JOHNS HOPKINS
CENTER *for* A LIVABLE FUTURE

The Johns Hopkins Center for a Livable Future
Bloomberg School of Public Health
615 North Wolfe Street, W7010
Baltimore, MD 21205

June 1, 2017

Michael Rife, Chairman
Matthew Funk, Supervisor
Gregory Weller, Supervisor
Montgomery Township Supervisors
11364 Fort Loudon Road
Mercersburg, PA 17236

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

RE: Proposed Herbruck's Poultry Ranch Egg-layer Poultry Operation

Dear Mr. Rife, Mr. Funk, and Mr. Weller,

We are researchers at The Johns Hopkins Center for a Livable Future, 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 regarding a wide range of public health issues surrounding that system.

We have been contacted by Franklin County residents about a proposed 2.4 million-layer capacity poultry operation in your jurisdiction. We understand that the county has a high density of industrial food animal operations, including dairy cows, hogs, broilers and layers, and that the proposed operation would more than double the layer inventory in this area. In response to concerns of county residents and in an effort to serve as a resource, we have summarized the primary public health concerns associated with industrial food animal production (IFAP), focusing specifically on poultry production.

To date, few scientific investigations have explored the public health risks posed to neighboring communities by large-scale egg layer operations. While meaningful differences in the production of broiler chickens and layers exist, particularly with regard to methods for manure management and the lifespan of the animals, key similarities are also evident. These include heightened

animal density, the use of ventilation fans, and the generation of massive quantities of manure. For this reason, we assert that studies of the public health risks from broiler operations, in the absence of information specific to layers, are informative regarding community risks posed by layer operations. An annotated bibliography is provided on pages 6-15.

Summary of Public Health Concerns Associated with IFAP

The primary human health concerns related to IFAP include: infections resulting from transmission of harmful microorganisms from IFAP operations to nearby residents; respiratory problems resulting from increased exposure to air pollution from animal operations; and multiple negative human health impacts due to increased exposure to ground and/or surface waters that are contaminated by manure from IFAP operations. These concerns are described in greater detail below.

Disease Transmission

The poor conditions characteristic of IFAP operations, including crowding, present opportunities for disease transmission among animals, and between animals and humans. [1,2] Those living near IFAP operations are vulnerable, especially if they live in close proximity to multiple operations, and may have an increased risk of infection from the transmission of harmful microorganisms from operations via flies or contaminated air and water. [3-7]

Of additional concern is exposure to pathogens that are resistant to antibiotics used in human medicine. Administering antibiotics to animals at levels too low to treat disease (non-therapeutic use) is common practice in many IFAP operations to promote growth or prevent disease. This practice fosters the proliferation of antibiotic-resistant pathogens. Resistant infections in humans are more difficult and expensive to treat [8] and more often fatal [9] than infections with non-resistant strains. A large body of evidence provides support that antibiotic-resistant pathogens are found in IFAP operations that administer antibiotics for non-therapeutic purposes [10] and that such pathogens are also found in the environment in and around production facilities, specifically in the litter [11,12] and on flies. [13]

Poultry operation workers are disproportionately exposed to these pathogens. [4,14] In a study on the Delmarva Peninsula, poultry workers were found to have 32 times the odds of carrying gentamicin- resistant *E. coli* compared with other residents in the community. [4] Colonized or infected workers may transport pathogens into their communities. [4]

Manure runoff from IFAP operations can introduce these harmful pathogens into nearby water sources. [11] Land application of manure presents a pathway for pathogens and chemicals contained present in the manure to leach into groundwater (which may be used for drinking water) or run off into recreational waters and drinking water sources, potentially causing a

waterborne disease outbreak.[11] The area proposed for the layer operation may be at particularly high risk of water contamination due to its location over a karst aquifer.[15,16] Sinkholes, sinking streams, open fractures and cracks characteristic of karst aquifers provide little to no filtration of incoming water, leaving groundwater in these aquifers even more vulnerable to pesticide, nutrient, and pathogen contamination from land use activities than other types of aquifers.[17] A review of groundwater quality in a Wisconsin karst aquifer found that the land application of animal waste in the area led to significant contamination of the aquifer and private wells by pathogens, pathogen indicators, and nitrates.[18] This is of particular concern for the approximately 31% of Franklin County residents who rely on private wells for drinking water and household use[19]; private wells are not routinely monitored by government agencies to ensure safe levels of pathogens.

