. [37] This is of particular concern for the approximately 8,359 Fulton County residents (23 percent) who rely on private wells for drinking water and household use [38]; private wells are not monitored by government agencies to ensure safe levels of nutrients and pathogens.

Nutrient runoff (including nitrogen and phosphorus) has also been implicated in the growth of harmful algal blooms, [27,39] which may pose health risks for people who swim or fish in recreational waters, or who consume contaminated fish and shellfish. Exposure to algal toxins has been linked to neurological impairments, liver damage, gastrointestinal illness, severe dermatitis, and other adverse health effects.[40,41]

3. Industrial swine operations release air pollutants and odors, which are associated with health and social impacts

Animal confinement operations have been linked to a range of airborne pollutants, including ammonia, hydrogen sulfide, and other gases emitted from animal waste; and airborne particulates, which may be comprised of dried feces, animal dander, fungal spores, and bacterial toxins.[42]

Much of the research on the health effects associated with exposure to airborne pollutants from confinement operations has focused on workers. At least one in four workers in these operations are estimated to suffer from respiratory illness. [43]

A growing body of evidence suggests residents living near animal confinement operations may also be at greater risk of respiratory illness. One study detected high concentrations of

particulate matter downwind from swine confinement operations, which was linked to wheezing, breathing difficulties, and eye, skin, and nasal irritation among residents of downwind communities.[44] Indicators of air pollution (e.g., odors) from swine confinement operations have also been linked to asthma symptoms among students at nearby schools.[45]

Odors associated with air pollutants from confinement operations have been found to interfere with daily activities, quality of life, social gatherings, and community cohesion.[43,46] In addition to the stigma and social disruption they often generate, odors from swine confinement operations have been associated with physiological and psychological effects, including high blood pressure, depression, anxiety, and sleep disturbances (38–40).[47-49]

We hope our summary of public health concerns is helpful in describing public health harms associated with large-scale swine operations. We strongly recommend that the Illinois Department of Agriculture and Fulton County Board take these concerns into consideration when deciding whether to approve the Memory Lane Acres, LLC and Runway Ridge Farms, LLC proposed operations. We would be happy to serve as a resource to your offices. Please do not hesitate to contact us if you have any questions.

Sincerely,

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References

1. Rostagno MH. Can stress in farm animals increase food safety risk? *Foodborne pathogens and disease*. 2009;6(7):767-776.
Link: http://online.liebertpub.com/doi/pdf/10.1089/fpd.2009.0315

This study reviewed current knowledge to assess the potential impact of stress—such as that from inadequate nutrition, deprivation of water and/or feed, heat, cold, overcrowding, handling and transport—in farm animals on food safety risk. The review focused on stress mechanisms influencing the colonization and shedding of enteric pathogens in food animals due to the potential for their dissemination into the human food chain, a serious public health and economic concern. The review concluded that there is a growing body of evidence that demonstrates the negative impact of stress on food safety through a variety of potential mechanisms, and recommends additional research to optimize animal welfare and minimize production loses and food safety risks.

2. Thurston-Enriquez JA, Gilley JE, Eghball B. Microbial quality of runoff following land application of cattle manure and swine slurry. *Journal of Water and Health*. 2005;3(2):157-171.
Link: https://www.ncbi.nlm.nih.gov/pubmed/16075941

This study examined the concentrations of human health-related microorganisms found in runoff from agricultural plots treated with fresh and aged cattle manure, swine slurry, and no manure following three consecutive simulated rainfall events. The results of the study suggest that runoff from livestock manure-applied agricultural lands following heavy precipitation events can release large microbial loads and have a significant impact on water bodies within the watershed.

3. Chee-Sanford JC, Mackie RI, Koike S, et al. Fate and transport of antibiotic residues and antibiotic resistance genes following land application of manure waste. *J Environ Qual*. 2009;38(3):1086-1108.
Link: https://www.ncbi.nlm.nih.gov/pubmed/19398507

This review article examined the mobility, transferability and persistence of antibiotic resistance genes and the dissemination and fate of antibiotic residues in the environment with a focus on the land application of animal waste. The review found that the agricultural use of antibiotics and the land application of animal waste were linked with increased and accelerated incidences of antibiotic resistant bacteria.