Air Pollution

Poultry workers and community members living near IFAP operations also face increased exposure to air pollution from these operations, which can cause or exacerbate respiratory conditions including asthma,[20-22] bronchitis, and allergic reactions.[21] Air emissions from poultry IFAP operations include particulates, volatile organic compounds, and gases such as ammonia.[20,22,23] Harmful microorganisms have been found in the air up to 3,000 meters from poultry operations, and variations in wind patterns make it difficult to predict which residents might be most affected.[5] Harmful bacteria such as *Campylobacter* have been reported to enter and leave poultry operations via insects and massive ventilation systems,[7] and infectious agents have been found on deposits of particulate matter several miles from operations.[5]

Contaminated Ground and Surface Water

A transition over the last several decades to large, high-density, confined animal feeding operations that tend to be clustered near processing facilities has resulted in the concentration of animal waste over small geographic areas.[11] Based on manure production data from the American Society of Agricultural Engineers,[24] a 2.4 million-layer operation would produce an estimated 456,000 pounds of waste per day (0.19 lbs. per hen), or roughly two and half times the equivalent amount of human waste generated daily by the entire city of Harrisburg, Pennsylvania. Although animal manure is an invaluable fertilizer when used in moderation, waste quantities of the magnitude produced by IFAP operations represent a public health and ecological hazard through the degradation of surface and ground water resources.[11]

Litter from IFAP operations can contaminate ground and surface waters with nitrates,[25] drug residues, and other hazards,[6,26] and studies have demonstrated that humans can be exposed to waterborne contaminants from livestock and poultry operations through the recreational use of contaminated surface water and the ingestion of contaminated drinking water.[27] Studies of community water systems in Maryland found that poultry and corn production are associated with higher nitrate concentrations (naturally occurring in manure) in surface and groundwater[25]

and drinking water wells.[28] Exposure to elevated levels of nitrates in drinking water is associated with adverse health effects, including cancer,[29-32] birth defects and other reproductive problems,[27,29,33,34] thyroid problems,[27,29] and methemoglobinemia (a condition that can be fatal to infants).[27,35]

There also may be health risks associated with exposure to drug residues and excreted hormones found in ground and surface water contaminated by poultry manure. Of particular concern is estradiol, which is naturally found at high levels in poultry manure and is an endocrine-disruptor in humans.[36] Environmental estrogens such as estradiol may be linked to increased incidence of male reproductive tract disorders, reduced sperm counts, and increases in the frequency of female breast cancer.[36]

Nutrient runoff (including nitrogen and phosphorus) has also been implicated in the growth of harmful algal blooms,[11,37] 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.[38,39]

We hope that this description of public health concerns associated with IFAP is helpful. Through our research, we know that local agencies can face many barriers in addressing issues associated with IFAP operations due to narrow regulations and/or limited resources for monitoring impacts to public health and/or the environment.[40,41] Please do not hesitate to contact us if you have any questions.

Sincerely,

James D. Yager, PhD
Edyth H. Schoenrich Professor Emeritus
Acting Director, Johns Hopkins Center for a Livable Future
Professor & Deputy Chair, Department of Environmental Health & Engineering
Senior Associate Dean for Academic Affairs (2000–2013)
Johns Hopkins Bloomberg School of Public Health
Johns Hopkins University

Robert S. Lawrence, MD, MACP
The Center for a Livable Future Professor Emeritus in Environmental Health & Engineering
Founding Director, Johns Hopkins Center for a Livable Future
Johns Hopkins Bloomberg School of Public Health
Johns Hopkins University