4. Sapkota AR, Curriero FC, Gibson KE, Schwab KJ. Antibiotic-resistant enterococci and fecal indicators in surface water and groundwater impacted by a concentrated swine feeding operation. *Environ Health Perspect*. 2007:1040-1045.
Link: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC1913567/

Surface and groundwater located up and down gradient from a swine facility were analyzed for the presence of antibiotic-resistant enterococci and other fecal indicators in this study. These were detected at elevated levels in down-gradient water sources relative to the swine facility compared to up-gradient sources, providing evidence that water contaminated with swine manure can contribute to the spread of antibiotic resistance.

5. Casey JA, Kim BF, Larsen J, Price LB, Nachman KE. Industrial food animal production and community health. *Current environmental health reports*. 2015;2(3):259-271.
Link: https://www.ncbi.nlm.nih.gov/pubmed/26231503

This study reviewed recent literature to assess the association between the elevated risk of health outcomes and living near industrial food animal production (IFAP) operations and manure-applied crop fields. The study found that respiratory outcomes, methicillin-resistant *Staphylococcus aureus* (MRSA), Q fever and stress/mood were all consistently and positively associated with living near IFAP operations. The study also found moderate evidence of an association with quality of life, and limited evidence of an association with cognitive impairment, *Clostridium difficile*, *Enterococcus*, birth outcomes, and hypertension.

6. Gilchrist MJ, Greko C, Wallinga DB, Beran GW, Riley DG, Thorne PS. The potential role of concentrated animal feeding operations in infectious disease epidemics and antibiotic resistance. *Environ Health Perspect*. 2007:313-316.
Link: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC1817683/

A working group of the "Conference on Environmental Health Impacts of Concentrated Animal Feeding Operations: Anticipating Hazards—Searching for Solutions" examined the potential risks for human infection resulting from high concentrations of animals. They also examined the means of transmission and propagation of infectious agents, focusing on influenza and antibiotic resistance. Based on the health risks compiled in this review, the working group concurred with the World Health Organization's call to phase-out the use of antimicrobials for growth promotion in animal and fish production, and require veterinary prescriptions for the therapeutic use of antimicrobials in food animals and fish. The working group also recommended regulations that restrict the co-location of swine and poultry concentrated animal feeding operations (CAFOs) on the same site and establish appropriate separation distances.

7. Rinsky JL, Nadimpalli M, Wing S, et al. Livestock-associated methicillin and multidrug resistant *Staphylococcus aureus* is present among industrial, not antibiotic-free livestock operation workers in North Carolina. *PLoS One*. 2013;8(7):e67641.
Link: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4709655/

This study explored the association of livestock-associated *S. aureus* with occupational pig contact and pet contact in North Carolina. Pig workers showed a greater prevalence of multidrug-resistant *S. aureus* (MDRSA) and methicillin-resistant *S. aureus* (MRSA) compared with the control workers, while the prevalence of MDRSA and MRSA was similar in pet-owning workers and controls. Frequency of pig contact was also positively associated with the prevalence of MDRSA and MRSA carriage. The study concluded that livestock-associated MDRSA and MRSA in humans is associated with occupational pig contact, not pet contact, and that these findings support the concern over antibiotic use in pig farms and the potential for occupational exposure to *S. aureus*.

8. Price LB, Graham JP, Lackey LG, Roess A, Vailes R, Silbergeld E. Elevated risk of carrying gentamicin-resistant *Escherichia coli* among US poultry workers. *Environ Health Perspect*. 2007:1738-1742.
Link: https://www.ncbi.nlm.nih.gov/pubmed/18087592

Occupational and environmental pathways of human exposure to antimicrobial-resistant bacteria were explored in this study by comparing the relative risk of antimicrobial-resistant *E. coli* among poultry workers compared with community referents. The study concluded that occupational exposure to antimicrobial-resistant bacteria may be an important route of entry for the bacteria into the community, as poultry workers had 32 times the odds of carrying resistant *E. coli* compared to the community referents.

9. Smith TC, Gebreyes WA, Abley MJ, et al. Methicillin-resistant *Staphylococcus aureus* in pigs and farm workers on conventional and antibiotic-free swine farms in the USA. *PLoS One*. 2013;8(5):e63704.
Link: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3646818/

The occurrence and prevalence of methicillin-resistant *Staphylococcus aureus* (MRSA) and livestock-associated MRSA (LA-MRSA) in pig and farm workers in Illinois, Iowa, Minnesota, North Carolina and Ohio were investigated in this study. The findings of the study confirm the presence of LA-MRSA in pigs and swine farmworkers in the United States. The study also found that this prevalence is relatively low compared with European studies.