Robert Martin
Senior Lecturer, Department of Environmental Health & Engineering
Johns Hopkins Bloomberg School of Public Health

Program Director, Food System Policy
Johns Hopkins Center for a Livable Future
Johns Hopkins University

Jillian P. Fry, PhD, MPH
Assistant Scientist, Departments of Environmental Health & Engineering and Health, Behavior and Society
Johns Hopkins Bloomberg School of Public Health
Project Director, Food Production and Public Health
Johns Hopkins Center for a Livable Future
Johns Hopkins University

Carolyn Hricko, MPH
Research Assistant, Food System Policy
Johns Hopkins Center for a Livable Future
Johns Hopkins University
Department of Environmental Health & Engineering
Johns Hopkins Bloomberg School of Public Health

References

1. Gomes A, Quinteiro-Filho W, Ribeiro A, et al. Overcrowding stress decreases macrophage activity and increases *Salmonella* enteritidis invasion in broiler chickens. *Avian Pathol*. 2014;43(1):82-90.
Link: https://www.ncbi.nlm.nih.gov/pubmed/24350836

This study sought to characterize the immunosuppressive effect of overcrowding stress in broiler chickens. Overcrowding was found to compromise the intestinal immune barrier and integrity of the small intestine, resulting in inflammation and decreased nutrient absorption. The study concludes that animal welfare measures and avoiding overcrowding stress factors in maintaining poultry health and decreased susceptibility to Salmonella infection.

2. 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.

3. 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 previously unrecognized route of exposure to pathogens and the further dissemination of these pathogens to the general environment.

4. 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/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.

5. Baykov B, Stoyanov M. Microbial air pollution caused by intensive broiler chicken breeding. *FEMS Microbiol Ecol*. 1999;29(4):389-392.
Link: https://academic.oup.com/femsec/article/29/4/389/527380/Microbial-air-pollution-caused-by-intensive

This study examined the extent of microbial atmospheric pollution caused by industrial broiler breeding operations and found that as birds aged, microbial numbers increased in the indoor air and were spread into the environment to a greater degree. The study also found that microorganisms could be spread by air flow up to 3000 meters from the production buildings.

6. Spencer JL, Guan J. Public health implications related to spread of pathogens in manure from livestock and poultry operations. *Public Health Microbiology: Methods and Protocols*. 2004:503-515.
Link: https://www.ncbi.nlm.nih.gov/pubmed/15156064

Objectionable odors, flies, excessive levels of nitrogen and phosphorus and the potential spread of human pathogens are among the public concerns with the disposal of animal manure and the spread of dust and manure blown from powerful building fans. The study also finds that importance of animal manure in the spread of infectious pathogens is often underestimated despite the linkages between livestock operations and gastroenteritis in humans.

7. 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*. 2008:282-299.
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.

8. Roberts RR, Hota B, Ahmad I, et al. Hospital and societal costs of antimicrobial-resistant infections in a Chicago teaching hospital: Implications for antibiotic stewardship. *Clin Infect Dis*. 2009;49(8):1175-1184.
Link: https://academic.oup.com/cid/article/49/8/1175/425330/Hospital-and-Societal-Costs-of-Antimicrobial

Medical and societal costs attributable to antimicrobial-resistant infections are considerable, and important factors in understanding the potential benefits of prevention programs. Medical costs attributable to antimicrobial-resistant infections range from $18,588 to $29,069 per patient, hospital stay durations from 6.4-12.7 days, and mortality of 6.5%. Societal costs were estimated at $10.7-$15 million.

9. 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.

10. Price LB, Lackey LG, Vailes R, Silbergeld E. The persistence of fluoroquinolone-resistant *Campylobacter* in poultry production. *Environ Health Perspect*. 2007:1035-1039.
Link: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC1913601/

Halting fluoroquinolone use was not found to have an impact on the proportion of fluoroquinolone-resistant *Campylobacter* on products from the conventional producers, indicating that antibiotic-resistant bacteria may persistently contaminate poultry products even after on-farm use of the antibiotic has ceased. Also, *Campylobacter* strains from the conventional producers were more likely to be resistant to fluoroquinolone than those from the antibiotic-free producers, indicating that antibiotic use in food animal production contributes to the develop of antibiotic-resistant pathogens.