10. Schulz J, Friese A, Klees S, et al. Longitudinal study of the contamination of air and of soil surfaces in the vicinity of pig barns by livestock-associated methicillin-resistant *Staphylococcus aureus*. *Appl Environ Microbiol*. 2012;78(16):5666-5671.
Link: https://www.ncbi.nlm.nih.gov/pubmed/22685139

This study examined the presence and concentration of MRSA in air and soil downwind from swine CAFOs. The results demonstrate regular transmission and deposition of airborne livestock-associated MRSA to areas up to at least 300 meters around pig barns that tested positive for MRSA, suggesting that swine CAFOs can expose other farm animals, wildlife, and people to MRSA.

11. Gibbs SG, Green CF, Tarwater PM, Mota LC, Mena KD, Scarpino PV. Isolation of antibiotic-resistant bacteria from the air plume downwind of a swine confined or concentrated animal feeding operation. *Environ Health Perspect*. 2006:1032-1037.
Link: https://www.ncbi.nlm.nih.gov/pubmed/16835055

This study evaluated the antibiotic- and multi-drug resistant bacteria levels in bio-aerosols upwind, within, and downwind of a swine CAFO. The study concluded that bacterial concentrations with multiple antibiotic resistances or multi-drug resistance were found inside the operation. They were also found outside to at least 150 meters downwind of the operation and at higher percentages than upwind of the operation. Even after sub-therapeutic use of antibiotics was discontinued, these bacterial concentrations with multiple antibiotic resistances were found within and downwind of the operation. The authors concluded that these findings demonstrate a potential human health effect for those who work within or live near these operations.

12. Chapin A, Rule A, Gibson K, Buckley T, Schwab K. Airborne multidrug-resistant bacteria isolated from a concentrated swine feeding operation. *Environ Health Perspect*. 2005:137-142.
Link: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC1277855/

This study examined whether the air within swine operations serves as a source of exposure to antibiotic-resistant bacterial pathogens. Analysis of air samples from within a swine CAFO detected the presence of high-level multidrug-resistant *Enterococcus*, coagulase-negative

staphylococci, and viridans group streptococci. The authors concluded that the findings suggest that the inhalation of air within these CAFOs may serve as an exposure pathway for the transfer of multidrug-resistant bacterial pathogens from swine to humans.

13. Hayes JR, English LL, Carter PJ, et al. Prevalence and antimicrobial resistance of *Enterococcus* species isolated from retail meats. *Appl Environ Microbiol*. 2003;69(12):7153-7160.
Link: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC309953/

The prevalence and antimicrobial resistance profiles of enterococci in retail meats from 263 stores in Iowa were examined in this study. Contamination rates ranged from 97% of pork samples to 100% of ground beef samples. The study also found resistance to a human analogue of a drug used in animal production in isolates from all meat types sampled, as well as high-level gentamicin resistance in a small percentage (4%) of isolates, primarily those from poultry meat. The study concluded that enterococci contamination of retail meats is common, and that the antimicrobial resistance patterns found among the enterococci recovered from different meat types may reflect the antimicrobial type and use profiles for each class of food animal production.

14. Donabedian SM, Thal LA, Hershberger E, et al. Molecular characterization of gentamicin-resistant enterococci in the United States: Evidence of spread from animals to humans through food. *J Clin Microbiol*. 2003;41(3):1109-1113.
Link: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC150269/

The molecular mechanism for resistance of 360 enterococci to gentamicin was evaluated in this study. The study found that when a gentamicin-resistant gene was present in resistant enterococci from animals, it was also present in the isolates recovered from food products of the same animal species. While there was diversity among the gentamicin-resistant enterococci, the study concluded that the similarities in resistance among enterococci isolated from humans, retail food, and farm animals representing geographically diverse locations provides evidence of the spread of antibiotic resistant bacteria from animals to humans via the food supply.

15. Graham JP, Price LB, Evans SL, Graczyk TK, Silbergeld EK. Antibiotic resistant enterococci and staphylococci isolated from flies collected near confined poultry feeding operations. *Sci Total Environ*. 2009;407(8):2701-2710.
Link: https://www.ncbi.nlm.nih.gov/pubmed/19157515

This study examined if and how antibiotic resistant bacteria are transferred from poultry operations to nearby communities, and found that flies caught near poultry operations carried the same drug-resistant pathogens as those found in poultry litter. The study concludes that flies may be an important vector in the spread of drug resistant bacteria from poultry operations and may increase human exposure to these resistant pathogens.

16. Carlson JC, Franklin AB, Hyatt DR, Pettit SE, Linz GM. The role of starlings in the spread of *Salmonella* within concentrated animal feeding operations. *J Appl Ecol*. 2011;48(2):479-486.
Link: http://onlinelibrary.wiley.com/doi/10.1111/j.1365-2664.2010.01935.x/full

This study examined the capacity of European starlings to spread *Salmonella enterica* to cattle, their feed and water at ten CAFOs in Texas in order to better understand the disease risks associated with wildlife use of CAFOs. *S. enterica* contamination of cattle feed and water troughs was positively associated with the number of starlings, and contamination in feed increased as the

number of starlings entering the feed troughs increased. Based on these findings, the study concluded that starlings are a source of *S. enterica* contamination in CAFOs and suggested that starling management tools may reduce the spread of disease within animal production operations.

17. Graham JP, Leibler JH, Price LB, et al. The animal-human interface and infectious disease in industrial food animal production: Rethinking biosecurity and biocontainment. *Public Health Rep*. 2008;123(3):282-299.
Link: https://www.ncbi.nlm.nih.gov/pubmed/19006971

The transition of food animal production from small-scale methods to industrial-scale operations has been accompanied by substantial evidence of the transfer of pathogens between and among industrial food animal facilities, the environment, and exposure to farm workers. This challenges the notion that modern animal production is more biosecure than smaller operations in regards to the introduction and release of pathogens. The study concludes that industrialized food animal production risk factors must be included in strategies to mitigate or prevent the emergence of pandemic avian influenza.

18. Rule AM, Evans SL, Silbergeld EK. Food animal transport: A potential source of community exposures to health hazards from industrial farming (CAFOs). *Journal of Infection and Public Health*. 2008;1(1):33-39.
Link: https://www.ncbi.nlm.nih.gov/pubmed/20701843

The results of this study support the hypothesis that current methods of food animal transport from farm to slaughterhouse result in the transfer of bacteria, including antibiotic-resistant bacteria, to the vehicles travelling the same road. Bacteria were isolated from air and surface samples from vehicles following open poultry trucks, suggesting a new route of exposure to pathogens and the further dissemination of these pathogens to the general environment.

19. Casey JA, Curriero FC, Cosgrove SE, Nachman KE, Schwartz BS. High-density livestock operations, crop field application of manure, and risk of community-associated methicillin-resistant *Staphylococcus aureus* infection in Pennsylvania. *JAMA internal medicine*. 2013;173(21):1980-1990.
Link: https://www.ncbi.nlm.nih.gov/pubmed/24043228

This study assessed the association between exposure to swine and dairy/veal industrial agriculture and the risk of methicillin-resistant *Staphylococcus aureus* (MRSA) infection. The study found that proximity to livestock operations and crop fields treated with swine manure were each associated with MRSA, a skin and soft-tissue infection.

20. Filice GA, Nyman JA, Lexau C, et al. Excess costs and utilization associated with methicillin resistance for patients with *Staphylococcus aureus* infection. *Infection Control & Hospital Epidemiology*. 2010;31(04):365-373.
Link: https://www.ncbi.nlm.nih.gov/pubmed/20184420

Healthcare costs of methicillin-resistant *S. aureus* (MRSA) infections and methicillin-susceptible *S. aureus* (MSSA) were compared in this study. MRSA infections were found to be independently associated with higher costs, more comorbidities, and higher likelihood of death than MSSA infections.

21. Carrel M, Schweizer ML, Sarrazin MV, Smith TC, Perencevich EN. Residential proximity to large numbers of swine in feeding operations is associated with increased risk of methicillin-resistant *Staphylococcus aureus* colonization at time of hospital admission in rural Iowa veterans. *Infection Control & Hospital Epidemiology*. 2014;35(02):190-192.
Link: https://www.ncbi.nlm.nih.gov/pubmed/24442084

The potential for the introduction of MRSA into the hospital setting from livestock via humans who are in close proximity to colonized livestock was explored in this study to better understand the role of CAFOs in hospital MRSA cases. After controlling for age and multiple admissions, the study found that residing within one mile of large swine CAFOs was associated with triple the odds of MRSA colonization at the time of hospital admission, indicating that residential proximity to swine CAFOs was associated with an increased risk of MRSA colonization.