11. United States Environmental Protection Agency. Literature review of contaminants in livestock and poultry manure and implications for water quality. July 2013:1-137.
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.

12. Graham JP, Evans SL, Price LB, Silbergeld EK. Fate of antimicrobial-resistant enterococci and staphylococci and resistance determinants in stored poultry litter. *Environ Res*. 2009;109(6):682-689.
Link: https://www.ncbi.nlm.nih.gov/pubmed/19541298

This study examined the survival of anti-microbial resistant enterococci and staphylococci and resistance genes in poultry litter to better understand how land application of poultry litter can affect the surrounding populations environment. The study found that poultry litter storage practices do not eliminate drug-resistant bacterial strains, thus allowing the spread of these drug-resistant pathogens into and through the environment via land application of poultry litter.

13. 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.

14. Mulders M, Haenen A, Geenen P, et al. Prevalence of livestock-associated MRSA in broiler flocks and risk factors for slaughterhouse personnel in the Netherlands. *Epidemiol Infect*. 2010;138(05):743-755. Link: https://www.ncbi.nlm.nih.gov/pubmed/20109255

Methicillin-resistant *Staphylococcus aureus* (MRSA) carriage in poultry and slaughterhouse personnel was examined in this study. The results indicated that employees are at a higher risk of exposure when compared to the general Dutch population (5.6% vs. 0.1% MRSA carriage rate). Among personnel, contact with live animals was associated with a significantly higher risk of MRSA carriage.

15. Weary DJ. An Appalachian Regional Karst Map and Progress Towards a New National Karst Map. *US Geological Survey Karst Interest Group Proceedings, Rapid City, South Dakota*. 2005:12-15. Link: https://pubs.usgs.gov/sir/2005/5160/PDF/sir2005-5160part3A.pdf

A new digital karst map for the Appalachian region was constructed using data compiled from various state and regional sources. The map includes the states of New York, New Jersey, Delaware, Pennsylvania, Ohio, Maryland, Virginia, West Virginia, Kentucky, North Carolina, Tennessee, South Carolina, Georgia, Alabama, and Mississippi. This map serves as the basis for a new national map and will be used as a test for new methodologies in developing karst maps and databases.

16. A quick guide to groundwater in Pennsylvania. PennState Extension, Penn State College of Agricultural Sciences Web site. http://extension.psu.edu/natural-resources/water/drinking-water/best-practices/a-quick-guide-to-groundwater-in-pennsylvania. Updated 2017. Accessed May 25, 2017.

This PennState Extension groundwater guide provides information on groundwater sources, uses, and risks in Pennsylvania.

17. Vesper DJ, Loop CM, White WB. Contaminant transport in karst aquifers. *Theoretical and Applied Karstology*. 2001;13(14):101-111. Link: http://homepages.uc.edu/~maynarjb/Frontpage%20sites/482/bowling/karst%20VOC%20review.pdf

This paper describes various types of karst aquifer contaminants and summarizes the ways in which they are stored, transported and released. Water-soluble organic and inorganic contaminants, slightly soluble organic contaminants, metals, pathogens, and trash are included in the review.

18. Erb K, Ronk E, Koundinya V, Luczaj J. Groundwater quality changes in a karst aquifer of Northeastern Wisconsin, USA: Reduction of brown water incidence and bacterial contamination resulting from implementation of regional task force recommendations. *Resources*. 2015;4(3):655-672. Link: http://www.mdpi.com/2079-9276/4/3/655

This article presents the impact of actions taken by local resource managers on water quality in the Silurian Dolostone region of eastern Wisconsin. These actions were initiated based on the recommendations of the Karst Task Force, a group convened in response to significant groundwater contamination from the land application of animal manure and organic waste. This report found that while counties within the task force area demonstrated increased awareness of groundwater quality issues, waste application educational efforts alone did not lead to improved water quality. The adoption of winter manure spreading restrictions on frozen or snow-covered

ground did result in statistically significant reductions in the instances of well water quality problems.