22. Pew Commission on Industrial Farm Animal Production. Putting meat on the table: Industrial farm animal production in America. The Pew Charitable Trusts and the Johns Hopkins Bloomberg School of Public Health; Baltimore, MD, USA. 2008.
Link: http://www.pewtrusts.org/en/research-and-analysis/reports/2008/04/29/putting-meat-on-the-table-industrial-farm-animal-production-in-america

This commission investigated the problems associated with industrial farm animal production (IFAP) operations in the United States, including the negative impacts on public health, the environment, rural communities, and the health and well-being of farm animals. The report provides an evidence-based review of these problems and makes recommendations to solve them, including: banning non-therapeutic use of antimicrobials in food animal production; implementing a disease monitoring system for food animals; treating IFAP as an industrial model and instituting a new system to handle farm waste; phasing out inhumane production practices; amending and enforcing state and federal laws for a more equitable, just contracting system between farmers and integrators; and increasing research on animal agriculture.

23. Ma W, Lager K, Vincent A, Janke B, Gramer M, Richt J. The role of swine in the generation of novel influenza viruses. *Zoonoses and public health*. 2009;56(6-7):326-337.
Link: https://www.ncbi.nlm.nih.gov/pubmed/19486316

This review article examined the role of swine in the ecology of influenza A viruses. The review describes how, due to their susceptibility to infection with both avian and human influenza viruses, swine can transmit viruses from avian reservoirs to humans and generate novel influenza viruses capable of infecting humans. Though the study found that human pandemics are difficult to predict, it concluded that influenza A can impact human, companion animal, livestock, and poultry health, and is therefore a serious threat to human wellbeing.

24. Myers KP, Olsen CW, Gray GC. Cases of swine influenza in humans: A review of the literature. *Clin Infect Dis*. 2007;44(8):1084-1088.
Link: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC1973337/

This literature review was undertaken to improve understanding of interspecies transmission of influenza in preparation for pandemic threats. The review found clinical cases of swine influenza in humans, though the true incidence of infection was unknown. The authors recommend including swine production operation workers in pandemic planning efforts due to their increased risk of zoonotic influenza virus infection.

25. Myers KP, Olsen CW, Setterquist SF, et al. Are swine workers in the United States at increased risk of infection with zoonotic influenza virus? *Clin Infect Dis*. 2006;42(1):14-20.
Link: https://www.ncbi.nlm.nih.gov/pubmed/16323086

Multiple swine-exposed human populations were examined for evidence of previous swine influenza virus infection in order to better understand the role of swine in the interspecies transmission of the virus. This study found that occupational exposure to pigs greatly increases workers' risk of swine influenza virus infection, and recommended that swine workers should therefore be included in pandemic surveillance and prevention strategies.

26. Saenz RA, Hethcote HW, Gray GC. Confined animal feeding operations as amplifiers of influenza. *Vector-Borne & Zoonotic Diseases*. 2006;6(4):338-346.
Link: https://www.ncbi.nlm.nih.gov/pubmed/17187567

In order to better understand the role of CAFOs as local amplifiers of new influenza strains and the risk to human populations, this study examined the transmission dynamics of a novel influenza virus among sequentially linked populations: the CAFO species, CAFO workers, and the broader human population. The study showed that a human influenza epidemic due to a novel virus could be amplified locally by CAFOs, and therefore recommends that the vaccination of CAFO workers would be an effective use of pandemic vaccines.

27. United States Environmental Protection Agency. Literature review of contaminants in livestock and poultry manure and implications for water quality. Updated July 2013. EPA 820-R-13-002.
Link: http://ow.ly/mTDw308qwbZ

This EPA report on the environmental occurrence and potential effects of livestock and poultry manure related contaminants on water quality found that 60-70% of manure nitrogen and phosphorus may not be assimilated by the farmland where it was generated due to the increasing concentration of industrial animal production. The report also notes the variety of pathogens contained in livestock and poultry manure, as well as the potential for their spread to humans when surface and groundwater and food crops come into contact with manure through runoff, spills, and land-application of manure. It also refers to research indicating that antimicrobial use in livestock and poultry production has contributed to the occurrence of anti-microbial resistant pathogens in animal operations and nearby environments. The report also presents that manure discharge to surface waters can occur by various means and have deleterious effects on aquatic life and contribute to toxic algal blooms harmful to animals, and to humans when exposed via contact with contaminated drinking water or recreational use of contaminated water.