19. United States Geological Survey (USGS). USGS Water Use Data for the Nation. http://waterdata.usgs.gov/nwis/wu. Updated June 8, 2016. Accessed May 25, 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.

20. 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 psychophysiologic 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.

21. Cambra-López M, Aarnink AJ, Zhao Y, Calvet S, Torres AG. Airborne particulate matter from livestock production systems: A review of an air pollution problem. *Environmental pollution*. 2010;158(1):1-17.
Link: https://www.ncbi.nlm.nih.gov/pubmed/19656601

This paper reviews research on particulate matter inside and emitted from livestock production system and reports that livestock housing is an important source of particulate matter emissions. The paper recommends additional research to characterize and control particulate matter in livestock houses, as high concentrations such as those found in livestock houses can threaten the environment and the health and welfare of humans and animals.

22. Viegas S, Faísca VM, Dias H, Clérigo A, Carolino E, Viegas C. Occupational exposure to poultry dust and effects on the respiratory system in workers. *Journal of Toxicology and Environmental Health, Part A*. 2013;76(4-5):230-239.
Link: https://www.ncbi.nlm.nih.gov/pubmed/23514065

This study examined the correlation between particle contamination in poultry farms and the prevalence rate of respiratory problems. The prevalence rate of obstructive pulmonary disorders was higher in individuals with longer exposure to poultry farm dust, even after smoking status was considered. The prevalence rate of both asthmatic (42.5%) and nasal symptoms (51.1%) was high among workers. The study concluded that poultry farm workers suffer from respiratory ailments at high prevalence rates, and suggested that this may be linked to high concentrations of particulate matter found in farm dust.

23. Hribar C, Schultz M. Understanding concentrated animal feeding operations and their impact on communities. *Bowling Green, OH: National Association of Local Boards of Health. Retrieved May 2017*;18:2013.
Link: https://www.cdc.gov/nceh/ehs/docs/understanding_cafos_nalboh.pdf

The National Association of Local Boards of Health produced this report with the support of the Centers for Disease Control and Prevention and the National Center for Environmental Health to assist local board of health members better understand their role in mitigating potential issues with CAFOs. The report concludes that large-scale industrial food animal production can cause numerous public health and environmental problems and should thus be monitored to prevent harm to surrounding communities. Suggested actions include passing ordinances and regulations, and increasing water and air quality monitoring and testing. The report also concludes that local boards of health, in collaboration with state and local agencies, are an appropriate body for instituting these actions due to the local nature of CAFO concerns and risks.

24. American Society of Agricultural Engineers. Manure production and characteristics (no. ASAE D384.2). 2005.
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.

25. Ator SW, Denver JM. Understanding the nutrients in the Chesapeake Bay watershed and implications for management and restoration: The Eastern Shore. Vol U.S. Geological Survey Circular 1406. (ver. 1.2, June 2015) ed. US Department of the Interior, US Geological Survey; 2015:72 p.
Link: https://pubs.usgs.gov/circ/1406/pdf/circ1406.pdf

This U.S. Geological Survey report examines the source and role of nutrients in the Chesapeake Bay watershed and provides management recommendations for reducing nutrient concentrations and restoring the health of the bay. The report found that the Eastern Shore, despite making up only 7% of the Chesapeake Bay watershed, has contributed disproportionately large nitrogen and phosphorus yields to the Bay, leading to harmful algal blooms and degraded water quality and ecosystems. The report also found that the majority of these yields are attributable to human land-use practices, with agriculture contributing the vast majority of nitrogen and phosphorus to the Eastern Shore landscape. These nutrients move from land to the bay through surface and groundwater, adversely affecting aquatic ecosystems and drinking water quality.