28. Heaney CD, Myers K, Wing S, Hall D, Baron D, Stewart JR. Source tracking swine fecal waste in surface water proximal to swine concentrated animal feeding operations. *Sci Total Environ*. 2015;511:676-683.
Link: https://www.ncbi.nlm.nih.gov/pubmed/25600418

The microbial quality of surface water proximal to swine CAFOs was investigated in this study to better understand the impact of CAFOs on the surrounding environment. The results demonstrate overall poor water quality in areas with a high density of swine CAFOs, with high fecal indicator bacteria concentrations in waters both up- and down-stream of CAFO lagoon waste land application sites. The swine-specific microbial source tracking markers used in the study were

also shown to be useful for tracking off-site conveyance of swine fecal wastes and during rain events.

29. American Society of Agricultural Engineers. Manure Production and Characteristics. 2005. Report No.: ASAE D384.2.
Link: http://extension.psu.edu/animals/dairy/nutrient-management/certified-dairy/tools/manure-prod-char-d384-2.pdf

This standard, developed by the American Society of Agricultural Engineers, provides information for estimating the characteristics of livestock and poultry manure.

30. Burkholder J, Libra B, Weyer P, et al. Impacts of waste from concentrated animal feeding operations on water quality. *Environ Health Perspect*. 2007:308-312.
Link: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC1817674/

This work-group, part of the Conference on Environmental Health Impacts of Concentrated Animal Feeding Operations: Anticipating Hazards—Searching for Solutions, found that current and generally accepted livestock waste management practices do not protect water resources from the pathogens, pharmaceuticals and excessive nutrients found in animal waste. As concern about the potential human and environmental health impact of long-term exposure to contaminated water grows, there is greater need for rigorous monitoring of CAFOs, improved understanding of the major toxicants affecting human and environmental health, and a system to enforce these practices.

31. Ward MH. Too much of a good thing? nitrate from nitrogen fertilizers and cancer. *Rev Environ Health*. 2009;24(4):357-363.
Link: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3068045/

Nitrate, the breakdown product of nitrogen fertilizers, accumulates in groundwater under agricultural land and can spread through waterways due to agricultural field runoff. Nitrates are associated with a range of adverse health effects, including methemoglobinemia, various cancers, negative reproductive outcomes, diabetes, and thyroid conditions. Additional research is needed to further evaluate the health effects of nitrate exposure, especially as environmental exposure to nitrates has increased over the last 50 years and 90% of rural Americans depend on groundwater for drinking water, many relying on private wells, which are not regulated by the Safe Drinking Water Act.

32. Manassaram DM, Backer LC, Moll DM. A review of nitrates in drinking water: Maternal exposure and adverse reproductive and developmental outcomes. Environ Health Perspect. 2005 Nov 3;114(3):320–7.
Link: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC1392223/

The relationship between maternal exposure to nitrates through drinking water and adverse reproductive and developmental outcomes was reviewed in this study. Animal studies support the association between nitrate exposure and adverse reproductive effects, and some studies report an association between nitrates in drinking water and spontaneous abortion, intrauterine growth restriction and various birth defects, though a direct exposure-response relationship remains unclear and there is insufficient evidence to establish a causal relationship.

33. Brender JD, Weyer PJ, Romitti PA, et al. Prenatal nitrate intake from drinking water and selected birth defects in offspring of participants in the national birth defects prevention study. *Environ Health Perspect*. 2013;121(9):1083-1089.
Link: https://www.ncbi.nlm.nih.gov/pubmed/23771435

The relationship between prenatal exposure to nitrates in drinking water and birth defects was examined in this study. The study concluded that higher maternal water nitrate consumption was associated with birth defects, including spina bifida, limb deficiency, cleft palate, and cleft lip.

34. Chiu H, Tsai S, Yang C. Nitrate in drinking water and risk of death from bladder cancer: An ecological case-control study in Taiwan. *Journal of Toxicology and Environmental Health, Part A*. 2007;70(12):1000-1004.
Link: https://www.ncbi.nlm.nih.gov/pubmed/17497410

The association between bladder cancer mortality and nitrate exposure from Taiwan drinking water was investigated in this study. The results showed a significant positive relationship between the levels of nitrates in the drinking water and the risk of death from bladder cancer, indicating that environmental exposure to nitrates plays a role in the development of bladder cancer.

35. Ward MH, Kilfoy BA, Weyer PJ, Anderson KE, Folsom AR, Cerhan JR. Nitrate intake and the risk of thyroid cancer and thyroid disease. *Epidemiology*. 2010;21(3):389-395.
Link: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2879161/

This study examined the association between nitrate intake through public water and diet with the risk of thyroid cancer and hypo- and hyperthyroidism. The study found an increased risk of thyroid cancer with high water nitrate levels and with longer consumption of water containing nitrates. The increased intake of dietary nitrate was associated with an increased risk of thyroid cancer, and with the prevalence of hypothyroidism.

36. Gulis G, Czompolyova M, Cerhan JR. An ecologic study of nitrate in municipal drinking water and cancer incidence in Trnava district, Slovakia. *Environ Res*. 2002;88(3):182-187.
Link: https://www.ncbi.nlm.nih.gov/pubmed/12051796

This ecologic study was conducted to assess the association between nitrate levels in drinking water with non-Hodgkin lymphoma and cancers of the digestive and urinary tracts in an agricultural district. The study found is that a higher incidence of some cancers was associated with higher levels of nitrate in drinking water. The trend was found in women for overall cancer cases, stomach cancer, colorectal cancer and non-Hodgkin lymphoma, and in men for non-Hodgkin lymphoma and colorectal cancer.

37. Knobeloch L, Salna B, Hogan A, Postle J, Anderson H. Blue babies and nitrate-contaminated well water. *Environ Health Perspect*. 2000;108(7):675-678.
Link: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC1638204/

Two cases of infant methemoglobinemia associated with nitrate contaminated private well water were described in this paper. The case studies underscore the danger that this contaminated water poses to infants during the first six months of life, as well as the risks of long-term exposure,

which include cancer, thyroid disease and diabetes. Steps to reduce nitrate inputs in groundwater and routine well water testing are recommended to protect health.

38. United States Geological Survey (USGS). Water Use Data for the Nation. http://waterdata.usgs.gov/nwis/wu. Updated February 14, 2017. Accessed February 14, 2017.

This United States Geological Survey website provides national water use data by area type (aquifer, watershed, county, state), source (rivers or groundwater), and category such as irrigation or public supply.

39. Heisler J, Glibert PM, Burkholder JM, et al. Eutrophication and harmful algal blooms: A scientific consensus. *Harmful algae*. 2008;8(1):3-13.
Link: http://www.sciencedirect.com/science/article/pii/S1568988308001066

The US EPA held a roundtable discussion to develop consensus among academic, federal and state agency representatives on the relationship between eutrophication and harmful algal blooms. Seven statements were adopted during the session, which include acknowledgement of the important role of nutrient pollution and degraded water quality in the development and persistence of many harmful algal blooms.

40. Carmichael WW. Health effects of toxin-producing cyanobacteria: "The CyanoHABs". *Human and ecological risk assessment: An International Journal*. 2001;7(5):1393-1407.
Link: http://www.tandfonline.com/doi/abs/10.1080/20018091095087

Current understandings of cyanobacteria toxin poisonings (CTPs) and their risk to human health were reviewed in this paper. CTPs occur in fresh and brackish waters throughout the world as a result of eutrophication and climate change. Cyanobacteria toxins are responsible for acute lethal, acute, chronic and sub-chronic poisonings of wild and domestic animals and humans. These poisonings result in respiratory and allergic reactions, gastrointestinal disturbances, acute hepatotoxicosis and peracute neurotoxicosis.

41. Paerl HW, Fulton RS,3rd, Moisander PH, Dyble J. Harmful freshwater algal blooms, with an emphasis on cyanobacteria. *Scientific World Journal*. 2001;1:76-113.
Link: https://www.ncbi.nlm.nih.gov/pubmed/12805693

This paper reviews the effects of harmful freshwater algal blooms, resulting from nutrient oversupply and eutrophication, on water quality. Algal blooms contribute to water quality degradation, including malodor and foul taste, fish kills, toxicity, and food web alterations, while algal bloom toxins can adversely affect human and animal health through exposure to contaminated recreational and drinking water. The control and management of blooms, and their negative outcomes, must include nutrient input constraints, particularly on nitrogen and phosphorus.

42. Heederik D, Sigsgaard T, Thorne PS, et al. Health effects of airborne exposures from concentrated animal feeding operations. *Environ Health Perspect*. 2007:298-302.
Link: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC1817709/

This report from a Conference on Environmental Health Impacts of Concentrated Animal Feeding Operations: Anticipating Hazards—Searching for Solutions working group states that

toxic gases, vapors and particles are emitted from CAFOs into the general environment, and that while these agents are known to be harmful to human health, there are few studies that explore the health risks of exposure to these agents for the people living near CAFOs. While there is evidence that psychophysiological changes may result from exposure to malodors and that microbial exposures are related to deleterious respiratory health effects, the working group concluded that there is great need to study and evaluate the health effects of community exposure to these CAFO related air pollutants to better understand the impact of CAFOs on the health of community members and farm workers.