26. Graham JP, Nachman KE. Managing waste from confined animal feeding operations in the United States: The need for sanitary reform. *Journal of water and health*. 2010;8(4):646-670.
Link: https://www.ncbi.nlm.nih.gov/pubmed/20705978

Trends affecting food animal waste production, risks associated with food-animal wastes, and differences between food-animal waste and human biosolid management practices were examined in this study. The study found that no standards exist for the 335 million tons of food animal waste applied to land in the US, while human biosolids, which make up just 1% of all land-applied wastes, are subject to standards. Hormones, arsenicals, high nutrient loads, antibiotics, and pathogens, including antibiotic-resistant pathogens, are often present in animal waste. The authors made recommendations for improving management of food-animal waste through existing and new policies.

27. 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.

28. Lichtenberg E, Shapiro LK. Agriculture and nitrate concentrations in Maryland community water system wells. *J Environ Qual*. 1997;26(1):145-153.
Link: https://dl.sciencesocieties.org/publications/jeq/abstracts/26/1/JEQ0260010145

This study examined nitrate concentrations in drinking water wells, hydrological characteristics of the wells, and measures of agricultural activity and land use to better understand the relationship between land use and well water quality in Maryland communities. The study found that deeper wells appeared less vulnerable to nitrate contamination, whereas wells in unconfined aquifers and limestone formations were more vulnerable. In addition, poultry and corn production were found to be associated with higher nitrate concentrations in drinking water. The study concludes that groundwater preservation efforts should focus on poultry and corn production.

29. 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.

30. 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.

31. 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.

32. 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.

33. Manassaram DM, Backer LC, Moll DM. A review of nitrates in drinking water: Maternal exposure and adverse reproductive and developmental outcomes. *Environmental Health Perspectives*. 2006.
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.

34. 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.

35. 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.

36. Dorabawila N, Gupta G. Endocrine disrupter—estradiol—in Chesapeake Bay tributaries. *J Hazard Mater*. 2005;120(1):67-71.

Link: http://www.sciencedirect.com/science/article/pii/S030438940400651X

This study was conducted to better understand the concentration of estradiol from agricultural land and sewage treatment plants in the rivers, tributaries and coastal bays of Maryland's Eastern Shore. Surface water samples from ponds, rivers, sewage treatment plants, and coastal bays from the Chesapeake Bay watershed contained estradiol concentrations above 1 ng g–1, a level sufficient to induce estrogenic effects in aquatic organisms.

37. 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.

38. 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.

39. Paerl HW, Fulton RS,3rd, Moisander PH, Dyble J. Harmful freshwater algal blooms, with an emphasis on cyanobacteria. *ScientificWorldJournal*. 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.

40. Fry JP, Laestadius LI, Grechis C, Nachman KE, Neff RA. Investigating the role of state and local health departments in addressing public health concerns related to industrial food animal production sites. *PloS one*. 2013;8(1):e54720.
Link: http://journals.plos.org/plosone/article?id=10.1371/journal.pone.0054720

The role of local and state health departments in responding to and preventing community concerns with industrial food animal production are explored in this study through qualitative interviews with state and county health department staff and community members in eight states. Political barriers, lack of jurisdiction, and limited resources, expertise and staff all limit health departments' ability to respond to IFAP concerns, while community members reported difficulty

in engaging with health departments. These limitations and difficulties contribute to limited health department engagement on these issues.

41. Fry JP, Laestadius LI, Grechis C, Nachman KE, Neff RA. Investigating the role of state permitting and agriculture agencies in addressing public health concerns related to industrial food animal production. *PloS one*. 2014;9(2):e89870.
Link: http://journals.plos.org/plosone/article?id=10.1371/journal.pone.0089870

This study explored how state permitting and agriculture agencies respond to environmental public health concerns regarding industrial food animal production through qualitative interviews with state agency staff in seven states. The study found that the agencies were unable to adequately address these environmental public health concerns due to narrow regulations, limited resources and a lack of public health expertise. When these constraints are considered alongside those faced by health departments, significant gaps in the ability to respond to and prevent public health concerns and issues are revealed.