43. Donham KJ, Wing S, Osterberg D, et al. Community health and socioeconomic issues surrounding concentrated animal feeding operations. *Environ Health Perspect*. 2007:317-320.
Link: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC1817697/

The Workgroup on Community and Socioeconomic Issues examined the impacts of CAFOs on the health of rural communities, using the World Health Organization's definition of health, "a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity." The workgroup recommended more stringent CAFO permitting, limiting animal density per watershed, improving local control, mandating environmental impact statements and considering bonding for manure storage basins.

44. Schinasi L, Horton RA, Guidry VT, Wing S, Marshall SW, Morland KB. Air pollution, lung function, and physical symptoms in communities near concentrated swine feeding operations. *Epidemiology*. 2011;22(2):208-215.
Link: https://www.ncbi.nlm.nih.gov/pubmed/21228696

This study examined the associations between reported malodor and monitored air pollutants with lung function and physical symptoms in people residing within 1.5 miles of hog operations to better understand the effect of CAFO air pollutants on human health. The study reported that acute physical symptoms, including eye irritation, respiratory symptoms, difficulty breathing, wheezing, declined forced expiratory volume, sore throat, chest tightness, and nausea were related to pollutants measured near hog operations.

45. Mirabelli MC, Wing S, Marshall SW, Wilcosky TC. Asthma symptoms among adolescents who attend public schools that are located near confined swine feeding operations. *Pediatrics*. 2006;118(1):e66-75.
Link: http://pediatrics.aappublications.org/content/118/1/e66

The relationship between exposure to airborne effluent from swine CAFOs and asthma symptoms in adolescents age 12-14 years old was assessed in this study to better understand the health effects of living near industrial swine facilities. The study found that estimated exposure to swine CAFO air-pollution was associated with wheezing symptoms in adolescents.

46. Wing S, Wolf S. Intensive livestock operations, health, and quality of life among eastern North Carolina residents. *Environ Health Perspect*. 2000;108(3):233-238.
Link: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC1637983/

Reports of decreased health and quality of life from people who live near industrial animal operations were explored in this study through community surveys in three rural communities, one located near a large swine operation, one near two intensive cattle operations, and one area

without nearby livestock operations using liquid waste management systems. Residents near the swine operation reported increased occurrences of poor health, such as headaches, diarrhea, sore throat, excessive coughing and burning eyes and reduced quality of life compared to those in the other two communities.

47. Wing S, Horton RA, Rose KM. Air pollution from industrial swine operations and blood pressure of neighboring residents. *Environmental Health Perspectives (Online)*. 2013;121(1):92.
Link: https://ehp.niehs.nih.gov/1205109/

The association of air pollution and malodor with stress and blood pressure were assessed in this study to improve understanding of the effects of industrial swine operations on human health. Malodor and some air pollutants were found to be associated with blood pressure increases and reported stress, which could contribute to the development of chronic hypertension.

48. Wing S, Horton RA, Marshall SW, et al. Air pollution and odor in communities near industrial swine operations. *Environ Health Perspect*. 2008;116(10):1362.
Link: https://www.ncbi.nlm.nih.gov/pubmed/18941579

This study quantified swine odor episodes reported by neighbors and the relationships of these episodes with environmental measurements to better understand how CAFO odors affect health and quality of life. The study found that malodor from swine operations was often present in communities in close proximity to industrial swine operations, and that the odors reported by neighbors were related to the objective environmental measurements and interruptions in daily activities. The study concluded that these findings contribute to evidence suggesting that swine CAFO odors and associated physical and chemical agents can negatively impact public health, especially in vulnerable communities.

49. Horton RA, Wing S, Marshall SW, Brownley KA. Malodor as a trigger of stress and negative mood in neighbors of industrial hog operations. *Am J Public Health*. 2009;99(S3):S610-S615.
Link: https://www.ncbi.nlm.nih.gov/pubmed/19890165

The association between malodor and air pollutants from nearby hog CAFOs and reported stress and negative mood was evaluated in this study to better understand the role of CAFOs in human health. The study found that malodor and air pollutants acted as environmental stressors and triggers of negative mood and recommended their inclusion in studies of the health impacts of environmental injustice.